AMBIENT AIR MONITORING STUDY

OF RESIDENTIAL WOODBURNING

IN MIO, MICHIGAN

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INTRODUCTION

From November 1, 1983 to April 30, 1984, the Michigan Air Quality Division conducted an ambient air monitoring study of residential woodburning. The study was conducted in the community of Mio, Michigan.

The monitoring study was prompted by a growing concern over the effects of residential woodburning. As in other parts of the country, Michigan residents have been using an increased amount of wood to heat their homes in recent years. The haze which is formed on still mornings in some areas is quite visible. The Division has received complaints from citizens experiencing trouble breathing because of woodburning. And industry has expressed concern about controls they may be required to install in areas not meeting the National Ambient Air Quality Standards for particulate. They feel that residential woodburning may be contributing significantly to the problem.

Several other states have conducted ambient monitoring studies. Oregon, Montana, Vermont, and New Hampshire are examples. As a result of those studies, Oregon, Montana, and several communities in Colorado have already developed control strategies for dealing with wood stove emissions. Some eastern states are considering that possibility. Many states have begun efforts to educate their residents in the most efficient methods of operating woodstoves in the hopes of obtaining some "voluntary" reduction in emissions. Vermont, however, feels differently about the impact of residential woodburning as a result of their monitoring study. They concluded that resulting particulate levels are not significant enough to warrant pursuing a control program.

Scientists have also conducted research to determine the composition of wood smoke. The primary constituents are particulate matter and carbon monoxide. But there are also a whole host of potentially toxic organic compounds present. Some are suspected carcinogens.

A number of factors can significantly alter the composition or vary the concentration of pollutants in wood smoke: type of stove, wood type, moisture content, method of stove operation, and so on. So developing a control strategy for woodburning is very difficult. Therefore, in order to determine if residential woodburning should even be controlled in Michigan, we decided first to determine just what the impact is.

The goals of the monitoring study were as follows:

1. To monitor ambient air quality in an area which represents a worst case situation with respect to residential woodburning, with minimum interference from industrial sources.

2. To determine the portion of total suspended particulates (TSP) which is smaller than 15 microns.

3. To determine the relationship between worst ambient air quality and meteorological conditions.

4. To determine the contribution of residential woodburning to ambient levels of pollutants during various periods of the day.

Michigan Fuelwood Use

In 1983, the Michigan Department of Natural Resources Forest Management Division conducted a statewide survey concerning fuelwood use in Michigan.[1] Information was gathered concerning the volume of fuelwood consumed for residential heating during the 1982-83 heating season. A summary of some of their results follow. Tables 1-3 contain more details.

Over one million Michigan households (32%) used wood during that heating season to heat their homes, either wholly or in part. Over 3.1 million standard cords of fuelwood were consumed in first homes. An additional 81,000 cords were consumed in second homes and garages. 47% of the households in the northern lower peninsula, the region in which Mio is located, used wood for heating their homes.

Almost 285,000 households statewide (almost 28%) used wood for their primary source of heat. Each user burned an average of 7.1 standard cords. Almost 320,000 households (31%) burned wood as a supplemental source of heat. Each user burned an average of 2.6 cords. And over 420,000 (41%) burned wood primarily for recreational or aesthetic purposes, each user burning an average of only 0.7 cords. Almost 90,000 households plan to install woodburning equipment within the next year.

STATEWIDE FUELWOOD USE SURVEY RESULTS

Table 1: NUMBER OF HOUSEHOLDS BURNING FUELWOOD[1]

	Number of Households	HOUSEHOLDS BURNING FUELWOOD				
		Number	Percent	Major Burner	Supplemental Burner	Pleasure Burner
Eastern Upper Penninsula	44,978	24,018	53.4	17,249	5,677	1,092
Western Upper Peninsula	67,319	33,966	50.5	20,502	8,874	4,590
Northern Lower Peninsula	289,939	135,566	46.8	61,122	37,614	36,830
Southern Lower Peninsula	1,383,261	485,067	35.1	150,042	145,931	189,094
Detroit Metropolitan Area	1,409,176	348,049	24.7	36,078	120,968	191,003
STATEWIDE	3,194,673	1,026,666	32.1	284,993	319,064	422,609

Table 2: TYPE OF FACILITY IN PERCENT BY UNIT[1]

Region	Stove	Regular Fireplace	Modified Fireplace	Furnace	Stove and Furnace	Fireplace and Furnace	Other Combinations
Eastern Upper Peninsula	51.8	15.4	0.9	21.8	2.7	5.5	1.9
Western Upper Peninsula	52.2	12.6	6.3	23.4	3.6	0	1.8
Northern Lower Peninsula	44.5	29.4	7.5	10.4	0.6	0.6	7.0
Southern Lower Peninsula	30.5	43.6	11.0	6.4	1.3	2.5	4.7
Detroit Metro Area	16.5	71.3	7.3	1.2	0.6	0	3.0
STATEWIDE	28.8	49.5	8.9	6.1	1.1	1.4	4.2

Table 3: STANDARD CORDS OF FUELWOOD CONSUMED BY USER CLASS, AVERAGE CONSUMPTION PER USER AND PERCENT CONSUMPTION BY USER & UNIT[1]

REGION	USER CLASS							
	Major		Supplemental		Pleasure		Area Total	
	No. Cords	Per User	No. Cords	Per User	No. Cords	Per User	No. Cords	Per User
Eastern Upper Peninsula	149,760	8.68	18,887	3.33	1,201	1.10	169,848	7.07
Western Upper Peninsula	186,905	9.12	28,703	3.23	2,479	0.54	218,087	6.42
Northern Lower Peninsula	543,436	8.89	131,649	3.50	41,453	1.13	716,538	5.29
Southern Lower Peninsula	950,607	6.34	355,783	2.44	123,116	0.65	1,429,506	2.95
Detroit Metro Area	190,789	5.29	297,326	2.46	120,119	0.63	608,234	1.75
STATEWIDE	2,021,497	7.09	832,348	2.61	288,368	0.68	3,142,213	3.06

WHY MIO?

Mio is a small community in the northern lower peninsula of Michigan. Approximately 1000 people live there. It is the county seat for Oscoda County.

Mio was chosen as the location for the monitoring study for several reasons: 1) Being in the northern part of Michigan, it was expected to stay fairly cold and the ground was expected to stay covered with snow throughout most of the winter. 2) As Mio is in the Au Sable River Valley, tucked among elevated terrain, the dispersion of pollutants is limited. 3) Mio residents rely heavily on wood for home heating. Otherwise, they must use fuel oil, liquid petroleum gas, or electricity. And the houses are located quite close to one another. 4) It was expected that there would be a minimum of interference from other sources of air pollution. Monitoring in Mio was expected to give us our best chance for data from a worst case situation in Michigan.

Industrial and Commercial Sources

There is one small industry in Mio. It is a pallet manufacturing company named Brooks Wood Products. They have had some problems controlling TSP emissions when they burn sawdust in their incinerator; however, such burning takes place infrequently. In order to minimize the influence those emissions might have had on this study, Brooks agreed to burn only on days when the particulate monitors were not in operation. The company adhered to that agreement and it appears that the impact of emissions from that incinerator has indeed been minimal.

A number of small businesses burn wood to heat their buildings. We considered them to be residential sources because the stoves used were the same types as those used for home heating.

Mio Woodburning Survey

In the summer of 1983, before the monitoring sites were established, a door-to-door survey was conducted in Mio. The purpose of the survey was to determine which households are burning wood, how much is being burned, devices being used, methods of operation, and so on. A copy of the survey is included as Appendix A. Results are summarized in Tables 4 and 5.

154 households (approximately 70% of Mio residents) responded to the survey. We learned that 50.% rely on wood as their primary source of heat, burning an average of 5.0 standard cords each winter. Another 9.1% use wood as a supplemental source of heat. And 3.9% use wood for recreational purposes.

Most of those burning wood (63.9%) use only a wood stove. Many different styles and brands are being used. Several households use handmade stoves. 15.5% use only a woodburning furnace. The remainder use a fireplace, a fireplace insert, or a combination of woodburning devices. 12% of the households surveyed planned to add a woodburning device in the near future. Just under half of those already had some form of woodburning device in their homes, but they wanted to install a more efficient system.

Oak is the principal type of wood burned. Maple, poplar, and pine are also burned, but much less frequently. Almost everyone said they allow their wood to dry at least six months before burning. Individuals who rely on wood as their primary source of heat stoke their fires an average of 3 to 4 times per day and clean their flues about 5 times each winter.

Table 4 : HOUSEHOLDS IN MIO BURNING WOOD

USE	NUMBER OF HOUSEHOLDS	PERCENT OF ALL HOUSEHOLDS SURVEYED	AVERAGE NUMBER OF STD. CORDS BURNED
Primary	77	50.	5.0
Secondary	14	9.1	1.8
Recreational	6	3.9	0.4
TOTAL	97	63.0	4.2

Number of Households Surveyed = 154

Table 5 : TYPE OF WOODBURNING DEVICES BEING USED IN MIO

	NUMBER OF HOUSEHOLDS	PERCENT
Wood Stove	62	63.9
Wood Furnace	15	15.5
Fireplace	7	7.2
Fireplace Insert	5	5.2
Furnace & Fireplace	5	5.2
Stove & Fireplace	2	2.1
Stove & Fireplace Insert	1	1.0
TOTAL	97	100.1

OVERVIEW OF MONITORING STUDY

Monitoring was conducted to determine ambient concentrations of total suspended particulates (TSP), inhalable particulates (IP), carbon monoxide (CO), and benzo(a)pyrene (BAP). Wind speed, wind direction, temperature and humidity data was also collected. Supplementary meteorological data (precipitation, snow cover, and data to fill in gaps during failure of our equipment) was provided by the National Weather Service at Houghton Lake.

Monitoring Equipment and Locations

Figure I is a map of Mio showing each of the five monitoring locations. Appendix B contains more detailed information and sketches of each site.

The meteorological equipment was located at site 001, the U.S. Forest Service District Headquarters. Climet wind speed and wind direction sensors were installed on their tower at a height of approximately 60 feet. It was necessary to install them at that height in order to minimize the impact of nearby trees. U.S. Forest Service personnel collected temperature and humidity data using their hygrothermograph, which is located next to the tower.

