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Department of Environment, and
Workplace Safety and Health

Environmental Management Division
Environmental Management Services

Lead Distribution in Winnipeg as Reflected by City Area Dogs

Environmental Standards and Studies
Terrestrial Standards and Studies Report #83-10

MG-8159

LEAD DISTRIBUTION IN WINNIPEG
AS REFLECTED BY CITY AREA DOGS

EXECUTIVE SUMMARY

Studies carried out by the Province of Manitoba have identified several concerns regarding lead in the City of Winnipeg. Elevated levels of lead were found in the blood of secondary smelter workers and of children from two elementary schools. Lead has been monitored in the air, soil, and vegetation of the concerned areas as well as in several other locations across the city, but there are no data on the blood lead concentrations of a cross section of Winnipeg population.

In this study the Winnipeg dogs were used as biomonitors of lead, because both normal and toxic concentrations of lead in the blood of children and dogs are similar.

Blood lead concentrations of 480 dogs from across the city were determined; all were within the normal range reported in the literature, most at the low end of the scale. Ninety five percent of samples had <8.0 μg/100 mL lead. Within this normal range, dogs from areas of heavy traffic had the highest lead levels. Blood lead concentration increased in proportion to the volume of nearby traffic (within 1 km). It was concluded that although the vehicular traffic contributes a significant portion of the total inhaled lead, the present levels do not exceed recommended medical limits for accumulation in the blood. A survey of lead in blood of dogs appears to be a feasible, low-cost alternative to large scale surveys of humans.

LEAD DISTRIBUTION IN WINNIPEG

AS REFLECTED BY CITY AREA DOGS

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Safety and Health.

Report 83-10

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Cooperating Veterinary Establishments

Pembina Veterinary Hospital

Birchwood Animal Hospital

Centennial Animal Hospital

Villa Veterinary Clinic

Dutch Hill Veterinary Clinic

Kildonan Animal Clinic

Henderson Animal Hospital

St. Vital Veterinary Clinic

Assiniboia Animal Hospital

Dakota Veterinary Hospital

McPhillips Animal Hospital

Crestview Veterinary Hospital

Seven Oaks Veterinary Hospital

Corydon Animal Clinic

Anderson Animal Hospital

Charleswood Veterinary Clinic

Kucera, E. 1983
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ABSTRACT

Lead concentrations in 480 samples of whole dog blood was determined by atomic absorption method. All samples were within the normal range of values reported in literature, 95 percent of the samples had <8.0 µg/100 mL lead. Within this low normal range, dogs from areas of heavy traffic had higher lead concentrations then dogs from areas with less traffic. About 10 percent of the lead concentration variability can be explained by the traffic flows near the animal's home. Although this finding indicates that traffic contributes a significant portion of the total inhaled lead, the present levels do not cause dangerous accumulation in the blood. Based on the similarity of blood lead concentrations in dogs and children it was concluded that a survey of lead in blood of dogs is a feasible, low-cost alternative to large-scale surveys of humans in non-occupational situations.

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INTRODUCTION

Lead (Pb) occurs naturally in varying quantities throughout the environment. However, with the advent of the industrial era increasing amounts of lead have been introduced to the environment from man-made sources, most prominent of which are smelters and vehicles burning gasoline with lead-containing additives. Intake of lead above the background, or "normal" levels produces a variety of toxic effects in both humans and other animals: from impaired activity of enzymes and anemia to learning disabilities, brain and kidney damage, and in extreme, acute cases, death. Many excellent reviews of the subject are available, both from Canada (NRCC 1973, Jaworski 1979) and elsewhere (e.g. NAS 1980).

