Ambient PM2.5, PM10, and Lead Measurements in Cairo, Egypt

James E. Howes, Jr.,

Air Quality Monitoring Manager, Cairo Air Improvement Project, CH2M HILL International, Cairo, Egypt

Noha Samaha

Monitoring Systems Supervisor, Cairo Air Improvement Project, Chemonics Egypt, Cairo, Egypt

Mounir Labib

Air Monitoring Specialist, Cairo Air Improvement Project, Chemonics Egypt, Cairo, Egypt

Mohamed Sabry

The Egyptian Geological Survey and Mining Authority, Dokki, Giza, Egypt

Hesham El Araby

Center for Environmental Hazards Mitigation, Cairo University, Giza, Egypt

ABSTRACT

The Cairo Air Improvement Project (CAIP) is undertaking several pollution reduction initiatives to improve the air quality in the Greater Cairo Area. As part of CAIP, a monitoring program has been implemented to quantify the improvement of air quality achieved by these initiatives

The CAIP Air Quality Monitoring Program currently focuses on the measurement of particulate matter (PM) and lead. The monitoring network includes 36 sites located in industrial, residential, mixed land-use, highly trafficked, and background areas. Meteorological monitoring is performed at four of the PM monitoring sites.

Monitoring for PM2.5, PM10, and lead began on 1 September 1998. PM2.5, PM10, and lead data obtained during the first year of monitoring (September 1998–August 1999) will be used to establish baseline levels of these pollutants.

Results obtained during the first 4 months of the monitoring program indicate that PM2.5 and PM10 mass concentrations are generally high throughout the Greater Cairo Area. PM10 values obtained for all sampling events at all monitoring sites exceeded the Government of Egypt's (GOE) Law Number 4 of 1994 limit of 70μg/m^3 (24-hour average). The highest PM levels were found in industrial and heavily trafficked areas. The monitoring results suggest that control of particulate matter in Cairo may be a difficult problem.

Lead monitoring data indicates that lead levels in ambient air exceed the GOE's Law 4/1994 limit of 1 μg/m^3 (annual mean) in areas downwind of secondary lead smelters and in heavily trafficked areas. The highest mean and single sampling event lead levels were observed in the heavily industrialized areas of Shoubra el-Kheima and Tebbin. Ambient air lead concentrations were generally near or below the Law 4 limit of 1 μg/m^3 (annual mean).

KEY WORDS

Greater Cairo

Air quality monitoring

Lead

Particulate matter

PM2.5

PM10

Egypt's Environmental Law 4 for Year 1994

INTRODUCTION

Cairo has experienced a rapid rate of economic and technological development over the last 20 years. The industrial development, combined with rapid population growth, has led to an increase in the pollutants released into Cairo's air, water, and soil. The high pollution levels have raised major concerns for public health. Particulate matter and lead are two of the atmospheric pollutants in Cairo that can produce adverse health effects.

Previous studies conducted in the Cairo area showed high levels of airborne particulate matter (PM). A study conducted in 1982–83 reported annual average total suspended particulate (TSP) concentrations up to 567 $\mu g/m^3$ at industrial sites.[1] A 4-day average TSP concentration of 293 $\mu g/m^3$ at a background site and a 15-day average of 675 $\mu g/m^3$ in the city center were observed during a 1994 Source Apportionment Study.[2] PM10 concentrations measured during the Source Apportionment Study were 74 $\mu g/m^3$ (7-day average) at a background and 215 $\mu g/m^3$ (5-day average) at an industrial site. The 4-day average of the PM2.5 concentration measured at the background site was 24.9 $\mu g/m^3$ and the 5-day average observed at a city center site was 81 $\mu g/m^3$.

Comparative data reported in 1992 showed that ambient air lead levels in Cairo are generally higher than in nine major cities in developing Asian Pacific and South/Central American countries.[3] Several studies have documented elevated lead levels in the blood of Cairo school children and traffic police.[4] In a recent study, ambient airborne lead levels as high as 17 $\mu g/m^3$ were measured in the industrialized area of Shoubra el-Kheima.[5] The maximum lead level measured at traffic sites during the same study, which was conducted

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[1] Hindy, K. T., S. A. Farag, and N. M. EL-Taeb, 1989.
[2] Rodes et al, 1996.
[3] Hindy, K. T., S. A. Farag, and N. M. EL-Taeb, 1989.
[4] Rodes et al, 1991/1992, and WHO and UNEP, 1992.

prior to the removal of lead from gasoline, was 3.4 $\mu g/m^3$. The lead levels measured at all industrial sites and most of the traffic sites during this study exceeded the World Health Organization (WHO) standard of $1\mu g/m^3$. Earlier studies have reported ambient air lead levels in the range of 2.8–12.5 $\mu g/m^3$ in Cairo residential areas and in the range of 10–50 $\mu g/m^3$ in industrial areas.[6] A mean ambient air lead concentration of 86 $\mu g/m^3$ was obtained during monitoring performed in the El-Waily district of Cairo.[7]

Unfortunately, the duration of the previous PM and lead monitoring programs and the limited number of sites at which monitoring was performed precludes establishment of accurate baselines and characterization the temporal and spatial trends in ambient airborne levels of these pollutants in the Cairo area.

The goal of the Cairo Air Improvement Project is to reduce air pollution, especially suspended PM and lead, in the Greater Cairo Area. The pollution abatement initiatives being pursued by the project include establishing a vehicle emission testing, tune-up, and certification program; introducing compressed natural gas (CNG)-fueled buses into the public transportation system; and redesigning and relocating secondary lead smelters. An air quality monitoring capability has been developed to assess air quality improvement resulting from the CAIP initiatives and other abatement measures being implemented by the EEAA.

This paper describes the CAIP air quality monitoring program and presents PM and lead data obtained during the first 4 months of the monitoring effort. Data obtained during the first year of the monitoring program will be used to establish baseline fine particulate

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[5] Egyptian Environmental Affair Agency, Technical Cooperation Office for the Environment, 1996.
[6] Chappell, F., P. Billig, E. P. Brantly, S. Ault, and H. S. Ezzeldin, 1997.
[7] *Environmental Data Report*, Third Edition, United Nations Environmental Programme.

matter and lead levels and define spatial and temporal patterns of these pollutants. Sustained monitoring will be performed to assess the efficacy of CAIP and other pollution mitigation initiatives in reducing levels of these pollutants in the Greater Cairo Area.

