IC 269

FOREWORD

Technology is changing rapidly and provides innovations which we are quick to accept and soon depend upon in an expanding urban way of life. This dependence on technology should be examined critically from time to time because of the pollution which it inevitably brings.

Fuels and mineral resources are the basis of modern technology and the Mines Branch has contributed to their economic exploitation through research. In this program the highest priority has been given to pollution abatement at fuel combustion and mineral process sources. Although improvements have been recorded, other forces are at work which require ever-increasing research effort.

John Convey

John Convey,
Director,
Mines Branch.

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INVENTORIES OF NATIONAL AND INDIVIDUAL AIR POLLUTION

by

E.R. Mitchell*

ABSTRACT

Advances in combustion technology have reduced pollution emission at individual fuel combustion and process sources. Other technological advances have made available a wide array of new luxuries, goods, and services which are within economic reach of most people and this, together with population and industrial growth, has resulted in more fuel use per capita and more air pollution.

This article explains these trends and attempts to illustrate the magnitude of the problem by presenting inventories of air pollution on both a national and an individual basis.

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Fuel Consumption - Canada

	1946 Btu $\times 10^{12}$	1969
oil	~~Oil~~ 463	2717
Coal	50.7	1133
Coal	1129	611.5
	1642	4462
E/person $\times 10^{6}$	134	212

Fuel Consumption Index Home

	Btu x 10^6
1946 Coal	133.5
1969 oil	105.2
N.G. } est.	100
Blue Flame	100

Similar improvements have come about in larger installations; the change is not so dramatic, however, because advanced combustion technology was first applied to large equipment such as that used for thermal power generation, & recent improvements have been relatively small.

Then, commercial fuel boilers - coal, oil, gas.

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Direction des mines, Circulaire d'information IC 269

LES INVENTAIRES ET NATIONAL ET PERSONNEL DE LA POLLUTION ATMOSPHERIQUE

par

E.R. Mitchell*

RÉSUMÉ

Les avances technologiques de la combustion ont réduit l'émission de la pollution et des traitements industriels et des individus. Beaucoup de luxes, nécessités, et services que la plupart des gens peut acheter ont causé plus de combustion par capita et donc un total plus élevé de la pollution atmosphérique.

Cette présentation explique ces tendances et essaie d'illustrer l'étendue du problème en présentant deux inventaires de la pollution atmosphérique, l'un est d'un plan national et l'autre est d'un individu.

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CONTENTS

TABLES

TABLES - (cont'd)

THE TECHNOLOGICAL URBAN WAY OF LIFE

Sources of Air Pollution

As population grows it concentrates, according to the present scheme of things, in urban areas. At the same time, people are convinced that the panacea of our time is to consume more and more of the world's natural resources including energy. We have now arrived at a stage where the majority of the population depends for survival on the application of technology.

The basis of technology is energy, much of it derived from the burning of conventional fuels. This is a process in which pollutants are produced according to unalterable natural physical laws, and is Canada's largest source of air pollution. This is also true of the rest of the world.

Two pollution inflationary forces are at work; increasing population and increasing consumption of fuel and energy per person. Table 1 shows that, in Canada between 1946 and 1970, fuel consumption per person increased at the rate of nearly 2% per annum while population increased at the rate of 2.52% per annum. Gross national product increased at a rate double that of population growth and slightly higher than the rate of increase of fuel consumption. If this suggests that either agricultural or raw materials production outpaced manufacturing, then the Canadian air pollution burden could have been held in check accordingly.

TABLE 1

Canadian Fuel Consumption 1946 and 1969 in Relation to Population and GNP

	1946		1969		Change 1946-1969	Change per annum compounded annually
Population[1]	12.292×10^6		21.061×10^6		+71.3%	+2.50%
GNP - 1961 Constant Dollars[1]	20.493×10^9		63.210×10^9		+208%	+5.24%
Fuel Consumption[2]						
Oil $\times 10^6$ bbl	80.861		470			
Oil $\times 10^{12}$ Btu		463.0		2,717	+487%	+8.87%
Natural Gas $\times 10^6$ cu ft	50,709.0		1,133,400			
Natural Gas $\times 10^{12}$ Btu		50.7		1,133.4	+2,136%	+14.44%
Coal - total $\times 10^6$ tons	43,685		25.4			
Coal - total $\times 10^{12}$ Btu		1,128.8		611.5	-46%	-2.85%
Total Fuel consumption Btu $\times 10^{12}$		1,642.5		4,461.9		+4.65%
Fuel Consumption per person - Btu $\times 10^6$	134		212		+58.2%	+2.15%

1/ Source: Dominion Bureau of Statistics.

