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LEAD AND ZINC CONTAMINATION OF ROADSIDE SOIL AND VEGETATION IN HALIFAX, NOVA SCOTIA

J.M. DALE and B. FREEDMAN

Department of Biology and
Institute for Resource and Environmental Studies
Dalhousie University
Halifax, N.S. B3H 4J1

Lead and Zinc concentrations were measured in roadside soils and vegetation *(Poa pratensis)* in the city of Halifax, Nova Scotia, and are related to: i) traffic density—soils and vegetation had higher concentrations near high volume roads than near low volume roads; ii) distance from the roadedge—concentrations decreased exponentially with increasing distance; and iii) soil depth—concentrations decreased with increasing depth.

Des mesures de la concentration en plomb et en zinc ont été effectuées sur les sols et la végétation *(Poa pratensis)* de la bordure des routes de la ville d'Halifax, Nouvelle-Ecosse. Ces concentrations sont relieés à: i) la densite de la circulation—les sols et la végétation situeés près des routes à grande circulation avaient des concentrations plus élevées que celles des sols et de la végétation situeés aux abords des routes à faible circulation; ii) la distance de la marge de la route—les concentrations décroissent, d'une facon exponentielle, avec une augmentation de la distance; iii) la profondeur du sol—les concentrations décroissent avec une augmentation de la profondeure.

Introduction

In 1923, lead was first introduced as a gasoline additive in the form of tetraethyl lead (TEL: Pb $(CH_2CH_3)_4$). TEL concentrates combustion processes in gasoline engines, allowing an increase in the compression ratio without the risk of knocking. The use of TEL creates a higher octane rating in gasoline and, hence, improved fuel economy (Phillips 1973). During the post-World War II period, leaded gasoline was introduced into most developed countries (Hutchinson 1973a). The use of leaded gasoline in the transportation sector, especially in automobiles, produces an increase in atmospheric lead concentrations to the extent that automobile lead emissions in the United States during 1974 were the major source of lead (60%) to the atmosphere (Nriagu 1978). The 1970 estimated world use of tetraethyl lead was 3.2×10^5 tonnes (Stubbs 1973). Alkyl leads are extremely toxic, volatile, and unstable, and they are human health hazards at their sites of production (Barry 1978). However, the lead emitted from automobiles and to a lesser extent planes, trains, etc., is in the form of lead halides (Anonymous 1973a). These are wind-dispersed in the environment according to particle size, and they amounted to 267×10^3 tonnes lead/yr globally during 1974-75 (Nriagu 1978). Total emissions of lead to the atmosphere in Canada were 21,400 tonnes in 1970, of which 66% originated from automobile exhaust (Anonymous 1973c).

Zinc compounds such as zinc oxide, and zinc dimethyl or diethyl carbamate are used in the vulcanization of rubber. As a consequence, zinc is emitted by the erosion of automobile tires. It was estimated that during 1972, 800 tonnes of zinc were released into the Canadian environment from tire erosion (Anonymous 1973b). Zinc is also found in lubricating oils as an additive, for example as zinc dithiophosphate (Lagerwerff and Specht 1970).

Since the early 1960's there have been numerous reports concerned with metal contamination, especially lead and zinc, of air, biota, and soils near roadways (Cannon and Bowles 1962; Warren et al. 1966; Lagerwerff and Specht 1970;

Creason et al. 1971; Page et al. 1971; Hutchinson 1972; Ward et al. 1975, 1977; Wheeler and Rolfe 1979; Fergusson et al. 1980; Flanagan et al. 1980; Muskett and Jones 1980, 1981; Ratcliff and Beeby 1980; Wade et al. 1980; Agrawal et al 1981; Chimiel and Harrison 1981; Gulson et al. 1981; Harrison et al. 1981; Miragaya et al. 1981).

Automobile lead emissions are a relatively local pollution source, occurring along roads with high traffic volumes. Rush hour traffic can increase the lead concentration in air by 100,000 fold (Peterson 1978). Similarly, Muskett and Jones (1980) measured air concentrations of lead, cadmium, and nickel continuously over a ten month period, at various distances from a heavily travelled road (40,000 Average Daily Traffic—ADT) in West London. All three metals were found to be most highly concentrated within 10 m of the road, and they were inversely correlated with distance.

In 1970, Lagerwerff and Specht demonstrated that cadmium, nickel, lead, and zinc concentrations decreased with increasing soil depth. They noted that their highest lead value in surface soils (540 μg/g) was by no means extreme, as they had previously measured 2,400 μg/g lead in soils next to a California highway.