Two General Metals Works High Volume Samplers (hi-vols), used to measure TSP concentrations, were operated at each of the four remaining sites, sites 002-005. BAP concentrations were analyzed from those filters by the Wayne County Air Pollution Control Division Laboratory using spectrophotofluorometry preceded by instant thin-layer chromatographic separation of the cyclohexane-soluble residue in pentane.[2] A Horiba AQM-11 carbon monoxide analyzer and the IP samplers were also located at one of those sites, site 003.

Sites 002, 003, and 004 were established in areas where residents rely on wood for space heating. The door-to-door survey conducted the previous summer helped provide that guidance. Because we were unable to establish a TSP site which would give us strictly background concentrations, site 005 was set up near the edge of town, as far as possible from any sources. From that location, we obtained data which could be used to estimate background levels. Both the hi-vols and CO analyzer were operated according to procedures described in Michigan's EPA-approved Quality Assurance Handbook. They were also audited by our Quality Assurance team and the results were found to be within acceptable limits.

Two types of IP samplers were used. EPA provided a Sierra 244, the same type that has been used across the nation for the past few years for the IP Network. It was used for 24 hour sampling on even-numbered days. The Michigan Air Quality Division provided two Sierra 240 samplers, one for sampling periods of less than 24 hours and the other for 24 hour sampling on odd-numbered days. The cutoff for fine particulates was 2.5 microns for the EPA sampler and 3.5 microns for the Michigan samplers. The cutoff for coarse particulates was 15 microns for both models.

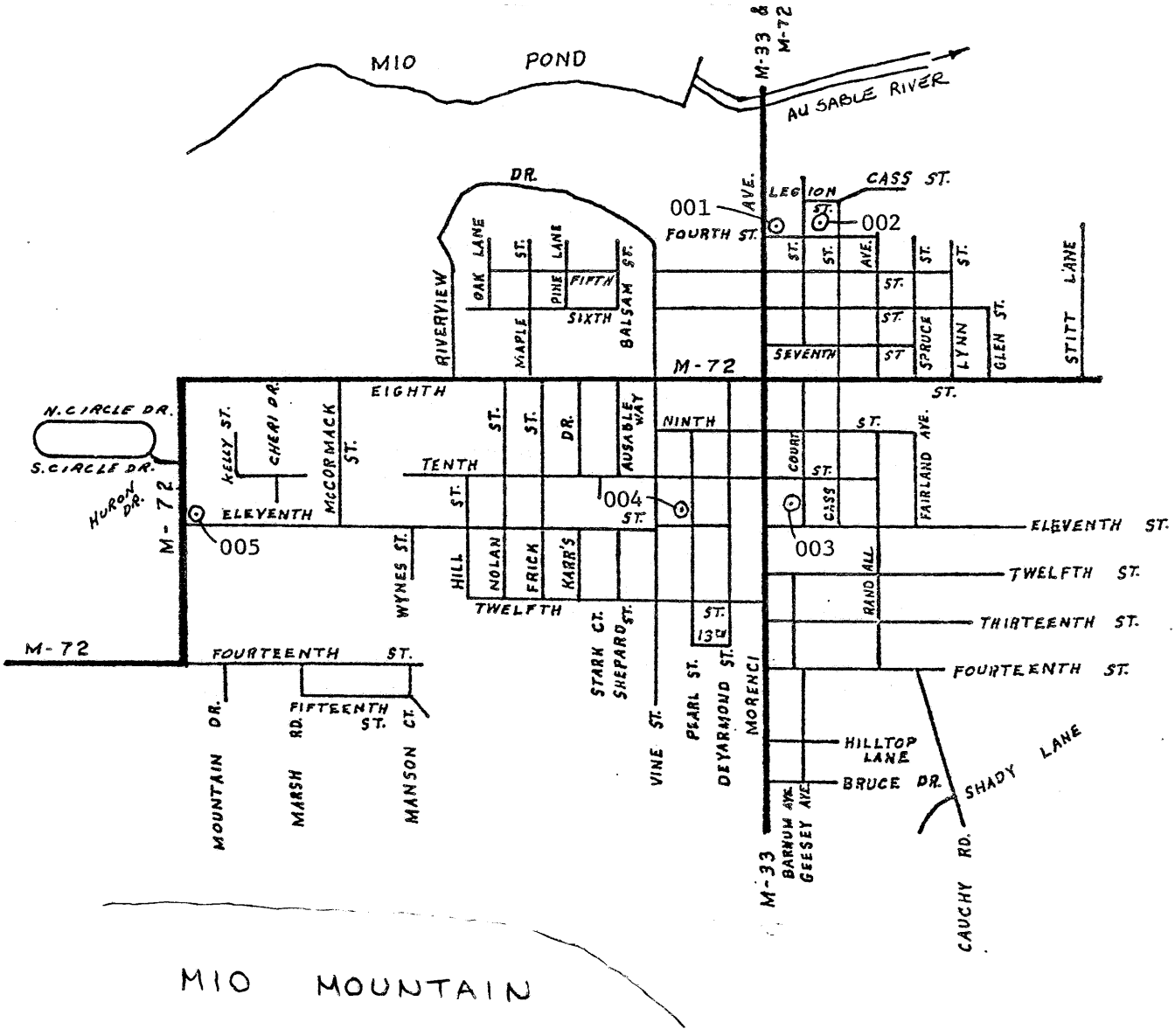
The IP samplers were operated according to the manufacturers instructions. Daily cleaning prevented problems with plugging from a build up of particulate or ice crystals. Table 6 gives precision data for the two types of samplers. Primarily because of the directional sampling capabilities of the Michigan samplers, they measured concentrations that were approximately 38% higher than those measured using the EPA sampler.

Monitoring Schedule

Monitoring was conducted from November 1, 1983 through April 30, 1984. The particulate monitors were operated according to two schedules. For most of the study, the hi-vols were run on a three-day schedule coinciding with EPA's national six-day schedule. During a two week period of intensive study, the two hi-vols at each site were run alternately from midnight to midnight. Therefore, samples were collected daily. Two of the IP monitors were operated simultaneously with the hi-vols. The third IP monitor was run daily for shorter periods of time based on the hours that high carbon monoxide concentrations had been measured. Most of those samples were collected between 3 and 9 a.m. Some were collected between 3 p.m. and midnight.

The intensive study period was chosen by examining meteorological data collected by the Houghton Lake National Weather Service for the previous ten years. The first two weeks of January and February have historically been the coldest and clearest, so the intensive study was conducted from February 4-17, 1984.

Figure I



Site No.	Location	Monitors
001	U.S. Forest Service	Wind Speed Wind Direction Temperature Humidity
002	American Legion	TSP
003	County Courthouse	TSP Carbon Monoxide Inhalable Particulates
004	Gordon Funeral Home	TSP
005	Tri-Town Fire Department	TSP

Table 6 : PRECISION OF MICHIGAN DICHOTOMOUS SAMPLERS WITH RESPECT TO THE EPA DICHOTOMOUS SAMPLER

Concentration Measured Using the DNR Sampler, ug/m^3	Concentration Measured Using the EPA Sampler, ug/m^3	Percent Difference
12	7	71.4
9	8	12.5
10	8	25.0
21	15	40.0
25	16	56.2
27	21	28.6
27	21	28.6
52	37	40.5
14	10	40.0
		342.8

Average Percent Difference = 38.1%
Standard Deviation = 17.5%
95% Probability Limit = 38.1 $\pm$ 24.3%

RESULTS

A noticeable haze develops at times in Mio as a result of residential woodburning. During the two week intensive study, a haze formed on three mornings between 6 and 8 a.m. Residents of the community have said a haze also develops around midnight, but this situation was never observed.

On days that the haze was observed, concentrations were elevated at all four pollutant monitoring sites. It is expected that on most of the other days that elevated concentrations were measured at all of the sites, it was because a haze had formed sometime during the day. Table 7 contains a listing of pollutant concentrations measured simultaneously. Hazy conditions were observed on February 9, 10, and 15, 1984.

Meteorological (Met) Conditions

The development of the haze seems to be associated with the morning and evening stoking of stoves, clear or partly cloudy skies, and little or no wind. The winds were usually most calm in the early morning hours. There was also little or no precipitation on those days. High temperatures were generally in the mid-40's (warm for that time of year) and the lows were in the high teens to low twenties.

The haze did not form on very cold days. It is suspected that it was because stove owners were trying to operate their stoves as efficiently as possible. They gave their fires lots of air, so combustion was more complete and less particulate went into the atmosphere. When temperatures became moderate, they reduced the amount of air going into their fires to cut down on the amount of heat that would be generated. Therefore, combustion was less efficient and more particulate was generated.

Winds were primarily out of the west, west-southwest, and east. That's to be expected because Mio is in a east-west running valley. Wind speeds were reported as hourly averages. 2.7% of the averages were less than 1 mph. 15% were between 1 and 2 mph. Most of the hourly averages during the periods a haze was observed were 2 mph and less. Figure II is a wind rose which graphically illustrates wind speed and wind direction during those six months.

Total Suspended Particulates (TSP)

The National Ambient Air Quality Standards (NAAQS) for TSP were never exceeded. But background levels were only approximately 20 ug/m^3. The highest concentration measured was 124 ug/m^3. The next highest was 103 ug/m^3. The secondary TSP NAAQS is 150 ug/m^3. Table 7 (Simultaneous Pollutant Concentrations) details the concentrations monitored at each site throughout the study.

On days that it is expected a haze had formed (approximately 20% of the days that sampling was conducted), TSP concentrations were generally between 60 and 80 ug/m^3. That includes background levels. An impact of 40-60 ug/m^3 from residential woodburning is lower than expected,

given the visibility and irritating nature of the haze. But the TSP standard is a 24 hour average. And monitoring for that length of time results in measurements that represent everything that happened during those 24 hours. If the particulate concentration is very high for just a few hours and very low for rest of the sampling period, the 24 hour concentration is also relatively low. This study provided a good example of that phenomena. In an area where background concentrations are much higher, the impact of an additional 40-60 ug/m^3 could be significant in trying to meet the NAAQS.

The highest six-month geometric mean was measured at site 004 (Gordon Funeral Home): 37.8 ug/m^3. The lowest was measured at site 005 (Tri-Town Fire Department): 25.8 ug/m^3. Figures III-VI illustrate the distribution of TSP concentrations measured at each site. The distributions seem to reflect the locations of the monitors with respect to nearby woodburning sources.

Carbon Monoxide (CO)

CO concentrations were well below the NAAQS. The highest 1 hour concentration was 6.9 ppm; the next highest was 3.2 ppm. The 1 hour standard is 35 ppm and the 8 hour standard is 9 ppm. Background levels were approximately 0.5 ppm. Figure VII is a distribution of readings taken after the monitor began operation on November 23, 1983.