Studies carried out by the Province of Manitoba have recently identified several concerns regarding lead in the City of Winnipeg. The Department of Health found a few cases of elevated blood concentrations of lead in children from two schools in the Weston area, where three secondary smelters are located. Some of the smelter workers also had excessive lead levels in blood. A survey by Terrestrial Standards and Studies Section (Wotton 1980) showed high levels of lead in vegetation and soil associated both with smelters and with heavy traffic areas. However, there are no data on the blood Pb levels of a cross section of the Winnipeg population. Lead concentration in blood is the best indicator of recently absorbed lead (Hernberg 1980).

The Air Standards and Studies section is monitoring atmospheric lead concentrations at several locations in the city, but monitoring with instruments is of necessity limited to a manageable number of stations and usually to fixed locations. Biological monitoring that uses live organisms as indicators of the levels of environmental contaminants is not restricted in this way (although it has its own set of limitations); thus it can profitably be used to supplement other data. Animals react to the total ambient combination of various factors, providing a measure of response to their antagonistic or synergistic effects as well.

Not many animals in the city are suitable indicators of environmental lead levels. Feral pigeons were used for the purpose by several investigators (Tansey and Roth 1970, Ohi et al. 1974, Ohi et al. 1981, Kendall and Scanlon 1982) but no mammals were monitored. However, Zook (1979) convincingly pointed out the potential of urban dogs as monitors of lead in the city environment. City dogs live in close symbiosis with humans, and their normal blood Pb concentrations are similar. The individual upper limit of 35 ug Pb/100 mL blood is the same for children (Goldsmith and Friberg 1977) and dogs (Zook 1979). Big cities usually have large dog populations from which a representative sample can be obtained.

This study was designed to supplement other lead monitoring programs of the Environmental Management Division. The objectives were as follows:

1. to determine blood lead concentrations in a sample of dogs from the entire Winnipeg city area;
2. to point out areas, if any, of conspicuously high levels;

3. to find possible correlations between blood Pb concentrations and known lead sources; and
4. to assess the potential of this method as a tool for monitoring of environmental lead.

METHODS

Blood samples were obtained from the participating veterinary clinics during May-August, 1981. No sampling was carried out specifically for this project, but when a blood analysis was required by the clinic, a 250 uL subsample was collected. The subsamples were kept refrigerated and once a week transported to W. M. Ward Technical Services Laboratory. The blood was analyzed for lead after Fernandez (1978), using a Perkin Elmer 5000 spectrophotometer with HGA-500 graphite furnace and an AS-4V autosampler.

The age and breed of each sampled dog was recorded, as well as its address (anonymously, to the nearest block). Subsequently, the distances to nearest streets with counted traffic were recorded, as well as the number of vehicle-passes/day. Information on traffic flows was supplied by the City of Winnipeg and the Manitoba Department of Highways. Traffic counts were available for Winnipeg streets with about 1000 or more vehicle-passes (one way) between 0700 and 1900 hours (Figure 1).

Standard statistical tests (Steel and Torrie 1960) and programs availabe in the VS-APL system at Manitoba Data Services were used to analyze the data.