2/ Sources: Dominion Coal Board Annual Reports 1946-1947 and 1969-1970.
Canadian Gas Association Gas Facts 1970.

Technological Advances

The air pollution problem today would be much worse than it is were it not for advances in fuel and combustion technology. To illustrate these advances, examples of fuel use for domestic heating, commercial, and industrial steam raising are described.

Dealing first with domestic heating, the problem of defining an average home was avoided by using the author's home as an example. This is a modest, two-storey, three-bedroom home on a foundation 26 ft x 25 ft. In 1946, it was heated by a gravity-type, warm-air furnace burning anthracite coal at an average rate of five tons per year. After conversion to an oil-fired warm-air furnace in the 1950's, the overall efficiency was improved by 21.2% and pollution emission was reduced by 46%. It is estimated, in Table 2, that further improvements could be made by converting to natural gas and to a "blue-flame" oil burner which is still in the laboratory research stage at the Canadian Combustion Research Laboratory (CCRL).

The improved efficiency is the result of improved, automatically controlled combustion, and improved heat extraction technology. But, to fully appreciate the reduction in pollution emission, one must examine combustion computations as summarized in Table 3.

TABLE 2

Air Pollution Comparison - 1946-1969

Heating of a Selected Residence[1/]

(based on reliable fuel data)

	Fuel Consumption Btu x 10^6	Air Pollution lb	% change for 1946-1969	
			Fuel Consumption	Air Pollution
1946 5 tons anthracite (5-yr av)	133.5	31,336	Base[2/]	Base
1969 633.5 IG No. 2 Furnace Oil (5-yr av)	105.161	16,998	-21.2%[3/]	-46%
1969 Natural gas Consumption Estimated	100.0	11,891	-25%[3/]	-61%
1976 Forecast Blue Flame Burning No. 2 Furnace Oil	100.0	16,139	-25%[3/]	-48.7%

[1/] Residence of the senior Author - 2-storey, 3-bedroom, 26 x 25 ft (1,300 sq ft)

[2/] The unavoidable overfiring with coal caused overheating of the premises, thereby increasing fuel wastage and pollutant emission.

[3/] This reflects both improved combustion efficiency and improved process control.

Similar improvements have been recorded in large fuel-fired furnaces but these improvements become less dramatic as the size of equipment increases. The reason, of course, is that advanced combustion technology was applied first to large equipment such as thermal power generation, and improvements in recent years have been small.

Considering next the commercial-fuel fired boilers, this is a class of equipment used in large numbers to heat public buildings, department stores, apartment buildings, warehouses, and small processes. In the 1940's, these boilers were coal-fired and the source of many operating and smoke emission problems. To overcome these problems the Canadian Combustion Research Laboratory (CCRL) developed a number of stoker-grate designs which contributed to "smoke abatement" through control of the combustion process. The Canadian stoker and boiler manufacturers made significant progress in applied coal combustion technology and Table 4 summarizes the overall thermal efficiency that could be expected for the most common stokers operating in a range of boiler types and sizes.

In the 1950's, shop fabricated, "package boilers" with oil and natural-gas firing became popular. As shown in Table 5, these boilers are significantly more efficient than the earlier coal-fired boilers and significantly reduce pollution emission, partly because of reduced fuel consumption and partly because they burn less polluting fuels, as illustrated in Table 3.

TABLE 3

Air Pollution Computations - 1946 and 1969

Heating of a Selected Residence*

	Anthracite 1946	No. 2 Furnace Oil 1969 (yellow flame)	Natural Gas 1969 Est.
	Air Pollution	Air Pollution	Air Pollution
	lb/lb coal x factor** = lb/10^6 Btu	lb/lb oil x factor** = lb/10^6 Btu	lb/10^6 Btu
CO_2	3.118 x 74.9 = 233.54	3.154 x 51 = 160.65	118.8
NO	1.929 x 10^{-3} x 74.9 = 0.1448	1.286 x 10^{-3} x 51 = 0.0656	.0397
CO	1.80 x 10^{-3} x 74.9 = 0.135	1.60 x 10^{-3} x 51 = 0.082	.07132
Particulates	.01 x 74.9 = 0.749	.0025 x 51 = 0.128	-
SO_2	0.014 x 74.9 = 1.049	.01372 x 51 = 0.700	-
SO_3	1.049 x .025 = 0.026	0.700 x .02 = 0.014	-
Total Pollution per 10^6 Btu	235.6438	161.6396	118.911

