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Abstract:

Measurements of airborne particulate lead in Ontario during the period 1971-1982 show an increase in average lead concentration during the period 1971 to 1972 and a decrease amounting to 79% from 1972 to 1982. Average lead concentrations measured at four sites adjacent to an expressway show a similar downward trend. During the same period, total gasoline consumption rose while the amount of lead emitted from gasoline combustion declined from 1973 to 1982 by 65%. The decrease in measured lead concentrations and lead consumption correlated well (r^2=0.96).

Introduction

Because of its many useful properties, lead has been utilized by man in his industry since antiquity. The health hazards of this metal have also long been recognized with the concern over these hazards focusing, during the 19th and 20th century on mortality due to lead poisoning. With the near elimination of lead poisoning as a cause of death in the past two decades, attention has now been turned to the subtle health effects of exposure to lead (1).

Much of the aerosol lead found in the atmosphere in recent years has resulted from the combustion of gasoline containing lead additives. (In Ontario, for example, 68% of the 1970 estimated lead emissions were due to automotive sources (2).) Since 1972, however, there has been a reduction in the lead content of leaded gasoline and, in 1975, unleaded gasoline was introduced. By 1982 unleaded gasoline comprised 50% of the gasoline sales in Ontario (3).

Although unleaded gasoline was mainly introduced because catalytic converters in the exhaust system required unleaded fuel, the result of its usage, along with the reduction of the lead content in leaded gasoline, has been to reduce the quantity of lead emitted in Ontario in 1982 to 41% of the 1971 emissions (3).

The Ontario Lead Monitoring Network

In order to determine ambient airborne lead concentrations, the Province of Ontario established lead monitoring in 1969 at a limited number of locations. In 1971, fifteen sites collected a sufficient number of samples to determine a valid annual geometric mean. By 1982, the network had expanded to 73 such sites, ten of which comprised a special intensive survey in the vicinity of lead processing plants in the Metropolitan Toronto area.

In order to determine ambient concentrations of lead in the air, suspended particulate matter is collected at the site on glass-fiber filters by the standard high-volume sampling method, and filter samples are analyzed for lead by either atomic absorption spectroscopy or x-ray fluorescence measurement techniques.

For the statistical analyses in this report, only data from those stations with at least five samples per quarter were used to calculate an annual geometric

mean. Stations from the special intensive survey surrounding the lead-processing plants in the Metropolitan Toronto area which began in 1973 were not included in this report.

Airborne Lead in Ontario

The network average of the annual geometric means at individual stations for particulate lead in Ontario for the years 1971 to 1982 are given in Table I along with the range of the annual geometric means in the network. There is a steady decrease in the annual average from 1972 to 1982.

Since automotive emissions are the most important sources of lead in Ontario, it is reasonable to assume that there would be a positive correlation between measured lead concentrations and automotive lead emissions. Data were obtained from Ethyl Canada Inc. (3) of the annual gasoline sales in Ontario, the annual leaded gasoline sales and the average lead content of the total (leaded and unleaded) gasoline consumed (Table II). From these figures, the annual lead consumption (the product of total gasoline consumption and average gasoline lead content) was calculated.

Since monitoring sites are located in a variety of locations and distances from traffic, a subset of the data was constructed of those sites which are most likely to be heavily exposed to traffic-generated lead. Several of the lead-monitoring sites are located close to major expressways. Two were located along Highway 401 in Metropolitan Toronto (Scarborough and North York), one along the Queen Elizabeth Way in Metropolitan Toronto (Etobicoke), one along the Burlington Skyway in Hamilton and one adjacent to the Conestoga Parkway in Kitchener. The annual geometric means of lead concentrations at these sites (Table III) show a similar and dramatic downward trend from 1974 to 1982 to that shown in the total network sample.

The averages of the annual geometric mean concentrations, both for the network and the expressway sites, have been plotted in Figure 1 along with the annual gasoline lead consumption. All three curves show a similar pattern: a steady decrease from 1973 to 1982. Prior to 1973, there had been a rise in lead consumption and average lead concentrations. Total gasoline sales, on the other hand, steadily increased during the 1971-80 period (Table I) and dropped off after 1980.

In order to more readily compare the trends in measured lead concentrations, lead emission and gasoline consumption over the period, the data were normalized by their 1971 values. A linear regression was calculated between the components resulting in the relationships:

$$X_N = -2.0 + 1.13\ Q_N \qquad (1)$$

with $r^2 = 0.93$ (significant at the 99 percentile),

and

$$X_N = 3.88 - 2.71\ G_N \qquad (2)$$

with $r^2 = 0.59$ (significant at the 99 percentile)

where X_N is the normalized lead concentration, Q_N is the normalized gasoline lead emissions, and G_N is the normalized total gasoline consumption (leaded plus unleaded).

