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Water Quality of the Upper Niagara River, 1975 and 1979

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SCIENTIFIC SERIES NO. 129

INLAND WATERS DIRECTORATE
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Abstract

In 1975 and 1979, surface water samples were collected on the Upper Niagara River for a wide variety of analyses including nutrients, major ions, trace metals, toxic organic contaminants and microbiological parameters.

Results indicated higher concentrations of nutrients, trace metals and bacteriological parameters in the Tonawanda Channel than in the Chippawa Channel of the Upper Niagara River. Major ion concentrations have remained relatively constant between 1975 and 1979. Nutrients data remain unchanged except for an increase in nitrate nitrogen and a decrease in particulate organic carbon. Total iron concentrations and total and fecal coliform counts in the Tonawanda Channel frequently exceeded water quality objectives of the 1972 Canada/United States Great Lakes Water Quality Agreement.

Résumé

En 1975 et en 1979, on a prélevé des échantillons d'eau de surface dans la haute Niagara pour analyser un large éventail de paramètres comprenant les éléments nutritifs, les principaux ions, les métaux en traces, les contaminants organiques toxiques et des paramètres microbiologiques.

Les résultats ont indiqué que la concentration des éléments nutritifs et des métaux en traces de même que les paramètres bactériologiques étaient plus élevés dans le chenal Tonawanda que dans le chenal Chippawa. La concentration des principaux ions n'a pratiquement pas changé entre 1975 et 1979. Celle des éléments nutritifs n'a pas varié sauf que la concentration de l'azote nitrique a augmenté et celle des particules de carbone organique a diminué. La teneur en fer total ainsi que le nombre de coliformes totaux et de coliformes fécaux dans le chenal Tonawanda excédaient les objectifs de qualité de l'Accord Canada - USA de 1972 relatif à la qualité de l'eau dans les Grands lacs.

Water Quality of the Upper Niagara River, 1975 and 1979

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INTRODUCTION

The Niagara River, with an average flow of 226 000 cubic feet per second as measured at Queenston between 1975 and 1979 (1), provides a place for recreational activities, a source of municipal drinking water for 400 000 people (2) and a source of industrial process waters. The Niagara River is also a receiver of industrial and municipal wastes generated by its sizeable basin population. The resulting pollution has been the focus of several International Joint Commission Reports in 1951, 1967 and 1971 (2,3,4).

The 1951 report indicated that (i) coliform counts above the Canada-U.S. 1972 Great Lakes Water Quality Agreement objective of 1000 CFU/100 mL occurred frequently along the U.S. side of the river but not on the Canadian side, (ii) high phenol concentrations (mean values up to 40 μg/L) were observed along the U.S. shore, and (iii) oil pollution was becoming a serious problem, with a surface film sometimes observed to cover the entire Tonawanda Channel.

The 1967 and 1971 reports of the IJC again recorded coliform counts above the objective of 1000 CFU/100 mL in a large portion of the river, particularly along the U.S. shore. The 1967 report also reported phenol and oil pollution problems in some areas of the river along the U.S. shore. In the 1971 report of the IJC it was observed that phenols along the U.S. shore were above 5 μg/L at times, but Canadian waters were essentially free from phenol. Oil pollution still remained a problem, and iron concentrations were often above the 1972 Agreement objective of 0.3 mg/L on the U.S. side of the river.

In response to the signing of the initial Canada-U.S. Great Lakes Water Quality Agreement in 1972 and its updating in 1978, the Water Quality Branch, Ontario Region, conducted major water quality surveys on the Upper Niagara River in 1975 and 1979. As detailed in the Great Lakes International Surveillance Plan, the objectives for surveillance of International Connecting Channels are:

(i) to determine trends in environmental water quality data;

(ii) to provide water quality information needed for management and protection of the environment;

(iii) to identify instances where environmental water quality objectives are being violated; and

(iv) to identify new and developing problems in the environment.

The present report provides water quality information on the upper Niagara River for 1975 and 1979 and identifies occurrences of violations of water quality objectives as defined in the 1978 Water Quality Agreement.