AMBIENT AIR MONITORING NETWORK

The CAIP air quality monitoring network consists of 36 stations located throughout the Greater Cairo Metropolitan Area. The map shown in Figure 1 indicates the geographical location of the monitoring stations. The numbers assigned to the sites, the site type, and the district and governorate in which each station is located are listed in Table 1. The numbers beside the site locations in Figure 1 are referenced to site numbers shown in Table 1.

The site type is designated according to the primary land use in the vicinity of the monitoring station. The site types are divided into the following categories: residential; mixed commercial/residential or industrial/residential; industrial; source; traffic; and background. The stations within the industrial areas have been located to maximize the ability to monitor the impact of emissions from nearby lead processing facilities. The two source sites (Nos. 17 and 24) are located immediately downwind of secondary lead smelters, and provide measurements of fugitive emissions from these facilities. The two background sites are located in a northerly direction from Cairo and these sites typically provide PM measurements of the air mass prior to introduction of the pollutants generated in the Greater Cairo Area.

PARTICULATE MATTER AND LEAD MONITORING PROCEDURES

PM and lead samples are collected using AIRmetrics samplers. Twenty-six sites have samplers for collecting both PM2.5 and PM10 samples. Only PM10 samples are collected at 10 sites. The last three columns of Table 1 indicate the monitoring equipment deployed at

each of the monitoring sites.

The PM samples are collected concurrently at all monitoring stations by sampling for a 24-hour period (0000–2400 hours) every sixth day. The mass of particulate matter collected is determined by weighing the quartz fiber filters on a microbalance before and after sample collection. Prior to weighing, the filters are pre-conditioned at constant temperature and humidity. Lead (Pb) in the filter catch is determined by digestion of the filter in nitric acid and measurement of the lead content in the digestate by flame atomic absorption spectrometry (FAAS).[8] Field sampling operations and laboratory analysis of the filter samples are performed through contractual arrangements with Cairo University's Center for Environmental Hazard Mitigation (CEHM) and The Egyptian Geological Survey and Mining Authority, respectively.

Meteorological measurements are performed at four monitoring sites indicated in the last column of Table 1. Wind speed (WS), wind direction (WD), ambient temperature (AT), and barometric pressure (BP) are measured at each site. Solar radiation (SR) is measured at the two background sites (Nos. 15 and 26). Meteorological data are being collected to permit correlation of PM levels and wind characteristics and to develop a database for future dispersion modeling application.

QUALITY ASSURANCE

Quality control (QC) and quality assurance (QA) procedures are incorporated into both the field operations and the laboratory analysis to ensure collection of high quality monitoring data. QC procedures included in the sample collection operations are quarterly multi-point flow calibrations and pre- and post-sampling flow checks. Field blanks are collected to

measure any contamination deposited on filters while the samplers are in a passive mode, i.e. the period when the filters are installed, but an air sample is not being pulled through them.

Laboratory QC procedures performed during the gravimetric analyses include calibration of the microbalances with Class S weights before each weighing session, periodic zero and calibration checks during weighing sessions, duplicate tare and final weighing of all filters, and weight checks by a second analyst.

Laboratory QC procedures performed during the lead analyses include multi-point calibration of the FAAS system, analysis of reagent and method blanks, analysis of continuing calibration standards and blanks, replication of sample analysis, and analysis of matrix-spiked samples.

All field operation and laboratory analysis data are subjected to rigorous analysis and validation procedures prior to reporting the monitoring results.

Quality assurance performance audits are performed at least quarterly to assess the accuracy of the AIRmetrics sampler flow rates and the microbalances used for weighing filters. The accuracy and precision of the lead analyses are determined by submitting sets of filters containing known quantities of lead to the analytical laboratory. At two sites, samples are collected with collocated PM2.5 and PM10 samplers to determine the overall precision of the particulate matter measurement method.

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[8] "Reference Method for the Determination of Lead in Suspended Particulate Matter Collected From Ambient Air," *40 Code of Federal Regulation*.

RESULTS AND DISCUSSION

PM2.5 and PM10 Measurements

Figure 2 shows the mean PM2.5 and PM10 mass concentrations measured at the 34 ambient monitoring sites during the period of September–December 1998. Sites of like land-use type are grouped together in the figure and the numbers of the sites at which the measurements were obtained are shown over the bars (see Table 1 for site information). In general, relatively high mean PM2.5 and PM10 concentrations (>150 $\mu g/m^3$) were observed at all monitoring sites. The highest mean PM levels were observed at industrial sites (Site Nos. 19 and 20) in the Shoubra el-Kheima area.

The monthly and September–December mean PM concentrations for the various site types are presented in Table 2. The September–December mean PM2.5 and PM10 levels for the various site types are shown graphically in Figure 3. The PM levels were the lowest during September and increased during the following 3 months with the highest mean levels generally occurring during December. For the 4-month period, mean respective PM2.5 and PM10 concentrations ranged from high values of 165 $\mu g/m^3$ and 311 $\mu g/m^3$ at industrial sites to lower values of 131 $\mu g/m^3$ and 261 $\mu g/m^3$ at the background sites. The mean PM2.5 and PM10 levels for all sites are 131$\mu g/m^3$ and 261 $\mu g/m^3$, respectively. Maximum PM2.5 and PM10 levels measured during single sampling events over the 4-month period were 447 $\mu g/m^3$ and 858 $\mu g/m^3$, respectively.

Table 3 provides a summary of the September–December mean PM2.5 and PM10 levels with the sites listed according to decreasing mean PM10 concentration. Maximum and minimum PM2.5 and PM10 levels measured at the various sites during the 4-month monitoring period are also shown in the table. The highest mean PM2.5 and PM10 levels were measured at two sites (Nos. 20 and 19) located in the heavily industrialized area of

Shoubra el-Kheima. Industries in the vicinity of these monitoring sites include a steel mill, ceramics plant, and numerous ferrous and non-ferrous metal smelters and foundries. Site No. 34 is located in El-Massara in the nominally downwind direction from a major cement plant. Site Nos. 1, 9, and 2 are located in heavily trafficked areas in the central part of Cairo (El-Qualaly Square, Ramses Square, and Gomhuriya Street, respectively). PM2.5 and PM10 levels at the remainder of the sites ranged from 145 $\mu g/m^3$ to 78 $\mu g/m^3$ and 303 $\mu g/m^3$ to 156 $\mu g/m^3$, respectively.