The strong correlation shown in (1) makes it reasonable to assume that the decrease in measured lead concentrations was due to a decrease in lead emissions from automobiles. The correlation beween measured lead and gasoline consumption, on the other hand, shows a negative relationship, indicating that the decrease was not due to a decrease in total gasoline consumption.

The concentration of lead measured on any given day is influenced by a number of factors such as the quantity of lead emitted, meteorological factors such as wind speed, and traffic factors such as traffic volume near the monitor. The Province of Ontario has set as its criterion for the maximum desired concentration of lead in ambient air for a 24-hour sampling time at a value of 5.0 ug/m^3. While both traffic and weather factors strongly influence daily concentrations, it is interesting to note the effect of the aforementioned emission reductions on the number of samples exceeding the criterion. During the period 1971 to 1975, the total number of days on which the 5.0 ug/m^3 concentration was exceeded ranged from 26 to 42 times per year for the full monitoring network (excluding those stations around lead industries). In comparison, during the years 1976 to 1982, the number of days on which the criterion was exceeded ranged from 0 to 9 occasions per year.

Conclusions

The trend in measured lead concentrations during the period 1971 to 1982 shows a significant decrease from 1972 to 1982 amounting to 79%. Lead

concentrations at several expressway sites showed an average decrease of 77% from 1973 to 1982. Lead emitted from gasoline combustion has decreased since 1973 by 65%. During the same period (1973-82), gasoline consumption rose by 3%. It is therefore concluded that the decrease in lead concentrations was due to the decrease in the lead content of leaded gasoline and the increased usage of unleaded gasoline.

The number of days on which the Ontario criterion for lead of 5.0 ug/m^3 was exceeded dropped from between 26 and 42 days annually during the 1971-1975 period to between 0 and 9 days annually for the period 1976-1982.

References

(1) Chant, D.A., F.A. DeMarco, and H.R. Robertson, 1974: Effect on Human Health of Lead from the Environment, Ontario Ministry of Health, Toronto, 108 pp.

(2) The Working Group on Lead, 1974: Studies of the Relationship of Environmental Lead Levels and Human Lead Intake, Ontario Ministry of the Environment, Toronto, 407 pp.

(3) Personal Communications, Ethyl Canada, Inc., 1983.

Table I

AVERAGE ANNUAL CONCENTRATION OF AIRBORNE PARTICULATE LEAD IN ONTARIO

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Average of Annual Geometric Means (ug/m^3)	0.99	1.11	1.03	0.96	0.81	0.72	0.50	0.46	0.35	0.30	0.24	0.22
Range of Annual Geometric Means (ug/m^3)	0.5-1.7	0.3-3.5	0.2-3.5	0.1-3.6	0.2-2.7	0.2-2.0	0.2-1.7	0.1-1.2	0.1-1.0	0.1-0.8	0.0-1.1	0.0-0.7
Standard Deviation of Annual Geometric Means (ug/m^3)	.38	.95	.78	.84	.63	.52	.33	.26	.22	.24	.19	.13
Sample Size	15	19	25	22	21	23	20	54	38	52	61	63

Table II

LEAD CONSUMPTION DUE TO GASOLINE USAGE IN ONTARIO

Year	Annual Sales of Leaded Gasoline (10^6 Imp. Gal.)	Total Sales of Gasoline (10^6 Imp. Gal.) G	Average Lead Content of Gasoline* (gPb/Imp. Gal.) L	Lead Consumed (10^9g Pb) LG
1971	2224.0	2224.0	2.47	5.49
1972	2335.9	2335.9	2.61	6.10
1973	2539.7	2539.7	2.52	6.40
1974	2612.2	2612.2	2.27	5.93
1975	2509.5	2681.1	1.93	5.18
1976	2341.0	2706.4	1.84	4.98
1977	2168.7	2734.8	1.59	4.35
1978	2027.1	2800.1	1.36	3.81
1979	1751.0	2858.7	1.13	3.23
1980	1640.6	2930.0	1.02	2.99
1981	1485.3	2827.8	1.05	2.97
1982	1300.0	2608.9	0.86	2.24