Carbon monoxide readings were used primarily as an indicator. When CO levels rose, TSP levels generally rose as well. On the days that the haze was observed, hourly CO concentrations peaked at 2.4, 6.9, and 2.6 ppm. Elevated CO concentrations were generally measured in the early morning hours or very close to midnight. Table 7 (Simultaneous Pollutant Concentrations) details peak CO concentrations and the hours they occurred on days that TSP data was collected.

Benzo(a)pyrene (BAP)

48 High Volume Sampler Filters (19% of the total) were analyzed for BAP by the Wayne County Air Pollution Control Division. The highest BAP concentration measured was 42.7 ng/m^3; the next highest was 13.8 ng/m^3. The lowest was 1.1 ng/m^3. Table 8 details the BAP concentrations and associated TSP concentrations that were measured on each filter.

If an industrial facility was to apply for a permit from the Michigan Air Quality Division, based on an estimate of one in a million increased risk of cancer, a 24 hour limit of approximately 3 ng/m^3 would be applied. 35% of the 24 hour concentrations measured in Mio exceeded that limit.

The Wayne County Air Pollution Control Division has been analyzing for BAP at several locations since 1971. Coke ovens are known to release significant amounts of BAP, yet they are difficult sources to control. Therefore, two of Wayne County's sites are located near coke ovens. During the 12 years sampling has been done, quarterly averages at those two sites have ranged from 1.85 to 23.92 ng/m^3. 93% of the averages were above 3 ng/m^3. A quarterly average greater than 10 ng/m^3 has not been measured since 1980, but the Allied Chemical coke ovens were closed

for approximately one and a half years between 1981 and 1983. During 1981 and 1982, quarterly averages at those two sites ranged from 1.86 to 9.76 ng/m^3.

At the other Wayne County sites, four located in residential areas and one rural site, quarterly averages have ranged from 0.20 to 6.74 ng/m^3 since 1971. Only 18% of the averages were above 3 ng/m^3. In comparing the maximum quarterly averages for each year at each site, 46% of the maximums occurred over the first quarter, (January - March), 25% over the second quarter (April - June), and the rest were evenly distributed over the third and fourth quarters (July - September and October - December).

In Mio, higher TSP concentrations were generally associated with higher BAP concentrations. But it is not a strong correlation. Some of the higher BAP concentrations can be traced back using wind direction data to sources of woodburning near the monitoring site, but the associated TSP concentrations were not necessarily higher than usual. Figure VIII illustrates the relationship between TSP and BAP for all of the samples taken. Figure IX is an illustration for only those days that it is expected a haze had formed.

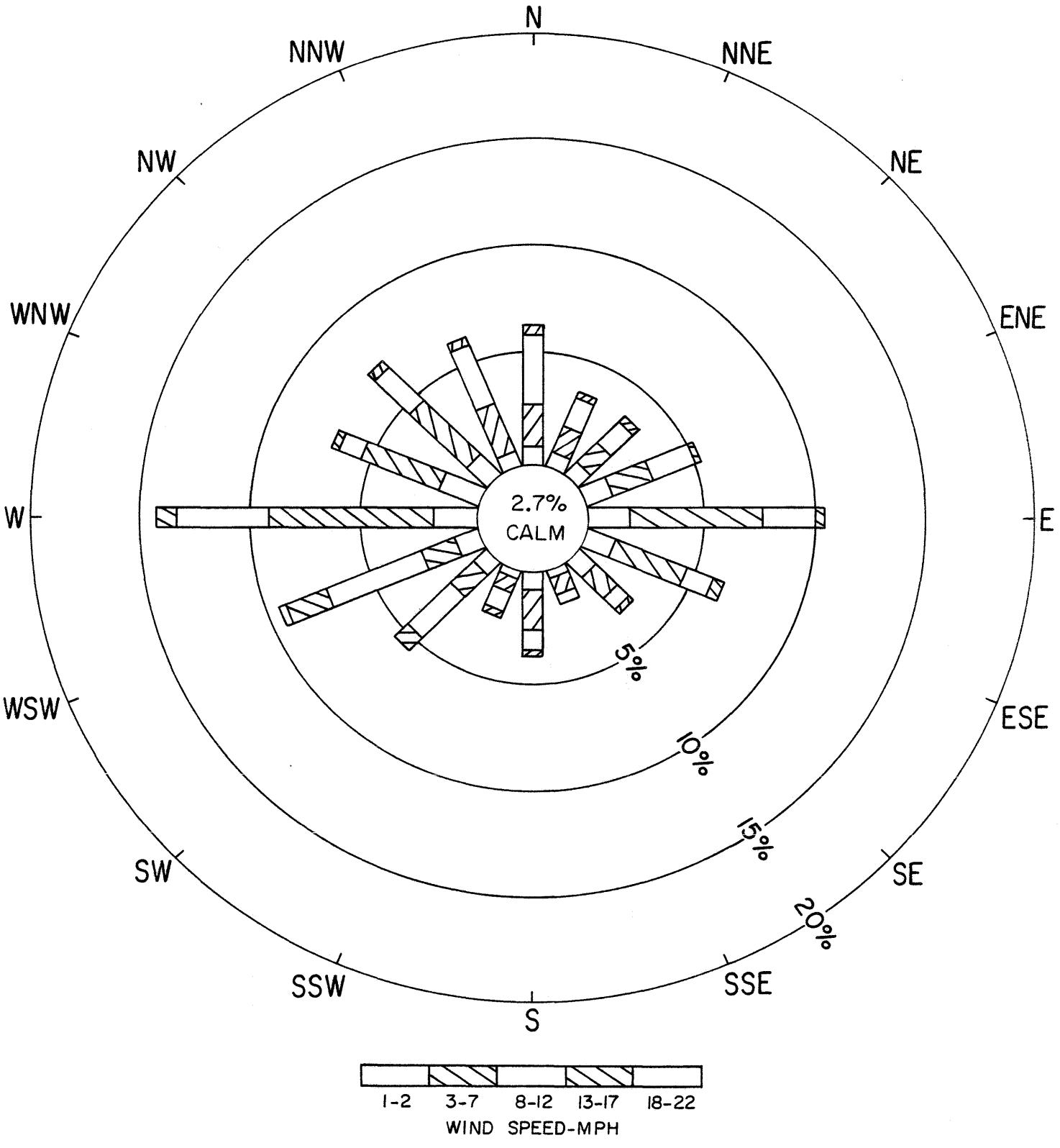
Inhalable Particulates (IP)

Although the samplers were designed to collect particles smaller than 15 microns and the proposed new standard is for particles smaller than 10 microns, PM-10 concentrations can be estimated using a conversion factor of 0.8. That is the ratio that EPA suggests using to approximate the ratio of IP to PM-10. The proposed 24 hour standard is 150-250 ug/m^3.

The highest 24 hour IP concentration measured was 58 ug/m^3. That corresponds to a PM-10 concentration of approximately 46 ug/m^3. The highest IP concentration measured over a period of less than 24 hours was 108 ug/m^3, which corresponds to a PM-10 concentration of approximately 86 ug/m^3. Table 9 details all the readings.

A significant portion of the TSP appears to be fine particulate. At least half of the 24 hour TSP concentration was smaller than 15 microns. On hazy days, at least two-thirds was. And the short term IP concentration was up to three times the associated 24 hour concentration. Those relationships are illustrated in the bar graphs contained in Figure X.

Figure II



U.S. FOREST SERVICE
MIO, MICHIGAN
NOVEMBER 1, 1983-APRIL 30, 1984

Table 7 : SIMULTANEOUS POLLUTANT CONCENTRATIONS

Sampling Date	TSP: 24 hr. conc., ug/m^3 Site No. 002	003	004	005	CO conc., ppm max. 1 hr.	ending hour	Max 24 hr BAP TSP, ug/m^3	BAP, ng/m^3	Inhal. Part., ug/m^3 24 hr. total	<24 hour hours	total
11/2/83	38		54	40							
11/5/83	70		-	27			70	5.6			
11/8/83	43		33	33			43	7.8			
11/11/83	9		29	12							
11/14/83	-		55	39							
11/17/83	61		34	38			61	1.6			
11/20/83	18		16	15							
11/23/83	16	21	18	12	0.4	12,14,16-21	21	1.1			
11/26/83	27	46	53	19	1.5	17	53	6.0			
11/29/83	16	V.3	12	8	0.7	10-12,22-24					
12/2/83	22	22	21	16	0.9	24					
12/5/83	40	53	65	34	2.1	6	65	2.9			
12/8/83	78	72	89	61	2.6	3, 8	89	42.7			
12/11/83	14	14	38	13	0.6	1, 24					
12/14/83	13	23	24	19	1.0	21					
12/17/83	25	15	19	18	2.5	24	25	5.3			
12/20/83	-	79	66	49	-	-	79	13.4			
12/23/83	-	17	17	11	1.2	17					
12/26/83	16	16	18	13	0.7	1-4					
12/29/83	19	15	13	11	0.9	17	19	2.4			
1/1/84	39	38	41	41	1.3	1, 4	41	2.2			
1/4/84	-	17	20	14	1.0	17					
1/7/84	22	36	46	47	-	-					
1/10/84	25	38	49	32	3.1	23	49	8.5			
1/13/84	18	19	32	23	-	-					
1/16/84	-	32	45	21	1.5	3	45	3.8			