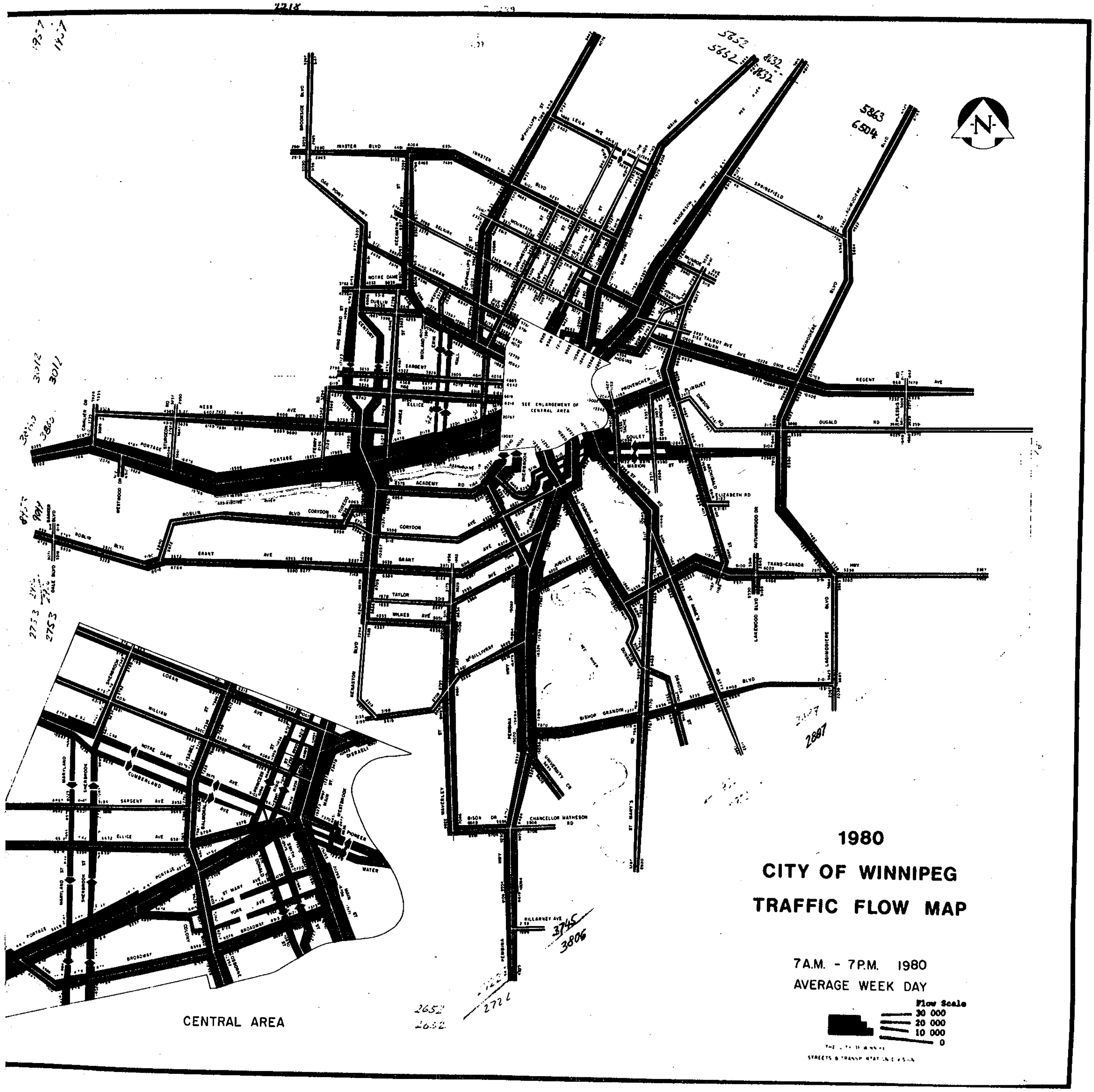

Figure 1: City of Winnipeg Traffic Flow Map.

RESULTS

Blood samples (total 545) were obtained from dogs ranging in age from 1 month to 15 years, belonging to 62 recognized breeds and miscellaneous crosses. Sixty-five samples were discarded: insufficient address (1); broken container (3); insufficient volume (17); blood clotted (44). The remaining 480 were analyzed, and form the basis of this report. From the city proper there were 398 dogs - i.e. about 2.5% of the "official" dog population of Winnipeg (15676 dog licenses were sold in Winnipeg during 1981; D. Smith, City of Winnipeg, personal communication).

The blood Pb concentrations (ug/100 mL) ranged from 0.04 to 28.35; only a single sample was that high, the second highest concentration was 15.45. Table 1 shows the representative percentiles; detailed descriptive statistics are presented in Appendix 1. The mean for all 480 samples was 2.9 ug/100 mL.

The concentrations did not appear to be related to the age of the dogs, except that the youngest animals ($\leq$ 2 years) had slightly higher levels (Figure 2).

