LEAD CONTENT OF SOILS ALONG CHICAGO'S EISENHOWER AND LOOP-TERMINAL EXPRESSWAYS

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The lead content of soils along Chicago's two expressways, the Chicago Loop-terminal Expressway and the Eisenhower Expressway, have been determined in various seasons of the year and at various distances from the roadway. The concentration of lead in soils along the Chicago Loop-terminal Expressway and adjoining city streets show positive correlation (correlation coefficient = 0.988) with the average traffic volume near the sampling sites during the same season. The levels of lead in soils along the Eisenhower Expressway, at the same site, vary with the season; the lead levels are the least during fall and winter and they increase during spring and attain peak values during summer. This seasonal variation in the lead levels is similar to the seasonal variations in average monthly traffic volumes on the expressway. The soil contains as much as 7,600 parts per million of lead (micrograms per gram of dried soil) up to 45 feet and 900 parts per million up to 150 feet from the Eisenhower Expressway. There is a need to investigate the contamination of human beings that live or work in buildings within these distances from the expressways and wider buffer zones need to be provided along future expressways.

Lead is a natural, but minor, constituent of soil, being present at an average of 20 parts per million (ppm, 1 microgram per gram) (Swaine 1955). However, soils of agricultural land contaminated by pesticides, of urban areas contaminated with paint from demolished buildings and from automobile exhaust, and of industrial and mining areas in which wastes are dumped can have higher contents of lead. In such areas, the greatest contamination is found in the surface soil and the lead level decreases with depth (Wright *et al.* 1955). Urban soils in old residential sections where lead paints have been used contain up to 360 ppm lead; the soils in industrial sites, such as smelters, contain up to several thousand ppm lead (Motto 1970).

Lead deposited from automobile exhaust is widely distributed. As early as 1934, the dirt from streets of the city of New York contained 1,190 to 1,760 ppm lead (Haar, 1970). The vegetation growing five feet away from an expressway contained from 100 to

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770 ppm lead (Cannon and Bowles 1962). The contamination decreased with distance from the highway, being 50 ppm at 500 feet and 5 ppm at 1,000 feet from the road. The ash from grass at the intersection of two highways contained 500 ppm lead in case of a moderately travelled road and 3,000 ppm in case of heavily travelled road (Cannon and Bowles 1962).

Several factors affect the levels of lead contamination of soils by automobiles along the expressway. These are: traffic volume, prevailing wind direction, weather conditions, type of soil, and vegetation (Cannon and Bowles 1962, Everett *et al.* 1967).

Automobile exhaust contains lead bromochloride particles which are blown with the wind and deposited on objects around the expressways. Since most of the expressways in the Chicago area pass through thickly populated residential areas, most of which comprise middle-class housing complexes, the residents are and will be continuously exposed to lead and other pollutants in the exhaust from the ever increasing volume of vehicle traffic. In view of the fact that soils along the expressway act as an immediate sink for particles of lead compounds, a periodic analysis of lead in such soils can be used for the determination of the rate of deposition, as well as of dissipation, of lead released in vehicle exhausts. We chose two sites to determine lead concentration in urban soils: 1) a ten-mile-long strip along the Eisenhower expressway which contains homes, hospitals, schools, and colleges, etc., and 2) the Chicago Loop-terminal Expressway which forms a loop of three different expressways receiving one of the largest traffic volumes reported in the United States (Fig. 1 and Fig. 2).

Materials and methods

Sample sites. Fig. 1 shows the sites from which samples were collected alongside the Eisenhower Expressway. Generally, the shoulders are raised at an angle of about 15° to 30° inclined upwards from roadway over a distance of about 150 feet, except when mentioned. There is grass all along this 10-mile strip except in certain places which have gravel instead of grass or which have bushes in addition to the grass. (These details are described in the Results section). Samples of soil (5 cm deep) were collected at distances of 10 to 50 feet from the line marking the inner boundary of the 13-foot-wide emergency lane of the road. These were taken from areas near exits, merging lanes, and areas between them.

Fig. 2 shows the location of sampling sites along the Chicago Loop-terminal Expressway System. Most of the shoulders are made of concrete except in few places which either have wood fillings or grass and bushes. There is sharp angular elevation of the shoulder from roadway all along ranging from about 20° to 45° over a distance of approximately 60 feet from the road. Pigeon litter, organic matter, and vegetation is much more concentrated on the shoulder in the Loop than along the Eisenhower Expressway. Distances of sample sites from the shoulder and streets are shown in Table I.

