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Pacific Region
Yukon Branch

WOOD SMOKE AND AIR POLLUTION AT WHITEHORSE, YUKON TERRITORY 1981 - 1982

Regional Program Report 82 - 16

by

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ABSTRACT

An ever-increasing number of homes in northern Canada rely on wood stoves for heating, alone or in combination with oil furnaces or electric heating. However, wintertime air conditions in the north are particularly stable and conducive to air pollution. The Environmental Protection Service, Yukon Branch, has responded to inquiries from the public by monitoring air conditions in a neighbourhood of Whitehorse. This report includes data from two winters' monitoring of total suspended particulate matter from Riverdale. On those days which had low temperatures in combination with calm or low wind conditions, levels of suspended particulate matter exceeded national guidelines. Also, measured levels of polycyclic aromatic hydrocarbons or PAH in that particulate matter at times exceeded those reported from monitoring surveys conducted in industrial cities. Since several of these compounds are known to have carcinogenic properties, these levels are of interest from an environmental health standpoint. This report recommends action by government to inform the public about possible health risks associated with air pollution from wood combustion, and preventative techniques available to reduce this air pollution.

RÉSUMÉ

Dans un nombre sans cesse croissant d'habitations des régions septentrionales du Canada on a recourt au chauffage au bois, soit seul, soit combiné avec le chauffage au mazout ou à l'électricité. Or, les conditions atmosphériques hivernales qui sont propres à ces régions ont pour effet de faire stagner les masses d'air, et par voie de conséquence d'augmenter les risques de pollution. Des enquêtes ayant été réclamées par le public, le Service de la protection de l'environnement a procédé aux environs de Whitehorse à des analyses des masses d'air. Le rapport comprend les données fournies par l'analyse faite deux hivers de suite de toutes les particules en suspension dans l'air et provenant de Riverdale. Durant ces journées où les températures étaient basses et où, en même temps, il y avait peu ou pas de vent, on a constaté que la proportion de particules en suspension dans l'air dépassait les niveaux recommandés a l'échelon national. En outre, on a constaté que les proportions d'hydrocarbures aromatiques polycycliques présents dans ces particules dépassaient quelquefois celles relévees au cours d'analyses faies dans les villes industrielles. Étant donné que plusiers de ces composés sont considérés comme cancérigènces, ces proportions sont inquiétants, si l'on considère l'effet qu'a l'environnement sur l'état de santé. Le rapport recommande que des mesures soient prises par le gouvernement pour informer le public des dangers pour la santé que comporte la pollution de l'air causée par le chauffage au bois, ainsi que des techniques préventives destinées à réduire ce type de pollution.

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CONCLUSIONS

Regional and local climate factors and the increasing use of domestic wood heating are contributing to the development of an air quality problem in Whitehorse, Yukon Territory. Specific conclusions of this study can be summarized:

1. Total suspended particulate matter in Whitehorse and its suburb Riverdale during the study periods varied between 3 and 222 micrograms per cubic metre (ug/m^3).
2. Concentrations of benzo (a) pyrene, a carcinogenic polycyclic aromatic hydrocarbon, averaged 7780 nanograms per 1000 cubic metres ($ng/1000m^3$) as analyzed from 12 filters having over 50 mg/m^3 of particulate matter, while concentrations of other PAH compounds were several times higher.
3. Domestic wood use presently averages 5.5 cords (1052 kg/cord) per wood-using home, and at present nearly 700 of the 1200 homes in Riverdale burn wood. The number of wood-using homes is increasing.
4. The necessary atmospheric conditions conducive to severe pollution - intense ground level inversion, still air and extreme cold - did not occur together on days sampled, thus these results may not have included a 'worst case'.
5. Values of PAH measured on the filters may be understated due to oxidation and volatile losses.
6. There is insufficient data to evaluate the significance to human health of the reported PAH levels.

RECOMMENDATIONS

1. The public must be educated in ways to reduce air pollution through proper loading and firing of airtight wood stoves.
2. Considerations of terrain, climate and density of wood-burning appliances should be included in applying government programs which encourage the use of cordwood as a substitute for oil as a domestic fuel.
3. Monitoring of Riverdale air quality should continue including sampling of carbon monoxide, in conjunction with local meteorological observations.
4. The feasibility of implementing an air quality indexing system for Whitehorse should be investigated.

1 INTRODUCTION

Whitehorse is a small city in the south-central part of the Yukon Territory (lat. 60° 43'N. 135° 03'W - See Figure 1). The city has a population of 14,800 by the 1981 census. Riverdale is a suburb on the east side of the city containing 1200 single-family homes and an estimated population of 3300. The city has no heavy industry and emissions of air pollutants must be considered to be from mobile and domestic sources only. The climate of Whitehorse is described as continental subarctic and comparable to Yellowknife, Northwest Territories and Fairbanks, Alaska. However Whitehorse is only 150 km from the waters of the Gulf of Alaska to the southwest, so barometric highs associated with arctic air masses in winter are less stable. Also, the terrain around Whitehorse is mountainous and wind patterns are therefore local and variable.

This report includes the results of 64 high-volume filter samples collected in Riverdale in January and February, 1981, and in November to February, 1982. Analyses of PAH compounds on 41 of these samples are reported in Table 6. Study results are presented in relation to the continuous monitoring of air quality in downtown Whitehorse done by the Environmental Protection Service as part of the National Air Pollution Surveillance program (NAPS), and 8 years of records are available. The Atmospheric Environment Service maintains a class one (WO 1) weather office at the Whitehorse airport, which is only 3.3 km from the Riverdale sample site. This report will therefore make a preliminary synthesis of this data in assessing the environmental significance of air pollution in the Whitehorse area.

To evaluate results given later in this report, the reader is referred to the Ambient Air Quality Objectives issued persuant to the Clean Air Act, in which the following objectives are stated:

Pollutant	Desirable	Acceptable	Tolerable
Carbon Monoxide	0-6 (8 hr)	6-15 (8 hr)	15-20 (8 hr)
(mg/m^3)	0-15 (1 hr)		15-35 (1 hr)
Suspended Particulate	0-60 (year)	60-70 (year)	120-400 (24 hr)
Matter (ug/m^3)		0-120 (24 hr)	

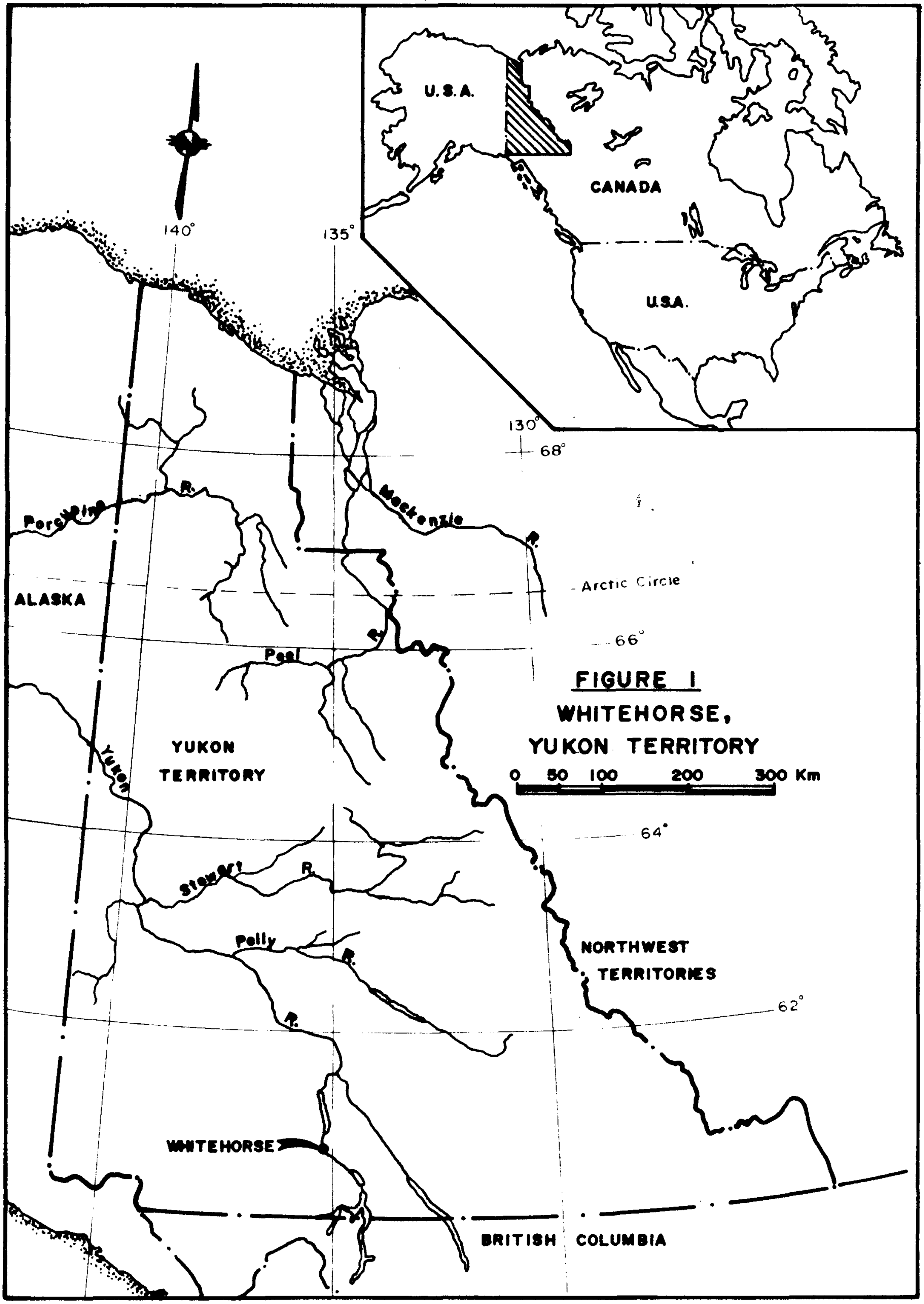


FIGURE I
WHITEHORSE,
YUKON TERRITORY

2 SAMPLING PROCEDURE AND ANALYSIS

Late in 1980, the Environmental Protection Service, Yukon Branch, began receiving inquiries and complaints about pollution from wood smoke in Riverdale. EPS personnel then installed two high-volume particulate samplers at different locations in Riverdale during January and February, 1981, and operated them simultaneously on a four day cycle using a 24 hour sampling period. Pre-weighed filters were supplied by the Air Pollution Control Directorate in Ottawa, and the same agency furnished particulate weights and concentrations after sample exposure. When these results were received, it became apparent that the sampling schedule had not been frequent enough to include some apparent pollution events, and the sampling months proved to be unusually warm and windy, so it was decided to repeat the experiment during the winter of 1981/82.

Starting in late November, 1981, two machines were installed temporarily at the same residential location in Riverdale used for one machine earlier in the year. This location is shown on the plan of Whitehorse of Figure 2, and in larger scale in Figure 3. Samples were taken every three days commencing on November 24, 1981 using one machine while the second was used occasionally for short-term sampling of a few hours duration, and for standby in case of failure of the first. Since the regular six-day sampling regime with the NAPS machine in downtown Whitehorse continued, there was simultaneous sampling of particulate matter every 6 days. In addition, the NAPS station recorded carbon monoxide and nitrogen oxides in downtown Whitehorse on a continuous basis throughout the winter months. Machine operation and sample handling were performed by experienced personnel using standard methods and precautions.