The mean PM2.5/PM10 ratio calculated from paired PM2.5 and PM10 measurements at the various sites ranged from 0.44 to 0.62. Variation in the ratio, as indicated by the standard deviation, was approximately the same for all sites. The mean ratio calculated from monitoring data obtained at all sites during the 4-month period is 0.55 ± 0.16.

Lead Measurements

The mean lead concentrations measured at the 34 ambient monitoring sites during the period of September–December 1998 are shown in Figure 4. Sites of like type are grouped together in the figure and the numbers of the sites from which the measurements were obtained are shown over the bars (See Table 1 for site information). The highest mean lead concentrations were observed at Sites Nos. 18, 19, and 20, which are located in the Shoubra el-Kheima area. Mean lead levels exceeding 1 $\mu g/m^3$ were observed at most of the mixed land use and traffic sites. Mean lead levels measured at residential sites were generally at or below 1 $\mu g/m^3$.

The monthly and September–December mean PM2.5 and PM10 lead concentrations for the various site types are presented in Table 4. The September–December mean PM10 lead levels for the various site types are shown graphically in Figure 5. The September–

December mean PM10 lead concentration (10.2 $\mu g/m^3$) are the highest for the sites located in industrial areas. The mean PM10 lead levels for traffic and mixed land use sites are approximately 3 $\mu g/m^3$ and 2.5 $\mu g/m^3$, respectively. The mean PM10 lead levels are approximately 1 $\mu g/m^3$ for the residential site group and below 1 $\mu g/m^3$ for the background site group. Mean lead levels for the industrial and traffic site groups are the highest in October and show less variation during the other three months. Mean lead levels for the mixed, residential, and background sites do not exhibit a large variation during the 4-month period.

A summary of the lead data obtained during the period September–December 1998 is provided in Table 5. In the table, monitoring sites and associated data are arranged in order of decreasing mean PM10 lead level (Column 6) measured at the sites during the 4-month monitoring period. The maximum lead concentration measured at each of the sites during the 4-month period is shown in the last column of the table.

The four sites (Nos. 18, 19, 20, and 23) at which the highest means and single sampling event lead levels were observed are in the heavily industrialized areas of Shoubra el-Kheima and Tebbin. Site Nos. 18 and 19, in the Shoubra el-Kheima area, are nominally downwind from a complex of secondary lead smelters. The mean and maximum lead levels measured at these sites were about 20 $\mu g/m^3$ and 79 $\mu g/m^3$, respectively. Sites 1, 9, and 2 are located in areas of high motor vehicle traffic in the central part of the city. The mean lead level at these traffic sites was about 4 $\mu g/m^3$, and the maximum levels ranged from approximately 10–20 $\mu g/m^3$. Of the remainder of the sites, the mean lead concentrations were between 2–3 $\mu g/m^3$ at three sites; between 1–2 $\mu g/m^3$ at 16 sites; and below 1 $\mu g/m^3$ at eight sites.

The mean ratios of lead in the PM2.5 and PM10 size fractions in samples collected at the various sites ranged from 0.66 to 0.88 and the within-site variation, as indicated by the standard deviation, was approximately the same. There is no discernable difference between PM2.5/PM10 lead ratios observed at the ambient sites and the two sites (Nos. 17 and 24) that measure fugitive emissions from secondary lead smelters. The mean PM2.5/PM10 lead ratio calculated from monitoring data obtained at all sites during the 4-month period is 0.76 ± 0.11.

CONCLUSIONS

PM2.5 and PM10 Measurements

One of the most significant features of the PM data is the relatively high mass concentrations measured at all monitoring sites in Cairo. PM10 values obtained for all sampling events at all monitoring sites during the September–December monitoring period exceeded the GOE Law 4/1994 limit of $70\mu g/m^3$ (24-hour average).[9] The highest PM levels were found in industrial and heavily trafficked areas. However, even the lowest mean PM 10 levels that were observed at the outlying cities of 10^{th} Ramadan and 6^{th} October and the background sites at Kaha and Beilbeis are more than twice the Law 4 limit.

The PM2.5/PM10 ratio data suggests that naturally occurring geologic material comprises a significant fraction of the mass concentrations. Typically, particulate matter in motor vehicle emissions are highly concentrated in the PM2.5 size fraction. However, the PM2.5/PM10 ratios at the Cairo traffic sites were approximately the same as those observed at all other sites. The traffic site data and the relative uniformity in the PM2.5/PM10 ratios at all sites indicates the presence of a significant fraction of naturally occurring particulate matter in Cairo's air. Due to the arid nature of the Cairo area, which

typically receives about 1 inch of rainfall per year, it is not surprising that there are high levels of airborne PM that originates from natural sources.

Thus far, the data collected during the CAIP monitoring program indicates that control of fine PM in Cairo may be a difficult problem. A source apportionment study, currently being conducted in Cairo by CAIP, will permit attribution of the PM to various sources.[10] It will then be clearer what control measures are appropriate to reduce fine PM levels, and what level of control can be achieved. However, current background site data indicates that compliance with the current GOE Law 4 PM10 limit of 70$\mu g/m^3$ will be very difficult, if not impractical.

Lead Measurements

Law Number 4/Year 1994 specifies a limit of 1$\mu g/m^3$ (annual mean) for lead in ambient air. It is evident, from the monitoring results reported in this paper, that annual mean lead levels in some areas of Cairo will exceed the Law 4 limit. The highest ambient air lead concentrations result from secondary lead smelter emissions.

The source(s) of high lead levels at heavily trafficked sites is less clear. One source may be roadway dust containing lead from the leaded gas era that is re-suspended in the air by the wind and anthropogenic activities. Another possible source is the emissions from vehicles still using leaded gasoline. Although leaded gas is not sold in Cairo, it is still sold in some of the Egyptian governorates. The use of leaded gasoline in Egypt will be completely phased out in the year 2000. However, the arid climate is likely to cause elevated lead levels to persist near roadways for some time due to re-suspension of lead-bearing dust.

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[9] GOE Law for the Environment, 1994.

[10] Gertler, A. W., D. H. Lowenthal, J. E. Howes, Jr., J. C. Sagebiel, M. W. Labib, M. Abu-Allaban, and N. Samaha, 1999.

The GOE is taking action to eliminate the lead problem in Cairo through implementation of the LEAP.[11] A major component of LEAP is the LSAP.[12] CAIP is playing a major role in implementation of the LSAP by assisting a major producer in the greater Cairo area with design and construction of a new secondary leader smelter with state-of-the-art emission control and material handling systems at a site remote from densely populated residential areas. CAIP is also assisting smaller smelters to reduce lead emissions through use of process modifications and/or installation of emission control systems.