Table 7 : SIMULTANEOUS POLLUTANT CONCENTRATIONS

Sampling Date	TSP: 24 hr. conc., ug/m^3 Site No. 002	003	004	005	CO conc., ppm max. 1 hr.	ending hour	Max 24 hr BAP TSP, ug/m^3	BAP, ng/m^3	Inhal. Part., ug/m^3 24 hr. total	< 24 hour hours	total
1/19/84	22	-	18	21	0.7	7-10					
1/22/84	-	31	33	30	-	-	33	1.8			
1/25/84	27	27	26	22	-	-					
1/28/84	41	45	57	32	2.3	3	57	4.3			
1/31/84	27	34	39	40	-	-					
2/2/84	80	68	72	57	1.6	1,3-5	72	3.1			
2/4/84	20	21	22	19	0.3	3,5-7,9	20	6.2	13	3-9a	19
2/5/84	13	16	24	11	0.4	13	24	3.4	9	-	-
2/6/84	13	15	-	12	0.9	9			7	3-9a	23
2/7/84	15	26	30	17	1.1	8	30	4.3	16	-	-
2/8/84	-	30	-	23	0.4	13			19	3-9a	32
2/9/84	65	70	71	73	2.4	9	71	3.4	58	3-9a	68
2/10/84	57	73	81	76	6.9	9	81	4.6	56	3-9a	108
2/11/84	34	32	32	26	0.8	19	34	2.7	29	3-9a	36
2/12/84	25	28	27	25	0.9	19			21	3-9a	32
2/13/84	36	29	23	25	0.9	23,24			28	3-9a	27
2/14/84	58	39	32	37	0.9	1-3			25	-	-
2/15/84	61	72	75	55	2.6	9	75	6.9	47	15-24	56
2/16/84	20	46	-	37	2.0	7			22	15-24	19
2/17/84	34	103	54	45	1.7	21,22	103	4.1			
2/18/84	40	57	33	29	0.7	1	57	2.4			
2/21/84	39	34	20	17	-	-					
2/24/84	19	57	49	25	0.7	2-7,10-11					
2/27/84	49	86	92	30	-	-	92	3.8			
3/1/84	18	41	30	14	0.9	8-10					
3/4/84	79	67	80	37	-	-	79	9.8			

Table 7 : SIMULTANEOUS POLLUTANT CONCENTRATIONS

Sampling Date	TSP: 24 hr. conc., ug/m^3 Site No. 002	003	004	005	CO conc., ppm max. 1 hr.	ending hour	Max 24 hr BAP TSP, ug/m^3	BAP, ng/m^3	Inhal. Part., ug/m^3 24 hr. total	<24 hour hours	total
3/7/84	34	48	48	-	1.5	24					
3/10/84	95	73	81	-	3.1	3	81	12.1			
3/13/84	21	26	25	24	0.8	1-9,12,21 23-24	26	2.4			
3/16/84	-	25	25	20	1.2	15					
3/19/84	-	21	21	19	0.5	1-2,4,8-9					
3/22/84	13	21	21	14	0.9	8	21	2.2			
3/25/84	94	71	-	32	1.1	23	94	8.7			
3/28/84	33	54	80	24	1.8	1	80	2.1			
3/31/84	36	62	87	31	-	-	87	3.4			
4/3/84	66	90	124	43	-	-	66	3.6			
4/9/84	49	77	91	-	-	-	91	3.8			
4/15/84	10	10	13	-	0.3	9, 17, 20 23-24	13	2.5			
4/18/84	47	70	56	32	0.8	23	70	3.0			
4/21/84	55	73	91	47	1.0	23	73	3.2			
4/24/84	22	39	26	21	0.9	9-10					
4/27/84	67	85	92	60	0.4	4-5	85	2.2			
4/30/84	65	61	63	51	0.6	2, 12-13, 18-19,21-24	61	2.2			