In an attempt to determine whether - even within this normal range - in any area of the city the concentrations may be higher the total sample was arbitrarily divided into nine "rank classes", with approximately the same number of dogs in each (Table 2). The rank classes symbols were color-coded and plotted onto the map of the city according to the dogs' addresses. It became apparent that the areas towards the city centre and along major traffic arteries had a greater

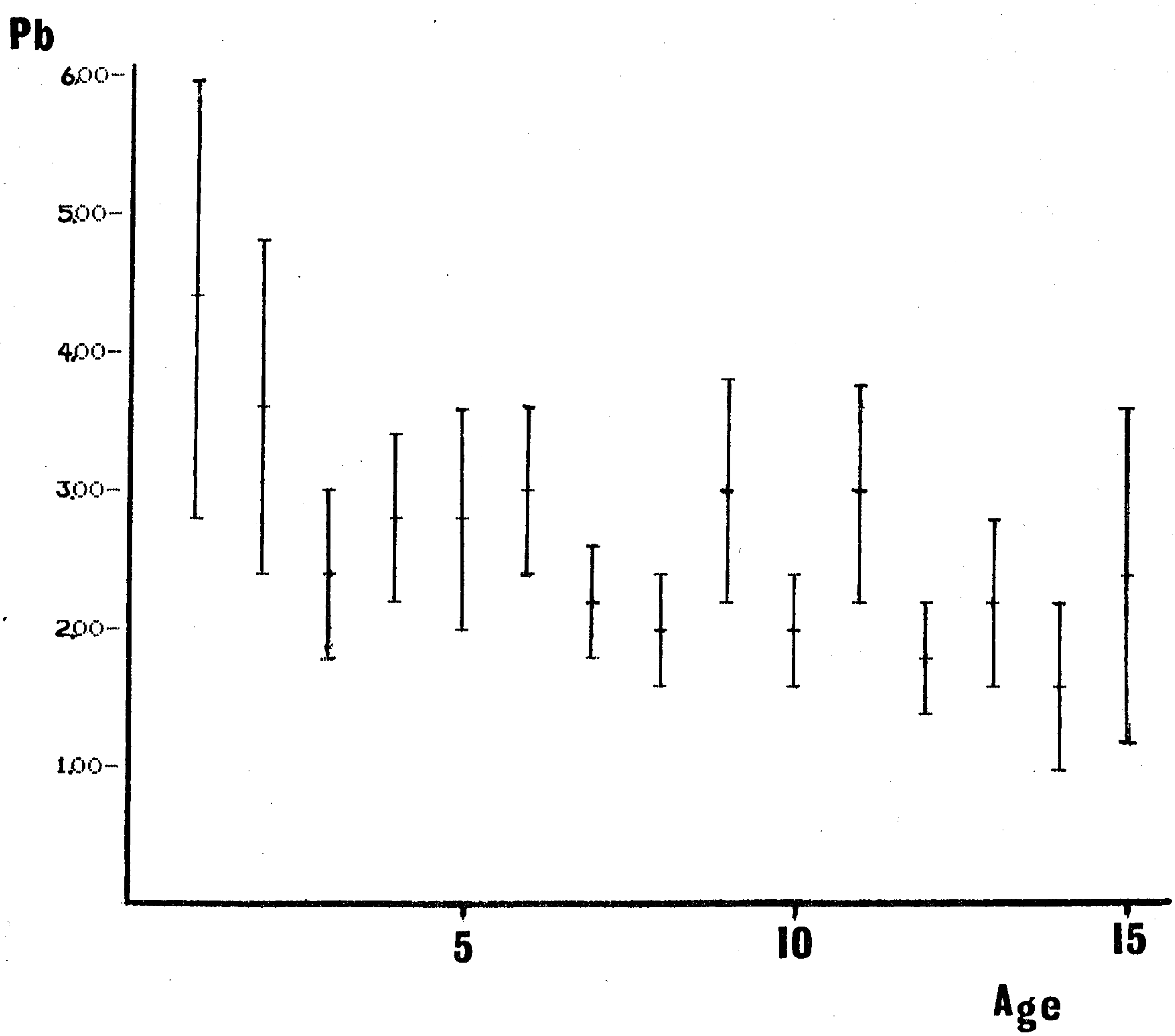

Figure 2: Blood Pb concentration (μg/100mL of Winnipeg dogs plotted against their age (≤ years). Means ± 2 Standard Errors.