Residence Fuel Used per Year

1946 - 5 tons anthracite (5 yr average) = 133,500,000 Btu = 31,458 lb air pollution + 1,200 lb ash

1969 - 633.5 IG No. 2 fuel oil (5 yr average) = 105,161,000 Btu = 16,998 lb air pollution

1969 estimate Natural Gas = 100,000,000 Btu = 11,891 lb air pollution

*Residence of the author - 2 storey, 3 bedroom home, 26' x 25' (1,300 sq ft)

**Factor = pounds of fuel required to produce 10^6 Btu.

TABLE 4

EFFICIENCY GUIDE FOR COAL-FIRED STOKER BOILERS

(Based on average daily operation)

BOILER TYPE	Rated Capacity Hp	Rated Capacity Lb Steam/ Hour	STOKER TYPE: WORM FEED Coal Feed - lb/hr 50-100	WORM FEED 100-500	WORM FEED 500-1000	RAM (Piston)	MULTIPLE Retort Ram	CHAIN Grate	SPREADER Stationary Grate	SPREADER Dump Grate	SPREADER Travelling Grate	Pulverized Fired
Cast Iron Sectional			59	62	66							
Firebox Tubular or Locomotive			60	65	68	68						
H R T	50 to 100	1700 to 3500		65	68	68						
	Over 100	Over 3500			70	72		72	72	72		
Water Tube Boilers	150 to 300	5000 to 10,500				74		74	74	74		
	300 to 1000	10,500 to 35,000				76	76	76	76	76	77	77
	Over 1000	Over 35,000	(Secondary heat recovery equipment is assumed for efficiencies stated)				82	82		82	83	84

TABLE 5

Typical Performance Data at Minimum Pollution Emissions*

Shop-Fabricated Fire-Tube Package Boilers

	Package boiler type		Two-pass		Three-pass				Four-pass
	Fuel used:		No. 6 Fuel Oil		Natural Gas		No. 2 Fuel Oil		No. 6 Fuel Oil
	Boiler horsepower and (lb steam/hr)		250 (8700)	350 (12,200)	250 (8700)	350 (12,200)	250 (8700)	350 (12,200)	150 (5200)
Full	Flue gas temperature	°F	450	387	481	440	490	426	398
	Combustion air temperature	°F	71	76	65	71	87	89	82
	CO_2 in flue gas	%	11.4	13.2	10.5	10.2	13.1	13.6	13.3
	Excess air	%	38.5	20.5	10.0	13.0	15.0	12.0	21.0
	Losses - dry gas	%	9.5	6.8	7.4	6.8	8.1	6.6	7.0
	- combustion of H_2	%	6.6	6.4	11.9	11.7	7.1	6.9	6.1
	- radiation	%	1.9	1.5	1.9	1.5	2.0	1.5	2.7
	Efficiency	%	82.0	85.3	78.8	80.0	82.8	85.0	84.2
Half	Flue gas temperature	°F	410	352	-	371	449	380	374
	Combustion air temperature	°F	72	78	-	77	88	87	86
	CO_2 in flue gas	%	8.5	11.8	-	9.6	11.0	11.4	10.4
	Excess air	%	83.0	34.0	-	19.0	36.0	32.0	53.6
	Losses - dry gas	%	11.5	6.7	-	5.8	8.7	6.8	8.0
	- combustion of H_2	%	6.4	6.3	-	11.3	7.0	6.8	6.0
	- radiation	%	3.4	3.4	-	3.0	3.4	3.2	4.9
	Efficiency	%	78.7	83.6	-	79.9	80.9	83.2	81.1
Low	Flue gas temperature	°F	370	344	372	343	391	364	344
	Combustion air temperature	°F	70	76	69	90	79	77	86
	CO_2 in flue gas	%	8.6	9.2	7.2	7.4	10.9	11.1	10.2
	Excess air	%	81.3	70.0	53.0	51.0	37.0	35.0	56.4
	Losses - dry gas	%	9.8	8.3	7.7	6.4	7.5	6.8	7.2
	- combustion of H_2	%	6.4	6.3	11.4	11.1	6.8	6.8	5.9
	- radiation	%	6.0	4.0	6.5	6.5	6.5	5.0	8.0
	Efficiency	%	77.8	81.4	74.4	76.0	80.7	81.4	78.9

*Results of heat balance tests by the Canadian Combustion Research Laboratory, Mines Branch, Department of Energy, Mines and Resources.