Figure III

DISTRIBUTION OF TSP CONCENTRATIONS AT SITE 002

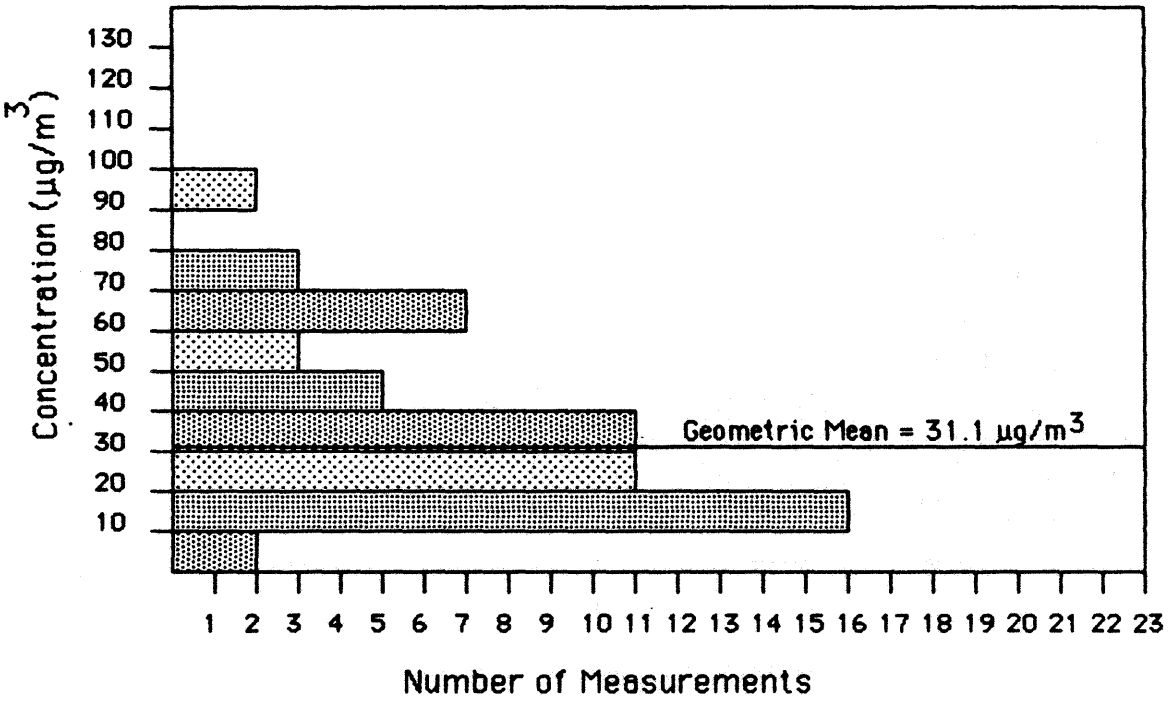


Figure IV

DISTRIBUTION OF TSP CONCENTRATIONS AT SITE 003

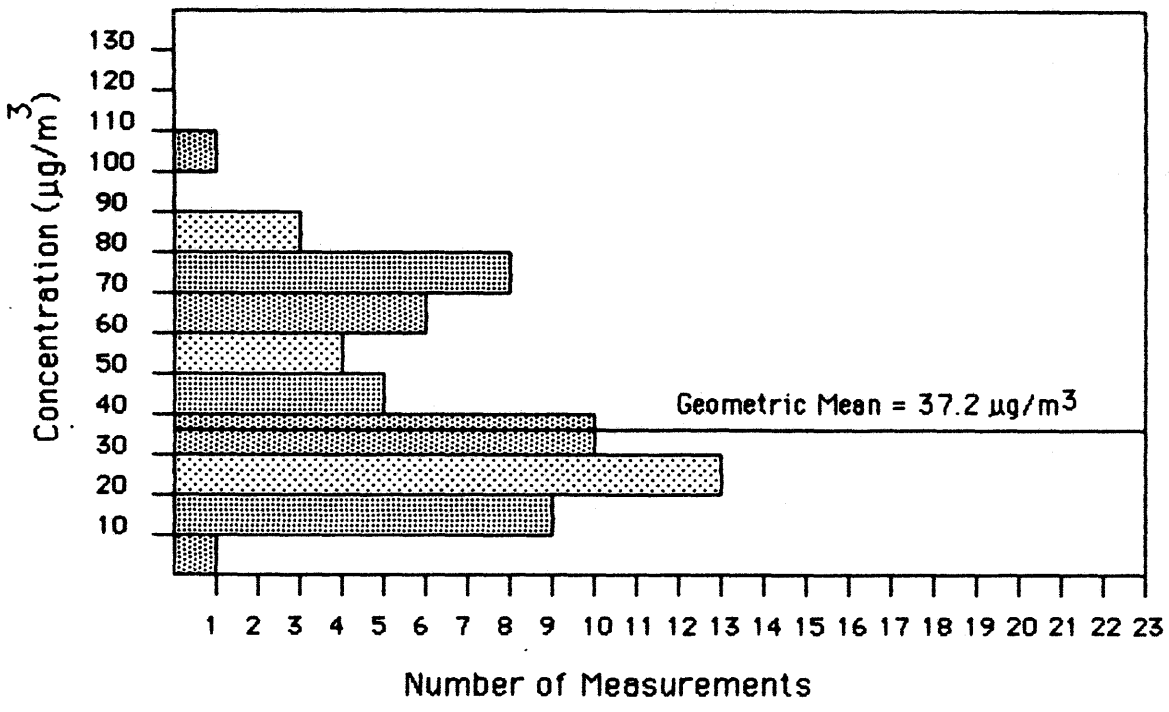


Figure V

DISTRIBUTION OF TSP CONCENTRATIONS AT SITE 004

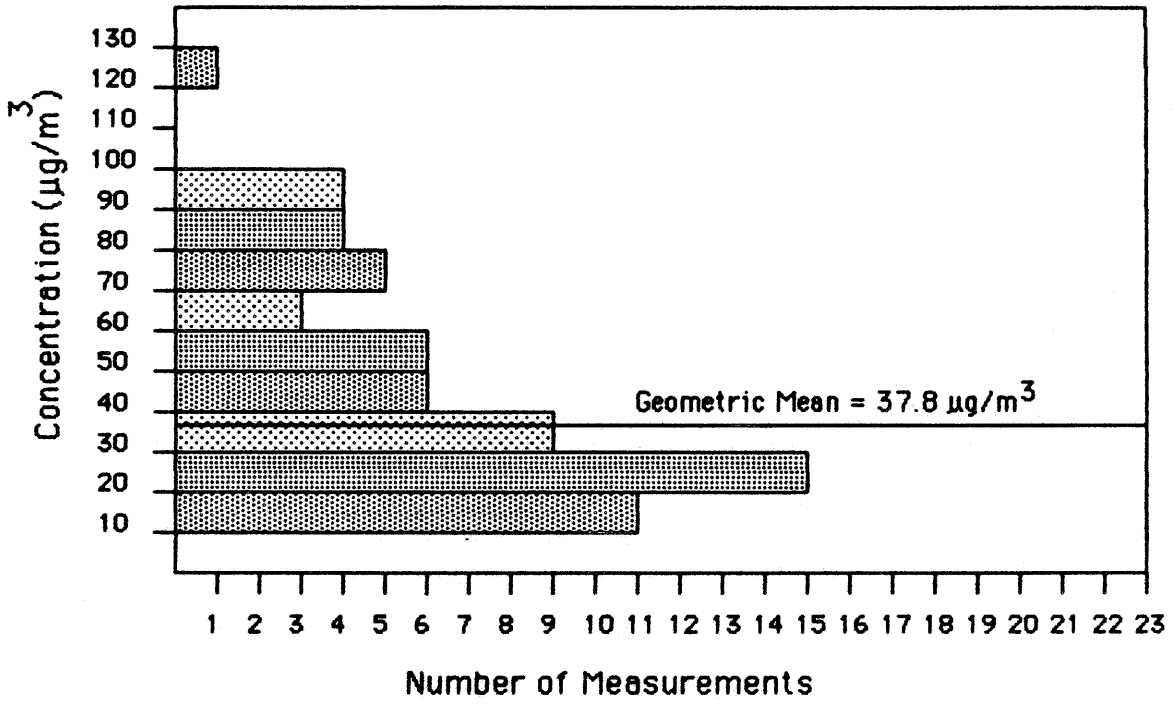


Figure VI

DISTRIBUTION OF TSP CONCENTRATIONS AT SITE 005

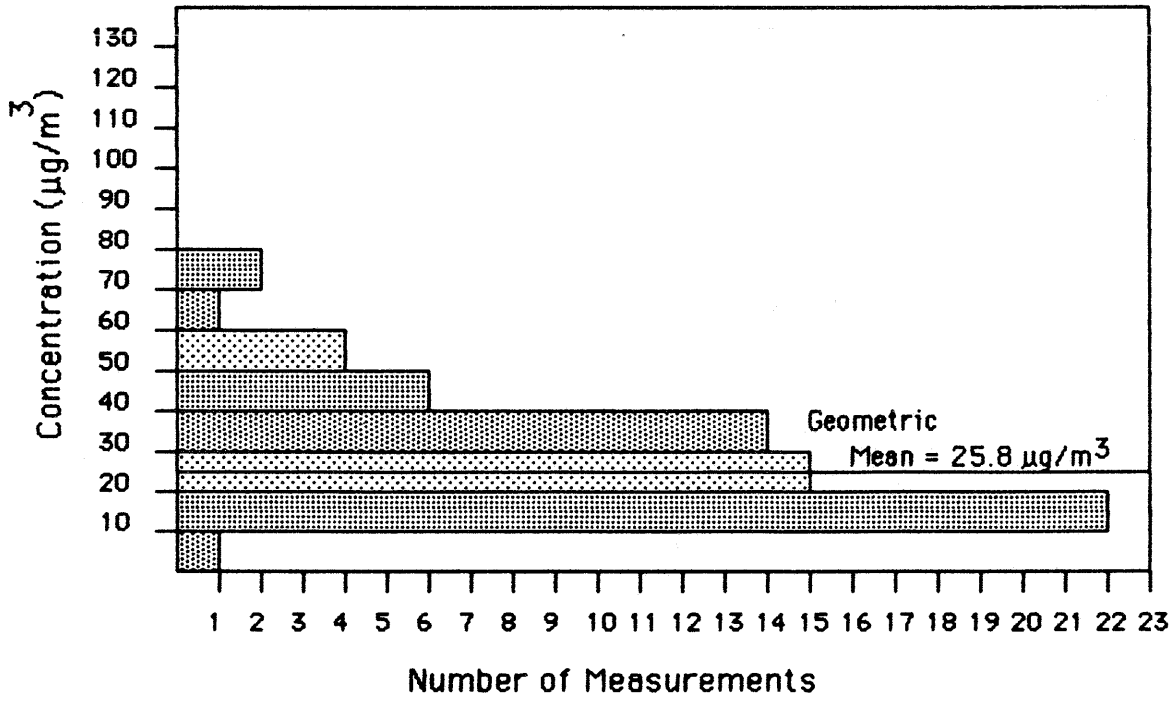


Figure VII

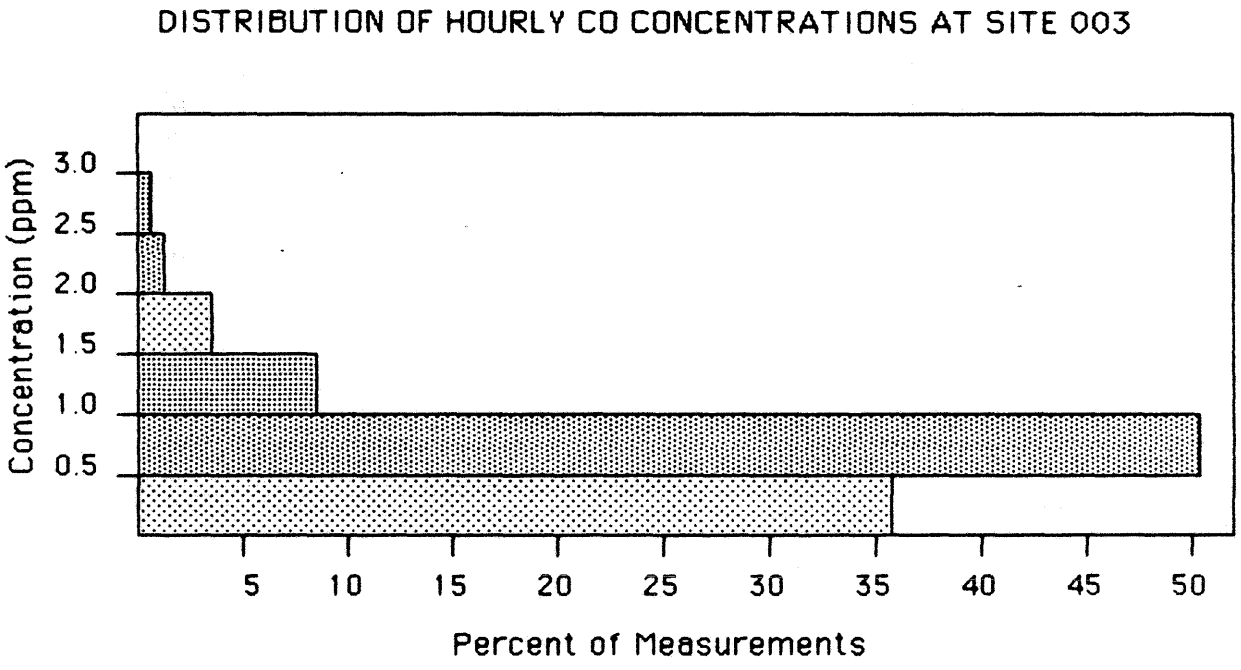

DISTRIBUTION OF HOURLY CO CONCENTRATIONS AT SITE 003
Concentration (ppm)
3.0
2.5
2.0
1.5
1.0
0.5
5
10
15
20
25
30
35
40
45
50
Percent of Measurements

Table 8 : RELATIONSHIP BETWEEN BAP AND TSP
(24 hour concentrations)

Date	Site	TSP, ug/m^3	BAP, ng/m^3
11-5-83	002	70	5.6
11-8-83	002	43	7.8
11-17-83	002	61	1.6
11-23-83	003	21	1.1
11-26-83	004	53	6.0
12-5-83	004	65	2.9
12-8-83	002	78	13.6
	003	72	13.8
	004	89	42.7
	005	61	5.2
12-17-83	002	25	5.3
12-20-83	003	79	13.4
	004	66	10.4
12-29-83	002	19	2.4
1-1-84	004	41	2.2
1-10-84	004	49	8.5
1-16-84	004	45	3.8
1-22-84	004	33	1.8
1-28-84	004	57	4.3
2-2-84	002	80	3.0
	003	68	2.6
	004	72	3.1
2-4-84	002	20	6.2
2-5-84	004	24	3.4
2-7-84	004	30	4.3
2-9-84	002	65	2.5
	003	70	2.5
	004	71	3.4
	005	73	2.7
2-10-84	002	57	2.5
	003	73	3.8
	004	81	4.6
	005	76	3.4
2-11-84	002	34	2.7

Table 8: RELATIONSHIP BETWEEN BAP AND TSP
(24 hour concentrations)

Date	Site	TSP, ug/m^3	BAP, ng/m^3
2-15-84	002	61	6.5
	003	72	5.6
	004	75	6.9
	005	55	4.4
2-17-84	003	103	4.1
2-18-84	003	57	2.4
2-27-84	003	86	3.4
	004	92	3.8
3-4-84	002	79	9.8
	003	67	3.7
	004	80	6.8
3-10-84	002	95	8.6
	003	73	9.2
	004	81	12.1
3-13-84	003	26	2.4
3-22-84	004	21	2.2
3-25-84	002	94	8.7
	003	71	6.8
3-28-84	004	80	2.1
3-31-84	003	62	3.0
	004	87	3.4
4-3-84	002	66	3.6
	003	90	3.2
	004	124	3.5
4-9-84	003	77	3.5
	004	91	3.8
4-15-84	004	13	2.5
4-18-84	003	70	3.0
4-21-84	003	73	3.2
	004	91	2.7
4-27-84	002	67	2.0
	003	85	2.2
	004	92	2.1
	005	60	1.9
4-30-84	002	65	1.9
	003	61	2.2
	004	63	2.1