[11] O'Toole, L. J., E. P. Brantly, P. Billig, and J. A. Phoenix, 1997, and O'Toole, L. J., J. A. Phoenix, and M. W. Gamaleldin, 1996.

[12] Egyptian Environmental Affair Agency, Technical Cooperation Office for the Environment, 1997.

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DISCLAIMER

The opinions and conclusions stated in this paper are those of the authors and do not necessarily represent those of USAID, EEAA, OEP, or any of the consulting organizations associated with the conduct of the Cairo Air Improvement Project. Any reference to trade names does not constitute an endorsement of the product.

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Table 1. CAIP Air Quality Monitoring Sites

Site No.	Site Type[a]	District	Governorate	Monitoring Equipment[b]		
				PM2.5	PM10	Met
1	Traffic	Boulak	Cairo	X	X	
2	Traffic	Azbakia	Cairo	X	X	
3	Residential	El-Waily	Cairo	X	X	
4	Residential	Nasr City	Cairo	X	X	
5	Traffic	Old Cairo	Cairo		X	
6	Residential	Maadi/ Digla	Cairo	X	X	
7	Industrial	Tebbin	Giza	X	X	
8	Mixed	Old Cairo	Cairo	X	X	
9	Traffic	Azbakia	Cairo		X	
10	Residential	Old Maadi	Cairo	X	X	X
11	Residential	Giza	Giza	X	X	
12	Residential	El-Darb el-Ahmer	Cairo		X	
13	Residential	6th October	Giza	X	X	
14	Residential	10th Ramadan	Sharkiya	X	X	
15	Background	Beilbeis	Sharkiya	X	X	X
16	Residential	Mokatom	Cairo		X	
17	Source	Shoubra el-Kheima	Qaliobiyya	X	X	
18	Industrial	Shoubra el-Kheima	Qaliobiyya	X	X	
19	Industrial	El-Sahel	Cairo	XC	XC	
20	Industrial	Shoubra el-Kheima	Qaliobiyya	X	X	
21	Residential	El-Mataria	Cairo	X	X	
22	Mixed	El-Waily	Cairo		X	
23	Mixed	Tebbin	Cairo	X	X	

[a] Mixed: site located in a mixed industrial/residential, commercial/residential, or traffic/residential area.
[b] XC indicates that there are collocated samplers at the site.

Site No.	Site Type[a]	District	Governorate	Monitoring Equipment[b]		
				PM2.5	PM10	Met
24	Source	Tebbin	Cairo	XC	XC	X
25	Residential	Imbaba	Cairo		X	
26	Background	Kaha	Qaliobiyya	X	X	X
27	Residential	15th May	Cairo		X	
28	Commercial/ Residential	Almaza	Cairo		X	
29	Mixed	El-Basatin	Cairo		X	
30	Mixed	Giza	Giza		X	
31	Mixed	El-Abdeen	Cairo	X	X	
32	Residential	Zamalek	Giza	X	X	
33	Residential	Helwan	Cairo	X	X	
34	Mixed	El-Massara	Cairo	X	X	
35	Residential	Heliopolis	Cairo	X	X	
36	Industrial	Abbasiya	Cairo	X	X	

Table 2. Mean Monthly and September–December PM2.5 and PM10 Levels

Site Type	Mean Particulate Matter Concentration, μg/m³								September - December, 1998			
	September		October		November		December		PM2.5, μg/m³		PM10, μg/m³	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	Mean	Max	Mean	Max
Industrial	141.2	251.1	191.8	346.8	154.3	300.6	165.3	331.9	165.4	446.7	311.6	674.2
Traffic	124.3	242.5	164.7	257.9	154.1	284.6	173.0	347.5	154.4	269.9	288.8	703.3
Mixed	114.7	215.6	127.5	251.4	122.8	273.8	164.9	339.8	134.1	332.5	270.0	858.3
Residential	95.3	201.0	116.0	218.0	112.9	225.5	124.9	280.7	114.3	281.9	234.2	821.9
Background	71.2	154.4	136.9	214.6	94.1	164.0	93.7	219.7	100.3	219.0	189.8	437.8
All	110.3	217.8	137.5	250.1	126.7	253.0	141.4	309.8	131.1	446.7	260.9	858.3

Table 3. Summary of Ambient PM2.5 and PM10 Levels at CAIP Monitoring Sites, September–December 1998

Site No.	Site Type	PM2.5 Concentration, μg/m³			PM10 Concentration, μg/m³		
		Mean	Max	Min	Mean	Max	Min
20	Industrial	220.8	446.7	122.1	373.3	648.6	206.0
19	Industrial	189.4	269.4	120.8	358.4	674.2	204.6
34	Mixed[a]	137.1	271.9	69.6	328.7	707.1	171.5
1	Traffic	147.0	284.7	101.8	313.9	681.7	196.9
9	Traffic	[b]			306.2	703.3	111.9
2	Traffic	160.6	296.9	84.0	304.5	649.6	200.7
8	Mixed	145.3	332.5	40.0	302.5	858.3	126.5
7	Industrial	129.3	200.6	65.3	299.1	596.5	120.5
18	Industrial	159.0	259.7	75.7	293.8	658.5	126.0
29	Mixed	[b]			287.2	795.8	117.1
21	Residential	126.8	261.1	46.1	285.9	821.9	110.1
22	Mixed	[b]			280.0	626.1	104.3
12	Residential	[b]			279.7	684.7	162.4
33	Residential	119.6	220.4	37.1	278.2	578.9	112.1
31	Mixed	141.4	292.5	55.0	270.9	637.9	162.0
6	Residential	112.9	281.9	38.6	263.3	639.6	93.2
3	Residential	129.8	236.6	41.7	260.5	515.1	138.9
16	Residential	[b]			254.6	428.9	116.3
23	Mixed	114.2	209.0	38.7	234.9	409.8	127.6
28	Mixed	[b]			231.5	576.5	126.3
32	Residential	139.2	250.8	74.9	231.3	521.1	130.8
11	Residential	136.7	272.2	73.9	230.6	474.2	113.1

[a] Sites where surrounding land use is a mixture of residential and commercial, industrial., or high vehicle traffic areas.

[b] PM2.5 measurements are not performed at these sites.