METHODOLOGY

In 1975, four surveys, each of 3 days duration, were conducted in May, July, September and December. During 1979, 11 single-day surveys were completed at approximately 3-week intervals, between May and December. In 1975, five rows or ranges of four stations were sampled, and in 1979, six ranges of four stations were sampled. The range number indicates miles upstream from Lake Ontario. Range locations are shown in Figure 1, and range widths, distance from shore and brief landmark descriptions are given in Table B-1. Specific dates and parameters measured for each survey during both 1975 and 1979 are given in Table B-2.

Sampling

Surface water samples (from 1 m deep) of approximately 4 L each were collected at each site in polyethylene bottles using an all-plastic hand pump. The pump was flushed before each station and the 4-L bottle was rinsed with the water to be collected before it was filled.

During 1975, this 4-L sample was brought back to the Canada Centre for Inland Waters (CCIW) laboratory where it was split into smaller individual sample bottles, preserved (2-4 h after collection) as described in Table B-3 and filtered as required for each individual analysis. During 1979, splitting and preservation for all analyses except those requiring filtration was completed immediately in the boat.

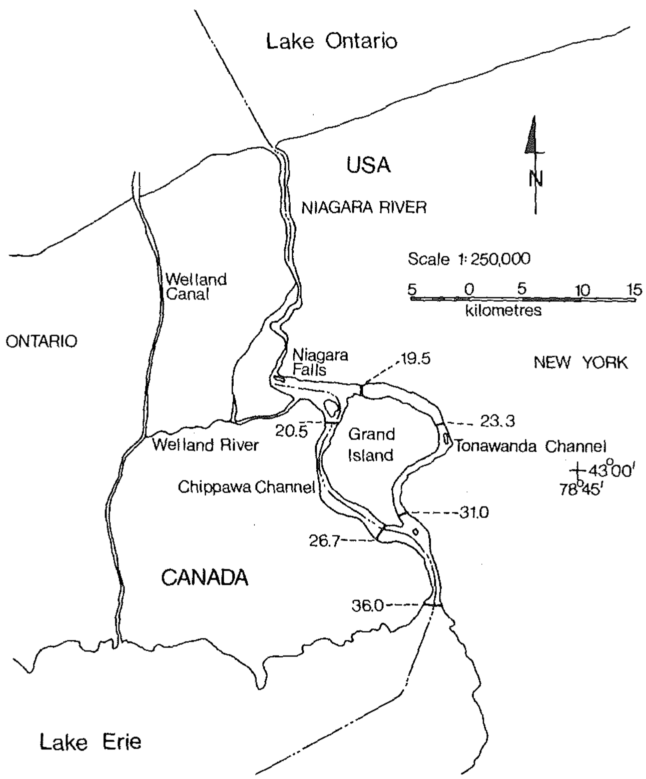

Figure 1. Sampling locations on the upper Niagara River.

Chemical Analysis

Physical Parameters

(a) Temperature

Temperature measurements were made *in situ* by means of a mercury thermometer or a portable digital electronic thermometer.

(b) pH, Conductivity and Turbidity

In 1975, pH was measured using a Tek-Mar Model BYK-1 pH meter with a single combination glass calomel electrode. In 1979, pH was measured using a Corning Model 124 pH meter with dual glass calomel electrodes.

Conductivity measurements were made with a Radiometer CDM-3 conductivity meter (without temperature compensator) and a CDC Type 314 flow-through cell. These conductivity measurements were later corrected to 25°C by using a specific conductance conversion table for Niagara River water.

Turbidity measurements were made in 1979 using a Hach Model 2100A turbidimeter with measurement made in Jackson turbidity units.

Nutrients, Major Ions, Trace Metals, Organics, Microbiology

Nutrients, major ions, trace metals and trace organics were analyzed at the Water Quality Branch Laboratory in Burlington. Analytical methods used have been described elsewhere (5,6).

