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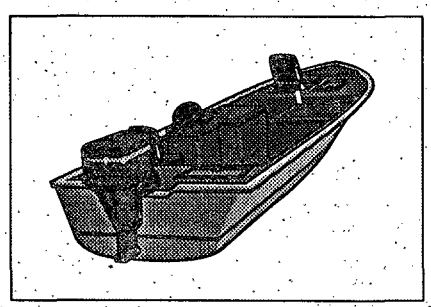

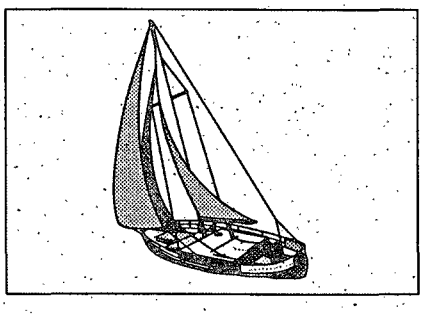

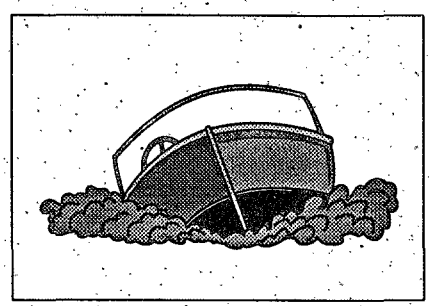

Estimates of Emissions from Pleasure Craft in Canada

Report EPS 5/AP/5
March 1994

Canada

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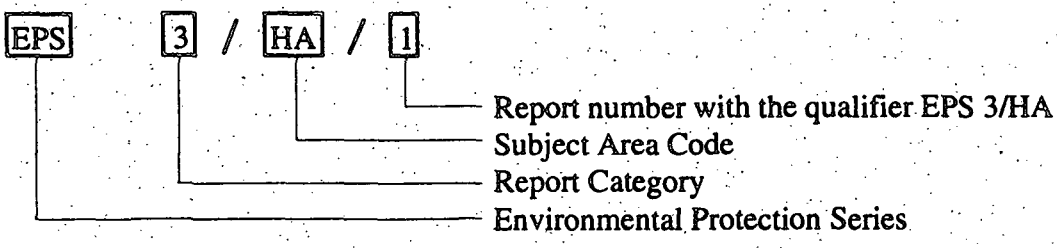

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by

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for the

Industrial Sectors Branch
Environmental Protection Service
Environment Canada

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Abstract

Pleasure craft are classified as nonroad vehicles in the United States and emissions from this source are considered to be significant. The object of this study was to estimate the significance of emissions from this source in Canada. To carry out this task, data were required on the number of craft and the average fuel used by each type of craft during the season. Statistics Canada (1990) only provides the number of craft either as sailboats or power boats. Further data as to the numbers of each type and the total fuel consumed by each type were obtained from a small sample survey conducted at marinas across Canada. Using the United States Environmental Protection Agency's generated emissions factor, the amount of pollutants emitted by this sector was estimated.

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Section 1

Introduction

According to a recent study by the United States Environmental Protection Agency (U.S. EPA), pleasure craft may contribute up to 7% of the total volatile organic compounds (VOCs) emitted in some non-attainment areas* in the United States (U.S. EPA, 1991). No comparable study appears to have been carried out to see if a similar situation exists in Canada. Statistics Canada (1990) gives some information on the number of sailboats or power boats owned by Canadians, without providing any further information. If more information became available, such as types of power boats and fuel consumed, a similar calculation could then be carried out for Canada.

The U.S. EPA classifies pleasure craft into five categories:

- sailboats with inboard engines;
- sailboats with outboard engines;
- power boats with inboard engines;
- power boats with outboard engines; and
- vessels with stern drive.

The U.S. EPA (1991) also states the emissions factor for each type, but only based on the amount of fuel consumed. It is necessary, therefore, to determine the data required to estimate emissions in Canada.

In the absence of any usable data, any procedure that would provide a reasonable data base to estimate emissions was considered appropriate. It was assumed that a survey based even on a small sample could quickly provide a reasonable data base that could be used to at least estimate emissions. About 300 survey forms were distributed at various marinas across Canada, asking boat owners appropriate questions for obtaining relevant information. The response rate was 25%, which was considered average.

No attempt was made to make the survey a scientific one, since this would have entailed a more elaborate effort than was possible with the limited resources available. Most marinas to be surveyed were chosen on the basis of proximity to Ottawa, but marinas as far away as Manitoulin Island and Vancouver Island were also surveyed. It was hoped that the differences in the rate of boat use could be determined this way. The survey form used to obtain the required data is given in Appendix A. Generally, marinas that were visited harboured sailboats as well as power boats, although sometimes they harboured exclusively one kind or the other.