Site No.	Site Type	PM2.5 Concentration, μg/m³			PM10 Concentration, μg/m³		
		Mean	Max	Min	Mean	Max	Min
36	Industrial	119.3	215.4	44.4	227.6	518.1	105.1
25	Residential	[b]			227.5	423.2	104.4
10	Residential	117.1	240.9	38.6	224.7	509.1	130.8
4	Residential	107.5	207.9	50.7	224.3	414.3	100.4
30	Mixed	[b]			222.8	530.2	108.8
5	Traffic	[b]			219.6	431.0	109.4
27	Residential	95.7	160.5	36.2	213.6	372.9	109.5
35	Residential	112.2	210.6	46.5	207.0	408.9	113.6
15	Background	107.8	219.0	37.4	193.3	306.9	135.6
26	Background	94.2	203.6	36.1	186.6	437.8	113.9
13	Residential	78.2	146.4	28.9	172.4	247.8	109.2
14	Residential	77.5	123.3	32.6	156.0	206.1	100.4

Table 4. Mean Monthly and 4-Month Lead Levels by Site Type

Site Type	Mean Lead Matter Concentration, μg/m³								September - December, 1998			
	September		October		November		December		PM2.5, μg/m³		PM10, μg/m³	
	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	PM2.5	PM10	Mean	Max	Mean	Max
Industrial	7.3	9.0	14.4	21.2	4.2	5.4	5.1	6.0	7.8	56.3	10.2	79.8
Traffic	1.9	2.4	3.7	5.0	2.4	2.5	2.1	2.2	2.6	8.2	3.1	20.7
Mixed	1.7	1.7	1.4	1.8	1.8	1.8	3.6	3.4	2.0	27.8	2.0	31.1
Residential	0.5	0.8	0.7	1.4	0.6	1.1	1.3	1.9	0.8	6.5	1.3	23.6
Background	0.3	0.4	0.3	0.3	0.2	0.2	0.7	1.1	0.4	2.6	0.5	4.2
All	2.4	2.5	3.7	4.2	1.7	2.0	2.5	2.7	2.6	56.3	2.9	79.8

Table 5. Summary of Ambient Air Lead Measurements–PM10 Size Fraction

Site No.	Site Location	Site Type	Lead in PM10 Size Fraction, µg/m³					
			Sep	Oct	Nov	Dec	Mean	Max
19	El-Sahel	Industrial	17.0	39.9	9.8	8.9	20.8	78.9
18	Shoubra el-Kheima	Industrial	21.3	32.1	8.5	12.3	18.6	79.8
20	Shoubra el-Kheima	Industrial	2.3	9.0	6.1	5.9	5.8	20.9
23	Tebbin	Mixed	3.4	2.1	4.0	8.0	4.2	31.1
1	Boulak	Traffic	3.9	5.1	2.9	3.0	4.0	13.5
9	Azbakia	Traffic	1.1	7.1	3.4	2.3	3.9	20.7
2	Azbakia	Traffic	3.0	5.3	2.9	2.7	3.4	9.5
31	El-Abdeen	Mixed	2.7	2.9	2.5	1.8	2.5	7.6
7	Tebbin	Industrial	1.9	6.4	2.4	0.7	2.4	15.1
12	El-Darb el-Ahmer	Residential	1.0	2.4	1.9	3.3	2.2	8.3
16	Mokatom	Residential	(a)[a]	0.8	2.1	3.2	2.0	9.6
22	El-Waily	Mixed	2.4	1.7	1.2	2.0	1.8	10.7
29	El-Basatin	Mixed	0.6	2.0	1.8	2.7	1.8	6.3
36	Abbasiya	Industrial	1.4	3.2	0.8	2.2	1.8	7.4
32	Zamalek	Residential	2.5	0.8	1.9	1.3	1.7	6.9
3	El-Waily	Residential	0.9	2.1	1.0	2.6	1.6	7.1
34	El-Massara	Mixed	0.4	0.8	0.8	3.7	1.5	8.4
30	Giza	Mixed	2.0	1.7	1.3	0.9	1.5	4.8
10	Old Maadi	Residential	0.4	1.6	0.8	3.2	1.4	4.9
8	Old Cairo	Mixed	1.0	1.9	1.6	0.3	1.4	4.4
6	Maadi/Digla	Residential	0.3	0.9	1.0	3.3	1.4	7.5
11	Giza	Residential	1.7	1.0	1.5	1.3	1.3	3.1
33	Helwan	Residential	0.4	0.7	1.1	2.8	1.3	6.1
21	El Mataria	Residential	0.2	2.0	0.7	1.4	1.2	6.8

[a] Data were not collected at this site during September.

Site No.	Site Location	Site Type	Lead in PM10 Size Fraction, $\mu g/m^3$					
			Sep	Oct	Nov	Dec	Mean	Max
5	Old Cairo	Traffic	0.3	1.5	1.1	1.3	1.2	4.3
25	Imbaba	Residential	1.2	0.8	1.6	1.1	1.1	4.8
28	Almaza	Mixed	0.3	1.2	0.8	1.6	1.0	4.9
4	Nasr City	Residential	0.2	0.7	1.0	1.7	0.9	5.3
27	15th May	Residential	0.3	0.3	0.9	1.6	0.8	4.7
35	Heliopolis	Residential	0.2	6.0	0.2	2.1	0.7	3.8
15	Beilbeis	Background	0.2	0.4	0.2	1.3	0.6	2.9
26	Kaha	Background	0.5	0.2	0.2	1.0	0.5	4.2
14	10th Ramadan	Residential	0.3	0.2	0.3	0.4	0.3	0.7
13	6th October	Residential	0.20	0.2	0.2	0.2	0.2	0.4

