DECREASED LEAD CONCENTRATION IN CAIRO ATMOSPHERE DUE TO USE OF UNLEADED GASOLINE

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ABSTRACT: In order to reduce lead concentration in the environment of Cairo, several measures have been taken. These caused notable decrease of lead concentration in the atmosphere of Cairo. Lead concentration in suspended particulate matter was determined in two urban areas (city centre and Dokki) in Greater Cairo from winter 1998 up to autumn 1999. The seasonal mean concentrations of lead ranged from 1.3 $\mu g/m^3$ (summer) to 2.2 $\mu g/m^3$ (winter), with an annual mean of 1.7 $\mu g/m^3$ at the city centre area. In Dokki, it ranged from 1.1 $\mu g/m^3$ (summer) to 1.7 $\mu g/m^3$ (winter), with an annual mean of 1.4 $\mu g/m^3$. A comparative study of lead concentrations and their seasonal variations before (1994–1995) and after (1998–1999) changing leaded to unleaded gasoline at the city centre area showed similar seasonal trends of lead concentration, with maxima during winter and minima during summer. With the use of unleaded gasoline the lead level was also decreased in the four seasons throughout. The maximum percentage decrease was observed in winter (–43.87%) and the minimum in summer (–29.73%). The ambient air concentration of lead during the last four years showed a decrease of 39.50% (about 10% decrease per year). Due to future implementing the use of unleaded gasoline in all of the provinces of Egypt, further considerable decrease is to be expected.

KEY WORDS: Urban air pollution, suspended particulate, lead, leaded gasoline, unleaded gasoline, nickel

INTRODUCTION

According to WHO (1977), the sources of atmospheric lead are either natural (e. g., rocks, volcanoes, buildings emitting only traces or small amounts) or man-made ones. Quantitatively, the rank order of the latter is the following: lead batteries, traffic and combustible fuels, smelting, and lastly coke, paints and pencils.

Although atmospheric lead originates from a number of industrial sources, leaded gasoline appears to be a principal source of general environmental lead pollution. Tetraethyl lead was introduced as an antiknock agent in gasoline in the 1920s (EPA, 1986) and since then has played an increasingly important role as a pollutant of the general atmosphere. The heavy traffic flow of vehicles that burn gasoline with high lead content is the main cause of the high levels of lead in street dusts and in airborne particles (Durando and Aragon, 1982). Atmospheric lead

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concentration differs from one country to another. It depends on motor vehicle density and efficiency of efforts to reduce the lead content of gasoline (WHO, 1987, 1989). It has been estimated that vehicles contribute 80–96% of all lead emissions to the atmosphere (Moriber, 1974). It has been shown that 70–80 % of the lead intake to the motor is expelled to the atmosphere whereas the remaining 20–30 % accumulates in the exhaust system and in the lubricating oil (Turk et al., 1973). The annual mean lead concentration measured in various high density traffic streets in Rome during 1989 ranged from 1.2 to 3.3 $\mu g/m^3$ (Morisi et al., 1992). In the United States, the decrease that has occurred in the lead levels of gasoline has had as a consequence an effective decrease in airborne lead levels (Kleinman et al., 1980). In Canada, a similar study on gradual replacement of leaded gasoline by unleaded one (Loranger and Zayed, 1994) showed that a decrease in atmospheric lead concentration observed since 1981 corresponds to the decrease of about 30% per year of emission from mobile sources over the same period. Thus, encouragement of the use of unleaded gasoline is considered an important solution to this problem.

Recently, the Government of Egypt introduced measures to reduce the lead concentration in the environment. These include the use of natural gas as fuel in houses and in some vehicles, as well as, the establishment of a long net underground metro in Cairo City. Beginning from the year 1991, the Egyptian authorities reduced significantly the lead content of gasoline sold in Cairo, where the lead problem had been the most serious. It was planned that in a five-year period by 1996, the gasoline sold must be completely unleaded.

The aims of the present study are to assess and compare the atmospheric lead concentrations in the city centre of Cairo before and after the introduction of unleaded gasoline and to make clear the trends started with this intervention.

METHODS

Suspended particulate matter was collected from two sampling stations representing particular urban areas. The sampling sites were selected on the basis of their traffic densities. The first station was in the city centre of Cairo and the second one in Dokki. Samples were collected from winter 1998 up to autumn 1999.