Ward et al. (1977) measured cadmium, chromium, copper, lead, nickel and zinc in soils and pasture species along a major motorway in New Zealand. All of the elements were present at elevated levels beside the road, and were significantly correlated with traffic density. Mean concentrations (μg/g dry weight) of lead and zinc in surface soils and vegetation from 17 interchanges, grouped according to traffic density, are shown in Table I. Ward et al. (1977) also showed that elemental concentrations of lead and zinc decreased with depth in the soil profile, and that this decrease was most apparent at the high traffic density sites.

Other studies have described lead contamination of roadside vegetation. Cannon and Bowles (1962) demonstrated that crops growing close to highways in the United States had lead contents that were four to twenty times higher than background samples. For example, pasture grass sampled next to major intersections in Denver, Colorado contained 3000 μg/g lead compared with 50 μg/g at a distance of 150 m from the road. Warren et al. (1966) showed that the stems and needles of coniferous trees growing close to a major highway in Stanley Park, Vancouver, had elevated lead concentrations ranging from 110-2000 μg/g. Normal background vegetation lead concentrations are generally less than 5 μg/g (Hutchinson 1972; Ward et al. 1975; Peterson 1978).

Page et al. (1971) reported lead data for 27 varieties of consumer crops growing adjacent to major highways (22,000-175,000 ADT) in southern California. The

Table I Relationships between average daily traffic (ADT) and surface concentrations (μg/g d.w.) of lead and zinc in soils, and lead in vegetation. After Ward et al. (1977)

ADT	SOILS		VEGETATION
	Lead	Zinc	Lead
50,000	2200	480	350
40,000-50,000	1650	250	320
20,000-39,000	1250	180	270
10,000-19,000	780	130	140
Background	14	64	5

amount of lead in and on the plants was shown to be, "influenced by (a) distance from the highway, (b) extent of surface exposed, (c) nature of the collecting surface, (d) duration of exposure, (e) motor vehicle traffic density, and (f) direction of prevailing winds". They concluded that aerial deposition was principally responsible for the high lead accumulation by the crops next to the highways. Absorption of lead from the contaminated soils was felt to be of minor significance.

Hutchinson (1972) analyzed herbarium samples of tree foliage collected from downtown Toronto during the past 100 years. Lead levels in basswood (*Tilia*) were 20-40 μg/g before 1900, but increased to 90 μg/g by 1960. Hutchinson noted that the main increase in lead levels occurred during the 1940's and 1950's, coinciding with an increase in the number of automobiles and the use of tetraethyl lead. His results for Oak (*Quercus*) and Pine (*Pinus*) were similar.

Halifax (1981 population 114,600), the capital of Nova Scotia, is located on Canada's eastern seaboard. It is a major urban center which, to date, has not been studied with regard to roadside effects of automobile-derived lead and zinc. The present paper reports the results of a study done in Halifax. The main objective was to study the effect of traffic density and distance from the roadedge on soil and vegetation concentrations of lead and zinc.

Materials and Methods

Three roadways within the city limits of Halifax and one roadway in a suburban area were chosen for sampling based on their traffic densities (ADT data were obtained from the Halifax Engineering and Works Department):

City Roads	—Macdonald Street	3,000 ADT
	North Park Street	16,000 ADT
	Armdale Rotary	50,000 ADT
Suburban Roadway	—Cole Harbour Road	18,000 ADT

A 100 m-transect running perpendicular to each road was sampled at distances of 0, 1, 5, 15, 30, 50, and 100m. Three above-ground collections of grass (*Poa pratensis*) were made at each site, and were later pooled. The grass was dried at 65°C for 48 h and then ground in a Wiley Mill (the samples were not washed prior to processing). The ground material was redried and subsamples of ca. 0.5 g were placed in 50 ml acid-washed digestion tubes. The plant material was predigested in 5 ml of concentrated nitric acid for 2 h. The digestions were then completed over a hotplate at 100°C, vacuum-filtered, and then diluted to 20 ml with distilled-deionized water. All digests were stored in plastic vials until later analysis.

Three cores of mineral soil were extracted at each site using a 2.0 cm diameter cylindrical sampler. Each core was subsequently divided into 0-2 cm and 2-4 cm sections. The three 0-2 cm and 2-4 cm sections collected at each site were then pooled. The soils were dried at 65°C for 48 h and were then sieved through a 2 mm mesh. The soils were redried and subsamples of ca. 0.5 g were placed in 50 ml acid-washed digestion tubes. These were then digested in the same manner as described for the grass.