2.1 High Volume Sampling

The three high-volume air samplers used were manufactured by General Metal Works of Cleves, Ohio, and conform to international standards. The Pollution Measurement Division of the Air Pollution Control Directorate supplied pre-weighed glass Fibre Filters and the same agency subsequently determined particulate loadings and flow

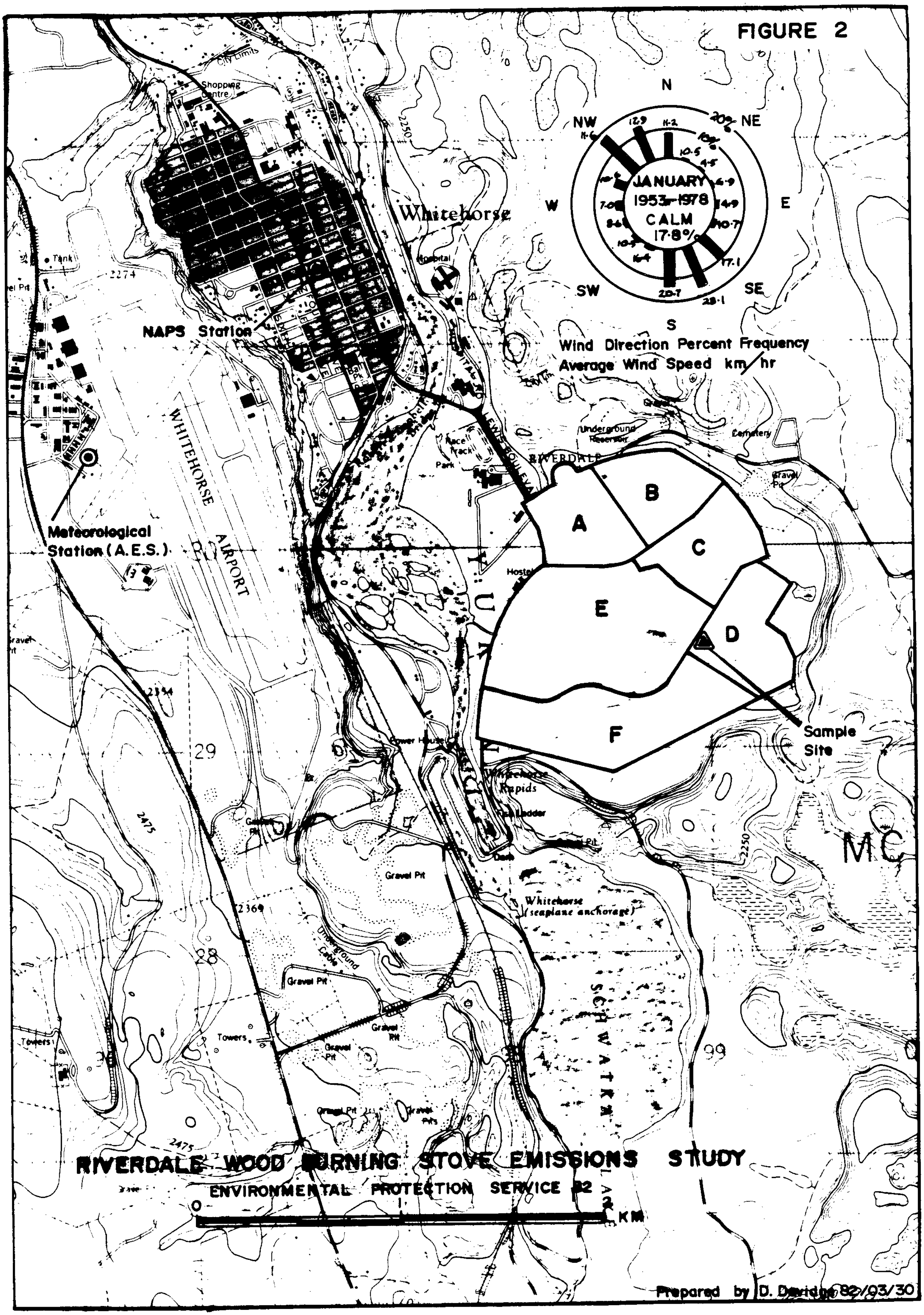


FIGURE 2
N
NW
NE
W
E
SW
SE
S
JANUARY
1953-1978
CALM
17.8%
Wind Direction Percent Frequency
Average Wind Speed km/hr
Whitehorse
NAPS Station
Meteorological
Station (A.E.S.)
WHITEHORSE AIRPORT
A
B
C
D
E
F
Sample
Site
RIVERDALE
Whitehorse Rapids
Gravel Pit
Towers
Underground Cable
Whitehorse (seaplane anchorage)
SCHWATKA
RIVERDALE WOOD BURNING STOVE EMISSIONS STUDY
ENVIRONMENTAL PROTECTION SERVICE 82
0
1
2 KM
Prepared by D. Davidge 82/03/30

rates. In February 1982, after discussion with the Laboratory Service Division, it was realized that the exposed filters could be losing some volatile constitutents of the particulate matter during times when stored at room temperature, so filters taken during that month were sandwiched in aluminum foil prior to mailing. Determination of total suspended particulate matter is a straightforward gravimetric analysis of loaded filters returned to the pre-weigh ambient conditions.

2.2 PAH Determination

After weighing and determination of total suspended particulate matter, the filters were available for PAH determination. The gas chromatography - flame ionization detection (GC-FID) method used has been described by Daniel Wang of the Pollution Measurement Division of the Air Pollution Control Directorate in Ottawa:

> One half of the exposed filter was soxhlet extracted in 500 ml benzene for 24 hours. After the extraction, the benzene solution was filtered through anhydrous Na_2SO_4 to remove solid particles and water. This extract was then concentrated to approximately 2 ml by rotatory evaporation. The water bath temperature was maintained between 35 to 38°C. The extract was cleaned up to separate PAH from a complex mixture of other organic compounds.
>
> Twenty millilitres of cyclohexane were added to the benzene extract. The extract was shaken with 20 ml of DMSO (Me_2SO) in a separatory funnel. The layers were allowed to separate and the DMSO layer was transferred to another separatory funnel. The cyclohexane phase was extracted again with another 20 ml of DMSO and the DMSO pahses were combined. By adding 120 ml of distilled water and 40 ml of cyclohexane, the PAHs were back-extracted into the cyclohexane. The extraction of PAH was repeated once with 40 ml of cyclohexane. The cyclohexane extracts were combined, washed with 150 ml of water, and dried with sodium sulphate.
>
> The cyclohexane extract was concentrated to about 10 ml by rotatory evaporation. The extract was chromatographed with the activated silica gel column (20 cm x 1 cm id). The column was first eluted with 150 ml of hexane and the eluent was discarded; the column was then eluted with 150 ml of benzene. The benzene eluent was evaporated to 1 ml by rotatory evaporation. Further concentration was performed in a calibrated centrifuge tube at 20°C by directing a gentle stream of UHP nitrogen onto the liquid surface, reducing the

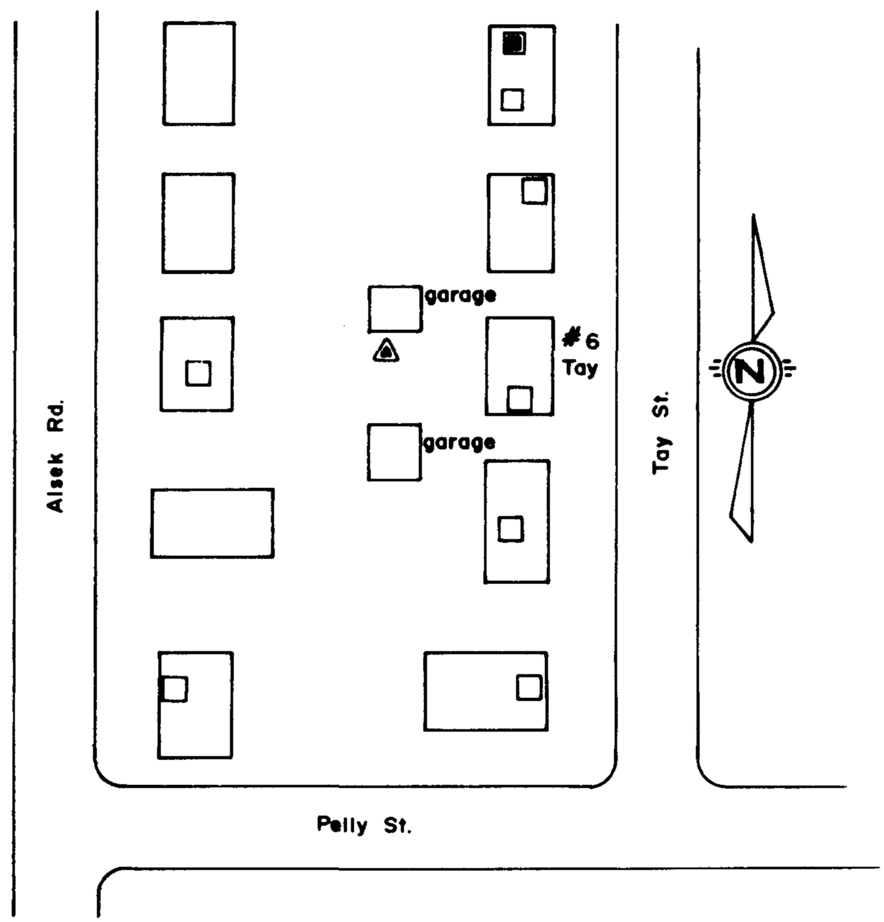
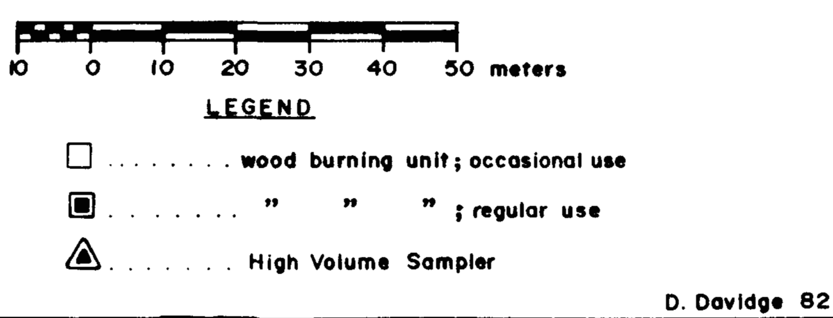


FIGURE 3 : DETAIL OF HIGH VOLUME SAMPLER LOCATION IN RIVERDALE



final volume to 0.5 ml. The analysis was carried out on a Perkin Elmer Sigma 3B gas chromotograph with DB-5, 30 meter fused silica capillary column and flame ionization detector.[1]

In addition, other analyses on Riverdale Filter samples were performed under contract by Farrington Lockwood Co. Ltd. using gas chromatography - mass spectroscopy (GC/MS). Laboratory Services Division checked three GC-FID results with GC/MS and found close agreement.

Analyses results gave weights of up to 14 specific PAH compounds in micrograms per filter, which when calculated with the total weight of particulate matter per filter, and the concentration of particulate per cubic metre, yielded PAH in micrograms per gram of particulate, and nanograms per 1000 cubic metres of air sampled. Results appear in Table 6. All numbers are rounded to four significant figures.

2.3 Carbon Monoxide Monitoring

The Whitehorse NAPS office maintains a Bendix Model 8501-5BA infrared gas analyzer for carbon monoxide. This machine operates continuously from October to April, and records CO on a paper chart with a 50 ppm full scale range. The intake is three metres above a downtown Whitehorse street, and close to a location where vehicular traffic is concentrated. Since the station does not operate year round, CO levels for Whitehorse are not included in 'Annual Summary: National Air Pollution Surveillance' published by the Air Pollution Control Directorate. The only published summary of Whitehorse CO levels appears in a paper by Lafleur, Wituschek and Emslie in 1976.[2] This report gives daily Whitehorse maximum and mean CO levels for the periods of particulate sampling in Riverdale, supplemented for illustrative purposes by an analysis of CO results compared to weather conditions for December 1980, a month when levels were extremely high.

3 DOMESTIC FUEL WOOD CONSUMPTION

Whitehorse is situated in a forested part of the Yukon Territory and it is natural that its residents should make good use of fire-killed stands of pine adjacent to the city. While most homes burn wood as a supplement to other heat sources, an increasing number rely almost entirely on wood furnaces. It was felt that an attempt should be made to determine wood use in the area of the experiment as an aid to interpreting the results of sampling, and to estimate emissions of pollutants. There is a growing body of literature on the subject of wood smoke pollution, and emissions factors are becoming better understood.

3.1 Results of Questionnaire and Ground Survey

Early in December, 1981, each of the 1200 detached homes in Riverdale received a mailed questionnaire. The questionnaire was sponsored by the Environmental Protection Service in conjunction with the Government of Yukon and the federal departments of Indian and Northern Affairs, and of Energy Mines and Resources, since all of these agencies had an interest in the replies. The questionnaire included questions on the method of heating the home, wood use per year, stove type and so on. It is reproduced in Appendix I together with the method used to calculate total wood use in Riverdale. The public response to the questionnaire was a generous one; 337 replies were received out of 1200 mailed. Even if one allows for the likelihood of no two homeowners agreeing as to what consitutues a 'cord' of wood, especially depending upon whether they cut it themselves or purchased it from a dealer, it is still possible to estimate Riverdale wood consumption with a fair degree of confidence.