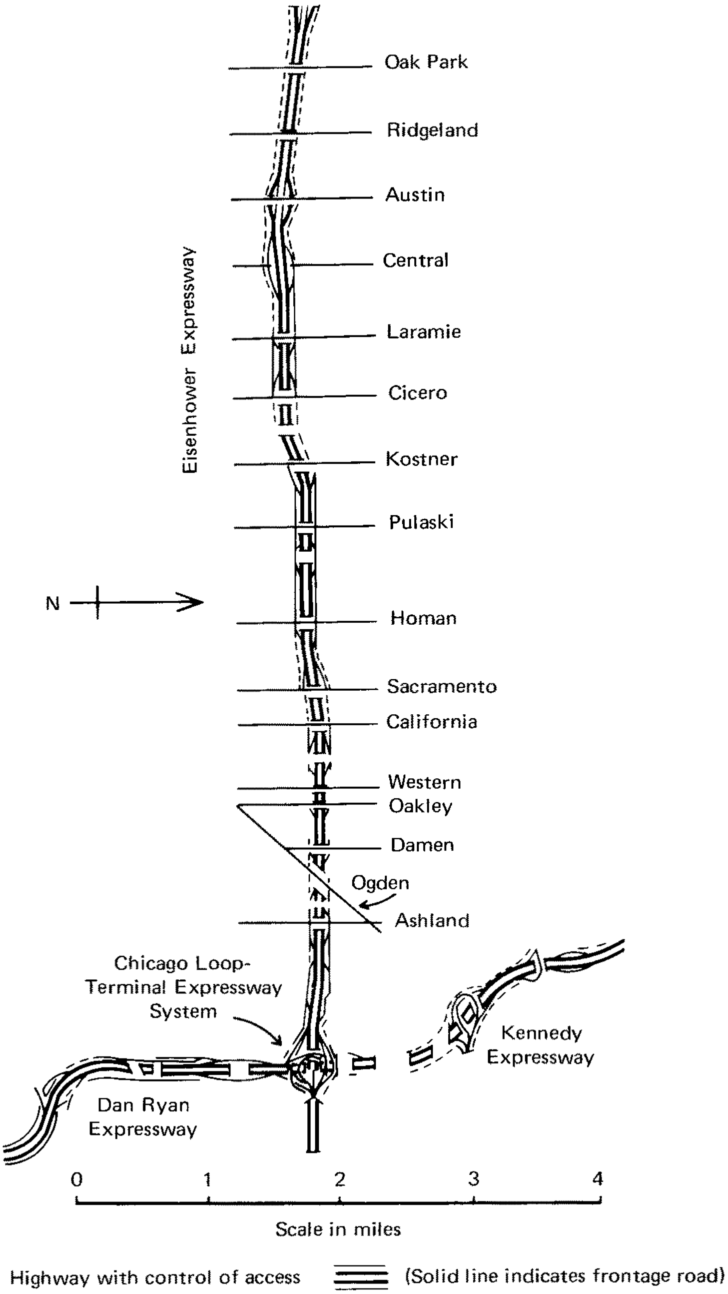

Fig. 1. Outline map of the Eisenhower Expressway (Westbound from Chicago Circle) showing the sampling sites. (Courtesy of the Cook County Expressway Department)