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* Non-attainment areas may be defined as the areas in which the air quality standard for any pollutant is being frequently violated during the course of the year.

Section 2

Analysis of Results

Data on fuel consumption obtained from the survey results are summarized in Table 1.

It can be seen from this table that no vessels have outboard diesel engines and the stern-driven boats are exclusively equipped with four-stroke engines. It is also apparent that sailboats consume much less fuel than power boats, since the engines are used almost exclusively for going in and out of harbours.

2.1 Estimating the Total Amount of Fuel Consumed

Since no data are available on the percentage of different types of boats, it was assumed that the number of responses received were proportional to the types of boats in each category. For example, there were 34 responses from sailboat owners, 22 of whose boats had inboard engines, and therefore, it was assumed that 64% of sailboats have inboard engines. Out of the 124 000 sailboats recorded by Statistics Canada (1990), there would be $124\,000 \times .64 = 79\,360$ sailboats with inboard engines. Responses also indicated that 77% of the inboard engines are diesel, with 13% being four-stroke engines, and 10% two-stroke engines. The rest of the information derived from the survey is given in Table 2.

Table 1 Average Yearly Fuel Consumption

Type of Vessel	Fuel Consumption (L)		
	Diesel Engine	**Gas Engine Four-stroke**	**Gas Engine Two-stroke**
Sailboats with Inboard Engines	58	276	160
Sailboats with Outboard Engines	0	55	50
Vessels with Inboard Engines	846	2 110	1 778
Vessels with Outboard Engines	0	1 150	453
Vessels with Stern Drive	0	1 280	0

Table 2 Percentages of Vessel Type Calculated from the Survey

Type of Vessel	Percent of the Total (%)	Diesel Engine (%)	Four-stroke Engine (%)	Two-stroke Engine (%)
Sailboats with Inboard Engines	64	77	13	10
Sailboats with Outboard Engines	36	0	33	67
Vessels with Inboard Engines	51	26	57	17
Vessels with Outboard Engines	20	0	22	78
Vessels with Stern Drive	29	0	100	0

Using the information from Table 2 and Statistics Canada (1990), the number of vessels of each type in Canada can be estimated. The results are shown in Table 3, along with the total amount of fuel consumed.

2.2 Estimating Emissions

Emissions are estimated using the data on fuel consumption and emissions factors for each pollutant taken from the recently published U.S. EPA report (1991). These factors are given in Appendix B. The total fuel used by each type of vessel is multiplied by the appropriate emissions factor to obtain the amount emitted for each pollutant. The results of these calculations are shown in Tables 4, 5, and 6 for each type of engine, and for a given type of vessel. Table 7 shows the combined total emissions from pleasure craft.

Table 3 Estimated Number of Vessels and Fuel Consumed by Each Type

Type of Vessel	Estimated Number	Total Fuel Consumed (L)	
		Diesel	Gasoline
Sailboats with Inboard Engines	80 000	3 572 800	4 150 400
Sailboats with Outboard Engines	44 000	0	2 272 500
Vessels with Inboard Engines	354 700	77 832 000	534 045 000
Vessels with Outboard Engines	138 800	0	84 344 000
Vessels with Stern Drive	200 000	0	256 640 000

Table 4 Emissions from Vessels Equipped with Diesel Engines

Type of Vessel	Emissions* (tonnes/year)			
	HC	CO	NO_x	Particulate
Sailboats with Inboard Engines	116	206	154	10
Vessels with Inboard Engines	502	761	3 547	224
Total	618	967	3 701	234

* HC - hydrocarbons
CO - carbon monoxide
NO_x - nitrogen oxides

Table 5 Emissions from Vessels Equipped with Four-stroke Engines

Type of Vessel	Emissions* (tonnes/year)			
	HC	CO	NO_x	Particulate
Sailboats with Inboard Engines	55	920	35	0.6
Sailboats with Outboard Engines	18	300	14	0.2
Vessels with Inboard Engines	8 147	136 506	5 147	84
Vessels with Outboard Engines	821	13 307	623	7
Vessels with Stern Drive	4 913	82 316	3 105	50
Total	13 954	233 349	8 924	142