A discussion of the questionnaire results requires reference to Figure 2 showing the reply zones in Riverdale and to Table 1, which gives the results by zone. The high volume sampler was located in Zone D, which is an area of high wood use. The same is true of Zone F.

TABLE 1

FINAL QUESTIONNAIRE RESULTS OF RIVERDALE WOODBURNING SURVEY, January, 1982

Zone	# returned	Heat Source					total % burn wood	total cords	cords per woodusing home	No. of wood units	cords per wood unit	% bothered by smoke
		oil	electr.	wood	wood & oil	wood & electr.						
A	47	33	0	1	13	0	30	62	4.4	28	2.2	39
B	47	28	1	1	14	3	38	88	4.9	32	2.8	40
C	63	30	2	0	22	9	49	151	4.9	46	3.3	51
D	52	2	9	3	12	26	79	248	6.0	63	3.9	29
E	61	12	16	0	18	15	54	162	4.9	51	3.2	38
F	67	11	6	2	29	19	75	326	6.5	73	4.5	29
TOTALS (average)	337	116	34	7	108	72	(54)	1037	(5.2)	293	(3.3)	(38)

Note: over-all response 337/1200 = 28%

February 18, 1982

While zone locations were arbitrary, they represent different ages of homes with those in Zone A dating from the late 1950s and those in Zone F being the most recent, some being less than five years old. Rather than rely on the response to a mailed questionnaire, it was agreed to make a house-by-house check in two zones, D and F. These results warranted an adjustment to an otherwise straightforward extrapolation of the questionnaire results. The assumption was made that a homeowner who used wood was more likely to return his questionnaire than one who did not. The rationale and method of calculation is explained in Appendix I. Total wood use in Riverdale is therefore estimated at 3500 cords per year, with wood use being concentrated in the most modern homes, especially in those thermally-efficient houses having electrical space heating. If each wood user's estimate has an error of + 0.5 cords, the total will vary + 350 cords or 10 percent.

The reader will note that the percentage 'bothered by smoke' seems to be inversely proportional to wood use in a given zone, which is a curious but perhaps not unexpected result.

3.2 Estimated Emissions of Pollutants

In planning this study it was hoped that a determination of Riverdale smoke emissions and the application of atmospheric factors such as mixing and inversion strength could lead to an estimate of particulate loadings. Such an estimate could have been compared to actual results to guage whether or not a 'worst case' event had been sampled. It now seems that this would have been a difficult if not impossible exercise as will be explained in Section 5. The calculations of emissions which follow are therefore presented to compare with national totals and to show the wide variation within the Riverdale subdivision.

The estimation of emissions from wood stoves and other appliances has several severe limitations-the stove type, the rate of firing, the regulation of air supply and the nature of the fuel.

The United States Environmental Protection Agency published a study of the problem through the Monsanto Research Corporation by D.G. DeAngelis, D.S. Ruffin and R.E. Reznik.[3] Since to date this work has not been superceded, it will form the basis of emissions calculations in this report.

Emission rates for airtight stoves and appliances are not the same as those for excess air appliances such as open fireplaces or Franklin stoves. Airtights have greater emissions per kilogram of wood burned of particulate matter, carbon monoxide and polycyclic aromatic hydrocarbons (PAH) than do the other kind, however emissions of nitrogen oxides are lower. Secondly, the rate of firing in conjunction with the combustion air supply has an important effect. Each householder is likely to follow his own pattern of loading and air supply depending on his heating requirements. Finally while there is some variation in emissions depending on wood type, virtually all the wood used in Riverdale is likely to be drawn from the same supply, stands of fire-killed lodgepole pine to the west of the city of Whitehorse, with only minor quantities of seasoned aspen and spruce.

Thus it was necessary to make some assumptions about the manner and rate of wood consumption in order to estimate emissions. These assumptions and their application are described in Appendix II. First is the selection of a ratio between airtight and excess air appliances according to the questionnaire response. Second is the selection of an arbitrary seven kilogram per hour firing rate for all appliances in all zones for those times when the temperature is -25°C and colder. Use of a temperature-dependent firing rate was not attempted.

Table 2 shows annual emissions of pollutants from wood burning in Riverdale derived from annual wood use per zone, the DeAngelis emissions factors, and a ratio of 1.89 cords burned per airtight per cord burned in excess air appliances. A cord is defined as 1052 kilograms of wood.

TABLE 2

ANNUAL EMISSIONS FROM RIVERDALE YUKON WOODBURNING, kilograms
a-airtight stoves and furnaces b-open (excess air) applicances

Zone	Wood Used kg/yrX10^5	Particulate Matter	Condensable Organics	Total Particulates	NO_x	CO	PAH
A	2.56a	768	1228	1996	77	53,760	94.7
	1.35b	243	797	1040	189	2,835	4.1
B	2.93a	879	1406	2285	88	61,530	108
	1.56b	280	920	1200	218	3,276	4.7
C	4.33a	1299	2078	3377	130	90,930	160
	2.29b	412	1351	1763	321	4,809	6.9
D	4.31a	1293	2069	3362	129	90,510	159
	2.28b	410	1345	1755	319	4,788	6.8
E	4.29a	1287	2059	3346	129	90,090	159
	2.27b	409	1339	1748	318	4,767	6.8
F	5.68a	1704	2726	4430	170	119,280	210
	3.00b	540	1770	2310	420	6,300	9.0
		9,524	19,088	28,612	2,508	532,875	929

Table 3 was derived in a different manner. The total number of wood appliances in each zone was extrapolated from the questionnaire, and an arbitrary firing rate of seven kilograms per applicance determined hourly wood consumption. Then the DeAngelis factors were applied to give first hourly, then daily emissions.

TABLE 3

RIVERDALE CALCULATED EMISSIONS FOR 24 HOURS, Kilograms

Zone	Total Particulates	NO_x	CO	PAH
A	89	13	820	1.4
B	103	15	850	1.4
C	149	18	1890	3.1
D	202	23	2710	4.8
E	164	21	1780	3.1
F	232	28	3000	5.0
	TOTALS 939	118	11,050	18.8

As a check on these quantities it is useful to divide the results in Table 2 by those in Table 3. This yields from 25 days' emissions for NO_x to 50 days' emissions for PAH. Since the two tables originated from quite different assumptions, this is offered as a check on orders of magnitude. The range from 25 to 50 days represents the approximate number of days in a Whitehorse winter when one can expect temperatures colder than -25°C. A more rigorous estimate of wood smoke emissions cannot be made without much more data on local wood use. All the assumptions used need closer definition, including factors for wood use per degree-day per house heated volume, for stove type, for firing rate, and for emissions factors and compounds identified for the dominant wood type.

Riverdale air will be receiving contaminants from other sources as well, from domestic and institutional oil heating and from mobile sources. The method used to calculate other emissions is shown in Appendix II-mobile sources and institutional heating have not been attempted. Domestic oil consumption may contribute the following annual emissions, which should be compared to Table 2: particulate matter-899 kg, NO_X-6670 kg, CO-1830 kg, and hydrocarbons-348 kg. The nitrogen oxides are substantially higher than from wood heating, but the other quantities are not significant. Automobile sources have not been estimated due to the difficulty of selecting a meaningful emission rate per vehicle, but it is likely that even during rush hour, the CO contribution of automobiles is likely to be an order of magnitude less than that of wood heating.

4 OVERVIEW OF THE CLIMATE OF WHITEHORSE

Any presentation on an air pollution problem must include climatic factors, and the most important of these is the stability of the air mass receiving the pollutants. The climatology of Whitehorse is comparable to that of Fairbanks, Alaska where air pollution has been studied for many years. In addition, the city airport has an Atmospheric Environment Service weather station (WO 1) with 40 years of records, including twice-daily radiosonde measurements of upper air. This data is supplemented by specific studies done by AES along the route of the proposed Alaska Highway Gas Pipeline. However, the author has been advised that one cannot predict with any certainty that a significant pollution event will occur, given a set of atmospheric conditions usually favourable to it. Therefore this section can only summarize those conditions which will enhance any pollution.

The most important feature of Whitehorse air pollution is ice fog. At temperatures below -35°C, air contains virtually no moisture, so emissions from automobiles and domestic heating stacks, all of which contain water, become visible as fog plumes. During times of extreme cold, visibility in downtown Whitehorse can be reduced to a few tens of metres simply from ice fog from automobile exhausts. It is common during cold winters to have the city blanketed with a layer of fog nearly 100 metres thick, with contributions from automobiles, furnaces, and most importantly, from open water on the Yukon River below the Whitehorse Rapids hydroelectric installation. While the ice fog is in itself a visible pollutant, most important is its effect on other pollutants such as carbon monoxide.

Carl Benson and Kenneth Rizzo have described the effects of ice fog on pollutant concentrations in Fairbanks.[4] At these latitudes, winter ground-level inversions are very common, but when the ice fog builds up, the base of the inversion moves to the top of the fog layer. This disturbs the normal dispersion process for low level emissions such as home chimneys and automobiles, and the pollutants distribute evenly throughout the fog layer. Another effect can be the formation of a 'heat island', in which ice fog prevents heat losses of built-up areas from radiating to space. The ice fog warms slightly, but remains trapped beneath the inversion and atmospheric mixing is further reduced. Ice fog then confines the pollution and makes it visible.

The second most important factor controlling Whitehorse air pollution is the frequency and intensity of ground-based inversions. Whitehorse upper air measurements have been reviewed by R.E. Munn, J. Tomlain and R.L. Titus in a 1970 paper.[5] Wintertime inversions are no more frequent here than other parts of Canada such as the Mackenzie valley or the central southern Prairies, but their intensity and duration makes them very significant from a pollution standpoint. Elsewhere in Canada, inversions tend to break up temperarily during the day, allowing pollutants to disperse. It is not known if a similar phenomenon occurs in Whitehorse because the local times of release of the radiosondes in winter are 0300 hrs and 1500 hrs, but inversions can persist all day in Fairbanks, Alaska, and likely do in Whitehorse as well.

It seems clear from Alaska work that the level of pollution experienced, at least for carbon monoxide, is directly proportional to intensity of the ground level inversion. Benson reports inversion intensities to 21°C per 100 metres; that is, the ground temperature is 21°C colder than the air 100 metres above it. These are among the strongest inversions measured. Whitehorse may not experience intensities of this magnitude, since monthly mean winter temperatures are warmer than Fairbanks. This study records 1982 inversions to 8°C/100m, and an unpublished report by D.A. Faulkner, R.R. McLaren and S. Nikleva for the Atmospheric Environment Service in 1978 records inversions to 6°/100m at Beaver Creek, Y.T.[6] During such times winds are very low to calm at the ground but may show quite different speeds and directions a few hundred metres above the surface. Conditions essential for the mixing of pollutants are absent.

R.V. Portelli has written about the potential for pollution in Canada on a regional scale.[7] He defined the concept of ventilation coefficient, and related it to the vertical height of mixing times the mean transport wind, with units in $metres^2/sec$. For Whitehorse in winter, the average mixing height is 250 metres and the mean wind speed is 4 metres per second, both figures being less than those for other seasons. The Whitehorse January ventilation coefficient is 87 m^2/sec, which translates to ten times the pollution potential of spring and summer conditions. He stated that values of mixing coefficients less than 6000 m^2/sec are indicative of high pollution potential in the United States. Portelli's work uses averages which may conceal the significance of ground level inversion conditions, and low to absent winds.

This section will conclude with some observations on weather conditions in Whitehorse during the study periods, compiled from monthly Yukon weather summaries published by the Whitehorse office of the Atmospheric Environment Service. The winter of 1980-81 was a study of contrasts. December 1980 was colder than average, with a mean of -27.6°C compared to the typical December of -15.3°C. Seven days had minimums below -40°C. Wind conditions were 11 km/hr with a prevailing direction of NNW, contrasted with average conditions of 15.8 km/hr from the SSE. The significance of this month will be shown in the discussion of carbon monoxide levels to follow in Section 5. January 1981 showed a mean temperature of -4.0°C to the normal January average of -18.9°C, and winds of 22.5 km/hr from the south compared to the average of 13.8 km/hr from the SSE. February 1981 was similarly warmer than average, with slightly reduced winds. High volume samples taken during January and February 1981 cannot represent typical sampling conditions during a Whitehorse winter.