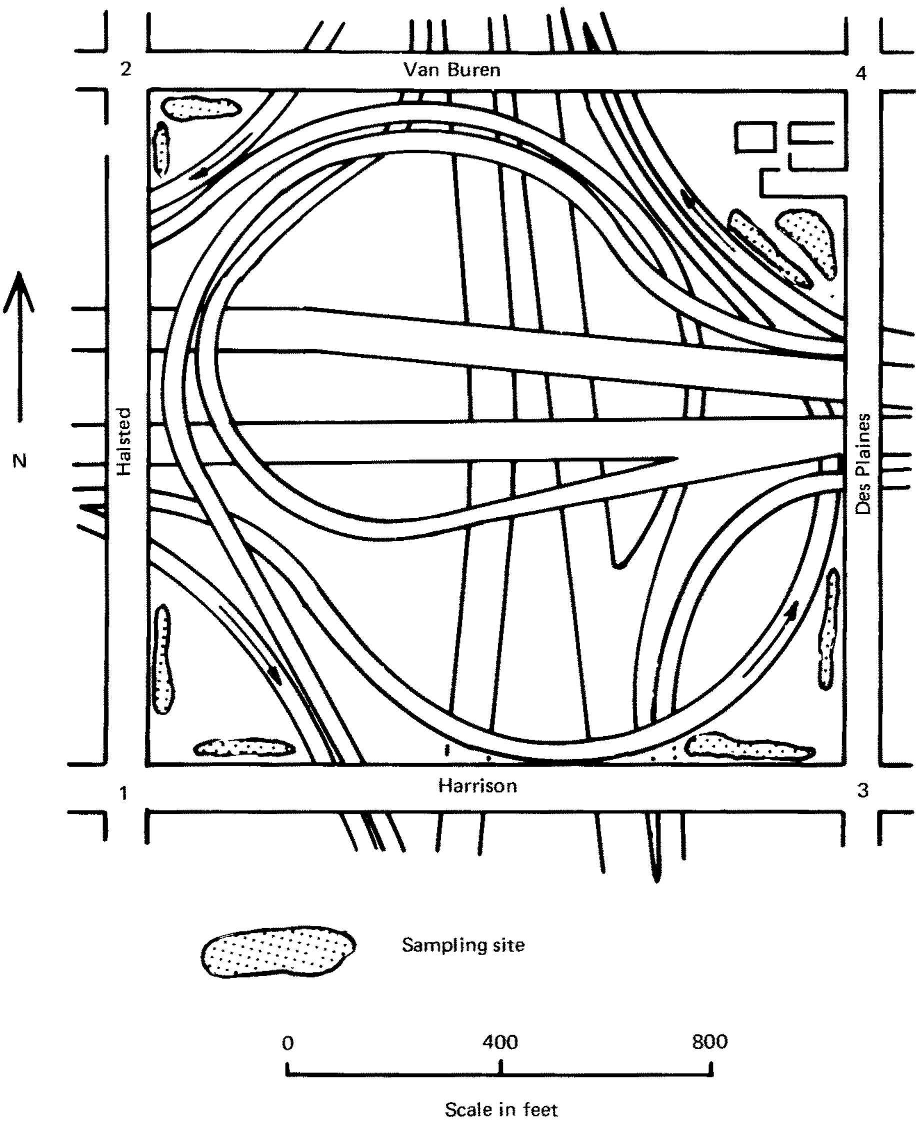

Fig. 2. Outline map of the Chicago Circle showing sites used for counting vehicles (solid arrows) and for the collection of soil samples, and numbered as described in Table I and Table II. (Courtesy of Cook County Expressway Department)

Table I. *Description of Sites Along the Chicago Loop-terminal Expressway from Which Samples Were Collected in Spring, 1971*

Site No.	Location[a]	Distance, feet from		Number of motor vehicles per hour[b]		
		Street	Expressway	Street	Expressway	Average
1	Harrison/Halsted	20-25	20-200	57,600	50,400	54,000
2	Van Buren/Halsted	20-25	20-120	86,400	97,200	91,800
3	Harrison/Des Plaines	20-40	20-180	42,500	21,600	32,050
4	Van Buren/Des Plaines	25-200	20-180	28,100	17,300	32,700

[a]The locations are shown in Fig. 2.
[b]Average traffic volume per hour between 4:00 and 4:30 PM.

Average number of vehicles passing per hour at these sites (Fig. 2 solid arrows) between 4 and 4:30 pm in spring is 47,000 on the expressway and 54,000 on the streets (Table I).

Soil sample characteristics. Most of the soils at the sampling sites consist mainly of clays with top layer of black dirt containing organic matter. The soils closer to the shoulder are generally sandy loams, sometimes mixed with clay.

The soil samples were dried in an oven at 150° for 2 to 3 hours. The samples were analyzed for lead either as taken or after ashing at 600°C for 4 hours in an electric furnace (Lindberg Heavy Duty, Sola Basic Industries).