* HC - hydrocarbons, CO - carbon monoxide, NO_x - nitrogen oxides

Table 6 Emissions from Vessels Equipped with Two-stroke Engines

Type of Vessel	Emissions (tonnes/year)			
	HC	CO	NO_x	Particulate
Sailboats with Inboard Engines	246	459	3	16
Sailboats with Outboard Engines	284	529	3	19
Vessels with Inboard Engines	20 862	38 894	251	1 378
Vessels with Outboard Engines	9 410	17 545	113	622
Total	30 802	57 427	370	2 035

* HC - hydrocarbons, CO - carbon monoxide, NO_x - nitrogen oxides

Table 7 Total Emissions

Type of Vessel	Emissions* (tonnes/year)			
	HC	CO	NO_x	Particulate
All Types	45 374	291 743	12 995	2 411

* HC - hydrocarbons, CO - carbon monoxide, NO_x - nitrogen oxides

Section 3

Discussion of Results

Examination of these tables shows that the total fuel consumed by sailboats and subsequent emissions constitute only a small portion of the whole sector. This is understandable as these boats do not have large engines and their engines are only used for short periods. Vessels with inboard engines or those that are stern-driven appear to consume a greater amount of fuel and account for most of the total emissions.

It is interesting to compare emission estimates from Table 5 with those reported from nonroad vehicles, such as farm, construction, forestry, and others (Environment Canada, 1994). Those results are reviewed here, for the convenience of the reader, and presented separately for diesel or gasoline engines in Table 8. This table indicates that emissions from pleasure boats constitute 30% of the total hydrocarbon (HC) emissions, 25% of the carbon monoxide (CO) emissions, 7% of the nitrogen oxides (NO_x), and 11% of the particulate emissions. This is expected, since pleasure craft are usually equipped with gasoline engines that emit large quantities of HC and CO and relatively low quantities of NO_x and particulate. Because of the large quantity of fuel consumed by pleasure craft, however, their contribution to HC and CO emissions appears to be substantial.

Table 8 shows that the percentage contribution of nonroad vehicle emissions to the total emissions in Canada from all

Table 8 Comparison of Pleasure Boat Emissions to Other Emission Sources

Source	Emissions* (tonnes/year)			
	HC	CO	NO_x	Particulate
Diesel Nonroad	18 195	45 612	136 052	15 927
Gasoline Nonroad	84 195	847 098	19 902	3 170
Total	102 390	892 710	155 954	19 097
Pleasure Craft	45 374	291 743	12 995	2 411
Grand Total	147 764	1 184 453	168 949	21 508
Total of All Sources	2 315 754	10 780 747	1 959 492	1 709 484
Percentage Contribution of Nonroad Sources	6.3	10.9	8.6	1.2

* HC - hydrocarbons, CO - carbon monoxide, NO_x - nitrogen oxides

sources is 6.3, 10.9, 7.6, and 1.2% for HC, CO, NO_x, and particulate, respectively. Except for particulate, it can be assumed that the contributions of nonroad vehicles to total emissions is important. It must be added, however, that the grand total given in Table 8 does not include the contribution of emissions from commercial marine and airport services vehicles which may increase these percentages. The percentages shown in the table are very similar to those reported by the U.S. EPA for the United States, indicating that emissions are similar in the two countries, a conclusion that could be derived based on the economic similarity of both countries.

Section 4

Further Analysis of the Survey Data

To assess the accuracy of the limited survey results, the responses were further analyzed and compared with more detailed survey results from the United States (Table 9). The responses were analyzed to obtain average horsepower and fuel used for each type of vessel. The number of days boats are used was also compared for each type of vessel, as this may indicate the accuracy of the survey results.

The United States survey was sponsored by the National Marine Manufacturers Association and conducted by Irwin Broth & Associates,Inc. of Illinois. The survey was carried out in Baltimore, Boston, Chicago, Denver, Hartford, Houston, Milwaukee, and Seattle (Irwin Broth & Associates,Inc., 1991). Some 7654 questionnaires were mailed to boat owners in these areas and 3794 responses were received. Three hundred and two of these were not usable because of incomplete information. As shown in Table 9, the average horsepower is similar in Canada and the United States. There appears to be a good agreement on the amount of total fuel consumed and the average number of days the boats are being used per season. Based on this comparison, it can be stated that Canadian estimates are within the expected range and may be fairly accurate.