December 1981 had a mean temperature within one degree of the normal and the wind pattern and strength were typical. January 1982 came very close to setting records for cold temperatures. Its mean of -31.2°C was far below the normal of -18.9°C, and while average wind speeds were less than normal, their direction was from the north, in contrast to the prevailing SSE direction. February was similarly colder than normal, by 5°, and less windy, and its winds were similarly from the north. This study has therefore intercepted a very cold month, but it is not typical in that winds were from the north rather than the south, and this could be shown to weaken any conclusions about particulate matter concentrations in Riverdale.

5 RESULTS AND DISCUSSION

The results of this survey show that the Riverdale suburb of Whitehorse can experience significant air pollution on those days when atmospheric conditions confine the pollution to the basin enclosing the subdivision. Concentrations of particulate matter can exceed national guidelines for desirable levels. Concentrations of certain polycyclic aromatic compounds (PAH) can exceed those measured in major industrial cities. Similarly, carbon monoxide can accumulate in Whitehorse to levels which exceed maximum tolerable standards. The air pollution is strongly dependent on weather conditions. To the extent that those conditions are predictable, and assuming that environmental health authorities determine the pollution to be of concern, then it seems desirable to have some means of advising the public of the potential of air pollution.

5.1 Particulate Matter

At the outset the reader should be cautioned that this survey is based on 64 samples of Riverdale air, supplemented by a limited amount of other data. Conclusions drawn from these samples must be considered as tentative; however, the pollution measured is unlikely to overstate conditions. Table 4 includes the results of particulate sampling during the two winters, compared with results of the National Air Pollution Surveillance high volume sampling in downtown Whitehorse, less than two kilometres from the Riverdale sample site. Riverdale particulate matter averaged only 24 micrograms per cubic metre (ug/m^3) in 26 samples taken during January and February 1981. Results for the November 1981 to February 1982 period showed an average of 70 ug/m^3 in 38 samples. The downtown Whitehorse NAPS samples averaged 23 ug/m^3 in 18 filters taken the same time as the Riverdale sampling intervals. These are little more than indications of suspended particulate matter, and a graphical display can be helpful in understanding distribution.

TABLE 4

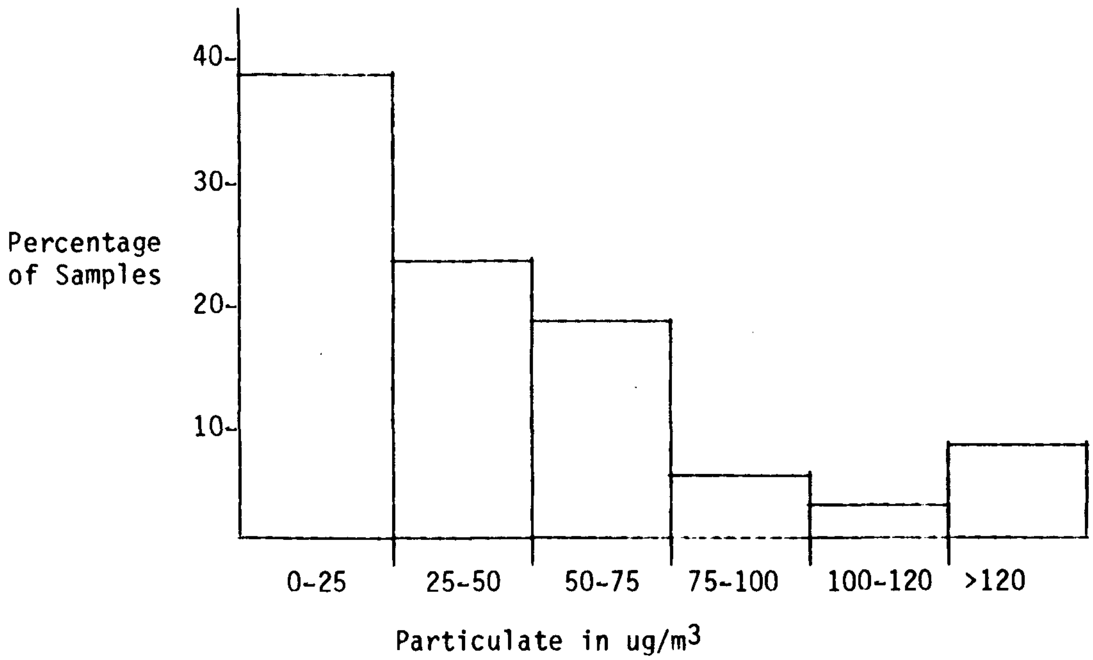
WHITEHORSE - RIVERDALE PARTICULATES

Date	Riverdale Part. ug/m^3	NAPS Part. ug/m^3
1980 Dec 5	-	36
11	-	26
17	-	27
23	-	26
29	-	21
1981 Jan 16	10	14
16	8	
20	31	
20	9	
22	9	14
22	20	
27	36	
27	17	
29	22	
29	20	
Feb 03	7	13
03	48	
05	62	
05	14	
10	36	
12	25	
12	39	
17	16	
19	31	
19	72	
21	31	6
21	14	
24	13	
24	7	
26	6	
26	19	
Nov 24	26	16
27	15	
29	95	
30	13	24

Date	Riverdale Part. ug/m^3	NAPS Part. ug/m^3
1981 Dec 03	15	
06	116	41
07	50	
09	23	
12	25	34
15	73	
18	9	12
21	101	
24	98	19
29	65	
29	59	
30	66	
31	31	
1982 Jan 02	60	
04	32	
05	28	23
06	46	
07	38	
11	222	30
17	196	37
18	34	
20	69	
21	180	
23	66	32
26	72	
29	17	25
Feb 01	72	
04	31	25
07	67	
13	87	
16	153	16
19	134	
22	20	26
25	138	

FIGURE 4

RIVERDALE PARTICULATE CONCENTRATION FREQUENCY



The 1981/82 loadings exceeded those of 1981 by more than a factor of two. They include all samples with particulate concentrations above 120 micrograms per cubic metre, which is the maximum acceptable limit under national air quality objectives. Section 4 of this report described the difference in weather between the two winters, and this seems to explain the two averages. The recent winter was colder, meaning more wood was burnt, and it had less wind to disperse pollutants. A second feature of the particulate concentrations during 1981/82 is the number of heavily-charged filters compared to 1981. The number of samples is small, but they suggest a bimodal distribution of particulate concentrations. Additional sampling may disprove this assertion. The environmental significance of samples with loadings above national guidelines of 120 ug/m^3 lies in their PAH loadings.

The procedures used in handling the particulate sample filters may have lost some PAH material, so the total particulate results may be understated. Some of these compounds are quite volatile at room temperature, and they can be oxidized by ozone. Future sampling should keep the exposed filters in aluminum foil and frozen until analysis. It is not possible to estimate the amount of hydrocarbon particulate matter lost in this way. A second point concerns the operation of a high-volume filter apparatus in extreme cold. Leaving aside the difficulties and risks of bare-handed work, the Riverdale samplers were plagued with timing faults in which the machine would not shut off after 24 hours. Another problem was the freezing of ink on the flow rate chart. The manufacturer's manual for the sampler gives a minimum temperature of -20°F (-29°C) to its operating range. Some modification to the samplers should be made to allow for trouble-free operation at very low temperatures.

5.2 Carbon Monoxide

Table 5 shows carbon monoxide levels at the Whitehorse NAPS monitor, 2 km northwest of the Riverdale sampling site. Elevated particulate concentrations in January and February of 1982 as compared to the same months in 1981 are not paralleled by the CO results over the same periods. No CO sampling was done in Riverdale itself, as the intention was to collect bag air samples there only at those times when CO exceeded 6ppm at the NAPS monitor. This was such a rare occurrence - as compared to December 1980, for example - that only one attempt was made, and suddenly-changing winds lowered the sampled Riverdale CO concentration to below the detection limit. Future measurements of pollution episodes should include CO sampling.

TABLE 5
WHITEHORSE DAILY CARBON MONOXIDE LEVELS, ppm (rounded)

Date		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Dec 1980	max	-	4	10	7	10	3	1	9	10	3	13	6	9	3	19	5	5	10	15	5	1	8	22	20	1	1	4	1	4	5	3
	av	-	-	3	2	3	1	1	3	4	1	5	4	2	1	7	1	2	3	2	1	1	2	6	4	0	0	2	1	1	1	1
Jan 1981		1	5	1	1	10	3	2	18	3	2	1	18	2	1	1	4	2	1	5	5	2	6	4	4	1	3	4	14	3	4	2
		0	1	1	0	4	1	1	4	1	1	1	6	1	0	0	1	1	0	1	2	1	2	1	1	0	1	1	4	1	1	1
Feb 1981		1	3	4	3	3	4	10	2	5	4	2	3	4	3	4	10	2	6	6	3	1	1	4	6	3	2	5	11			
		0	1	1	1	1	2	3	1	2	2	1	1	1	1	1	3	1	2	2	1	1	1	2	2	1	1	2	4			
Dec 1981		6	6	2	11	3	6	5	2	4	4	4	3	3	11	5	3	3	3	5	8	10	12	4	4	1	1	1	2	3	6	4
		1	2	1	4	1	2	2	1	1	1	2	1	1	2	1	1	1	1	2	2	4	6	1	1	0	0	0	1	1	2	1
Jan 1982		3	1	1	5	2	2	3	2	2	1	3	3	2	6	6	1	3	6	3	4	9	7	5	1	3	8	2	4	6	10	2
		1	1	1	2	1	1	1	1	4	1	1	1	1	2	3	1	1	1	1	2	3	2	1	0	1	2	1	1	1	2	1
Feb 1982		5	4	-	-	-	-	-	3	2	2	3	9	4	1	1	6	8	3	9	1	1	2	2	2	2	4	17	5			
		2	1						2	1	1	1	4	2	0	0	2	3	2	3	1	0	1	1	1	1	2	3	2			

Source: National Air Pollution Surveillance monitoring

Carbon monoxide levels for January and February 1982 do not include the extremes reported for Whitehorse during December 1980. Even though both December 1980 and January 1982 were very cold months by Whitehorse standards, the CO averages were quite different, being 2.2 ppm mean and 22.4 ppm maximum for that December and 1.2 mean and 10.2 maximum for January. These results are quite puzzling, since one would expect the CO levels to be similar. The difference suggests that December 1980 had more potential of air pollution than January 1982, or that the particulate sampling done and reported in this study did not intercept a worst case, despite January's record cold temperatures. Atmospheric mixing therefore becomes more important in evaluating the potential for air pollution than the sources or emissions of that pollution.

Mr. Lance MacLeod of the Environmental Protection Service, Pacific Region, kindly supplied the author with a statistical analysis of the December 1980 hourly carbon monoxide levels in correlation with weather conditions. He used CO in ppm as the dependent term and computed correlations using each of six independent terms: temperature, wind speed, wind direction, December date, hour of day and day of the week. Analysis was by a Hewlett-Packard 9826 computer with graphical display. The three sections of the analysis were CO versus each of the independent terms, CO versus temperature for increasing wind speeds, and CO versus temperature for each wind direction. He showed there were no significant correlations, a result which is frustrating to the development of any hypothesis about Whitehorse climate and air pollution. Comparison of three years of Whitehorse CO data with weather conditions led the authors of another study to the same conclusion, with the qualifier that while CO was elevated during low temperatures, extreme cold saw a reduction in concentration because fewer vehicles were being used.[2]

5.3 PAH Compounds

Polynuclear aromatic hydrocarbons or PAH are known to have environmental health significance. Some compounds are carcinogenic and will induce tumours in test animals. Others are less potent in their effects, have no effect, or are untested. It is an active area of research, closely tied to work on cancer in humans. The United States Environmental Protection Agency is working towards national standards for PAH in the environment and has sponsored many studies about ambient concentrations. Their paper titled 'Polynuclear Aromatic Hydrocarbons: Ambient Water Quality Criteria' contains the following (p.C-107):

> Convincing evidence from air pollution studies indicates an excess of lung cancer mortality among workers exposed to large amounts of PAH-containing materials such as coal gas, tars, soot, and coke-ovens emissions...However, no definite proof exists that the PAH present in these materials are responsible for the cancers observed. Nevertheless, our understanding of the characteristics of PAH-induced cancers in animals, and their close resemblance to human carcinomas of the same target organs strongly suggests that PAH pose a carcinogenic threat to man, regardless of their route of exposure.[8]

Benzo(a)Pyrene is a potent cancer agent: its concentration in the air of many cities has been measured for decades. For an assessment of PAH levels reported in this study, the reader is directed to a summary of opinions received from Health and Welfare Canada, in Appendix 3.