* Average Lead Content of Total (leaded + Unleaded) Gasoline Consumed

Table III

LEAD CONCENTRATIONS AT STATIONS ADJACENT TO EXPRESSWAYS

Station	Distance to Expressway (m)	Annual Geometric - Mean Lead Concentration (ug/m^3)										
		1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
26029 Edna / Frederick St. Kitchener	20	-	-	-	-	-	-	0.8	0.7	0.5	0.8	0.5
29008 North Park Hamilton	20	-	1.4	1.3	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.4
33002 Pharmacy / 401 Scarborough	16	3.5	3.5	3.6	2.1	2.0	1.7	0.9	-	-	-	-
34007 Bathurst / Wilson North York	32	-	2.8	2.7	2.7	1.5	1.5	1.2	1.0	0.8	0.5	0.6
35033 Evans / Arnold Etobicoke	101	2.2	1.8	1.7	1.4	1.4	1.2	1.0	0.8	0.8	1.1	0.7
Average of Sites		2.85	2.38	2.32	1.82	1.45	1.30	0.94	0.80	0.68	0.75	0.55

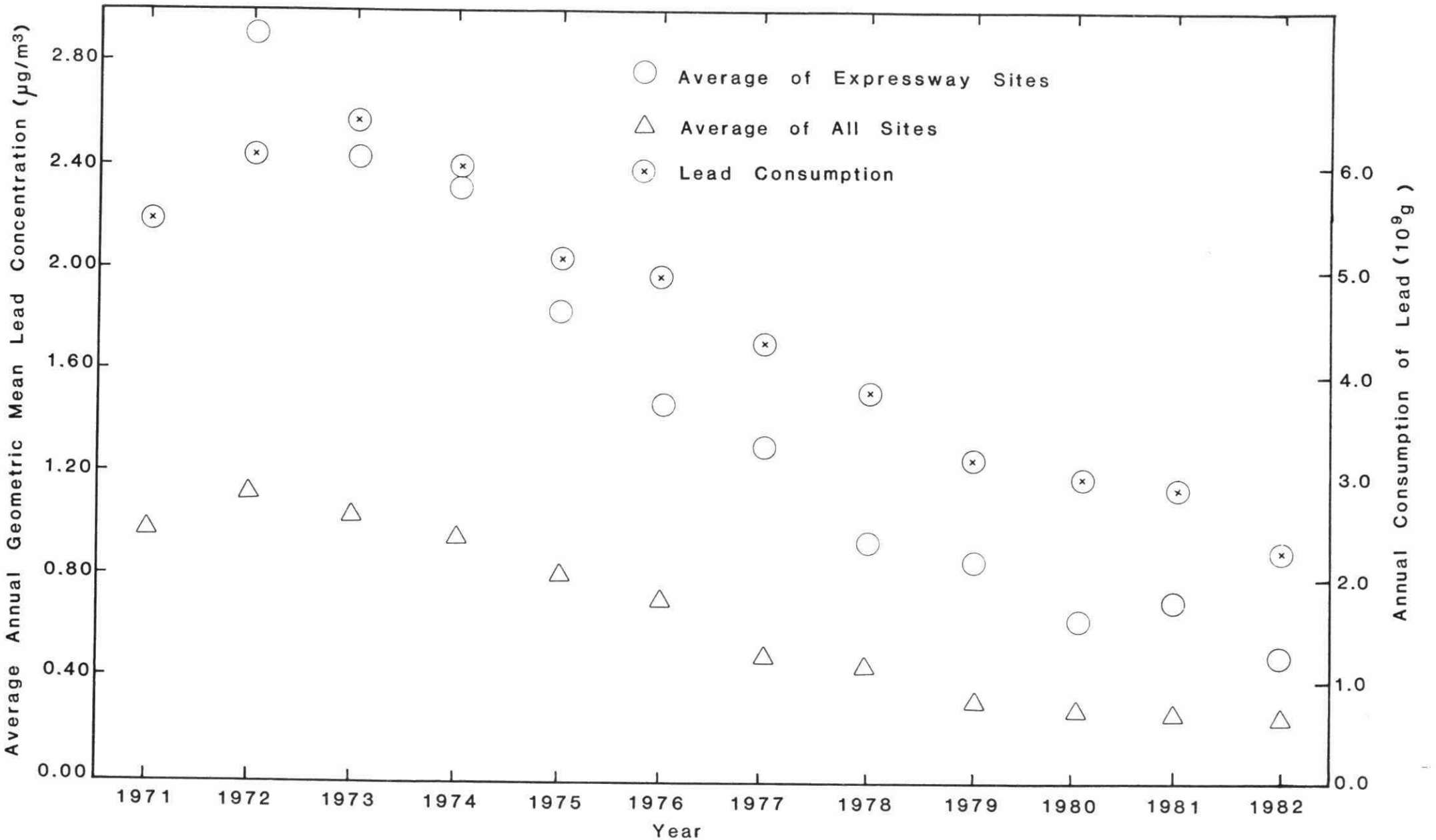

Figure 1. Average annual lead concentrations ($\mu g/m^3$) and lead consumption ($10^9 g$) for the period 1971 - 1982.