Table 9 Comparison of Boat Characteristics Between Canada and the United States

Type of Vessel	Canada			United States		
	Average Horse-power	Fuel (L)	Days Used per Season	Average Horse-power	Fuel (L)	Days Used per Season
Sailboats with Inboard Engines	8.5	98	43	9	121	31
Sailboats with Outboard Engines	25	166	48	26	57	48
Vessels with Inboard Engines	256	1 968	56	257	2 044	38
Vessels with Outboard Engines	80	605	N.A.	67	545	25
Vessels with Stern Drive	207	1 280	27	211	1 382	32

Section 5

Conclusions and Recommendations

The Canadian survey did not include large, private oceangoing vessels. In fact, as it is not clear from the Statistics Canada (1990) data whether those vessels are included in the count, their contribution cannot be assessed. When a boating association was contacted in Canada, however, Vollmer (1992) expressed some doubts about the data given by Statistics Canada (1990). Obviously, further work is necessary to verify the number of boats in Canada. Also, a better resolution of the various types of boats is required to increase accuracy of emissions estimates, and additional data on fuel consumption is required. Areas where these boats are used also becomes important when emissions contributions are considered in non-attainment areas. For example, the Quebec-Windsor corridor is a very populated area close to the St. Lawrence Seaway, which is used by commercial marine as well as pleasure craft. Since the natural width of the river dictates where the boats can travel, it can be assumed that emissions from these boats, being not far from the land, may be important. In fact, a quick calculation was carried out to assess this importance.

Approximately 14 million people live in the Quebec-Windsor corridor. If we use this figure to estimate the number of boats in this area as well as the emissions, we find that 8% of the total hydrocarbon emissions may be due to emissions from pleasure craft, which is a substantial amount. This simple calculation indicates the importance of a reliable data base for deciding whether to regulate.

Other uncertainties in the data base come from the lack of data on emissions from deteriorated engines. Although the U.S. EPA recently tried to correct that situation by incorporating data on emissions from deteriorated engines, the information used to obtain the same was based on surrogate engines rather than the actual engines in question. For example, if the U.S. EPA figures are included in the present calculations, HC and CO emissions would show an increase of 25 to 35% from the stated figures, which is not a negligible amount.

It is recommended that a more extensive survey be conducted to increase the volume of information available and to improve the accuracy of the estimate of emissions from pleasure craft. The survey that was conducted in the summer of 1992 was a relatively inexpensive one and results were judged to be reasonable and good enough to provide quick and useful answers. In fact, similar techniques should be used to obtain information on farm and construction equipment to improve the accuracy of emission estimates from these nonroad vehicles.

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Appendix A

Questionnaire Used for Survey of Pleasure Craft

ENVIRONMENT CANADA is in the process of assessing emissions from various sources including pleasure boats. Would you be kind enough to answer the following questions.

Address (optional) _____

_____

_____

Name _____ Location _____

What type of vessel do you own :

1. Sailboat auxillary inboard engine?
2. Sailboat auxillary outboard engine?
3. Vessel with inboard engine?
4. Vessel with outboard engine?
5. Vessel with stern drive?

Type of engines and the horsepower:

1. Gasoline 2-Stroke _____ Horsepower _____
2. Gasoline 4-Stroke _____ Horsepower _____
3. Diesel _____ Horsepower _____

How many hours do you use your vessel?

1. Per week _____
2. Per season _____

How much fuel do you use?

1. Per week _____ (litres)
2. Per season _____ (litres)

Do you remember how long in each of the following modes the engine is used?

1. Idle _____ Hours or percentage _____ %
2. Half load _____ Hours or percentage _____ %
3. Full load _____ Hours or percentage _____ %

What day(s) of the week do you use your boat most of the time?

1. Week ends _____
2. Week days _____
3. Season duration _____ Months _____

When you are boating, how far off shore do you stay?

1. Within a kilometre _____
2. More than a kilometre _____
3. Away from it all _____

Your response is a valuable contribution to our emissions inventory. Thank you for your participation. Please enclose this survey in the self-addressed envelope and mail.

Note: Confidential when filled-in.

Appendix B

Emissions Factors (adjusted values for in-use effect)

Type of Engine	Emission* Factors (g/L)			
	HC	CO	NO_x	Particulate
Sailboats with Inboard Diesel	32.35	57.52	43.14	2.87
Vessels with Inboard Diesel	6.44	9.77	45.57	2.87
Vessels with Inboard and Stern Drive, Four-stroke	19.14 (28.71)	320.74 (416.97)	12.08 (12.08)	0.195 (0.195)
Vessels with Outboard, Four-stroke	23.17 (34.76)	375.68 (488.38)	17.59 (17.59)	0.195 (0.195)
All Types, Two-stroke	192.35 (230.82)	358.61 (435.62)	2.32 (2.32)	12.70 (12.70)

(Deteriorated factors given in parentheses)

* C - hydrocarbons
CO - carbon monoxide
NO_x - nitrogen oxides