proportion of the higher rank classes (7, 8, 9) than the rest of the city. More specifically, the higher rank classes were most frequent in the West End and St. James area, approximately from the airport to Downtown, and from the Assiniboine River to Notre Dame Avenue.

To somewhat quantify the relationship between the blood concentrations and the traffic areas, four groups were identified according to their presumed exposure to the traffic, i.e. the distance of the dog's house from a street with counted traffic at least 1000 vehicles per 12 hour day:

Group I - dog's address within 300 m of a street with counted traffic;
Group II - more than 300 m, but no more than 1000 m away;
Group III - more than 1000 m away;
Group 1V - outside the city (outside the area enclosed by the Perimeter Highway, #100 and #101).

The 300 m distance represents an approximate radius of a circle with 0.1 sq mile area; 0.1 sq mile was reported by Beck (1974) to be the average home range of an urban dog. The 1000 m distance was arbitrarily chosen to provide a traffic count value for most of the dogs' addresses. Group III would represent dogs from areas reasonably remote from heavy traffic. Group IV includes dogs that are essentially rural, but also from other Manitoba towns, and some from outside of the Province.

Comparing the blood lead levels of the four groups, analysis of variance showed a significant difference among the means ($F=5.107$, $p<0.005$; Appendix 2). Dogs in Group I had the highest Pb levels, Group III the lowest. Table 3 shows the means for each group and the results of Multiple Range Tests.

The differences between the groups again strongly suggested a correlation between the blood Pb levels and the traffic. Mean lead concentrations in the blood of Group I and II dogs are shown vis-a-vis traffic flows in Table 4. Regression line fitting, using all individuals for which traffic data were available, showed a statistically significant positive correlation between the number of vehicle passes and the blood Pb levels. Best fit line is described by the equation:

$$Y = 2.00 + 4.93 \times 10^{-5}X, \qquad (1)$$

$(r = 0.30;\ p<0.001)$

where Y is the blood Pb concentration in ug/100 mL, and X is the number of vehicle passes (one-way) per a 12-hr day, 0700-1900 hours. The correlation marginally improved when 14 samples from Transcona west of Plessis Road (an area for which traffic information was very limited) were left out:

$$Y = 1.83 + 5.34 \times 10^{-5}X \qquad (2)$$

$(r = 0.33;\ p< 0.001)$

Exposure to lead usually decreases with the distance from its shource. However, attempts to account for the distance by using a traffic flow index (vehicle passes ÷ distance) as the independent variable failed to produce any more accurate description of the relationship. In fact, the best fit correlation, in this case described by power curve, was weaker than the ones above:

$$Y = 0.72\ X^{0.13} \qquad X = \frac{\text{vehicle passes}}{\text{distance}} \qquad (3)$$

$(r = 0.23;\ p < 0.001)$

This is probably due to the dispersed nature of vehicle-emitted lead.

To establish whether the blood Pb levels of dogs correlate with the air concentrations of Pb as measured at the air monitoring stations, average rank classes of dogs within 1000 m distance from the stations were calculated. Comparison with the air Pb concentrations is shown in Table 5. The order from low to high levels is the same for both air and blood concentrations except for the station No. 9102 at Portage Avenue and Woodlawn St. This is an area where many cars are likely to be just passing through rather then dispersing to the immediate neighborhood. Although the data in Table 5 suggest a correlation, this correlation is not statistically significant. Moreover, when the actual mean Pb levels were compared instead of the rank class means, there was no correlation at all. Because of the great overall variation in the blood Pb concentrations the number of values available for the comparisons may have been too low.