At each sampling site, suspended particulate matter was collected on membrane filters (0.45 μm pore size and 47 mm diameter) from air aspirated by a vacuum pump of a rate of 10 L/min. The total air volume during the sampling period was determined by means of a gas meter connected to the vacuum pump that gave a direct measure of sampled air in cubic meters. The sampling time was 24 hours. The membrane filters were then digested with a mixture of nitric acid and hydrochloric acid according to Harrison and Perry (1986) and analysed using an atomic absorption spectrometer (Varian 220 Spectr A A). The concentration of lead per cubic meter of air was obtained by dividing the total lead content of the filter by the total volume of sampled air.

The data of the present investigation were compared to those obtained in a recent study of our group (Khoder, 1997) performed before the use of unleaded gasoline.

Student's t test was used to estimate the significant difference between the mean of lead concentrations before and after the introduction of unleaded gasoline according to Gregory (1963).

RESULTS AND DISCUSSION

The seasonal mean variation of lead concentrations in suspended particulate matter at the city centre of Cairo and Dokki areas during the period from winter 1998 up to autumn 1999 are shown in *Table 1*. It reveals that the seasonal mean concentration maxima of lead were 2.2 and 1.7 μg/m³ in winter, while the minima were 1.3 and 1.1 μg/m³ during the summer season at the city centre and Dokki sites, respectively. The higher lead levels during the winter season may be due to the usual low atmospheric dispersion in this season. This leads to an increase in the accumulation of lead particles and hence to an increase of concentration. This is in agreement with Hassanien and Horváth (1995) and Khoder (1997) who found that the highest concentration of lead occurred in the winter season.

TABLE 1. Seasonal variation of lead concentrations (μg/m³) at the city centre of Cairo and Dokki areas from winter 1998 up to autumn 1999

Season	City centre				Dokki			
	N	Range	Mean	S.D.	N	Range	Mean	S.D.
Winter	12	1.3–3.3	2.2	0.61	12	1.0–2.6	1.7	0.48
Spring	11	0.9–2.2	1.5	0.40	11	0.6–1.9	1.2	0.42
Summer	12	0.7–1.6	1.3	0.30	12	0.5–1.5	1.1	0.26
Autumn	10	1.2–2.5	1.8	0.48	10	0.8–2.2	1.5	0.44
Annual	45	0.7–3.3	1.7	0.59	45	0.5–2.6	1.4	0.48

N: Number of samples; S.D.: Standard deviation

The annual mean concentrations of lead were 1.7 and 1.4 μg/m³ at the city centre and Dokki areas, respectively *(Table 1)*. These concentrations are much higher than those found in Helsinki (0.05 μg/m³) and in European and North American cities (0.2–0.8 μg/m³), as reported by OECD (1993). The annual mean concentrations of lead at both sampling sites of the present study exceeded the Egyptian standard (1μg/m³; EEAA, 1995). Although, the selling of unleaded gasoline has been implemented in Cairo City fuel stations, yet leaded gasoline is still being used in other Egyptian provinces surrounding Cairo City. So, the high lead concentration in Cairo may be due to lead emission of vehicles from the country that still use leaded gasoline, and from the accumulated lead particles in the exhaust system of the vehicles that formerly used unleaded gasoline. Another source of lead in Cairo may be due to the resuspension of street dust (lead-bearing dust) by the wind and anthropogenic activities. This was confirmed by the presence of high lead content in street dust of

Cairo (Shakour et al., 1999). It may also contribute to the excess lead that the areas investigated are located downwind of an industrial area in which smelters, foundries, and factories of paints and other sources of lead are to be found.