Figure 1. CAIP Monitoring Sites in the Greater Cairo Area

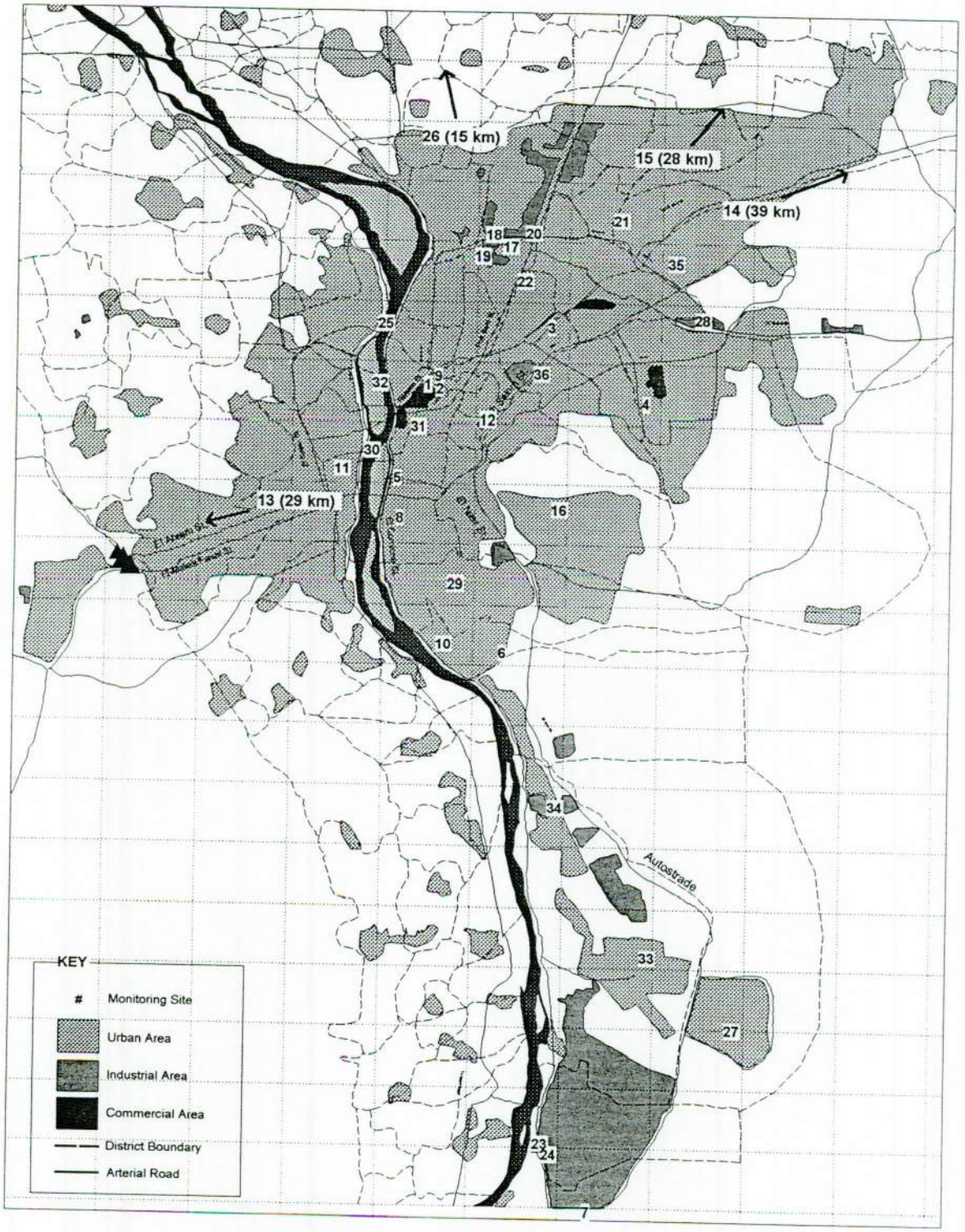
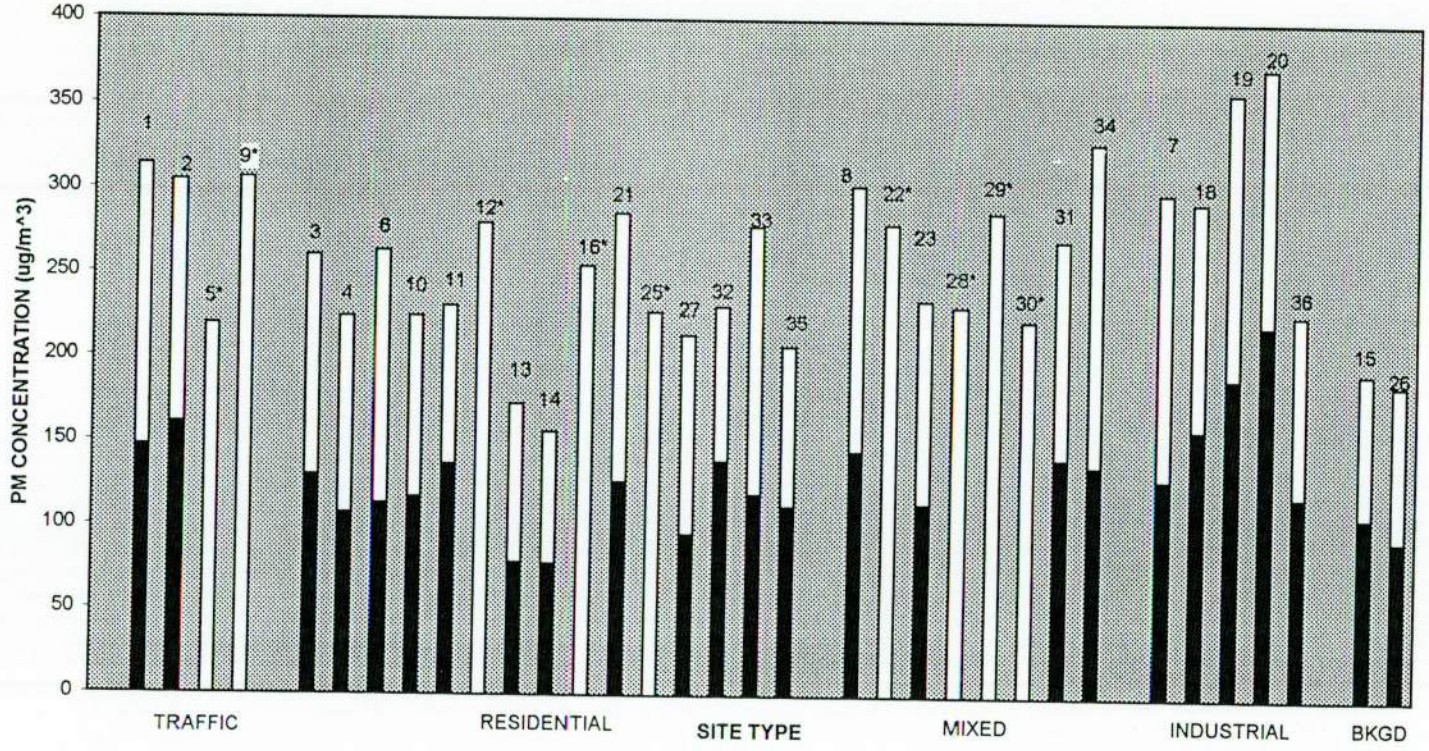