No conclusion could be made regarding the effects of the secondary smelters; only three samples were located within 1000 m of one of them (rank classes, from nearest to farthest from the smelter, were 1, 6 and 9) and two samples within 1000 m of the other (rank classes 5 and 8). With such limited data valid comparison is impossible.

DISCUSSION

Blood lead concentrations of Winnipeg dogs were at the lower end of the range of normal values reported in the literature (0 to 30-35 ug/g; Zook 1979, Bartik and Piskac 1981). This finding is in itself gratifying, and is sufficient from the point of view of a regulatory agency; however, the collected data permitted some consideration of the sources and distribution of the environmental lead as well.

The present study concentrated on the vehicular traffic, which in any city is a nearly ubiquitous source of lead emissions to the air. The low blood Pb concentrations probably are due to the flat, open, windy situation of Winnipeg, and may also reflect the decreasing trend of lead concentrations in the air apparent since 1974, when unleaded gasoline became more prevalent (D. Bezak, Air Standards and Studies, personal communication). There are many additional factors that may influence a dog's blood Pb level. The distribution of airborne Pb is affected by local topography and meteorological conditions, the absorption and retention of lead changes with age and sex. Other Pb sources include food, the secondary lead smelters, and the airport and railway yards with their attendant - unquantified - vehicle traffic. In addition to all these factors, the habits and daily routine of both the dog and its master play a major role.

The traffic levels explained about 9-11 percent of the variability in the dogs' blood Pb concentrations ($r^2 = 0.09, 0.109$; equations 1 and 2). Considering that inhaled lead comprises from 33 to 40 percent of total absorbed lead (Rabinowitz et al. 1973, Venugopal and Luckey 1978, NAS 1980) the lead from vehicle emissions is shown as being still a major source of absorbed Pb for the dogs, and - by extrapolation - for humans. Preliminary data from Turin, Italy suggested that about 20% of lead in blood (of humans) originated from gasoline lead (BCH 1982). Low coefficients of determination are not uncommon in lead studies; e.g. Stark et al. (1982) were able to explain 11.7% of variation of blood Pb concentrations of children, using a best 5 environmental variables model (their study did not include traffic levels).

The present study did not demonstrate a correlation between air Pb concentrations recorded at air monitoring stations and the blood Pb concentrations of dogs from near by. Give the variablity, the sample size was not large enough for proper comparison; however, it is also possible that the dogs "sample" a different component of the Pb emissions then do the air monitors.

Distances used to define Groups I and II (300 m and 1000 m), although independently chosen, are similar to those used by MOE (1975) in their analysis of Pb levels in blood of people who lived at various distances from secondary smelters (350 m, 1000 m). The Ontario Task Force found a significant correlation with distances up to 350 m, but not 1000 m from the smelters. In the present study, the regression on traffic levels (vehicle passes) was significant when data for combined Groups I and II were used, but not for Group I alone. This probably reflects the difference between smelters as point sources, and vehicle emissions as non-point, dispersed sources of lead.

POTENTIAL FOR ENVIRONMENTAL MONITORING

Dogs have many of the attributes of suitable indicators or monitors of lead in the city environment. They usually share the same abode as humans, most of the same water, parts of the same food, and they breathe the same air, albeit at a lower level above ground. The concentrations of lead in the blood of dogs are very similar to those of children. Increased lead levels in the blood of a family dog may signal a potentially dangerous exposure to lead, shared by the family's children. The importance of this is emphasized by a New Zealand regulation which requires veterinarians to report lead poisoning cases to health authorities (Hamir 1981).