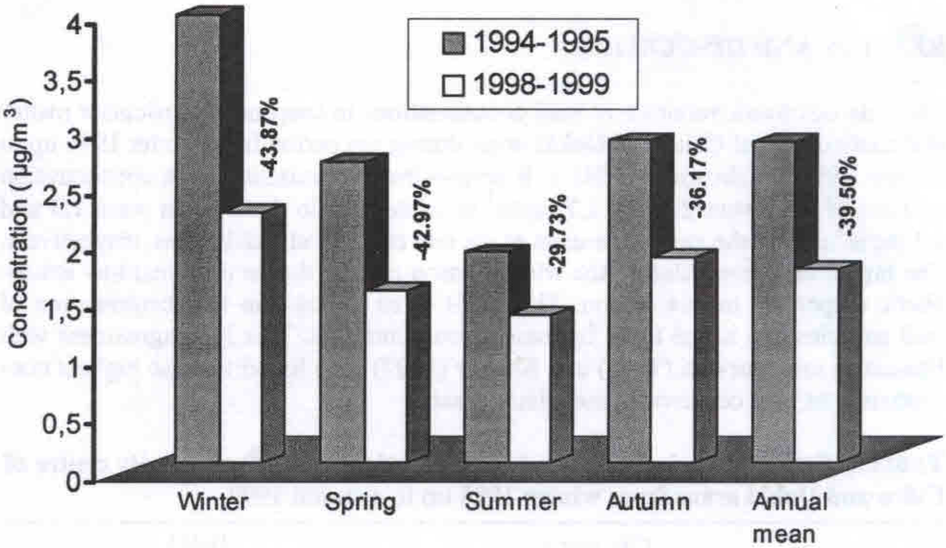

Fig. 1. Comparison of the seasonal and annual variations of lead concentrations in the city centre of Cairo during the years 1994–1995 (Khoder, 1997) and 1998–1999 (present study).

Similar seasonal patterns of lead concentration at the city centre area were observed during 1994–1995 (Khoder, 1997) before the use of unleaded gasoline, and during 1998–1999 after changing to unleaded gasoline *(Fig. 1)*. The mean values of seasonal and annual concentrations of lead, however, were less in 1998–1999 than in 1994–1995. The biggest decrease (–43.87%) took place in winter. On the other hand, the smallest percentage decrease (–29.73%) was observed in the summer season. The average drop of lead concentration between the two investigation periods amounted to –39.50% (about –10% per year). As we had expected, the absolute decrease of lead concentration was not great. This may be due to the factors discussed above. It is expected that with the introduction of unleaded gasoline in all of the surrounding provinces and after the elimination of the lead accumulated in the exhaust system of vehicles along with the removal of lead-bearing street dust, the concentration of lead will considerably decrease.

In the period of 1980–1995, the Egyptian authorities gradually reduced the lead content in gasoline sold in Cairo (Rhoda and Krause, 1993). By contrast, as *Fig. 2* shows, the annual mean concentration of lead in the atmosphere of city centre of Cairo remained actually unchanged: 2.83 $\mu g/m^3$ in 1978–1979 (Shakour, 1982) and 2.81 $\mu g/m^3$ during 1994–1995 (Khoder, 1997). This result was mainly due to the great increase in number of vehicles in the city during this period. However, the annual mean concentration of lead in the city centre of Cairo significantly ($p<0.001$) decreased from 2.81 μg/m³ (1994–1995) to 1.7 μg/m³ (1998–1999) due to the use of unleaded gasoline.

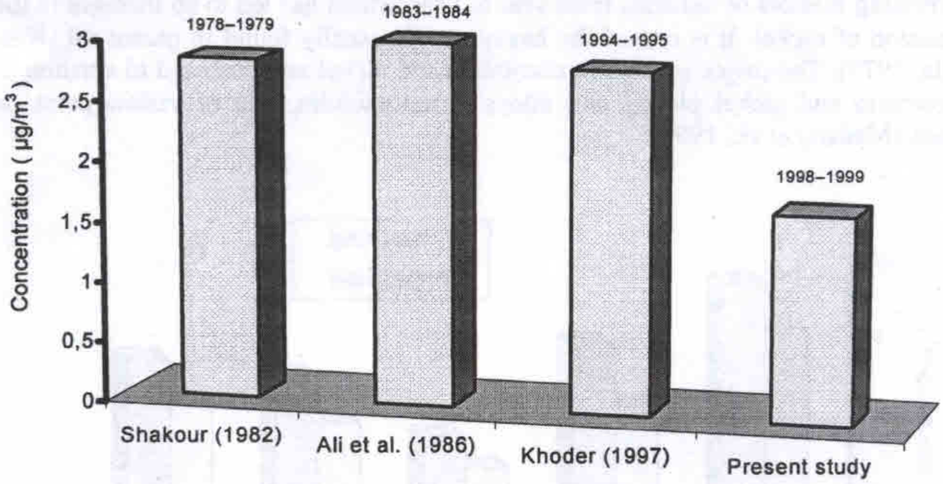

Fig. 2. Change of annual mean concentrations of lead in the city centre of Cairo from the years 1978–1979 up to 1998–1999.