Figure 2
MEAN AMBIENT PARTICULATE MATTER CONCENTRATION ACCORDING TO SITE TYPE
SEPTEMBER - DECEMBER 1998

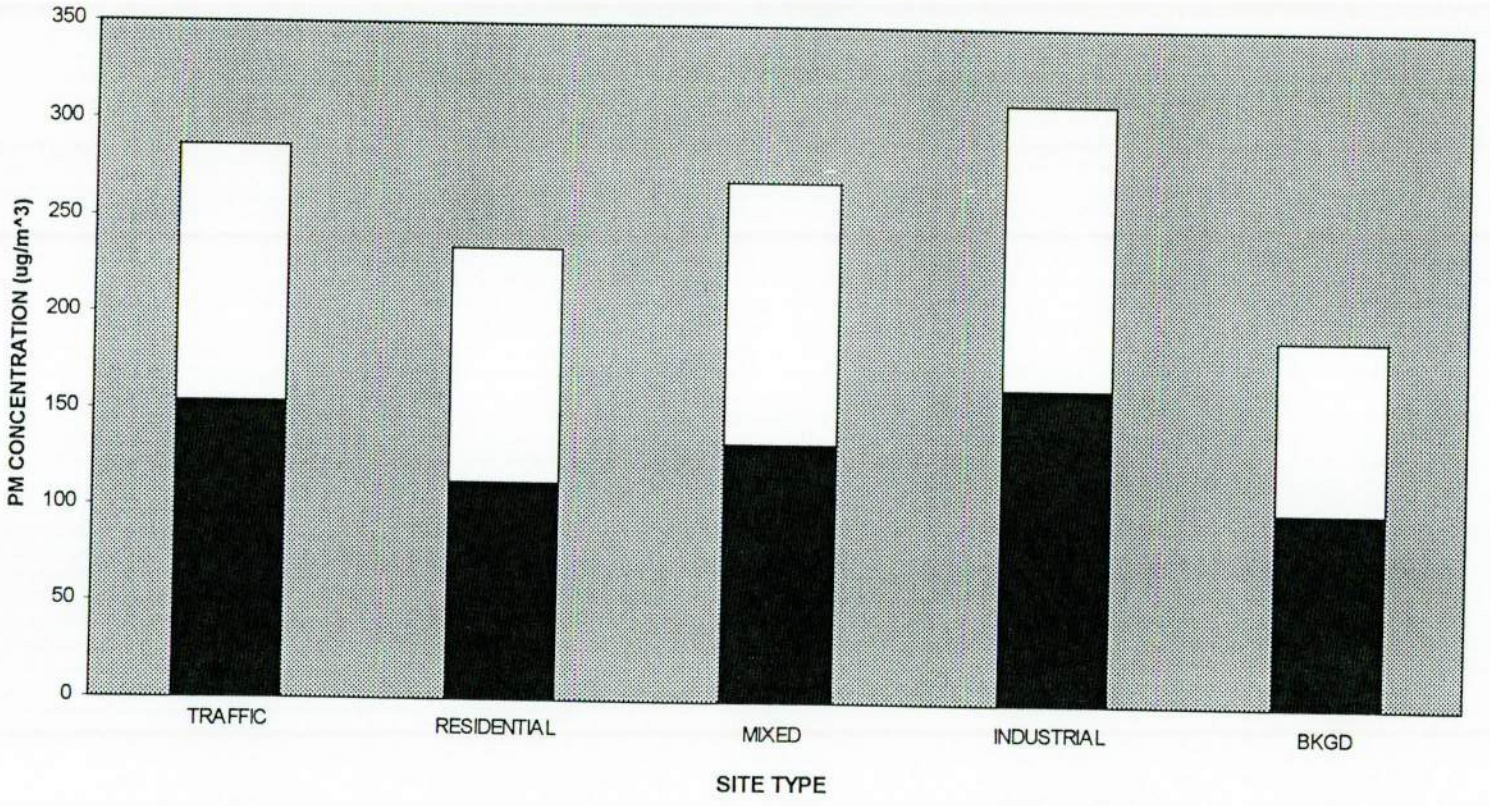


Black Only = PM2.5
Black plus White - PM10
White Only = PM10

* - PM2.5 measurement not performed at these sites

GOE Law 4 PM10 standard is 70 $\mu g/m^3$ (24-hr average)

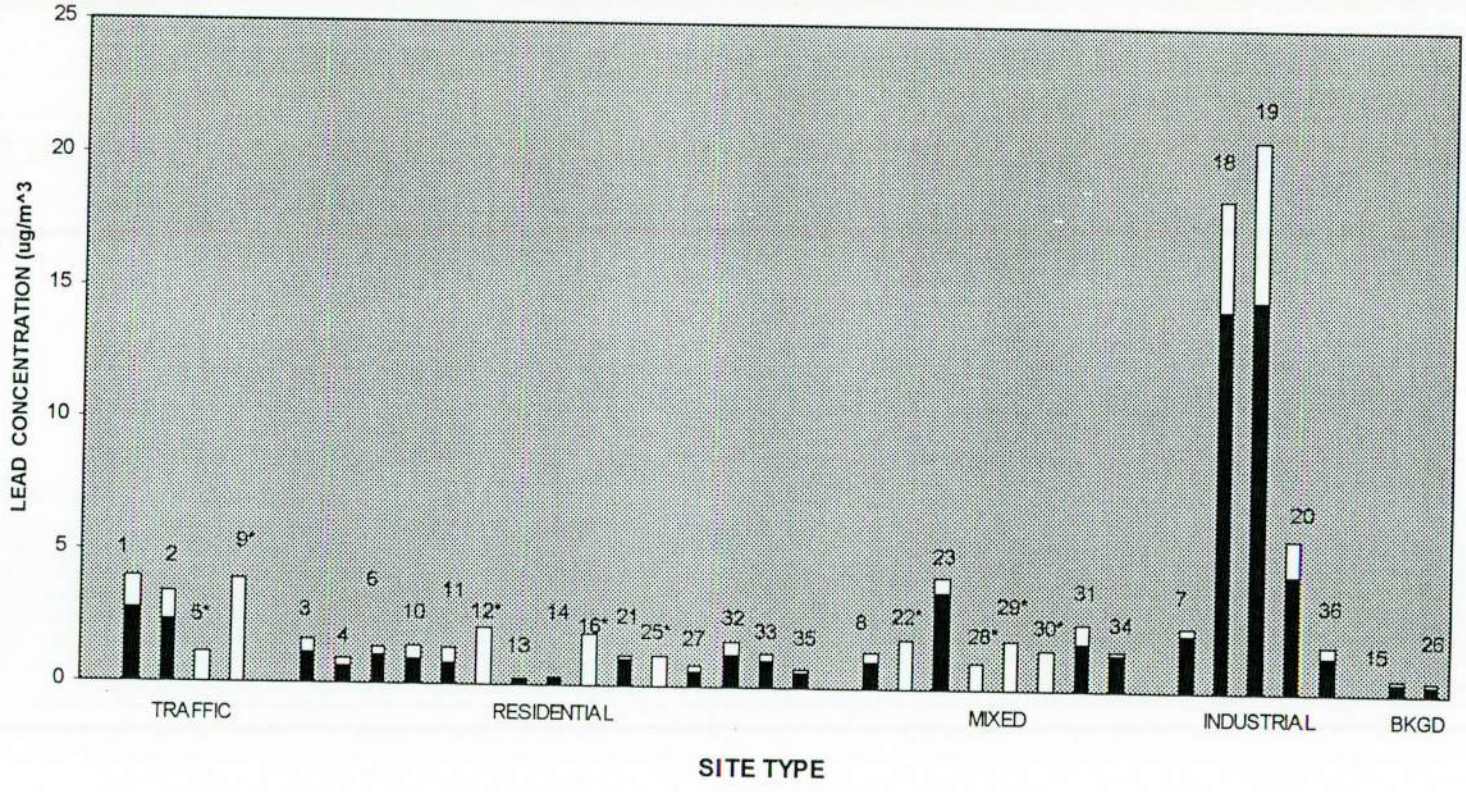
FIGURE 3
MEAN AMBIENT PARTICULATE MATTER CONCENTRATION ACCORDING TO SITE TYPE
SEPTEMBER - DECEMBER 1998