TABLE 6

Actual Thermal Efficiency of Steam Boilers
and High-Temperature Water (HTW) Generators
Measured at Minimum Pollution Emission*

Fuel	Oil		Natural Gas		Coal	
Fuel Firing Rate	low	high	low	high	low	high
High-pressure steam boilers (100-150 psi)						
(a) Originally coal-fired						
100,000 lb/hr - Field Erected	87.3	85.8	83.6	82.9	-	83.36
60,000 " " "	83.8	81.5	80.4	77.9	-	77.67
33,000 " " "	76.6	80.0	75.9	78.1	-	-
25,000 " " "	-	-	-	-	-	81.13
21,000 " " "	82.5	82.2	-	-	-	-
16,800 " " "	79.6	79.8	77.6	76.6	-	-
15,000 " " "	83.6	83.2	-	-	-	-
(b) Installed with oil-gas						
80,000 Field Erected	-	83.8	-	79.3		
60,000 Package	83.2	82.0	80.2	77.4		
50,000 (oil only) "	82.3	81.0	-	-		
40,000 "	80.5	81.0	78.5	78.7		
30,000 (oil only) "	82.5	82.9	-	-		
25,000 (gas only) "	-	-	79.0	79.0		
20,000 (oil only) "	81.7	82.9	-	-		
(c) Low-pressure steam (15 psi)						
8,625 lb/hr package fire tube (gas only)			77.0	81.1		
High-temperature water generators (HTW)						
Converted from coal firing						
30.0×10^6 Btu/hr	82.2	80.7	79.0	78.3		
Installed with No. 2 oil-gas						
16.6×10^6 Btu/hr	86.0	86.8	82.4	83.8		
Medium-temperature water generators (MTW)						
25.1×10^6 Btu/hr package fire tube	-	-	82.5	85.6		
16.7×10^6 Btu/hr " " "	85.8	85.4	-	-		
6.7×10^6 Btu/hr " " "	-	81.3	-	-		
5.02×10^6 Btu/hr " " "	-	-	80.3	82.7		

*Results of heat balance tests by the Canadian Combustion Research Laboratory, Mines Branch, Department of Energy, Mines and Resources. These are measured values on actual boilers and should not be interpreted as a general guide for efficiency vs boiler size.

As the boiler size increases, the efficiency of coal firing increases but, again, pollution emission from coal burning is higher than for other fuels mainly because of its ash and high carbon content. In Table 6, the overall thermal efficiencies are compared for large steam boilers and small boilers. Also, the efficiencies of burning coal, oil, and natural-gas in large boilers are compared.

The power utility steam generators operate consistently at still higher efficiencies with pulverized-coal firing. In these large steam generators, fuel oil firing is marginally less efficient and natural gas is significantly less efficient because of the higher hydrogen content of these fuels. However, coal firing results in fly-ash emission which can be a significant amount even when efficient electrostatic precipitators are used. On the other hand, SO_2 emission is a function of the sulphur content of the fuel whether it be coal or oil.

Other heat processes such as melting furnaces are more difficult to typify but similar improvements have been made in their fuel firing systems.

Barriers to Understanding the Magnitude of the Air Pollution Problem

The constant demand for more energy and more power raises the question: do people comprehend the significance of the pollution problem? For a number of reasons the answer seems to be no; but a limited awareness is developing. Many people are barred from realizing the magnitude of the problem by "average" figures computed on the basis of our great, largely uninhabited land mass. For example, as shown in Table 7, Canada with an "average" of 5.5 persons per square mile is one of the most sparcely populated countries in the world. Why, then, do we have a problem, if countries like Holland with 980.5 persons per square mile can survive? The answer, of course, is that 60% of our population is concentrated along the north shore of the Great Lakes and along the St. Lawrence River, especially in cities like Toronto and Montreal. It is in the cities where population and