Background grass (*Poa pratensis*) and soils were collected from a rural pasture location (Lantz, Nova Scotia) at a distance of approximately one km from the nearest road. These samples were prepared in the same manner as described for grass and soils above.

Lead and zinc concentrations were determined using a Perkin Elmer 2380 Atomic Absorption Spectrophotometer. The following spectral lines were monitored: lead—238.3 nm; zinc—213.9 nm. Standard orchard leaves (U.S. Department of Commerce, Reference Material Number 1571) and sewage sludge (sam-

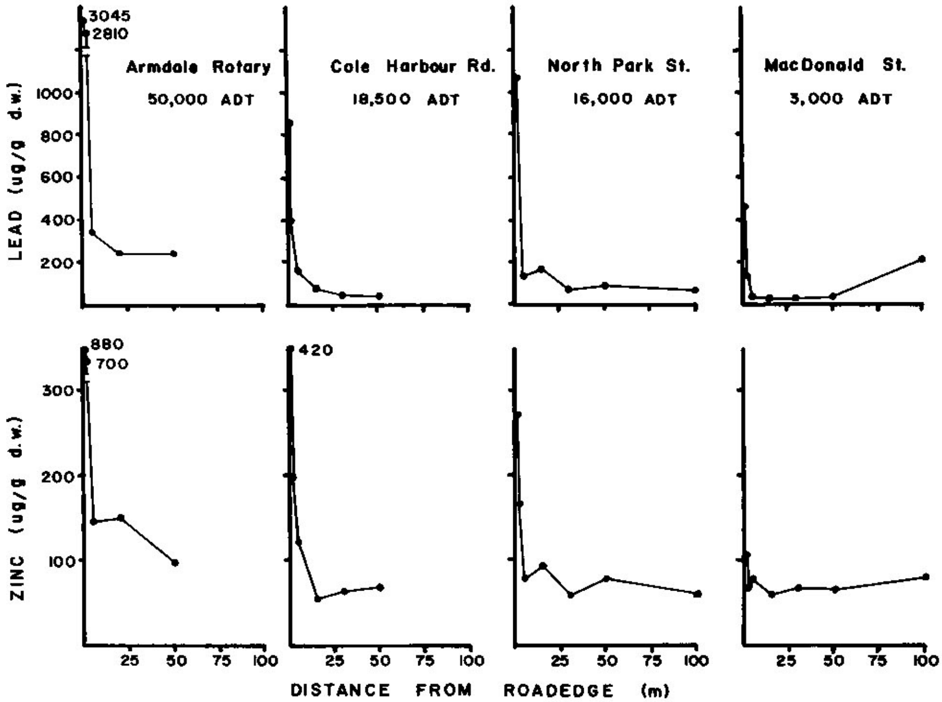

Fig 1 Lead and zinc concentrations (µg/g dry weight) in soils (0-2 cm) at various distances (m) from four streets in Halifax, Nova Scotia study area. ADT data indicated.

Table II Results of Analysis of Standard Reference Material

Reference Material	µg/g Lead		µg/g Zinc	
Standard orchard leaves*	42	(45)	31	(25)
Sewage Sludge A**	92	(101)	879	(735)
Sewage Sludge F**	607	(557)	1084	(927)

( ) certified value
* US Dept. Commerce Ref. Material 1571
** Environment Canada, Wastewater Tech. Center, Burlington, Ontario.

ples A and F, Environment Canada, Wastewater Technology Center, Burlington, Ontario) were analyzed as a check on accuracy.

Results and Discussion

The results of the lead and zinc analyses in roadside grass and soils (0-2 cm) are presented in Figures 1 and 2. Each concentration is the mean of three replicate samples, and is expressed as µg/g dry weight. Table II shows the results of the standard reference materials that were analyzed as a check on accuracy. The results indicate accuracy of ±10%.