One disadvantage of a study such as the present survey is that some areas within the city may not receive adequate coverage; it depends to a large extent on the dog population of a neighborhood. Owing to that, and to the considerable variability of the blood Pb concentrations, a fairly large sample is required to achieve credible results. However, large sample can be usually obtained within a reasonably short time. Being a pilot project, the present survey depended for samples entirely on the good will and interest of the veterinarians - it was somewhat imposing on the time schedule of busy people. When regular large-scale surveys are planned, some form of compensation or a set fee should be negotiated with the cooperating veterinary establishments.

Despite the few drawbacks, there are several advantages which make a dog blood survey well worth while. They can be listed as follows:

1. The cost is low, owing mainly to low manpower requirements.
2. A survey can be carried out without causing unnecessary public concern.
3. It is not necessary to secure permission to sample - something that hinders many surveys that involve sampling of human blood.
4. The large number of samples allows to delineate areas of concern so that other detailed sampling or testing can be carried out more efficiently, without wasting time on "clean" areas.
5. Individual cases of high blood Pb concentration can be brought to the attention of the vet surgeion, dog owners and regulatory agencies, and investigated promptly.
6. Unlike mechanical devices, the animal "samples" the biologically active lead.

In addition, the lead levels may be compared between communities to assess differences in their exposure to lead, and periodic surveys would be useful in identifying long-term trends.

CONCLUSIONS

1. Concentrations of lead in blood of Winnipeg dogs are in the lower range of normally encountered, non-toxic levels.
2. Within this low normal range, higher concentrations are found in areas of heavy traffic.

ACKNOWLEDGEMENTS

Most sincere thanks to the doctors and staff of all the participating veterinary clinics. Their interest and cooperation made the project possible. Mrs. Sheilagh Schwartz assisted with the logistics and with data compilation. Thanks also to Mr. Dale Jones, whose casual suggestion triggered the train of thought that lead to the design of this study.

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TABLE 1. Blood lead concentrations of Winnipeg dogs (ug/100 mL) - representative percentiles.

Percentile	Group I n = 211	Group II n = 162	Group III n = 25	Group IV n = 82	Combined n = 480
50	2.70	2.05	2.00	1.95	2.25
75	3.95	3.00	3.27	3.17	3.45
90	6.00	4.22	3.60	4.03	5.00
95	7.76	6.20	3.60	6.23	6.85

1 See text for definition of the groups

TABLE 2. Rank classes of blood lead concentrations, and the number of samples in each class.

Rank Class No.	Blood Pb Concentration (ug/100 mL)	n
1	0.40 - 1.05	50
2	1.10 - 1.50	67
3	1.55 - 1.80	54
4	1.85 - 2.10	53
5	2.15 - 2.60	56
6	2.65 - 3.00	50
7	3.05 - 3.65	53
8	3.70 - 5.05	50
9	5.35 - 28.35	47

TABLE 3: Mean blood lead concentrations of dogs living at different distances from streets with counted traffic[1,2].

Group	n	Mean Pb Concentration (µg/100 mL)
I	211	3.38[a]
IV	82	2.59[a,b]
II	162	2.52[a,b]
III	25	2.22[b]

1 See text for definition of Groups I to IV
2 Means with different superscripts are significantly different from each other ($p<0.05$; Tukey's test). The LSD test shows also the means of Groups I and II as significantly different at $p<0.05$ (see Appendix 2).

TABLE 4: Mean concentration of lead in blood of dogs living within 1000 m of streets with different traffic flows.

Vehicles-passes within 1000 m; thousands per 12-hr day	Mean blood Pb concentration; µg/100 mL	n
≤ 2	1.97	3
> 2 - 5	2.48	28
> 5 - 10	3.06	98
>10 - 20	2.72	152
>20 - 30	3.07	59
>30 - 40	3.58	21
>40 - 50	4.96	8
>50	10.49	4
	TOTAL	373

TABLE 5. Mean Pb concentrations in the air at air monitoring stations during May-August, 1981, and corresponding mean rank-class values for blood Pb concentrations of dogs living within 1000 meters of the stations.