TABLE 7

Population Density and Distribution*

Country	Area sq. mi.	Population x 10^3	Persons per sq. mi.	% of Economically Active People Employed in Agriculture		Mining and Manufacturing	
Canada	3,851,809	21,061	5.5	(1966)	10.0	(1966)	17.1
China	3,691,501	750,000	203.1	-		-	
France	211,209	50,223	239.1	(1962)	20.3	(1962)	29.9
Ghana	92,100	8,376	90.9	(1960)	13.5	(1960)	46.0
Netherlands	14,139	12,798	980.5	(1960)	10.7	(1960)	31.4
Norway	149,282	3,838	257.0	(1960)	13.4	(1960)	26.1
Switzerland	15,941	6,115	396.0	(1960)	11.2	(1960)	40.0
U.K.	94,220	55,282	594.0	(1961)	3.7	(1961)	29.5
U.S.A.	3,615,210	203,200	56.2	(1960)	6.6	(1960)	28.1
U.S.S.R.	8,649,489	237,808	27.4	(1959)	38.8	(1959)	36.9
West Germany	95,964	60,463	630.0	(1961)	4.7	(1961)	16.9
City							
Toronto (1966)	240	1,884.7	7,850				
Montreal (1965)	180	2,436.8	13,500				
Chicago	224	7,300.0	32,500				
Los Angeles (1960)	464	6,742.7	14,500				

*Source: Encyclopaedia Britannica, 1970 Book of the Year pollution are concentrated. Therefore, it is more meaningful to compare population density between cities like Toronto and Montreal and two cities in the United States, as given in Table 7. Already there are indications that unless our urban way of life is changed the same chronic pollution problems will occur in our cities as already exist in cities of the United States.

Another barrier to understanding the magnitude of the problem is that there was no inventory of air pollution in Canada until 1968[1], when one was published for fuel combustion sources. It did not seem to have the impact that it deserved, and this prompted a more dramatic inventory on a personal basis which is described in the following.

A NATIONAL INVENTORY OF AIR POLLUTION FROM FUEL COMBUSTION

Inventory Based on 1968 Combustion Technology

The first inventory on a national basis was intended to be a realistic estimate.[1] It was revised in 1970[2, 3] and minor additions were made in 1971.[4] The 1971 national inventory, based on 1968 fuel consumption, is given in Table 8. In preparing the inventory, it was assumed that all fuels are burned as efficiently as 1968 combustion technology allows. Other assumptions reported earlier[2, 3] have been revised only to separate aircraft turbine fuel from stove oil. CO_2 is included as a pollutant because it is reported to be accumulating in the atmosphere and it absorbs infra-red energy from the sun which plants need for the oxygen-producing photosynthesis process. Aldehydes, unburned fuel, and hydrocarbons are reported together with soot, ash and others as "particulates". Water, a product of fuel combustion, is not included as a pollutant. However, the main significance of CO_2 and H_2O lies in the amount of oxygen required to produce them. This is discussed in the personal pollution inventory that follows.

TABLE 8

NATIONAL INVENTORY OF AIR POLLUTION FROM FUEL COMBUSTION*

(Based on 1968 Fuel Consumption Statistics)**

Calculated May 1970 - Revised May 1971

Fuel	Weight of Pollutant Emitted, lb x 10^6					
	CO_2	NO	CO	Particulates	SO_2	SO_3
Domestic Fuels						
LPG	7541	9.426	3.91	-	-	-
Natural Gas	25670	8.588	15.41	-	-	-
Light Furnace Oil	86110	35.110	43.68	68.26	374.6	9.558
Stove Oil	8565	3.500	4.36	6.80	16.0	0.41
Sub-totals	127886	56.624	67.36	75.06	390.6	9.968
Total	128485.612 x 10^6 lb = 64.24 x 10^6 short tons = 58.28 x 10^6 metric tons					
Commercial Fuels						
Natural Gas	17230	24.930	10.34	-	-	-
Diesel Fuel	40260	192.800	119.90	16.56	153.20	-
Motor Gasoline	91430	846.800	19470.00	16440.	23.55	-
Aircraft Turbine	8975	14.450	21.87	29.30	16.73	0.43
Can.Bit. Coal	1339	2.716	0.564	3.972	8.208	0.201
Can.Sub-bit. Coal	684	1.320	0.274	2.235	2.869	0.072
Can. Lignite	207	0.395	0.082	0.951	1.101	0.028
Imported Anthracite	607	1.128	0.234	1.948	1.364	0.034
Imported Bit. Coal	2855	5.772	1.197	5.955	11.120	0.278
Sub-totals	163587	1090.311	19624.461	16500.921	218.142	1.043
Total	201021.878 x 10^6 lbs = 100.51 x 10^6 short tons = 91.18 x 10^6 metric tons					
Industrial Fuels						
Natural Gas	48710	70.490	29.240	-	-	-
Coke Oven Gas	3085	5.200	2.160	-	-	-
Blast Furnace Gas	831	0.230	0.215	-	-	-
Refinery Fuel	5259	7.260	1.613	4.170	52.476	2.316
Heavy Fuel Oil	106400	249.800	51.810	84.610	1692.000	42.300
Can.Bit. Coal	22930	46.520	9.648	34.010	140.500	3.512
Can.Sub-bit. Coal	9477	18.270	3.790	15.470	39.730	0.993
Can. Lignite	6044	11.540	2.393	13.890	32.160	0.804
Imported Anthracite	1784	3.313	0.687	2.861	4.006	0.100
Imported Bit. Coal	92920	187.900	38.960	96.920	361.900	9.046
Sub-totals	297440	600.523	140.516	251.931	2322.772	59.071
Total	300814.813 x 10^6 lb = 150.41 x 10^6 short tons = 136.45 x 10^6 metric tons					
Additional Major Pollution						
Smelting	-	-	-	440.00	9600.00	-
Cement & Lime	20000	-	-	-	-	-
Sub-totals	20000	-	-	440.00	9600.00	-
Total	30040 x 10^6 lbs = 15.02 x 10^6 short tons = 13.62 x 10^6 metric tons					
Grand total	660362.935 x 10^6 lbs = 330.182 x 10^6 short tons = 299.536 x 10^6 metric tons					