Figure VIII

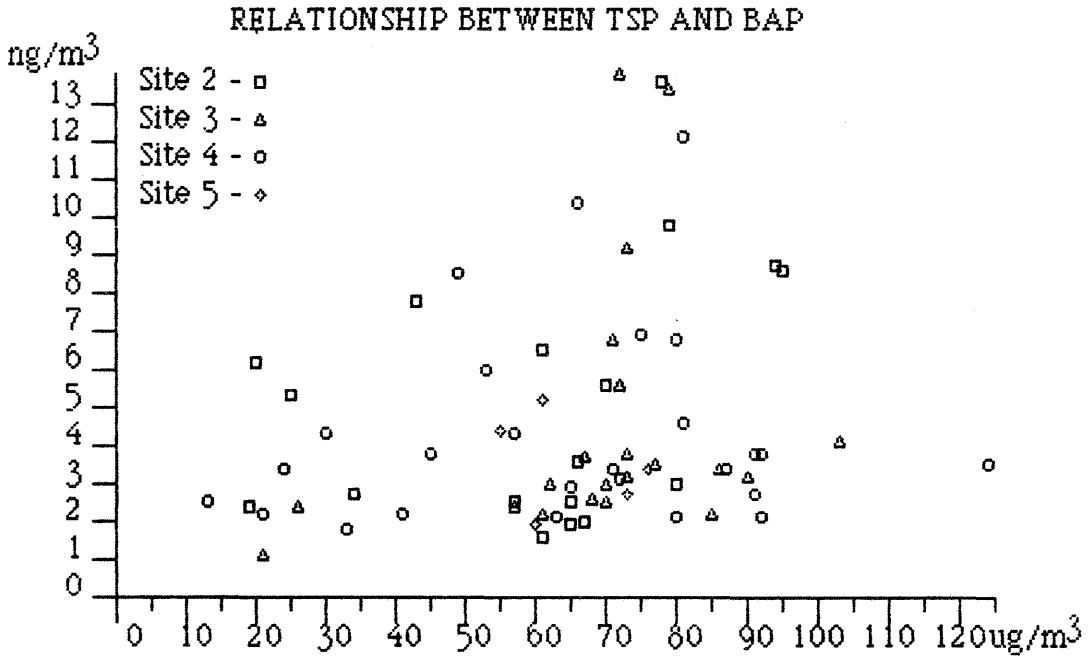
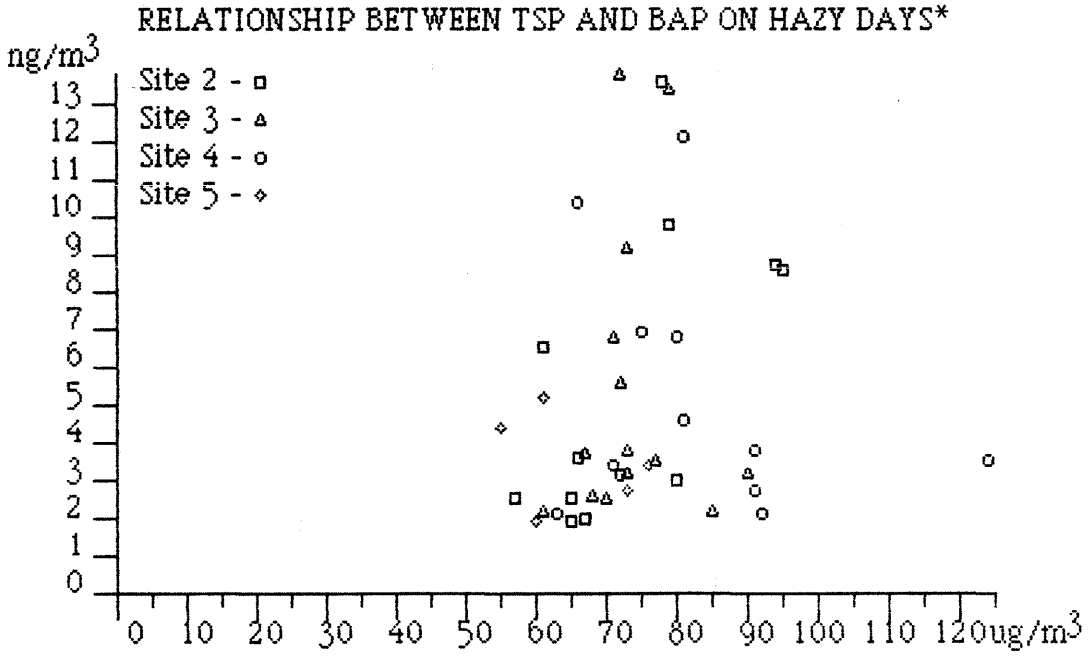


Figure IX



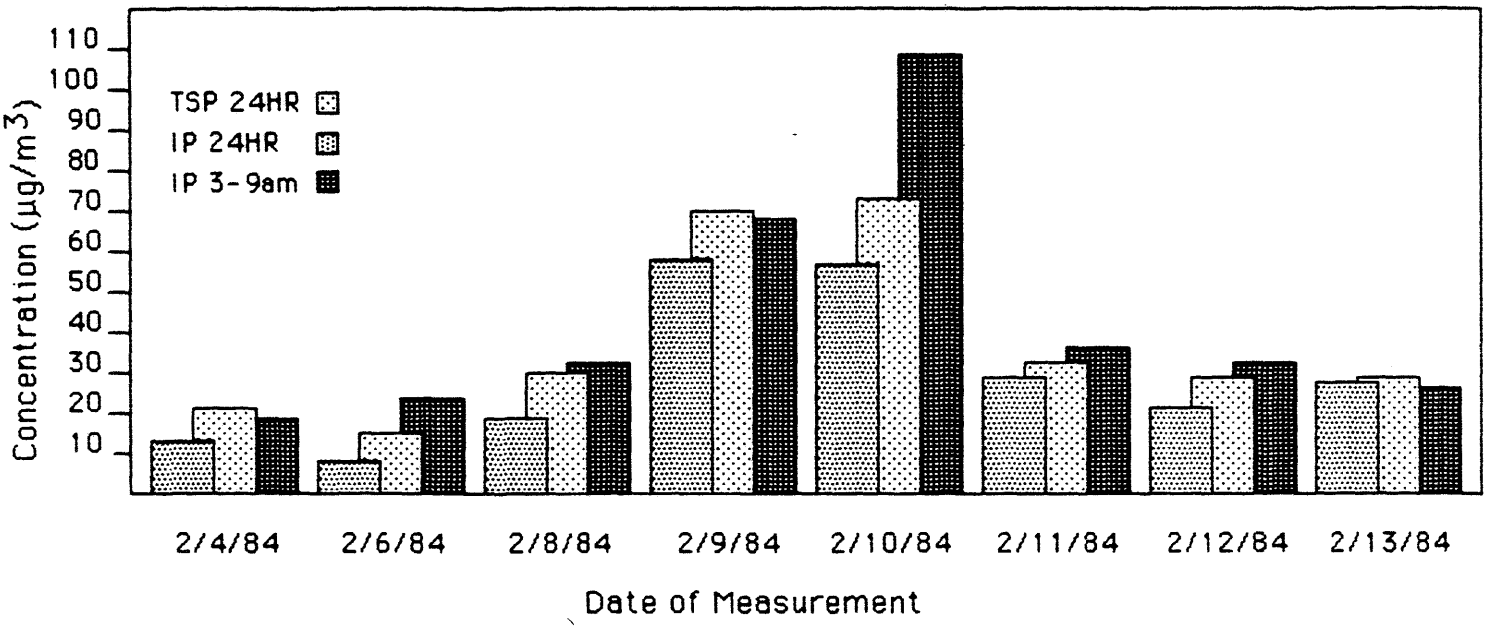
*Dates included: December 8 & 20, 1983
February 2, 9, 10, & 15, 1984
March 4, 10, & 25, 1984
April 3, 9, 21, 27, and 30, 1984

Table 9 : CONCENTRATIONS OF INHALABLE PARTICULATES IN ug/m^3

Sampling Date	24 Hour Concentration			< 24 Hour Concentration			
	Coarse / Fine	Total	Equiv. PM-10	Hours	Coarse / Fine	Total	Equiv. PM-10
2/4/84	1 / 12	13	10	3-9a	1 / 18	19	15
2/5/84	1 / 8	9	7	-	-	-	-
2/6/84	0 / 7	7	6	3-9a	10 / 13	23	18
2/7/84	2 / 14	16	13	-	-	-	-
2/8/84	2 / 17	19	15	3-9a	3 / 29	32	26
2/9/84	9 / 49	58	46	3-9a	4 / 64	68	54
2/10/84	6 / 50	56	45	3-9a	11 / 97	108	86
2/11/84	2 / 27	29	23	3-9a	3 / 33	36	29
2/12/84	3 / 18	21	17	3-9a	3 / 29	32	26
2/13/84	5 / 23	28	22	3-9a	7 / 20	27	22
2/14/84	4 / 21	25	20	-	-	-	-
2/15/84	8 / 39	47	38	15-24	13 / 43	56	45
2/16/84	8 / 14	22	18	15-24	9 / 10	19	15

Figure X

COMPARISON OF TSP AND IP CONCENTRATIONS AT SITE 003



SUMMARY

Based on the results of this study, residential woodburning appears to contibute significantly to pollutant levels in Michigan. Particulate levels were not high enough for the NAAQS to be exceeded in Mio, where woodburning is the principal source and background levels are quite low. But in other areas of Michigan, where there are other sources and consequently higher background levels, woodburning could put particulate levels over the NAAQS. And because a substantial portion of the particulate is smaller than 15 microns, the PM-10 standard may also be exceeded.

BAP levels were also high enough to raise concern. The concentrations measured in Mio were frequently greater than the one in a million risk level for cancer, Michigan's limit on industry. And BAP is only one of a host of potentially toxic compounds emitted from woodburning. The high levels of BAP may mean that significant levels of those other pollutants may be present as well.

ACKNOWLEDGEMENTS

I want to give special thanks to the people without whose assistance this project would not have been possible. Fellow staff members Ardon Toland, Janis Denman, Andrea Stewart, and Rich Alexander diligently changed filters and kept an eye on the CO analyzer. Jane Wei and Bob Nordlund provided lab support. Ken Smith, Dave Martin, Jim Brunk, and Dirk Lanting provided technical support. Pete Warner and his staff at the Wayne County Air Pollution Control Division conducted the analysis for benzo(a)pyrene. U.S. Forest Service technician Dave Kuhn operated the hygrothermograph and kept the met recorders operating. And my supervisor, John Schroeder, provided the graphics and kept me inspired.

I am especially thankful to the people who were gracious enough to let us locate our equipment on their property: Roger Moore (U.S Forest Service), Ernie Lucas (American Legion), Wayne Knepp (Oscoda County Courthouse), Dave Gordon (Gordon Funeral Home), and Gloid Money (Tri-Town Fire Department).

REFERENCES

1. "Fuelwood Use in Michigan Homes: 1982-83 Survey Results", Michigan Department of Natural Resources Forest Management Division, January 1984.

2. J. O. Jackson, P.O. Warner, and T. F. Mooney, Jr., "Profiles of Benzo(a)pyrene and Coal Tar Pitch Volatiles at and in the Immediate Vicinity of a Coke Oven Battery", American Industrial Hygiene Association Journal, May 1974, p. 276-281.

3. T. G. Pace and N. H. Frank, "Procedures for Estimating Probability of Nonattainment of a PM-10 NAAQS Using Total Suspended Particulate or Inhalable Particulate Data", U.S. Environmental Protection Agency, February 1984, p. 11-12.

APPENDIX A:

Door-to-Door Survey Form

WINTER WOODBURNING SURVEY

In an attempt to determine the effects of residential woodburning on air quality, a monitoring study is going to be conducted this winter. This survey will allow us to determine the number of households using wood to heat their homes. Your help in providing this information is appreciated.

Means of heating home: (more than one may apply)

Oil _____

Gas _____

Electricity _____

Coal _____

Wood _____

Other (please describe) _____

_____

_____

How would you rate your wood usage?