Air Monitoring Station	Air Pb Concentration $\mu g/m^3$	Mean Rank Class	n
#9118	0.18	4.7	10
#9120	0.26	4.8	4
#2011	0.30	5.2	14
#9102	0.35	3.1	13
#9119	0.38	6.5	2

Appendix 1

Descriptive Statistics

BLOOD LEAD CONCENTRATIONS (ug/100 mL) - DESCRIPTIVE STATISTICS

All samples combined:

SAMPLE SIZE	480
MAXIMUM	28.35
MINIMUM	0.4
RANGE	27.95
MEAN	2.89375
VARIANCE	6.026137891
STANDARD DEVIATION	2.45481932
MEAN DEVIATION	1.475135417
MEDIAN	2.25
MODE	1.5

Group I, within 300 m from counted traffic:

SAMPLE SIZE	211
MAXIMUM	28.35
MINIMUM	0.5
RANGE	27.85
MEAN	3.37535545
VARIANCE	9.342717373
STANDARD DEVIATION	3.056585901
MEAN DEVIATION	1.803278004
MEDIAN	2.7
MODE	3

Group II, over 300 m, but within 1000 m of counted traffic:

SAMPLE SIZE	162
MAXIMUM	11.05
MINIMUM	0.4
RANGE	10.65
MEAN	2.522839506
VARIANCE	2.735686297
STANDARD DEVIATION	1.653991021
MEAN DEVIATION	1.156149977
MEDIAN	2.05
MODE	2

Group III, more than 1000 m from counted traffic:

SAMPLE SIZE	25
MAXIMUM	3.7
MINIMUM	0.6
RANGE	3.1
MEAN	2.22
VARIANCE	1.059375
STANDARD DEVIATION	1.029259443
MEAN DEVIATION	0.8888
MEDIAN	2
MODE	1.8 3.5 3.6

Group IV, outside Winnipeg:

SAMPLE SIZE	82
MAXIMUM	15.45
MINIMUM	0.5
RANGE	14.95
MEAN	2.592682927
VARIANCE	4.551489009
STANDARD DEVIATION	2.133421901
MEAN DEVIATION	1.332361689
MEDIAN	1.95
MODE	1

Appendix 2

Analysis of Variance and Multiple Range Tests, Groups I-IV

```
ANALYSIS OF VARIANCE:TREAT., REP'S, MEAN, AND ANOVA TABLE
     1.000   25.000     2.220      .000
     2.000  162.000     2.523      .000
     3.000   82.000     2.593      .000
     4.000  211.000     3.375      .000
     3.000   90.008    30.003     5.107 = F;  p< 0.01
   476.000 2796.512     5.875      .000
   479.000 2886.520     2.424      .000

FOR DUNCAN'S TEST ENTER TABLE VALUES FOR P=2 TO 4,DF= 476
OR 0 TO SKIP TO TUKEY'S AND SNK
□:
      2.77 2.92 3.02
VALUES FOR DUNCAN'S COMPARISONS ARE:    .843  .889  .919
FOR SNK AND TUKEY'S TESTS:
ENTER TABLE VALUES FOR P=2 TO 4 AND DF= 476
ENTER 0 IF NOT DESIRED
□:
      2.77 3.31 3.63
W VALUES FOR SNK TEST ARE:   .843 1.008 1.105
TUKEY'S HSD =  1.105
DIFFERENCES BETWEEN ORDERED MEANS:
      2.220      2.523      2.593      3.375

       .000       .303       .373      1.155 *   (** by LSD-test)
       .000       .000       .070       .853 --->( * by LSD-test)
       .000       .000       .000       .783
       .000       .000       .000       .000
FOR LSD AND/OR DUNNETT'S TEST ENTER APPROPRIATE T VALUE(S) FROM TABLE(S)
      ; ENTER 0 IF NOT DESIRED
□:
      1.96
LSD AND/OR DUNNETT'S D' VALUE(S) IS (ARE):
  .844
```