% from Motor Gasoline: 19.4 % from Commercial Fuels less Gasoline: 11.0
% from Domestic Fuels: 19.5 % from Industrial Fuels: 45.6
% from Other Industrial Sources: 4.5%

*Assumptions and computations are given in references 1, 2, 3 and 4.

**Source: Mineral Resources Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

A projection of air pollution, based on 1968 combustion technology, from stationary sources of fuel combustion (excluding the automobile and other motor vehicles) has been published.[4] The total pollution will increase at a slower rate than the 4.6% annual increase of fuel consumption, given in Table 1, because it is expected that natural gas will continue to expand at a rate faster than other fuels and will replace some fuels.

AN INVENTORY OF AN INDIVIDUAL'S POLLUTION

Recognizing that the individual might have difficulty relating the tonnages of pollution from a national scale to himself, the author decided to summarize his personal contribution to pollution as an example. (5) For this, accurate records were kept for a full year of gasoline consumption for a new North American make of automobile. Incidentally, the gasoline consumption proved to be 16.3 miles per gallon for the year and reflects the influence of a cold climate. Similarly, consumption of fuel oil and electricity were accurately recorded and used as a basis for computations summarized in Table 9.

In preparing this inventory, it was decided that if a person accepts, and relies upon, the urban way of life, he has no alternative to assuming an equal share of responsibility for the pollution produced by others who provide goods and services on his behalf. Certainly, one cannot expect a lumber mill or brick manufacturer to produce materials of construction for his home alone and then go out of business to stop pollution. Clearly, we are all part of a way of life, and responsibility for the pollution of industry, farming and scheduled transportation must be shared equally.

A number of minor pollutants have been omitted because they add little to the overall totals. It is reasoned that the inventory can be in error by 20% without affecting the obvious conclusions that may be drawn.

TABLE 9

INDIVIDUAL POLLUTION INVENTORIES

1. AIR POLLUTION

A. National Basis

INDIVIDUAL INVENTORY ON A NATIONAL BASIS

Pollutants from Fuel Combustion and Smelting	Total National in Short Tons	AVERAGE - Short tons per person: For Total Population (21.061×10^6)	AVERAGE - Short tons per person: For Adult Population 16 yrs and over
CO_2	304.46×10^6	14.47	21.55
Harmful	25.72×10^6	1.22	1.82
Total Pollutants	330.18×10^6	15.68	23.37