Black Only = PM2.5
Black plus White = PM10

GOE Law 4 PM10 standard is 70 $\mu g/m^3$ (24-hr average)

Figure 4
MEAN AMBIENT LEAD CONCENTRATION
SEPTEMBER - DECEMBER 1998

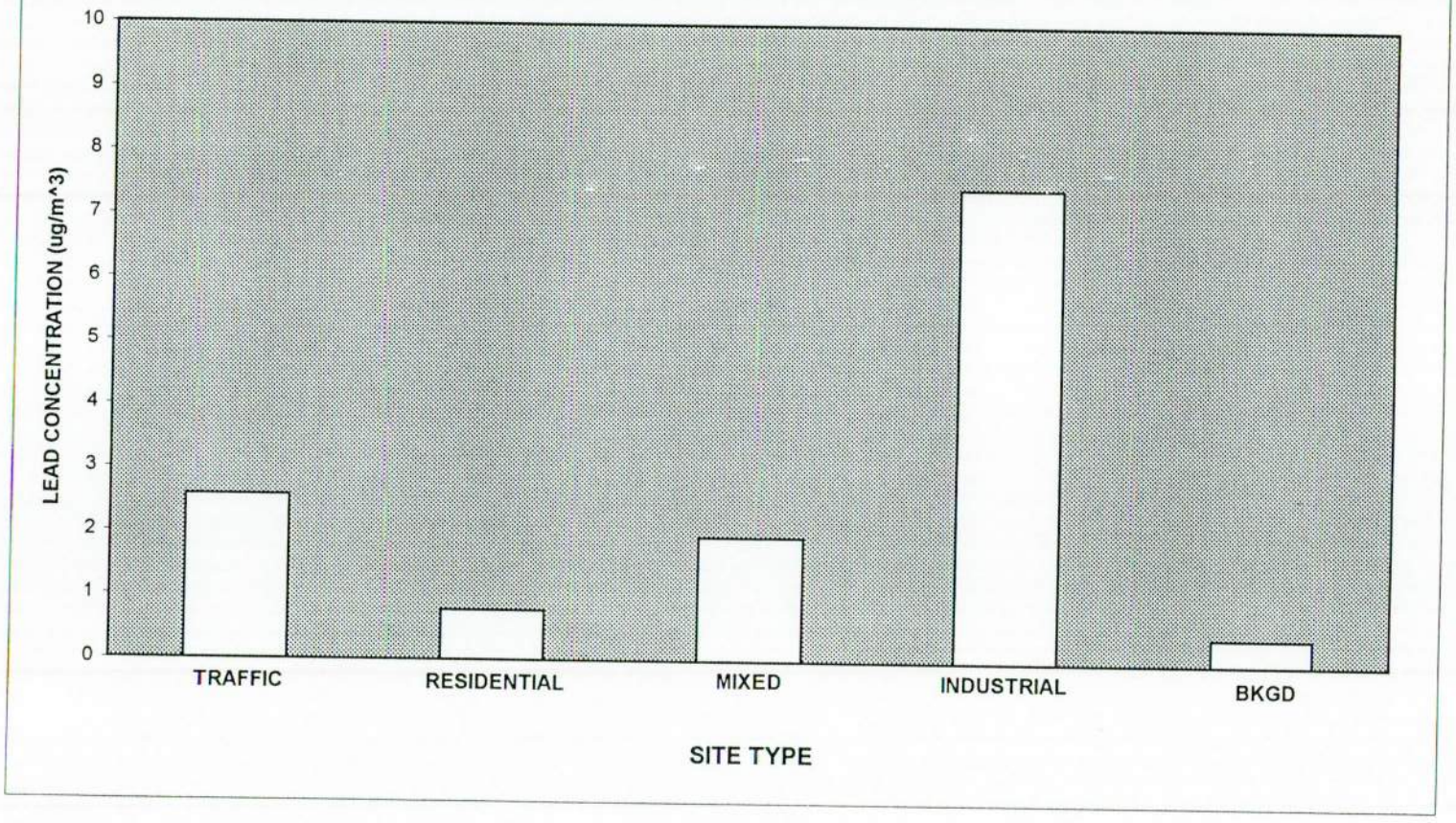


Black Only = Lead in PM2.5
Black plus White - Lead in PM10
White Only = Lead in PM10

* - PM2.5 measurement not performed at these sites

GOE Law 4 lead standard is 1μg/m^3 (annual average)

FIGURE 5
MEAN AMBIENT PM10 LEAD CONCENTRATION ACCORDING TO SITE TYPE
SEPTEMBER - DECEMBER 1998



GOE Law 4 lead standard is 1μg/m^3 (annual average)