One hundred milligrams of the soil was shaken in a separatory funnel with 100 ml of 13*N* nitric acid followed by five drops of metacresol to yield a purple color. To this mixture were added 10 ml of 50% citric acid followed with 50 ml of conc. ammonium hydroxide. The funnels were shaken for 1 to 2 min which resulted in a yellow color. After 4 to 5 min, 5 ml of 10% potassium cyanide were added followed by 30 ml of the dithiazone reagent (containing 200 μg range capacity). After vigorous shaking for 5 min, the lower layer was removed and diluted with chloroform (1:1 by volume) and read at 510 nm on the spectrophotometer. In later experiments, the soil sample was shaken with 25 ml of 20% nitric acid, filtered, and processed as above. The lead concentration in the soils, as determined by the method here described, were compared by analyzing the samples on a Jarrell-Ash Atomic Absorption spectrometer and results by two methods were found to be comparable.

Determination of lead in soil. The mixed-color method of Jacobs (1967) was used with following modifications. For the standard curve, 4, 8, 12, 16, and 20 ml of the solution B (10 μg lead nitrate/ml of 0.09% nitric acid) were made up to 50 ml with 0.1 *N* nitric acid in separatory funnels. To each portion were added 10 ml of ammonium cyanide solution (75 ml concentrated ammonium hydroxide added to 100 ml of 10% potassium cyanide and made up to 500 ml with water) followed by 30 ml of freshly prepared dithiazone reagent (200 μg-range lead dithiazone). After shaking, the separatory funnels were allowed to stand for 1 to 2 min. The bottom layer was removed and diluted with chloroform (1:1 by volume) and read at 510 nm on Beckman DBG sectrophotometer against the reagent blank. (Standard curves obtained on various times showed very little variation.) The values obtained in five different experiments were average and plotted, as shown in Fig. 3.

Results

Lead contents, during different seasons, of soils along shoulders of the city streets surrounding the Chicago Loop-terminal Expressway system are shown in Table II. The

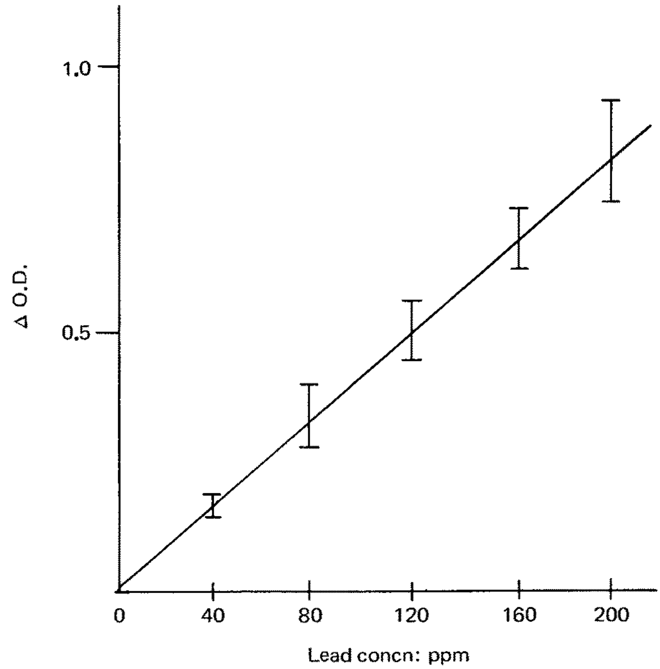

Fig. 3. Standard curve of lead concentration (ppm) vs. Δ optical density at 510 nm, using dithiazone mixed-color photometric method. The verticle bars on the curve show standard error calculated from curves obtained in 5 different experiments, using the same standard lead concentrations.

lead levels vary 1) as a function of the average distance of the soil sampling areas from the road; and 2) with seasons during which the soils were sampled.

Soil samples collected during March (spring) from the adjacent city streets showed a range of 520 to 2,230 ppm lead and those collected during December and January (winter) had lead contents of 10 to 510 ppm. The lead contents of soil samples collected during August through October (fall) showed a range of 110 to 1,000 ppm; this range of values is larger than the winter range and is smaller than the spring range of values. Lead concentrations in samples from sites 1, 2, and 3 (Fig. 2) were higher than those in samples from site 4, during all seasons.

Table III shows the average lead contents, during March, 1972, of soils along the right-hand shoulder of the westbound Eisenhower Expressway. The lead level of the soil is highest near the expressway, being as much as 2,530 ppm, and decreases gradually with increase in the distance from the expressway (420 ppm at 135 to 150 feet from the expressway).