Levels of PAH measured on Riverdale high volume filters are reported in Table 6, and displayed graphically in Figure 5. Because of the wide variation in particulate loadings, no averages of the PAH compounds were computed. It is obvious however that the highest particulate loadings correspond to the highest values of PAH. There is seemingly no characteristic mix of compounds appearing on the filters; the heaviest filter may not necessarily have the highest concentration of a specific compound. However, the filter taken January 11, 1982 is exceptional enough - the value of 127,000 nanograms per 1000 cubic metres for fluoranthene is higher than any the author has found reported in the literature.[9] Table 7 shows values for some PAH compounds measured in other cities. A comparison of these values with Table 6 shows that some individual Riverdale samples fall in the

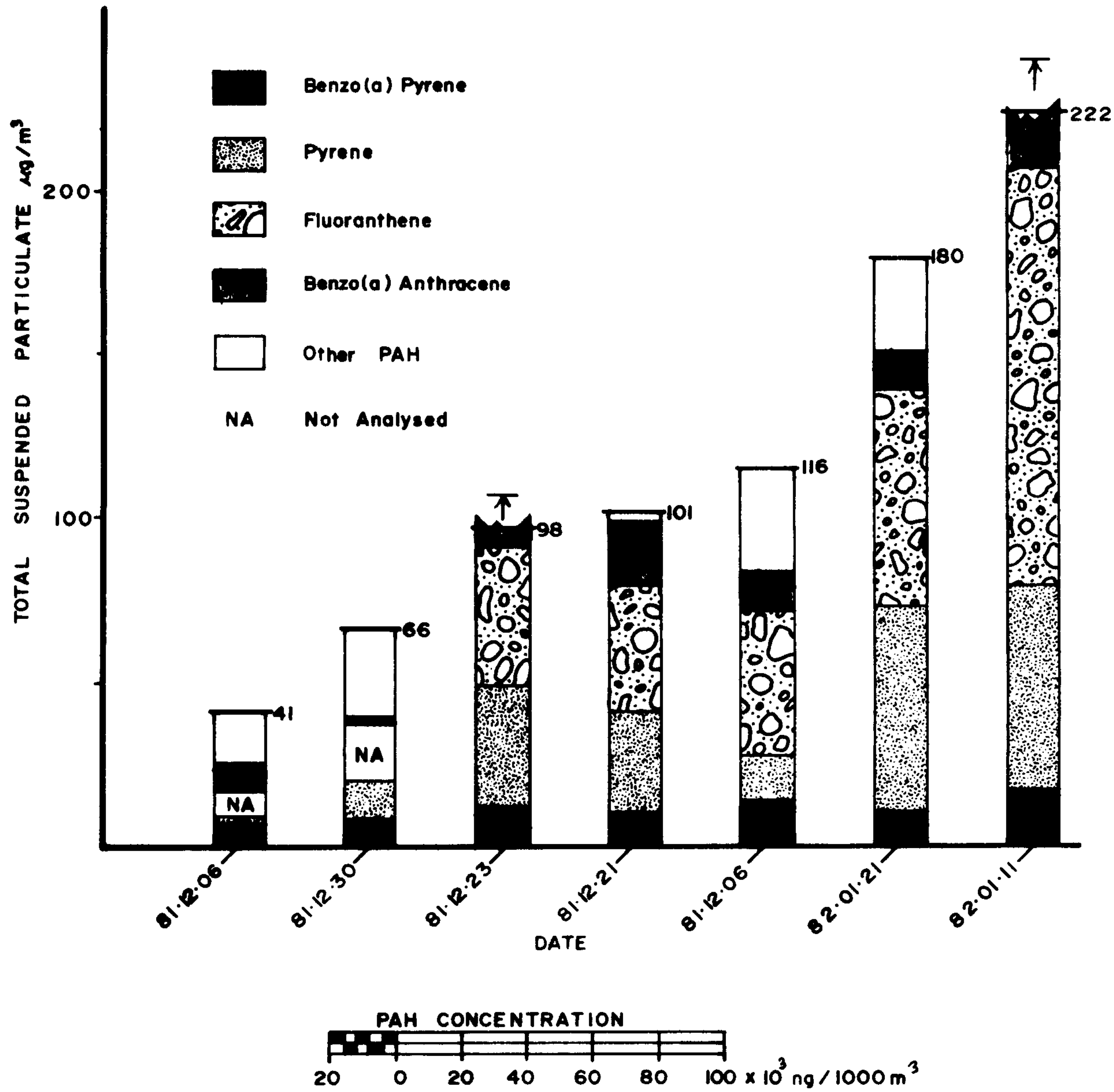


FIGURE 5: PAH LOADING, SELECTED FILTERS

TABLE 6

WHITEHORSE - RIVERDALE HIGH VOLUME FILTERS - PAH LOADINGS
ND = not detected - = not measured

Continued

Date	Total Suspended part. ug/m3	Benzo(a)Pyrene Part. ug/g	Benzo(a)Pyrene Air ng/1000m3	Pyrene Part. ug/g	Pyrene Air ng/1000m3	Fluoranthene Part. ug/g	Fluoranthene Air ng/1000m3	Benzo(a) Anthracene Part. ug/g	Benzo(a) Anthracene Air ng/1000m3
1981 Jan 16	10	10.12	101	6.65	67	8.53	85	ND	
"	8	35.83	287	11.41	91	20.70	166	ND	
Jan 20	31	ND		6.49	201	9.19	284	ND	
"	9	ND		3.55	32	5.14	46	ND	
Jan 22	9	ND		8.74	79	18.89	170	ND	
"	20	ND		7.20	144	6.01	120	ND	
Jan 27	36	133.5	4800	159.5	5741	90.29	3250	91.46	3292
"	17	8.48	144	6.66	113	4.79	81	ND	
Jan 29	22	12.59	277	3.31	73	5.22	115	ND	
"	20	ND		13.19	264	11.15	223	ND	
Feb 3	7	ND		15.74	110	15.05	105	ND	
"	48	30.84	148	34.76	1670	19.48	935	ND	
Feb 5	62	117.7	7299	204.2	12,660	127.3	789	94.63	5867
"	14	29.98	419	7.96	111	14.30	200	ND	
Feb 10	36	ND		19.37	697	1086.	39,900	ND	
Feb 12	25	38.91	973	38.31	957	26.21	655	11.83	296
"	39	35.22	1374	33.20	1295	15.76	614	ND	
Feb 17	16	ND		11.76	188	8.54	137	ND	
Feb 19	31	69.75	2162	40.21	1247	27.94	876	66.55	2063
"	72	134.9	9713	92.77	6679	53.80	3873	88.78	6393
Feb 21	31	17.34	121	16.19	113	32.92	230	ND	
"	14	98.35	1397	36.80	515	19.30	270	68.70	961
Feb 24	13	9.23	120	4.19	54	2.95	38	21.79	283
"	7	ND		33.70	236	11.71	82	-	-
Feb 26	6	ND		85.27	512	82.84	497	ND	
"	19	10.32	196	14.23	276	6.77	129	ND	

All Analyses by Laboratory Services Division (GC-FID)

TABLE 6 (continued)

WHITEHORSE - RIVERDALE HIGH VOLUME FILTERS - PAH LOADINGS
ND = not detected   - = not measured

Date	Total Suspended part. ug/m^3	Phenanthrene Part. ug/g	Phenanthrene Air ng/1000m^3	Anthracene Part. ug/g	Anthracene Air ng/1000m^3	Chrysene Part. ug/g	Chrysene Air ng/1000m^3	Benzo(a)Fluorene Part. ug/g	Benzo(a)Fluorene Air ng/1000m^3
1981 Jan 16	10	ND		ND		ND		2.88	29
"	8	6.25	50	9.97	80	ND		10.14	81
Jan 20	31	6.32	195	3.26	101	ND		6.26	194
"	9	3.95	36	5.83	52	ND		11.86	107
Jan 22	9	2.95	27	2.10	19	2.32	21	4.74	43
"	20	6.30	126	2.30	46	ND		5.14	103
Jan 27	36	25.80	929	2.30	83	53.16	1914	26.58	957
"	17	1.61	27	ND		1.61	27	1.51	26
Jan 29	22	2.61	57	ND		ND		4.96	109
"	20	11.65	233	3.32	74	2.41	48	6.07	121
Feb 3	7	10.18	71	20.60	144	ND		14.35	100
"	48	ND		ND		6.80	326	13.67	656
Feb 5	62	44.23	2742	4.20	260	56.58	3508	60.42	3746
"	14	ND		3.53	49	2.82	39	25.37	355
Feb 10	36	4.34	156	ND		10.03	361	9.50	342
Feb 12	25	8.27	206	ND		3.02	76	36.90	922
"	39	3.95	154	4.63	181	15.76	615	7.72	301
Feb 17	16	4.56	73	2.64	42	-	-	8.38	134
Feb 19	31	27.76	861	7.51	233	10.36	321	17.53	543
"	72	6.93	499	2.80	202	34.28	2468	64.03	4610
Feb 21	31	14.16	99	ND		8.85	62	44.69	313
"	14	9.13	128	ND		ND		9.41	132
Feb 24	13	ND		ND		1.15	15	3.93	51
"	7	10.75	85	8.83	62	-	-	8.26	58
Feb 26	6	41.10	247	43.12	259	78.79	472	71.15	427
"	19	ND		ND		ND		14.00	266

All analyses by Laboratory Services Division (GC-FID)

TABLE 6 (continued)

WHITEHORSE - RIVERDALE HIGH VOLUME FILTERS - PAH LOADINGS
ND = not detected   - = not measured

Continued

Date	Total Suspended part. ug/m³	Benzo(a)Pyrene Part. ug/g	Benzo(a)Pyrene Air ng/1000m³	Pyrene Part. ug/g	Pyrene Air ng/1000m³	Fluoranthene Part. ug/g	Fluoranthene Air ng/1000m³	Benzo(a) Anthracene Part. ug/g	Benzo(a) Anthracene Air ng/1000m³
1981 Nov 29†	95	-		147.6	14,070	121.56	11,590	68.68	6546
*Dec 6§	41	16.91	693.3	48.79	2000	-	-	21.2	8690
" †	116	123.0	14,230	44.72	5172	393.3	45,490	111.6	12,910
Dec 15†	73	119.8	8707	310.1	22,550	284.1	20,660	-	-
Dec 21†	101	105.6	10,690	335.3	33,940	396.6	40,140	169.3	17,140
Dec 23©	98	122.9	12,080	383.9	37,710	410.7	40,330	195.6	19,220
*Dec 24§	19	ND		13.73	260	-	-	ND	
Dec 29§	65	4.14	269.6	162.0	10,540	-	-	57.84	3759
" §	59	29.53	1742	137.7	8122	-	-	31.40	1852
Dec 30§	66	12.66	835	113.0	7460	-	-	27.13	1790
1982 Jan 2§	60	35.10	2105	187.9	11,273	-	-	62.63	3757
Jan 5†	28	138.3	3873	49.73	1392	112.7	3154	57.14	1600
Jan 6†	46	101.4	4664	123.5	5682	220.5	10,140	94.84	5362
Jan 11©	222	72.42	16,080	306.7	68,090	572.3	127,000	126.8	28,144
Jan 21©	180	53.05	9551	174.1	31,340	378.8	68,180	75.61	13,610

*Sampled at NAPS station in Whitehorse, corrected for partial filters.