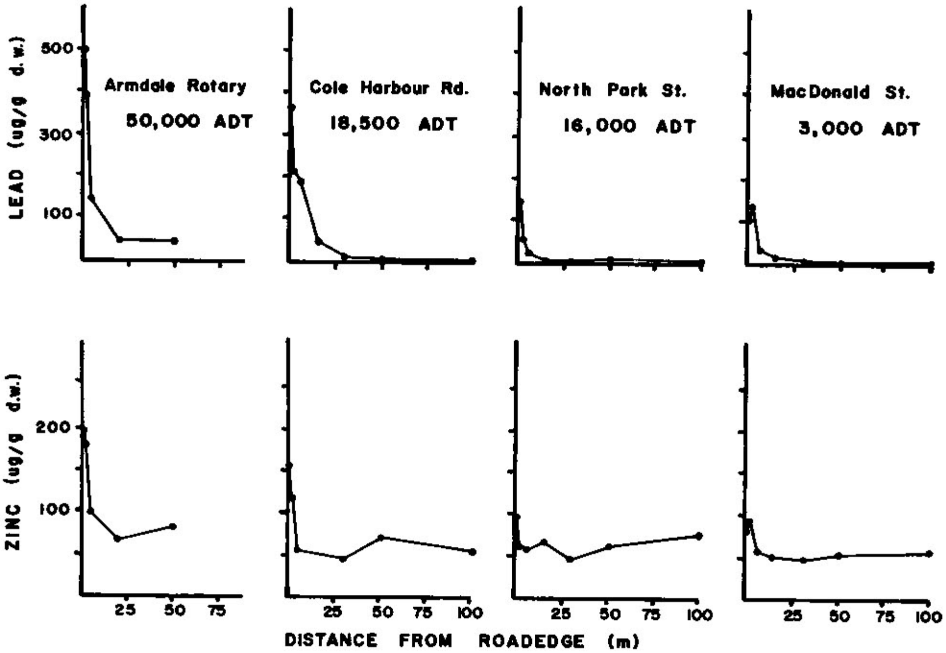

Fig 2 Lead and zinc concentrations (μg/g dry weight) in *Poa pratensis* at various distances (m) from four streets in Halifax, Nova Scotia study area. ADT data indicated.

There is an obvious relationship between metal concentration and traffic density. Macdonald Street (with a 3,000 ADT) consistently had the lowest lead and zinc concentrations in grass and soils near the roadedge. Concentrations increased from North Park Street (16,000 ADT), to Cole Harbour Road (18,500 ADT), and reached the highest concentrations at the Armdale Rotary (50,000 ADT). The range in concentrations measured at the curbside (0 m) were as follows: grass lead 140-500 μg/g; grass zinc 90-200 μg/g; soil lead 470-3,045 μg/g; soil zinc 110-880 μg/g. These compare with background rural values of $<$1 and 97 μg/g for grass, and 14 and 66 μg/g for soils. Thus, the data for Halifax are consistent with traffic density relationships reported for other major urban centers (Hutchinson 1972; Ward et al. 1977; Wheeler and Rolfe 1979; Fergusson et al. 1980).

The lead and zinc concentrations in the grass and soil decrease in a roughly exponential fashion with increasing distance from the road. This relationship existed at each location, with the exception of the grass sampled at Macdonald Street. Here the zinc and lead concentrations in the grass were higher at 1 m than at 0 m. However, the concentrations decreased exponentially from 1 to 100 m.

At all locations the lead and zinc concentrations in grass and soils were highest within 30 m of the road. Beyond 30 m the concentrations are comparable to the background levels. However, the grass samples beyond 30 m were at or below the detection limit for lead (1 μg/g), except at the Armdale Rotary. The background grass samples collected from Lantz were also below the detection limit for lead. Other studies have shown that a relationship exists between distance and metal concentration, and that background concentrations of lead and zinc in soils and vegetation are reached at distances from 15 to 100 m from the roadedge (Lager-

Table III Lead and zinc concentrations at 0-2 and 2-4 cm in soils collected at various distances from streets in Halifax, N.S. area. Average Daily Traffic (ADT) are indicated. Each value is the mean of 3 replicate samples

		Macdonald Street (3,000 ADT)		Cole Harbor Road (18,500 ADT)		North Park Street (16,000 ADT)		Armdale Rotary (50,000 ADT)	
	Meters	0-2 cm	2-4 cm	0-2 cm	2-4 cm	0-2 cm	2-4 cm	0-2 cm	2-4 cm
LEAD μg/g d.w.	0	465	133	858	96	1075	452	3046	96
	1	118	39	402	32	457	—	2813	250
	5	32	20	177	45	136	70	342	173
	15	26	20	75	39	163	58	—	—
	20	—	—	—	—	—	—	223	26
	30	26	26	45	39	63	57	—	—
	50	38	32	45	45	95	70	223	96
	100	210	205	—	—	60	26	—	—
	background	14)							
ZINC μg/g d.w.	0	106	85	422	93	272	166	880	57
	1	69	68	198	50	167	—	700	99
	5	75	59	122	47	79	69	144	89
	15	59	56	55	56	92	65	—	—
	20	—	—	—	—				
	30	65	58	63	61	—	—	150	36
	50	64	62	69	69	58	55	—	—
	100	78	68	—	—	76	64	95	59
	background	66)				60	54	—	—

werff and Specht 1970; Creason et al. 1971; Page et al. 1971; Hutchinson 1972; Ward et al. 1975; Wheeler and Rolfe 1979; Fergusson et al. 1980; and Muskett and Jones 1980).