The average lead content of the soils in the section between Oakley and Ridgeland (Fig. 1) exits along the westbound Eisenhower Expressway, during three different seasons of years 1971 and 1972, are shown in Table IV. The average lead concentrations decrease

Table II. *Average Lead Content of Soils Along the Chicago Loop-terminal Expressway During Different Periods of 1971-72*

Sample site No.[a]	Lead concentration,[b] ppm, in samples taken on		
	March, 1972	Aug.-Oct., 1971	Dec.-Jan., 1972
1	1,372 (1,290-1,450)	186 (110-260)	53 (20-80)
2	2,166 (2,010-2,230)	378 (270-460)	112 (60-190)
3	952 (890-990)	785 (660-1,000)	450 (310-510)
4	565 (520-620)	191 (140-220)	36 (10-50)

[a]Sample sites are described in Table I.
[b]Average values; values in parentheses show the range of the results.

Table III. *Average Lead Content of Soils Along the Right-Hand Shoulder of the West-Bound Eisenhower Expressway (March, 1972)*

Distance from expressway, feet[a]	Lead content,[b] ppm, in samples taken	
	Quarter mile east of Homan Ave. Exit	Quarter to half mile east of Cicero Ave. Exit
13-15	---	2,044 (1,670 to 2,530)
16-40	---	1,316 (1,050 to 1,490)
40-60	2,100 (2,110 to 2,330)	1,075 (970 to 1,210)
60-100	2,045 (1,990 to 2,140)	---
100-135	---	1,008 (880 to 1,340)
135-150	575 (420 to 690)	826 (800 to 880)

[a]Values include 13-feet wide emergency parking lane.
[b]Average values; values in parentheses show the range of the results.

gradually with distance from the expressway. This pattern is identical to that observed in Table III. The average lead content of the soil (Table IV) is generally lowest during fall-winter and highest during summer months; spring values are intermediate between the summer and fall-winter values. These seasonal changes are similar to the seasonal variations observed along the Chicago Loop-terminal Expressway (Table II).

Table IV. *Range of Average Lead Contents of Soils of the Entire Section Between Oakley and Ridgeland Exits, Along the Westbound Eisenhower Expressway, in Three Seasons of the Year (1971-72)*

Distance from expressway, feet[a]	Range of lead contents, ppm, in samples taken in		
	Summer (June, July, 1971)	Fall-Winter (Oct.-Jan., 1971-72)	Spring (March, 1972)
13-15	3,570-6,300	475-1,320	85-1,670
16-20	4,150-5,750	1,170-1,230	60-2,530
21-30	3,500-4,150	200- 560	160-1,490

[a]There is a 13-foot-wide emergency parking lane on either side of the expressway; this distance is included.

Table V shows average lead content of soils on both sides of the Eisenhower Expressway near different exits between Oakley and Ridgeland (Fig. 1). The average lead content of soils along both sides of the expressway near the same exit is about equal and vary slightly from exit to exit. However, the lead content is consistently higher at a distance of 13 to 20 feet from the expressway than at 30 to 45 feet, for all exits examined.

Discussion

The following factors can affect the lead levels in soils: 1) differences in soil types and texture; 2) presence of litter, filling materials, and living and dead vegetation; 3) traffic conditions, e.g., volume and type of traffic per unit time and special conditions such as regions near the merge lanes where acceleration takes place and those near the exit lanes when slowing occurs; and 4) weather conditions, e.g., wind speed and direction, humidity, rain, and snow, which affect driving speed, the fate of exhaust fumes, and traffic volume (Yamati *et al.* 1967, Daines *et al.* 1970). However, at any place, one or more of the above factors can be more important than other factors in regard to the contamination of soils with lead.

The results demonstrate that the lead content of surface soils along roads increases with the increase in traffic volume. Fig. 4 shows a direct relationship between the average traffic volume (Table I) and the lead content of soils at sampling sites, along the Chicago Loop-terminal Expressway (Table II). The average lead concentration (C) in soils during March, 1972 and average traffic volume (T) during March, 1971 in the area are related by

Table V. *Average Lead Content of Soils Along the Eisenhower Expressway (August, 1972)*

Sampling locations,[a] between indicated exits	Lead content,[b] ppm, in samples taken at indicated distance[c] from expressway			
	13-20 feet		30-45 feet	
	Westbound	Eastbound	Westbound	Eastbound
Oakley-Western	3,690 (2,320-5,630)	3,550 (2,430-4,270)	2,630 (860-4,620)	2,460 (910-3,900)
California-Sacramento	–	–	4,920 (325-7,590)	4,650 (300-7,420)
Pulaski-Kostner	–	3,450 (3,360-3,740)	–	3,220 (2,700-3,990)
Laramie-Cicero	4,980 (4,160-6,170)	4,260 (3,980-4,600)	2,230 (1,608-3,400)	2,220 (1,570-3,380)
Laramie-Central	3,650 (3,500-3,900)	–	1,730 (1,690-1,780)	–
Austin-Ridgeland	3,910 (3,400-4,325)	–	3,100 (2,200-3,700)	–