† - Analyses by Pollution Measurement Division (GC-FID)
§ - Analyses by Farrington Lockwood Co. Ltd.
© - Analyses by Pollution Measurement Division (GC-FID) and confirmed by Laboratory Servies (GC/MS)

TABLE 6 (Continued)

WHITEHORSE - RIVERDALE HIGH VOLUME FILTERS - PAH LOADINGS
ND = not detected   - = not measured

Continued

Date	Total Suspended part. ug/m^3	Phenanthrene Part. ug/g	Phenanthrene Air ng/1000m^3	Anthracene Part. ug/g	Anthracene Air ng/1000m^3	Chrysene Part. ug/g	Chrysene Air ng/1000m^3	Benzo(b)Fluoranthene Part. ug/g	Benzo(b)Fluoranthene Air ng/1000m^3
1981 Nov 29†	95	18.33	1747	2.74	261.0	85.18	8119	-	-
*Dec 6§	41	54.61	2239	12.84	526.9	37.99	1558	-	-
" †	116	101.9	11,780	17.89	2069	157.2	18,180	123.5	14,290
Dec 15†	73	111.7	8120	13.32	968.1	149.0	10,830	17.35	1262
Dec 23†	98	164.9	16,200	32.87	3196	175.3	17,220	122.8	12,070
*Dec 24§	19	24.2	459	3.60	68.4	ND	ND	-	-
Dec 29§	65	122.2	7941	33.86	2201	87.71	5701	-	-
" §	59	92.09	5433	20.23	1194	48.37	2854	-	-
Dec 30§	66	96.46	6366	21.48	1417	35.95	2372	-	-
1982 Jan 2§	60	151.4	9085	5.93	40.8	86.03	5162	-	-
Jan 5†	28	48.53	1220	32.91	921.5	71.79	2010	ND	ND
Jan 6†	46	105.4	4849	19.59	901.1	118.2	5437	158.2	7277
Jan 11©	222	396.2	87,970	46.76	10,380	60.05	13,330	93.97	20,860
Jan 21©	180	335.9	60,460	43.18	7772	70.56	12,700	56.38	10,150

*Sampled at NAPS station in downtown Whitehorse, corrected for partial filter.

† - Analyses by Pollution Measurement Division (GC-FID)
§ - Analyses by Farrington Lockwood Co. Ltd.
© - Analyses by Pollution Measurement Division (GC-FID) and confirmed by Laboratory Services (GC/MS)

TABLE 6 (continued)

WHITEHORSE - RIVERDALE HIGH VOLUME FILTERS - PAH LOADINGS
ND = not detected - = not measured

Date	Total Suspended part. ug/m^3	Benzo(k) Fluoranthene Part. ug/g	Benzo(k) Fluoranthene Air ng/1000m^3	Ideno(1,2,3-cd) Pyrene Part. ug/g	Ideno(1,2,3-cd) Pyrene Air ng/1000m^3	Dibenzo(a,h) Anthracene Part. ug/g	Dibenzo(a,h) Anthracene Air ng/1000m^3	Benzo(g,h,i) Perylene Part. ug/g	Benzo(g,h,i) Perylene Air ng/1000m^3	Benzo(a) Fluorene Part. ug/g	Benzo(a) Fluorene Air g/1000m^3
1981 Nov 29†	95	-	-	-	-	-	-	-	-	-	-
*Dec 6§	41	-	-	-	-	-	-	-	-	12.15	498.2
" †	116	186.9	15,830	58.85	6808	19.78	2288	78.23	9049	-	-
Dec 15†	73	86.68	6302	63.40	4610	222.8	16,200	12.54	911	-	-
Dec 21†	101	134.0	13,570	80.65	8163	27.86	2819	59.05	5977	-	-
Dec 23©	98	143.9	14,140	98.82	9708	55.86	5488	79.75	7835	-	-
*Dec 24§	19	-	-	-	-	-	-	-	-	ND	
Dec 29§	65	-	-	-	-	-	-	-	-	37.60	2446
" §	59	-	-	-	-	-	-	-	-	26.51	1564
Dec 30§	66	-	-	-	-	-	-	-	-	23.36	1541
1982 Jan 2§	60	-	-	-	-	-	-	-	-	46.39	2783
Jan 5†	28	ND		113.2	3170	ND		90.23	2527	-	-
Jan 6†	46	93.69	4309	80.33	3695	45.49	2093	86.07	3959	-	-
Jan 11©	222	84.88	18,840	49.62	11,020	27.07	6008	54.38	12,070	-	-
Jan 21©	180	55.74	10,030	35.36	6365	58.44	10,520	48.50	8730	-	-

* Sampled at NAPS station in downtown Whitehorse, corrected for partial filter.

† - Analyses by Pollution Measurement Division (GC-FID)
§ - Analyses by Farrington Lockwood Co. Ltd.
© - Analyses by Pollution Measurement Division GC-FID) and confirmed by Laboratory Services (GC/MS)

TABLE 7

COMPARISON OF PAH LEVELS REPORTED AT OTHER LOCATIONS

Place	Date	Total Suspended Part. ug/m^3	Benzo(a) Pyrene ng/1000m^3	Pyrene ng/1000m^3	Fluoranthene ng/1000m^3	Reference
Osaka, Japan	November 1978	226	24,300	5860	4520	1
Los Angeles	1973	-	1300	1800	1600	2
Birmingham, Al.	1978	-	17,800	6800	7400	2
Hamilton, Ontario	May 1978	105	2862			3
10 Ontario Cities (average)	1979	-	1440			4

References:

1. Yamasaki, Hiroyasu et al, "Effects of Ambient Temperature on Aspects of Airborne Polycylic Aromatic Hydrocarbons', Envir. Sci. Technol., Vol. 16, No. 4 (1982), p. 192.

2. Cited in White, J,B. and R.R. Vanderslice, POM Source and Ambient Concentration Data: Review and Analysis, for U.S. Environmental Protection Agency, Washington, D.C. (March, 1980), p. 46.

3. Katz, Morris and Cecilia Chan, 'Comparative Distribution of Eight Polycylic Aromatic Hydrocarbons in Airborne Particles Collected by Conventional High Volume Sampling and by Size Fractionation', in Envir. Sci. Technol., Vol. 14, No. 7 (1980), p. 841.

4. Cited in Malaiyandi, Murugan et al 'Measurement of Potentially Hazardous Polynuclear Aromatic Hydrocarbons form Occupational Exposure During Roofing and Paving Operation', Unpublished paper, Health Protection Branch, Health and Welfare Canada, Ottawa, n.d.

middle to upper range of concentrations reported for other cities. These values are significant enough in themselves: their assessment in terms of human health seems well warranted.

The results for PAH compounds may be understated. Some compounds especially those with only two or three benzene-ring nucleii are more volatile than others. The persistence of the compounds on the filters during sampling and afterwards has not been studied under Whitehorse climatic conditions. Then too, their handling procedures were not rigorously conservative either in the field or later in the laboratory. The experiments should be repeated with close control of losses from loaded filters. Finally, Table 6 does not report fluorene, as it was measured in only six of the filters analyzed, in concentrations only to 360 ng/1000m^3.

Figure 5 is intended to display the variations in concentrations of four PAH compounds on selected filters. The concentration of benzo (a) pyrene seems independent of particulate loading. This suggests that some of the compound has been lost from the filters, since one would expect its concentration to be in proportion to other compounds. Pyrene shows the same sort of variation. There is insufficient data to make a statistical comparison between filters and search for a characteristic mix of compounds and concentrations. After further sampling this should be attempted because the emissions derive from many similar sources using the same fuel, differing only in the rate and manner of firing.

5.4 Microclimate and the Identification of a 'Worst Case'

The assessment of air pollution in Whitehorse requires a synthesis of pollution measurements, weather conditions, the natural terrain and the types of sources. Using a specific date-January 11, 1982-does that fairly represent an incident which could be taken as typical of a worst case for Riverdale. Two features of the assessment are fixed, the terrain and the sources, so these can be discussed first.

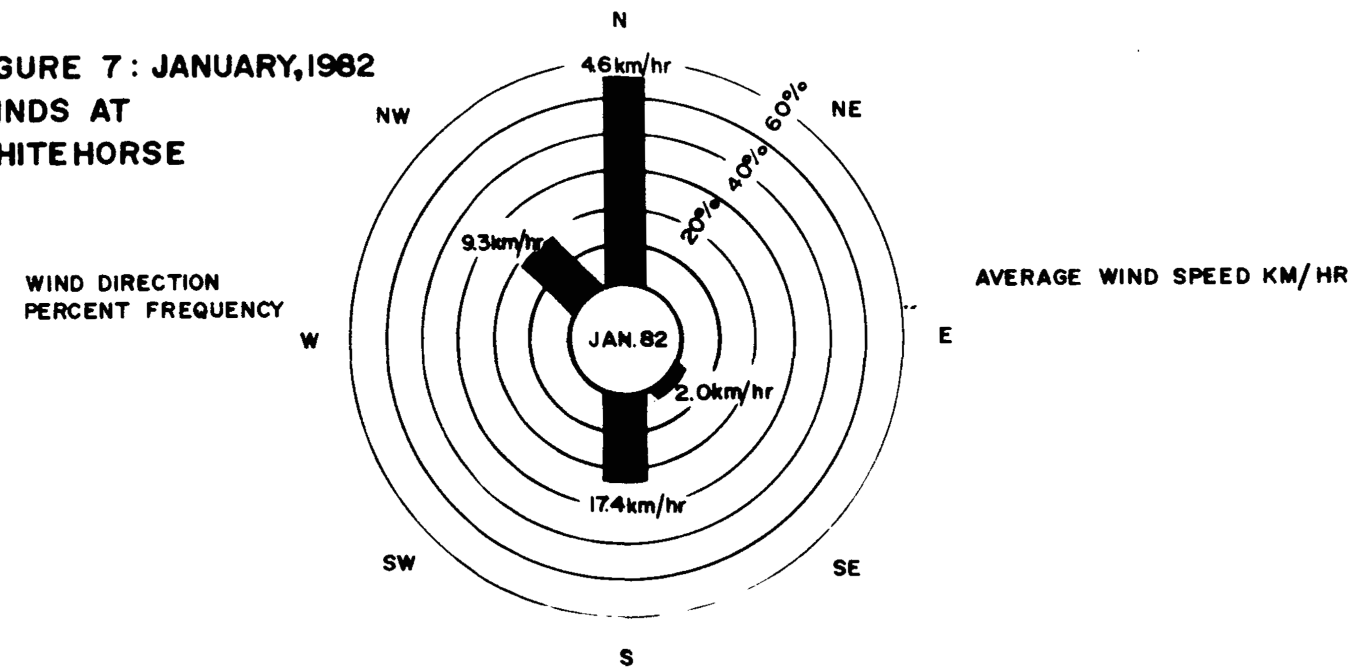
Riverdale fills an abandoned meander of the Yukon River. As Figure 2 shows, it is fringed on three sides-in fact, through almost 270 degrees-by steeply sloped bluffs from 18 to 20 metres in height. A fringing line of trees enhances to this basin effect. Reference to Figure 6, a north-south section through Riverdale, will be helpful. The Yukon River marks the western boundary of Riverdale. Turbulence and warmed water in this section cause it to remain open all winter and to form banks of ice fog. The inertia of any fog bank will prevent or severely restrict mixing of Riverdale air in this direction. The subdivision itself is virtually flat. Chimney heights will vary between five and seven metres for most homes, and never more than eight metres for the few two-story residences with wood heat. While lot sizes are average by Canadian standards, much of the original tree cover is preserved so that from the air, the subdivision presents a wooded aspect. This further retards local mixing and dispersion.

Riverdale residents have noticed and frequently commented about days in which smoke plumes form obvious strata at levels of roof peaks and below. An observer driving into Riverdale on such days will note a remarkable buildup of smoke to the southeast, and looking down into the basin from the bluff, one sees a bluish haze covering the homes. This can occur at times when it is not particularly cold by the standards of winter; the chief requirements seem to be still air and domestic smoke. During extreme cold the basin will fill with ice fog generated there or supplemented by that drifting in from the Yukon River. The pervasive smell of wood smoke can be noted even in those homes which do not burn wood, since their own oil heating gives them a negative internal pressure. The issue of wood smoke pollution is gaining a great deal of political visibility, and since conversions of Riverdale homes to partial or full wood heat are continuing, the problem will grow more acute with every new chimney added to the estimated 726 in use during the winter of 1981-82.

The final question concerns weather conditions during sampling and whether or not they were typical. Sampling during early 1981 took place during abnormally warm and windy periods. The best one can say about these filter loadings is that they were minimal and very close to those measured in downtown Whitehorse where wood smoke is rare to absent. December 1981 measurements took place during a month when conditions were similar to means of 40 years of Whitehorse meteorological records. Those samples taken during January and February 1982 will represent conditions close to but not necessarily indicating a worst case, because even though those months were unusually cold, their wind patterns were atypical. Figure 7 is the wind rose for January 1982: it is markedly different from the average January wind pattern shown in Figure 2. It may be risky to take wind measurements at the Whitehorse airport and apply them to Riverdale two kilometers away, but one can argue that the persistent January 1982 north wind prevented a maximum buildup of particulates in Riverdale, especially in comparison to prevailing northwest winds which would carry Whitehorse pollution and Yukon River ice fog directly into Riverdale. Table 8 shows weather and pollution observations on selected sampling days.