These results are not surprising since the amount of lead emitted from cars greatly exceeds the amount of zinc emitted from tire wear (43,000 tonnes of lead versus 800 tonnes of zinc in 1972 in Canada; Anonymous 1976). It would be expected, therefore, that lead concentrations would be much higher next to the curb. Conversely, background concentrations of zinc in soils are typically higher than lead (eg. zinc 90 μg/g, lead 20 μg/g; Warren et al. 1971).

Typical background concentrations reported in the literature range from 10-20 μg/g lead in soils, 3 μg/g lead in vegetation, 90 μg/g zinc in soils, and 15-200 μg/g in vegetation (Warren et al. 1971; Hutchinson 1972; Peterson 1978; and Freedman and Hutchinson 1981).

Table III is a presentation of lead and zinc concentrations in the soils at 0-2 and 2-4 cm depths. Both lead and zinc are more highly concentrated in the first 2 cm. It can be seen that the difference between upper and lower depths is greatest at sites closer to the road. As the distance from the road increases, the upper and lower concentrations are more similar. This can be interpreted in view of the observation that, as distance from the road increases, less metal is deposited, and thus the soil concentrations approach background values. Thus, the surface layer near the road is much more highly contaminated than the lower layer. These results are similar to findings published elsewhere, some of which measured metals to a depth of 50 cm (Lagerwerff and Specht 1970; Hutchinson 1972; Ward et al. 1977; Fergusson et al. 1980; Gulson et al. 1981).

An increased burden of lead and zinc has been demonstrated in soils and vegetation near streets in Halifax. Although both metals are highly concentrated within 15 m of the roads, there is no apparent damage to vegetation. Since soil lead is only slightly taken up by roots and subsequently translocated in plants (Marten and Hammond 1966, cited in Lagerwerff and Specht 1970; Page et al. 1971; Hutchinson 1973b), it is evident that the bulk of the excess metal burden in plants is due to aerial deposition. Even so, as of 1973 there had been no clear cut cases of plant damage due to automobile emitted Pb (Hutchinson 1973b). Thus, it seems that the effects of roadside lead and zinc contamination on vegetation are not critical. Generally, the most highly contaminated zones on either side of heavily travelled roadways are unproductive with respect to agriculture, and do not support an ecologically critical habitat (note, however, that in at least one case, the death of large herbivores due to grazing lead-contaminated roadside areas has been documented (Rabinonitz and Wetherill 1972), indicating the possibility of problems when mammalian herbivores are allowed to graze roadside vegetation).

The subject which remains of greatest concern to man is the health hazard of roadside metal pollution for people, especially young children. This is understandable since lead is a potential neurotoxin, and roadways with high traffic volumes are frequently associated with high population densities (eg. busy streets in major cities). Dwellings are often located within 5 m of roadedges, the zone with the highest metal concentrations in both street dust and air. Many studies have investigated the effects of this source of metal pollution on people, and a recent paper provides a good discussion concerning lead (Stephens 1981). The most thorough study to date has been that of Needleman et al. (1979). They used the dentine lead levels of milk teeth as an index of dose, and measured psychologic performance in 158 Boston children. The results, which were widely accepted in the literature, revealed that children with high dentine lead levels performed significantly less well on a range of tests than children with low dentine lead levels.

While the results of the study by Needleman et al. are alarming, recent findings indicate that automobile lead emissions are declining. Hoggan et al. (1978) reported a 50% decrease in Los Angeles atmospheric lead particulates from 1971 to 1976, and similar observations have been made in Canada (Anonymous 1981). On a national scale in the United States, automobile lead emissions in 1980 were half of the 1975 emissions (Anonymous 1980). Similarly, during a four year study at Hubbard Brook, New Hampshire, (1975 to 1979) the mean annual lead input to forest soils decreased each year (Smith 1981). In each of these studies the decrease was tentatively attributed to the increasing use of non-leaded fuels. With the installation of catalytic converters on many cars built after 1973 (as a control for certain gaseous emissions), it became necessary to use non-leaded fuel because lead was shown to inactivate the platinum catalyst in the converters.

In summary, it has been shown that both lead and zinc concentrations in soils and vegetation are related to traffic density and the proximity of the road. Lead and zinc concentrations in soils are inversely related to depth.

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