At the same time, the increase of vehicles has adversely affected the nickel concentration in the atmosphere of Cairo. The seasonal variation of nickel concentrations in suspended particulate matter at the city centre and Dokki sites during 1998–1999 is shown in *Table 2*. The seasonal mean concentrations of nickel at city centre area ranged from 0.13 μg/m³ (summer) to 0.23 μg/m³ (winter), with an annual mean of 0.18 μg/m³. While at Dokki site, it ranged from 0.11 μg/m³ (summer) to 0.18 μg/m³ (winter), with an annual mean of 0.15 μg/m³. The winter maxima of seasonal mean concentrations of nickel at both sites may be attributed to the factors previously discussed for the seasonal variation of lead concentration (high inversion and low dispersion).

TABLE 2. Seasonal variation of nickel concentrations (μg/m³) at the city centre of Cairo and Dokki areas from winter 1998 up to autumn 1999

Season	City centre				Dokki			
	N	Range	Mean	S.D.	N	Range	Mean	S.D.
Winter	12	0.14–0.35	0.23	0.062	12	0.11–0.27	0.18	0.049
Spring	11	0.12–0.30	0.19	0.052	11	0.10–0.26	0.16	0.044
Summer	12	0.08–0.20	0.13	0.035	12	0.06–0.18	0.11	0.034
Autumn	10	0.11–0.26	0.17	0.046	10	0.08–0.21	0.13	0.041
Annual	45	0.08–0.35	0.18	0.061	45	0.06–0.27	0.15	0.050

N: Number of samples; **S.D.:** Standard deviation

Similar seasonal patterns of nickel concentrations were observed at the city centre area in 1994–1995 (Khoder, 1997) and 1998–1999 (present study), with relatively higher concentrations in the latter period *(Fig. 3)*. This may be due to the increasing number of vehicles from year to year, which has led to an increase in the emission of nickel. It is one of the heavy metals usually found in parent oil (Nasralla, 1975). The major sources of chromium and nickel are attributed to attrition of chromium and nickel plating and alloys in automobiles, and of yellow paint on roads (Madany et al., 1994).

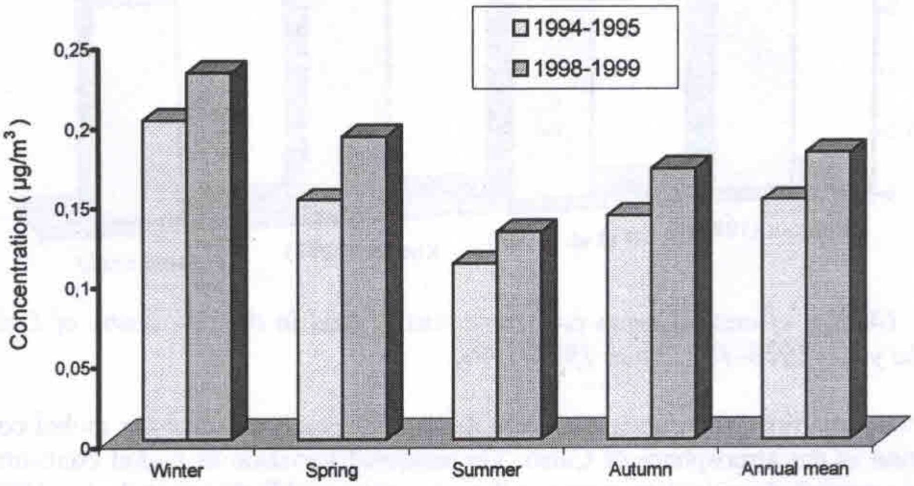

Fig. 3. Comparison of the seasonal and annual variations of nickel concentrations in the city centre of Cairo as measured during the years 1994–1995 (Khoder, 1997) and 1998–1999 (present study).

It is to be noted that some days of peculiar weathering conditions occurred in greater Cairo in autumn 1999. In these days, intense inversions occurred that caused low dispersion of pollutants over greater Cairo. Some samples of suspended particulate matter were collected during those days at both sites (3 samples at each site). These samples were excluded from the tabulated results. The average lead concentrations based on 3 samples were 5.30 and 4.5 $\mu g/m^3$ at city centre and Dokki sites, respectively. At the same time, the average nickel concentrations amounted to 0.58 and 0.46 $\mu g/m^3$ at the two sites, respectively.

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