[a]The distance between the two exits was divided into 3 sections; for each of these sections, soil samples were collected at the distances shown.
[b]Average values; values in parenthesis show the average range of results found in soil samples taken from all 3 sections.
[c]Distances include a 13-foot wide emergency parking lane.

C = 151.08 + 0.02219T with a statistically significant correlation coefficient of 0.988. All points in Fig. 4 do not fall exactly on the least square line probably because of the variations in distances of the sampling sites from the streets and expressways, and because of differences in soils at the different sites. However, the traffic data used in Fig. 4 is for spring, 1971, and the analytical data are for soil samples collected during spring, 1972. This lag possibly also has some effect on the correlation.

An examination of traffic data in the Chicago area (Anonymous, 1971) shows that the

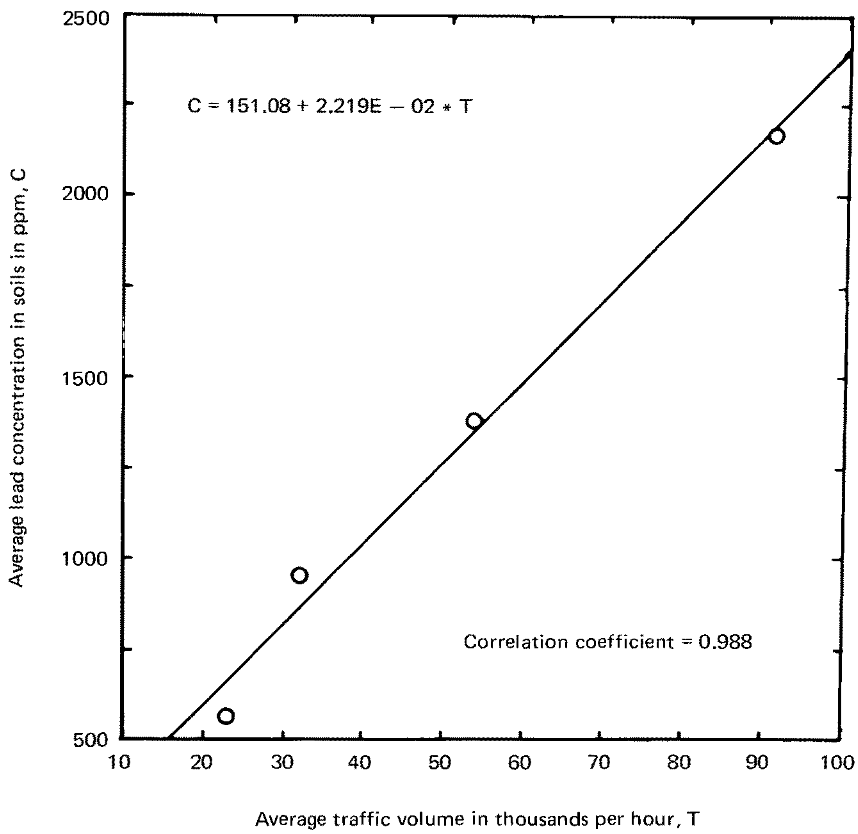

Fig. 4. Correlation between the average lead content of soils and the average traffic volume on Chicago Loop-terminal Expressway and surrounding city streets. Equation: C = 151.08 + 0.02219T; correlation coefficient = 0.988.

traffic volume at any given location varies each month. It is lowest in January (winter), increases gradually to a peak in July or August (summer), and drops to a value in December which is slightly higher than that in January. The lead contents of soils, according to this study (Table II, Table IV) are directly correlateable with changes in the traffic volume. However, other factors, e.g., weather changes which may affect physico-chemical characteristics of soils, possibly also contributes to the seasonal changes in lead levels in the soils.

The results reported here (Table III, Table IV, Table V) show that the lead level in soils along expressways decreases with the distance of the sampling site from the expressway (roadway), e.g., samples less than 15 feet away from the expressway contain as much as 7,200 ppm lead and those at 130-150 feet from the expressway contain as high as 580 ppm lead. Similar trends have been reported by several workers (Schuck and Locke 1970, Daines *et al.* 1970, Motto *et al.* 1970, Ebel 1969).