Primary source of heating _____ %

Supplemental source of heating _____ %

Recreation purposes _____ %

Type of wood heating device used: (more than one may apply, include model name)

Wood Stove _____

Wood Furnace _____

Fireplace _____

Fireplace Insert _____

Other (please describe) _____

_____

_____

Amount of wood normally used during the heating season (in face cords): _____

Type of wood used: _____

Is the effluent primarily smoke or steam? _____

Number of times each day you normally stoke your woodburning device: _____

Do you allow at least six (6) months for your wood to dry before burning it?

Yes _____ No _____

Number of times each year you clean the flue: _____

Is there a problem with creosote buildup? Yes _____ No _____

Explain: _____

_____

_____

Are you aware of catalyst and secondary combustion methods? Yes ____ No ____

Do you intend to add a woodburning device in the near future? Yes ____ No ____

Thank you for your cooperation.

APPENDIX B:

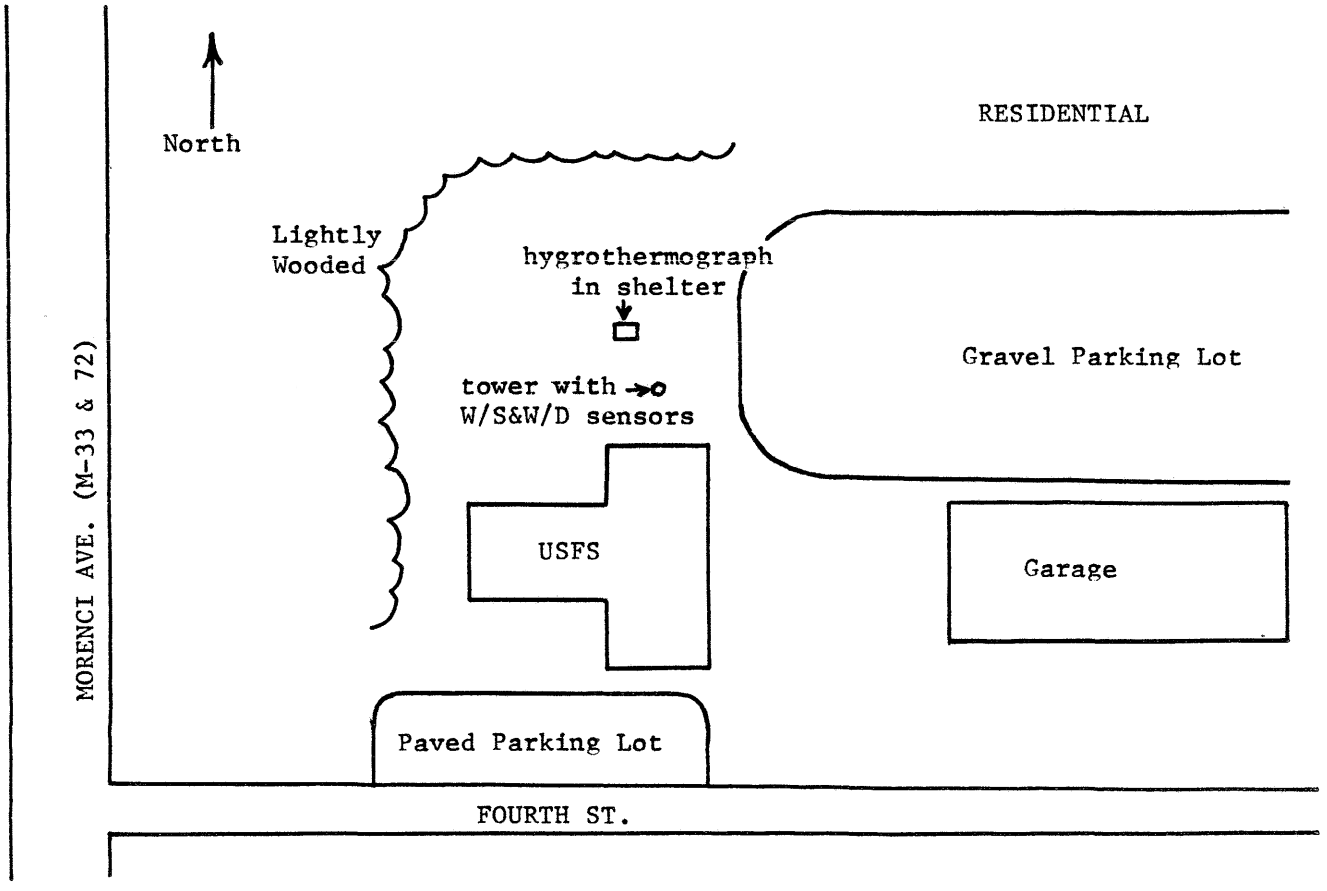
Detailed Site Information

DETAILED SITE INFORMATION

Site 001: U.S. Forest Service
Morenci and Fourth Streets
Mio

Equipment: Wind Speed Sensor
Wind Direction Sensor
Hygrothermograph -
temperature and humidity

The U.S. Forest Service District Headquarters (USFS) is located on the northeast corner of a heavily traveled county road and a residential street. To the north and west of the equipment, the area is lightly wooded with tall trees, including evergreens. It is relatively clear in other directions. A parking lot is immediately to the east and the garage and headquarters are to the south and southeast. In order to minimize the impact of the trees, the wind speed and wind direction sensors were located on the USFS tower at a height of approximately 60 feet. The hygrothermograph is housed in an instrument shelter at the foot of the tower.

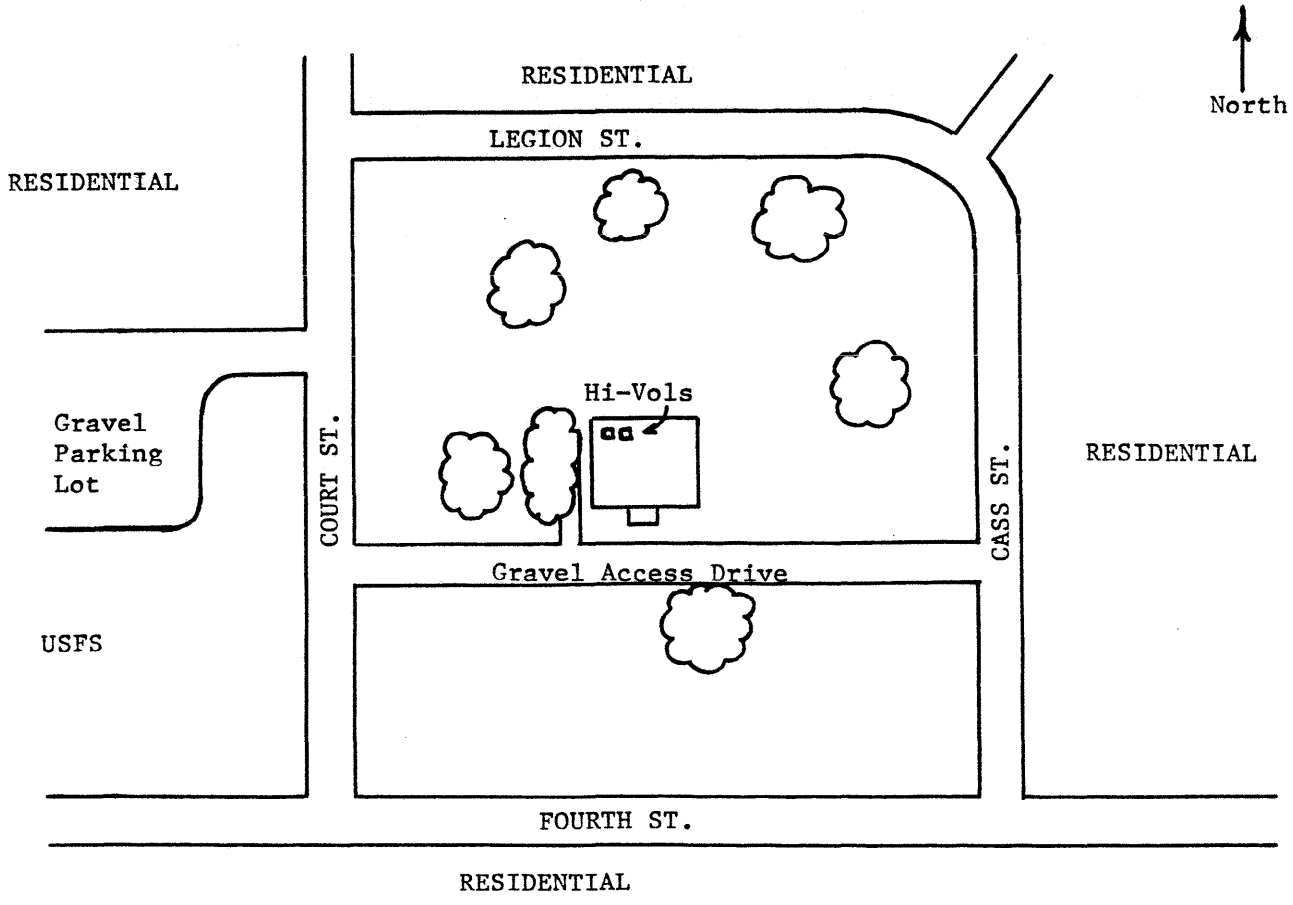


Site 002: American Legion Hall
Legion Drive
Mio

Equipment: 2 Hi-Vols

The American Legion Hall is located one block east of the U.S. Forest Service District Headquarters. The hi-vols were located on top of the one story building. It is the only structure in the middle of a small, grass-covered city block. A number of the households on the streets adjacent to this site rely on wood to meet most of their home heating needs, including the U.S. Forest Service.

This site met EPA siting criteria. There are a few scattered trees near the building, but their leaves were gone throughout the study. The residential streets surrounding the block are asphalt-covered with gravel shoulders. The access drive is gravel. But fugitive emissions could have had only a minimal impact on the samples because the streets were covered with snow during most of the study.