B. Personal Basis (Family of 4 adults)

Personal Inventory - short tons per year

	Pollution Produced		Using O_2 or Air				Additional Water Produced (fuel burning)	
			O_2		Air			
	(Family 4 adults)	(per person)	(Family 4 adults)	(per person)	(Family 4 adults)	(per person)	(Family 4 adults)	(per person)
(i) Motor gasoline (new 1969 automobile - 966.04 gals	10.16	2.54	11.25	2.81	48.50	12.12	4.80	1.20
(ii) Space Heating - 633.5 gals fuel oil	8.54	2.13	9.00	2.25	38.90	9.72	0.32	.08
(iii) Electricity - 6,494 kwh (hydro and thermal) 3,245 kwh thermal x 2.984	4.84	1.21	4.09	1.02	17.67	4.41	0.76	0.19
(iv) Services:								
Diesel fuel - transportation, farming, etc.	4.00	1.00	4.04	1.01	17.56	4.39	1.44	0.36
Aircraft fuel (avg)	1.68	0.42	1.76	0.44	7.60	1.90	.60	0.15
Industrial fuel	27.68	6.92	27.72	6.93	119.64	29.91	8.84	2.21
Smelting industry (other than fuel)	2.84	0.71	1.20	0.30	-	-	-	-
(v) Others:								
Tire rubber			negligible					
Asbestos brake lining			negligible					
Paper and chemical industry (other than fuel)			not included					
Incineration - Plastics, etc.			not included					
Pesticides, insecticides, herbicides			not included					
Construction dust - road building, etc.			not included					
(vi) Cottage:								
Gasoline for motor boat - 160 gals	1.68	0.42	1.89	0.47	8.05	2.01	0.80	0.20
Fuel oil - 200 gals	2.69	0.67	2.89	0.72	12.30	3.07	1.02	0.25
Electricity - 1,000 kw (Hydro and thermal) 500 kw thermal	.75	0.18	0.68	0.17	2.21	0.55	0.12	0.03
Wood - not used	-	-	-	-	-	-	-	-
(vii) TOTALS	64.86	16.20	64.52	16.12	272.43	68.08	18.70	4.670
CO_2 (92.2%)	59.80	14.94						
Harmful pollutants	5.06	1.26						

C. Comparison of personal air pollution with others:

- national basis (Canada) - Personal pollution is 3.32% higher than national average and 30.68% lower than the average for the adult population.

- Global basis - water produced from personal fuel use is almost 3 times greater than world average.

(World fuel combustion produces 413,000 acre ft of water/yr or 10 million acre ft in 25 yrs)

2. DOMESTIC WATER POLLUTION - personal records - per year

- Ottawa residence	- 381,250 lb (1970) .... 6,100 cu ft metered	190.62	47.65
- Summer cottage (2 months)	- 100,000 lb (1970) .... 1,600 cu ft	50.00	12.50
		240.62	60.15

Note 1. In breathing the human uses an additional 413 lb O_2 per year (2065 lb air) and exhales 1514 lb CO_2 per year or .757 tons CO_2 per year.

3. INDUSTRIAL PROCESS WATER - Impossible to estimate because recycling is coming into general practice.

4. LAND POLLUTION - per year

- Household garbage and paper only .... (no incineration in Ottawa)	2.00	0.50

5. SUMMARY OF ALL PERSONAL POLLUTION PER YEAR

Air	16.20 tons
Domestic Water	60.15 tons
Land	0.50 tons
GRAND TOTAL	76.85 tons

The most important fact of all is the large amount of oxygen which is consumed in producing this pollution. The agonizing question is: how many people can the world support who each use 16 tons of oxygen per year plus the oxygen needed to support animal life in the ecosystem? Nationally, another important question is: how many people can Canada's air environment support considering that oxygen-producing land plants are dormant for a large part of the year?

During the long winter months, Canada relies on the world's ventilation system for its oxygen supply, and all countries of the world are contributing to the destruction of this supply by killing the phytoplankton of the oceans with water pollution. Little comfort can be drawn from the fact that there is, as yet, no measurable reduction of oxygen in the air environment because if this ever happens the forces at work may be irreversible.

A NEW WAY OF URBAN LIFE

Everything that can be said about pollution seems to have been said before, except these inventories, and they support suggestions that have been made by others, too numerous to quote, for a new way of life; one based on conservation and recycling of wastes.

The author reduced his automobile pollution by 50% by changing to a half-size automobile. Mass transportation systems might further reduce this pollution burden. On the other hand, new sources are imposed from time to time such as incineration and new chemicals.

The dilemma is that there are still enough mineral resources in the world to support an expanding technological way of life, but the air and water of our environment do not have the capacity to accept the resulting wastes. If population continues to grow, the time will come for people to consume less natural resources, to burn less fuel, even as fuel and combustion technology continue to improve, and to conserve waste heat until massive non-fuel, non-oxygen consuming sources of heat and power become available.

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