It now seems possible to offer a hypothesis about those weather conditions likely to be experienced during a Whitehorse winter which will produce a worst case and high pollution. There could be two cases. In the first, winds would be from the northwest, below their average January and February speed of 11.5 km/hr. Temperatures would be colder than -30°C, and have persisted at that level for two or three days as an arctic high pressure ridge moves southeasterly through the central Yukon. Particulates, ice fog and carbon monoxide from downtown Whitehorse would be carried slowly into Riverdale to be added to emissions originating there. A second case could arise from light southerly or southeast winds caused by the weakening of an arctic high pressure ridge following a period of extreme cold. These winds would pass over the colder air trapped in the basin and severely restrict

FIGURE 7: JANUARY, 1982
WINDS AT
WHITEHORSE



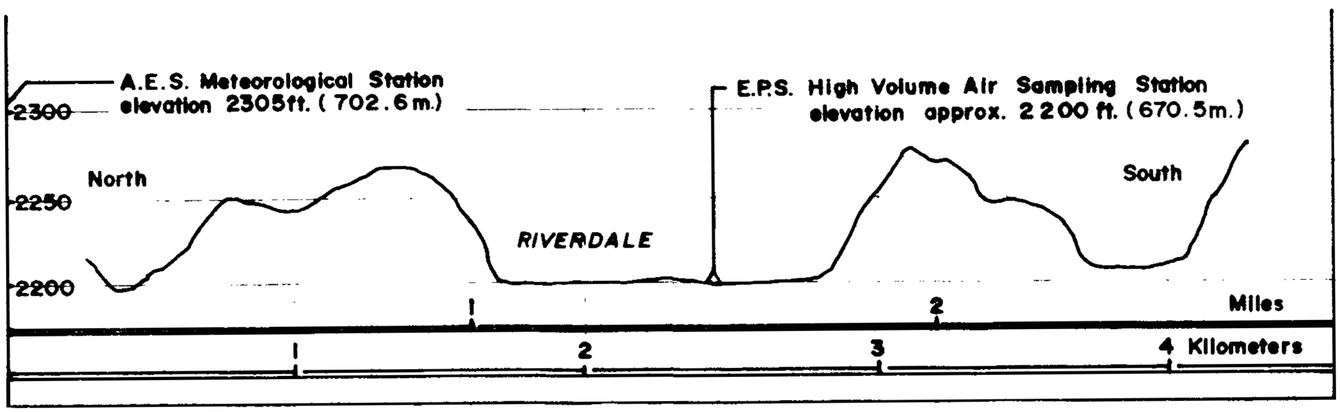


FIGURE 6: GROUND PROFILE OF RIVERDALE
LONGITUDE 135° 00' 45"

D. Davidge 82

TABLE 8

FILTER LOADINGS, CARBON MONOXIDE AND
WEATHER CONDITIONS, SELECTED DAYS

Date	Riverdale Total Suspended Part. ug/m^3	Sample Time Hours	Whitehorse CO, ppm Max.	Whitehorse CO, ppm Mean	Average Wind Speed km/hr	Average Wind Direction Azimuth	Temperature °C Max.	Temperature °C Min.	1100 GMT Inversion Intensity °C/100m
1981 Feb 5	62	24	2.8	1.2	5.4	SE	- 9	-17	4.7
Feb 19	72	24	5.9	2.2	6.0	S	-10.5	-19.5	2.7
Nov 29	95	40	1.8	0.7	6.7	NW	- 6.5	- 8.5	NIL
Dec 6	116		6.1	1.8	7.3	S	- 1.3	-20.9	2.6
Dec 15	73		4.8	1.2	18.2	S	-14.1	-20.7	2.5
Dec 21	101	24	10.1	3.8	9.6	S	- 5.2	-12.1	5.7
Dec 23	98	24	3.8	1.3	22.2	S	-12.2	-17.3	1.0
Dec 29	65	10	2.9	1.7	calm		-40.6	-39.8	-
"	59	25	2.9	1.1	1.5	N	-36.8	-41.3	8.0
Dec 30	66	24	5.9	2.2	1.1	N	-35.7	-41.2	6.9
1982 Jan 2	60	24	1.1	0.6	6.5	NNW	-37.5	-42.5	8.3
Jan 5	28	24	2.2	0.7	21.0	S	-24.6	-33.1	-
Jan 6	46	24	1.9	0.7	19.5	NNW	-24.5	-32.2	-
Jan 11	222	25	3.2	1.3	2.2	N	-17.7	-23.9	NIL
Jan 21	180	24	9.2	2.5	2.6	N	-35.5	-42.5	6.5

ventilation and upward dispersion of pollutants. In both cases one would experience strong temperature inversions typical of winter conditions, that is with gradients equal to or exceeding 5°C/100 m.

The development of a hypothesis about the dispersion of Riverdale wood smoke pollutants requires further work in describing the subdivision's microclimate. The airport meteorological observatory is 32 metres in elevation above Riverdale, and while temperatures at the Riverdale meteorological station can easily be compared with the airport, the station does not record winds. A temporary site should be established to monitor winds and temperatures above ground level. Occasional minisonde measurements during a strong inversion event will help to define the temperature profile between the subdivision, the airport and the 100 metre isobar. Wind gauging might indicate any channelling of winds caused by local terrain. These data are needed to refine any predictions of the intensity of pollution episodes. The observations made during this study indicate that such work should be undertaken.

5.5 Summary

It seems clear that during the winter, Riverdale can experience severe air pollution, strongly qualified by the local weather conditions. Suspended particulate concentrations can exceed national guidelines, and carbon monoxide concentrations might be expected to equal those of downtown Whitehorse where national guidelines of eight-hour maximum tolerable concentrations have been equalled. Since Riverdale homeowners continue to replace oil-fired or electric heating appliances with wood fueled stoves, the problem is certain to grow more acute.

Two approaches to this identified problem seem indicated, public education and investigation of regulatory means, and second, systematic measurements of both pollutants and microclimate with later mathematical modelling of the dispersion. It is possible that the general public is unaware of the environmental effects of wood smoke and the role that they have in preventing pollution through proper use of their wood burning appliances. Government publications thus far have seemingly emphasized stove efficiency and installation and said nothing about emissions beyond cautioning the user about creosote buildup and fire risk. Since the Yukon Territory has no air pollution legislation, regulatory instruments to reduce or limit Whitehorse air pollution devolve to the civic government. This would seem to be the proper locus of a request for an air quality indexing system for Whitehorse, so at least its residents can be alerted to the problem on those days when pollution is likely to be significant.

The second approach should be through an expanded program of field research towards understanding of pollution caused by wood smoke on a municipal scale. Whitehorse may not be unique in this respect, and models which describe multiple-source dispersion in this locale should have application to other places where wood use is concentrated and dispersion is limited by climate and terrain. The results of such research may well indicate that national programs to encourage the use of wood as a substitute for oil require an assessment of their long-term environmental impact.

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Note:

For an excellent summary of the possible significance of wood smoke, the reader is urged to read the secondary source S.M. Bayne and J.H. McCaughey, 'A Literature Review of the Possible Adverse Effects of the More General Use of Wood Stoves for Domestic Heating' an unpublished paper prepared for the Department of Energy, Mines and Resources, Ottawa (1981).

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APPENDIX I

THE RIVERDALE QUESTIONNAIRE

1. According to the map, what zone do you live in?________________
   How do you heat your home? Oil only______ electricity only______
   wood only________ oil and wood________ electricity and wood________
   Do you plan to install a wood heater in your home?________ If so, what kind?____
4. If you burn wood in your home, a) how many cords of wood will you burn per year_______ b) how do you obtain your fuelwood: cut and haul your own______ purchase from a dealer______ both of these____ other_________________________ c) do you ever cut green wood?____ burn green wood?_____ d) do you burn wood in: open fireplace_____ closed fireplace____ Franklin stove_____ airtight stove____ other (explain)____
5. Will you be burning wood when the temperature is -25°C (10 below F) and colder_____? always_____ most times_____ sometimes_____ never_
6. Have you ever been bothered by smoke around your house?________
7. Would you like information on how you can make the best use of firewood?_________

****

A house by house count of Riverdale zones D and F had the following results:

Zone D	- counted 166 houses of which 118 burned wood	71%
	- questionnaire response, those burning wood	79%
	- overall response, replies mailed 31.3%	
Zone F	- counted 140 houses of which 111 burned wood	79%
	- questionnaire results, those burning wood	75%
	- overall response, replies mailed 47.9%	

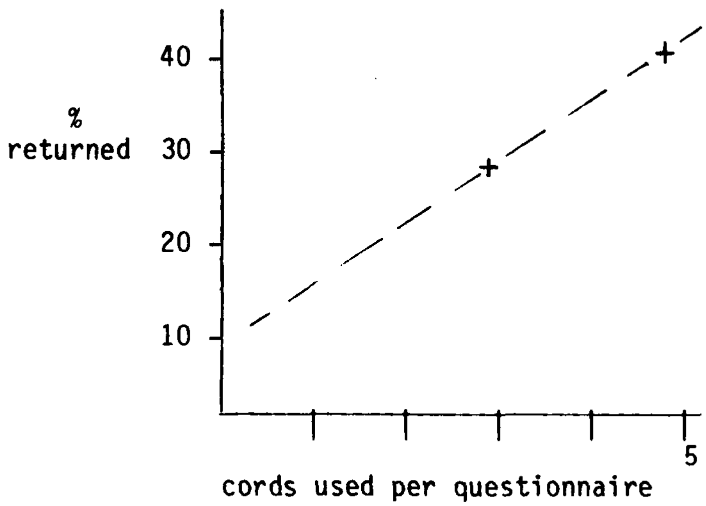
Referring to table of questionnaire results, Zones D and F have similar consumption in cords per wood-using home per year of between 6 and 6.5 cords, or more than the Riverdale average of 5.2 cords. Similarly, the number of replies received from Zones D and F is higher than the questionnaire average of 28%. For these reasons the assumption is made that wood users were more likely to return their questionnaires than those who do not burn wood.

Using data form the questionnaire table , we can calculate for each zone, total cords per number of questionnaires received. This is not the same as cords per home, since non-woodburning homes were excluded.

Zone	Cords per questionnaire received
A	1.3
B	1.9
C	2.4
D	4.8
E	2.7
F	4.9

average 3.0 cords per questionnaire

Taking zones D and F together, the average response was 40% and the average of cords per questionnaire is 4.8. Similarly we can take the total questionnaire response of 28% and a cords per questionnaire average of 3.0, to give a second point on a graph of percentage return versus cords per questionnaire. The assumption will be that there is a linear relationship between wood use and the likelihood of mailing back a completed questionnaire. A graph of these two points can be plotted,



The same two points can be used to derive the linear equation $y=6.7x + 8$; thus for those homes which do not use wood, the likelihood of their returning a questionnaire is the y intercept or 8%. Using the equation the following table can be calculated

Zone	Calculated return %	Factor to 100%	questionnaire wood used, cords	calculated wood used, cords
A	16.6	6.02	62	373
B	20.6	4.85	88	427
C	24.0	4.17	151	630
D	39.6	2.53	248	627
E	26.0	3.85	162	624
F	39.6	2.53	326	825
av.	28%		1037	3506 cords/yr

For comparison, the 28% total response can be applied as a factor to total wood consumption reported, yielding a total of 3704 cords, which is within 5% of the calculated figure. However, the same factor applied to wood use in Zone D, where the sampler is located, yields some 885 cords burnt as opposed to the 627 cords calculated by the graphical method. Emission calculations based on the larger number would therefore give results which could be overstated. Consequently the total cords burnt per year in Riverdale is suggested to be 3500 cords, using the method outlined above.

APPENDIX II

DERIVATION OF EMISSIONS IN RIVERDALE

Previous notes (Appendix I) have described how total wood use was calculated from the questionaire results and the house-by-house survey, leading to a total of 3506 cords per year. These notes will show the method used to calculate total emissions of pollutants including particulates, nitrogen oxides, carbon monoxide and polycyclic aromatic hydrocarbons (PAH) emitted per year, assuming all that wood is burnt. A second calculation will show the emission rate of each pollutant, assuming all wood appliances are in use, and burning at some approximate or arbitrary firing rate.