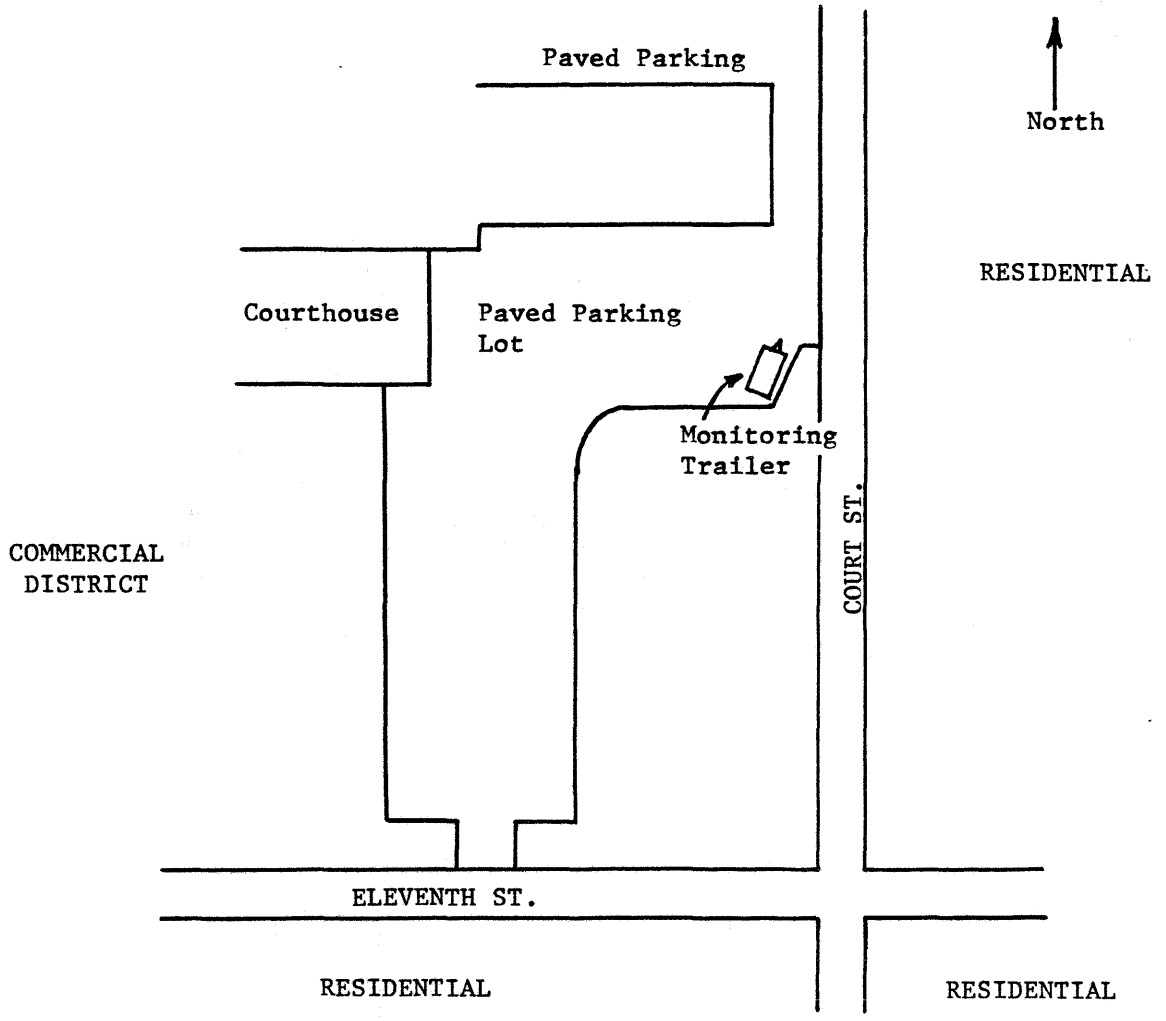
Site 003: Oscoda County Courthouse
311 Morenci Avenue
Mio

Equipment: 2 Hi-Vols
3 Dichotomous Samplers
Carbon Monoxide Analyzer

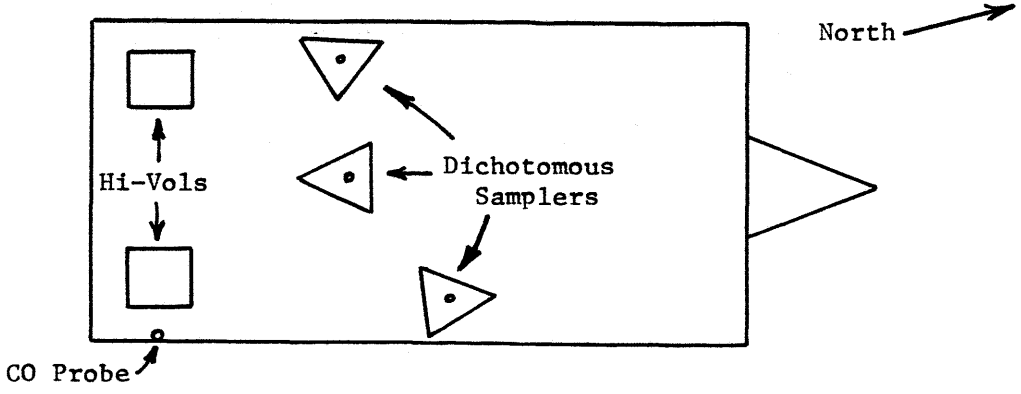
The monitoring trailer was located at the east end of the paved parking lot behind the Oscoda County Courthouse. The particulate monitors were on top of the trailer and the carbon monoxide analyzer was inside.

The Courthouse is located on the east side of a heavily traveled county road at one end of Mio's business district. Many of those businesses rely on wood for heating their buildings and use the same types of stoves and furnaces that homeowners use. Some of the residents immediately east and south of the Courthouse also rely on wood for home heating. Brooks Wood Products is approximately four blocks to the northwest.

This site met EPA siting criteria. To the north was a paved parking lot. To the east was Court Street, a lightly traveled paved road with gravel shoulders. To the south was Eleventh Street, a paved residential street with gravel shoulders, and an open grass-covered area next to a paved parking lot. The only obstruction to air flow was the three-story Courthouse 100 feet to the west. A few trees were within 65 feet of the trailer, but their leaves were gone throughout the study.



Top View of Trailer

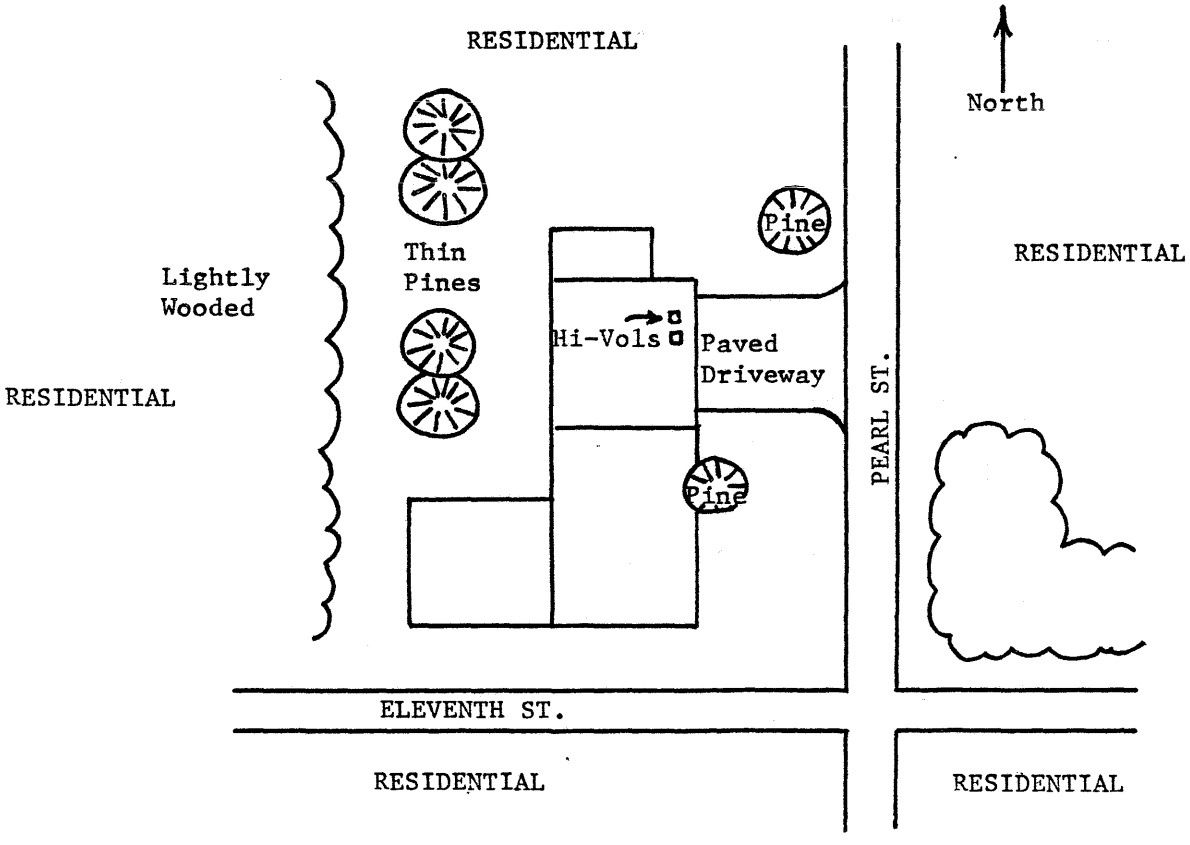


Site 004: Gordon Funeral Home
318 Pearl
Mio

Equipment: 2 Hi-Vols

Gordon Funeral Home is a one-story building located in the midst of a residential area. Several households rely on wood for home heating, including the ones immediately to the north and east. The funeral home uses electric heat. The hi-vols were located on the roof of the attached garage.

This site met EPA siting criteria. The funeral home is on the northwest corner of two paved residential streets with gravel shoulders. The only obstructions to air flow were a thick pine tree approximately 20 feet south-southeast of the monitors and a thin stand of pine trees approximately 40 feet to the west. There were a few other trees within 65 feet of the monitors, but their leaves were gone throughout the study. Brooks Wood Products is approximately two blocks north of the funeral home.



Site 005: Tri-Town Fire Department
Eleventh Street
Mio

Equipment: 2 Hi-Vols

The Tri-Town Fire Department is isolated from houses on the southwest edge of Mio. Most of the time background levels were measured at this site. But, because it was still in the valley, elevated levels were measured during stagnant periods.

This site met EPA siting criteria. Approximately 150 feet to the west is a heavily traveled county road; to the south is a lightly traveled local road. Both are paved with gravel shoulders. The monitors were located on the northwest corner of the building. There were no obstructions to air flow. A stand of trees is located to the north and west, but the nearest tree was 54 feet from the monitors. And the leaves on most of the trees were gone throughout the study.