Some soil samples collected from sites at approximately the same distance from the expressway and during the same season contain different levels of lead. This random variation is as much as 830 to 5,630 ppm and can be attributed to the above-mentioned factors. However, on the average, the lead contents of soils do show systematic variations, as discussed above.

The average lead content of the upper 5-cm layer of the soil is 4,470 ppm[1]. The expected level of lead in the soil of this 10-mile long and 200-feet wide strip of shoulder along the Eisenhower Expressway (only one side of the expressway), is 7,653 ppm[2], as a result of deposition of lead from the automobile exhaust since October 1960 when this section of the expressway opened. So, only about 58% of the lead is retained in the soil. The 42% loss of lead from the soil possibly is the result of 1) experimental error, 2) not all lead falls on this 200-feet-wide shoulder, some being carried away with the wind, 3) some of the lead is washed off the soil by rains or melting of snow, 4) some of the lead migrates deeper than 5 cm in the soils, 5) some of it is secondarily lost due to heavy winds or volatilization, and 6) some of it may be absorbed by vegetation.

The lower levels of lead along the Loop-terminal Expressway (which has raised

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[1]Calculated from 7590 ppm lead present up to 45 feet (Table V) and 880 ppm lead present up to 150 feet (Table III).

[2]Volume of the 10 mile x 200 feet x 5 cm strip = 34.9×10^{10} in.^{3}, the wt. of this much soil is 9.81×10^{10} gm (1 in. soil weighs 44 gm). Since October 1960, the average daily traffic volume on this 10-mile lane strip has increased from 60,000 vehicles/day to 87,000 vehicles/day (only one side of the expressway), giving a total number of 3.75×10^8 vehicles which have used this section of the expressway. If average consumption of gasoline for these 10 miles is 1 gallon (each containing 2 gm lead), then the total amount of lead exhausted during this time = $2\ (3.75 \times 10^8) = 7.5 \times 10^8$ gm. This will result in a soil concentration of lead = $(7.5 \times 10^8/9.8 \times 10^{10}) \times 10^6 = 7653$ ppm.

shoulders), compared with the Eisenhower Expressway, can be explained on the basis that it is washed off more easily by rains or melting snow.

The loss of lead from soil can possibly have serious effects on the organisms which come in contact with the lost material, especially human beings who can inhale this material and ecosystems which receives the water contaminated with lead. Analysis of samples of drinking water, as well as ground water, soil, vegetation and animals which receive this water, needs to be done and the health and ecological effects need to be studied.

In this study, determinations were not made of lead concentrations in the air (data are obtainable from the Illinois State Department of Health) or in the lawns and soils of buildings located along the Eisenhower Expressway. However, determinations were made of the levels of lead in the soil, vegetation, animal excreta, and hairs and feathers in animal cages in the Chicago's Brookfield Zoo (which is located along a local expressway). The samples of these materials contain as high as 600 ppm lead (Coello and Khan, unpublished data), although up to 3,900 ppm lead is present in the soil and animals of the Staten Island Zoo, in New York (Bazell 1971). In this study, the highest lead levels are found in the bark of trees and outer tissues of bushes along highways and expressways (several hundred thousand ppm in bark of trees on expressways and up to 15,000 ppm in the bark of the trees in lawns away from city streets).

Public buildings, houses, etc., should be built at safe distances from the expressways and much wider buffer zones should be provided if the slow poisoning by lead of human beings and animals is to be stopped.

Conclusions

The levels of lead found in soils in various seasons and at various distances along the Chicago Terminal-loop Expressway, the adjoining city streets, and the Eisenhower Expressway show a relationship between these parameters. The lead content of the soil along the former expressway is directly correlated with the traffic volume which is in turn affected by seasons.

The lead levels in soils at a particular site along the Eisenhower Expressway also varies with seasons. It is minimum during fall and winter, increases during spring and reaches peak levels in summer. Again, this pattern is similar to the average monthly traffic volumes which are lowest during winter, highest during summer, and intermediate during spring.

The lead content of soils along expressways decreases with distances from the road. As much as 7,600 ppm and 880 ppm lead is present in soils at less than 45 and 150 feet, respectively, from the expressway.

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