The fuelwood used almost universally in Riverdale is lodgepole pine (pinus contorta), cut from fire-killed stands west of Whitehorse. This wood has been standing since the 1958 or 1969 fires and must be considered to be at a stable humidity. According to Dave Morgan, Head of Forest Management for Department of Indian and Northern Affairs in Whitehorse, the moisture content of this wood will be about 12%. Applying a factor for stacking used by his section, he said that a cord will include 1052 kilograms of wood. This is the figure that will be used in subsequent calculations.

To derive pollutant emissions per kilogram of wood, reference was made to a 1980 study commissioned by the U. S. Environment Protection Agency. This study measured pollutants from different types of wood burners, fuels and firing rates. Since none of these tests used lodgepole pine, stated emissions factors for 'seasoned pine' will be used. It is hoped that resinous southern pine species would not produce lower emission rates that Yukon species.

For the following, reference should be made to the tabulation of questionnaire results as Table 1 in Section 3.

TABLE 1

STOVE TYPE AND AVERAGE WOOD USED BY QUESTIONNAIRE

Zone	# of Wood units	# of Airtights	Tot. Cords used/yr.	Av. Cords Per Airtight	Calculated Cords Used	
					a/t	other
A	28	7	62	4.7	33	29
B	32	7	88	6.0	42	46
C	46	19	151	5.9	112	39
D	63	28	248	6.6	184	64
E	51	17	162	5.2	88	74
F	73	30	326	6.6	198	128
					657	380

Using the above results, a ratio of wood use between airtight stoves and other (excess air) wood appliances can be calculated. This ratio is important because the emissions for airtight appliances are much higher for any quantity of wood burnt than those for Franklin stoves and fireplaces. Calculating the ratio of airtight wood use over open-fire wood use for each zone using the last two columns in Table 1 shows a range between 0.91 for Zone B and 2.87 for Zones C and D, or an average of 1.73. Applying this figure may understate wood used in airtights so some weighting must be given to zones with high wood use The following table can be made.

TABLE 2

RATIOS OF WOOD USED PER STOVE TYPE

Zone	Ratio of a/t to other, cords	# of Wood-burning homes	Product, Column 2X3
A	1.14	14	16.0
B	.91	18	16.3
C	2.87	31	89.0
D	2.87	41	117.7
E	1.18	33	38.9
F	1.54	50	77.0
		187	354.9

A weighted ratio can be calculated, $\frac{354.9}{187} = 1.89 = \frac{\text{airtights}}{\text{others}}$

This ratio can then be applied to the total estimated wood use per zone as shown in the previous notes (Appendix I) to give Table 3.

TABLE 3

CALCULATED TOTAL WOOD USED PER STOVE TYPE, PER ZONE

Zone	Cords used Per Year	Applying Ratio, 1.89:		Apply 1052 kg/cord	
		Airtights Cords/yr	Other types Cords/yr	Airtights kg/yrX10^5	Other types kg/yrX10^5
A	373	244	129	2.56	1.35
B	427	279	148	2.93	1.56
C	630	412	218	4.33	2.29
D	627	410	217	4.31	2.28
E	624	408	216	4.29	2.27
F	825	540	285	5.68	3.00
	3506	2293	1213	24.10	12.75

Having determined total wood use per year in Riverdale it is possible to estimate total pollutant emissions for the complete combustion of that wood. Research commissioned by the U.S. Environmental Protection Agency has yielded comprehensive data on emissions from wood-burning appliances (DeAngelis, Ruffin and Reznik, 1980). At time of writing this work has not been superceded (Bayne and McCaughtey, 1981 and Ron Braaten CCRL/EMR, pers. com.). There is the possibility of error in that Yukon lodgepole pine may yield different emissions from Ohio pine species. Any error here should be proportional to the difference if any between densities of the two woods, and since the densities are nearly identical, the error should be negligible. Table 4 shows the Hall and DeAngelis emission factors, and Table 5 applies those factors to the total wood used per year.

TABLE 4

EMISSION FACTORS FOR SEASONED PINE, grams per kilogram wood
(after De Angelis et.al., 1980)

Wood Unit Type	Particulate Matter	Condensable Organics	Total Particulates	NO_x	CO	PAH
Fireplace, Franklins	1.8	5.9	7.7	1.4	21	0.03
Airtight stoves	3.0	4.8	7.8	0.3	210	0.37

TABLE 5

ANNUAL EMISSIONS FROM RIVERDALE YUKON WOOD BURNING, kilograms

a-airtight stoves and furnaces b-open (excess air) appliances

Zone	Wood Used kg/yrX10^5	Particulate Matter	Condensable Organics	Total Particulates	NO_x	CO	PAH
A	2.56a 1.35b	768 243	1228 797	1996 1040	77 189	53,760 2,835	94.7 4.1
B	2.93a 1.56b	879 280	1406 920	2285 1200	88 218	61,530 3,276	108 4.7
C	4.33a 2.29b	1299 412	2078 1351	3377 1763	130 321	90,930 4,809	160 6.9
D	4.31a 2.28b	1293 410	2069 1345	3362 1755	129 319	90,510 4,788	159 6.8
E	4.29a 2.27b	1287 409	2059 1339	3346 1748	129 318	90,090 4,767	159 6.8
F	5.68a 3.00b	1704 540	2726 1770	4430 2310	170 420	119,280 6,300	210 9.0
		9,524	19,088	28,612	2,508	532,875	929

As an aid to interpretation of these results, the totals can be compared to published estimates for the Yukon and Canada in _A Nation-wide Inventory of Emissions of Air Contaminants (1976)_, by _the Air Pollution Control Directorate (Environmental Protection Service, 1981)_. This comparison shows that emissions totals may require some revision, especially since Riverdale contains something less than 10% of the combined Yukon/Northwest Territories population.

TABLE 6

TOTAL EMISSIONS, RESIDENTIAL FUEL COMBUSTION, tonnes
(Riverdale 1982, Canada and Yukon/NWT 1976)

	Particulate Matter	Sulphur Oxides	Nitrogen Oxides	Hydro-Carbons	Carbon Monoxide
Riverdale (1982 Resid. only)	28	--	2.5	19	532
Yukon, NWT (Residential & Commercial)	281	--	14	985	1688
Canada Total (Residential & Commercial)	35,228	--	1762	123,249	211,363

Finally there is the matter of estimating emission rates for the identified pollutants. Emission rate calculations must assume some constant rate of stove firing. This has serious implications for any estimate because emissions are highly dependent upon stove type, rate of firing or frequency of loading, and the stage of the burning cycle (Bayne and McCaughey, 1981). It is beyond the validity of the data to calculate the firing rate and burning cycle used by a typical Riverdale wood user, especially in conjunction with degree-day heating requirements.

The questionnaire response shows that by far, most wood-using homes will be burning wood when the temperature is -25°C and colder, either in airtights or in excess-air units. The DeAngelis study used conventional retail wood appliances loaded with between 6 and 14 kilograms of wood. They regulated combustion to maintain visible flames, that is, no air starvation, and showed that the combustion rates were from 6.0 to 8.4 kg/hr for airtight stoves and 9.6 to 11 kg/hr for fireplaces. They noted that these rates "are substantially higher than what would be representative for a wood stove or appliance being used for auxilliary heat....". Bayne and McCaughey report that emissions are highest on start-up and during air starvation: the DeAngelis firing rates will not give 'worst case' emissions of pollutants, and calculated emission rates for Riverdale may be understated. The writer has therefore arbitarily selected a firing rate of 7 kg/hr for all wood appliances in Riverdale at those times when the temperature is -25°C and colder.

Some expansion factor must be applied to the number of wood units reported in the questionnaire return, since the house by house check of 2 zones showed that not all wood users mailed their returns. Zone D showed 41 homes burning wood out of 118 homes seen to have woodpiles; Zone F returned 50 out of 111 homes. By averaging, 40% of wood-using households were likely to return their questionnaires, which generates a factor of 2.5 to be applied to reported numbers of wood burning units in each zone. Note that many homes had 2 units each. This allows Table 7 to be made from Table 1, and the factors from Table 4.

TABLE 7

RIVERDALE CALCULATED EMISSIONS FOR ONE HOUR, Kilograms
a = airtight stoves b = excess air units

Zone	Total units		Total particulates	NO_x	CO	PAH
	a/t	other				
A	18		.98 a	.04	26	.05
		51	2.7 b	.50	7.5	.01
B	18		.98	.04	26	.05
		61	3.3	.60	9.0	.01
C	48		2.6	.10	71	.12
		67	3.6	.65	9.7	.01
D	70		3.8	.14	103	.18
		82	4.6	.83	12	.02
E	43		2.3	.09	63	.11
		85	4.5	.81	12	.02
F	75		4.0	.16	110	.19
		108	5.7	1.0	16	.02
		TOTALS	39.0	5.0	465	.79

TABLE 8

RIVERDALE CALCULATED EMISSIONS FOR 24 HOURS, Kilograms

Zone	Total Particulates	NO_x	CO	PAH
A	89	13	820	1.4
B	103	15	850	1.4
C	149	18	1890	3.1
D	202	23	2710	4.8
E	164	21	1780	3.1
F	232	28	3000	5.0
	TOTALS 939	118	11,050	18.8

Emissions of contaminants in Riverdale will include those from domestic oil heating and mobile sources. No allowance will be made for pollutants entering the Riverdale area from other parts of Whitehorse. A study commissioned by the Government of Yukon by Hildebrant Young and Associates (October, 1981) suggested an annual heating oil consumption of 878 gallons per house. The author has used this figure for oil-heated houses and arbitrarily chosen 500 gallons per year for wood-oil homes and 300 for apartments. The City of Whitehorse Planning Department advised the author that the 1981 assessment roll for Riverdale showed 276 apartments. Returning to the questionnaire results, 116 returns showed oil heat and 108 used both wood and oil. Extrapolation using an overall return rate of 28 percent gives 414 oil-heated homes and 385 oil and wood-heated. Table 9 can be constructed;

Table 9

RIVERDALE HEATING OIL CONSUMPTION

Home Type	Consumption gals/yr	Consumption litres/yr	Estimated No. of units	Oil Consumption 1 X 10^3/year
oil only	878	3990	414	1650
oil & wood	500	2270	385	874
apartments	300	1360	276	375
			Total	2900

Emissions from this annual quantity of oil can be derived from factors given by Environment Canada in 'A Nationwide Inventory of Emissions of Air Contaminants (1976)' (Environment Canada, APCD, January 1981). Stated in kilograms per 1000 litres, these factors are Particulate matter - 0.31, NO_x - 2.3, CO - 0.63 and hydrocarbons - 0.12. Riverdale annual emissions from light fuel oil consumption in kilograms derived from total fuel times these factors;

Particulate Matter	NO_x	CO	Hydrocarbons
899	6670	1830	348

Calculation of emissions for Riverdale automobiles cannot be attempted. While each home has at least one vehicle, and most of these would be operating during rush hours, there is too much variation in vehicle size and operation to be able to make a meaningful estimate. However, it should be noted that on cold mornings, most homeowners will allow their vehicles to idle for long periods and emissions are higher for cold engines. Vehicular carbon monoxide will add to any estimate of Riverdale pollutant levels, but this contribution is likely to be an order of magnitude less than the contribution of wood smoke CO to the ambient air on cold days.

APPENDIX III

COMMENTS FROM HEALTH AND WELFARE CANADA

Draft copies of the body of this report were sent to both the Health Protection Branch and the Medical Services Branch of Health and Welfare Canada, Ottawa. The former branch has expertise in specific organic contaminants such as PAH compounds, while the latter has responsibilities for public health in northern Canada. In personal communications to the writer both branches indicated their interest in obtaining more sample results and a better definition of PAH concentrations in Riverdale.

The Medical Services Branch compared reported values for the January 11, 1982 sample with both coke oven emissions and ambient cigarette smoke and concluded that the levels were much below those for coke ovens, and above those for cigarette smoke in a small room. They concluded with the warning that if that particular sample is representative, then a potential for a health hazard is indicated.

The Health Protection Branch compared the reported range of values for benzo(a)pyrene to measurements of the compound in the air of urban environments without coke ovens and concluded they were similar. They decided that the small number of samples and the methodology prevented them from determining and therefore evaluating the significance of average PAH levels in Riverdale. Both Branches made recommendations for further work on the subject, particularly for indoor air quality in homes heated by wood.