Microbiological samples were stored in ice when collected in the field and then transported to the Microbiological Laboratory at Burlington for analysis. These samples were usually received 2-4 h after collection and all tests were performed on the same day as sampling. Techniques used were those outlined in *Standard Methods for the Examination of Water and Wastewater* (7) and those described in *Methods for Microbiological Analysis of Waters, Wastewaters and Sediments* (8).

Quality Control

Consecutive samples were collected daily and blank or control samples (i.e., bottle and preservative) were taken on each survey. Data are summarized in Appendix A.

Statistical Treatment of Data

Arithmetic means and standard deviations were calculated for all parameters except bacteria, where geometric means were obtained.

A one-way analysis of variance using the SPSS (Statistical Package for the Social Sciences) subprogram ANOVA (9) was performed on the calculated yearly means for each parameter measured at each station in both Tonawanda and Chippawa Channels in 1979. Water quality parameters were dependent variables and range and station numbers, independent variables. Levels of significance were calculated using yearly mean values for each station and have been summarized according to parameter. Contaminants data were not analyzed in this manner owing to the large number of below detection limit values observed.

Standard Student t-tests were run on mean values for 1975 and 1979 to determine any significant differences between the two data sets.

RESULTS AND DISCUSSION

Physical Parameters

Seasonal variations in temperature observed in the upper Niagara River during both 1975 and 1979 surveys are summarized in Table B-4. Some small variations were observed between the Chippawa and Tonawanda Channels, with the Tonawanda Channel generally being 1-2°C warmer, particularly near the U.S. mainland shoreline in the earlier part of the year (Fig. 2).

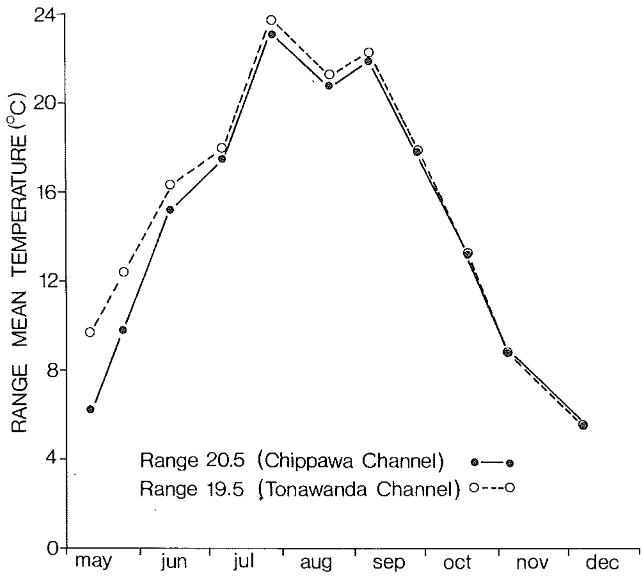

Figure 2. 1979 mean temperature (°C) in upper Niagara River.

Average values of specific conductance at 25°C and pH for both 1975 and 1979, Secchi depth (1975) and turbidity (1979) are given for each range of stations in Table B-5. These data show little variation between ranges and between years. The Student's t-test indicated that specific conductance was significantly higher ($P \geq 0.05$) in 1975 than in 1979.

A one-way analysis of variance of the 1979 data indicated that cross stream variations for specific conductance (25°C), temperature and turbidity were significant ($P \geq 0.05$) at stations in the Tonawanda Channel (ranges 31.0, 23.3 and 19.5). A similar analysis of 1979 data for the Chippawa Channel (ranges 26.7 and 20.5) showed that cross stream variations for specific conductance (25°C) and temperature (°C) were also significant ($P \geq 0.05$).

During the December 1979 survey, turbidity values in the upper Niagara River were an order of magnitude higher than observed on previous surveys. This was caused by a storm in eastern Lake Erie during the three days previous to the survey. Average daily wind speeds for the three days previous to and during the survey, as measured at Buffalo by the National Oceanic and Atmospheric Administration (10), ranged from 26.4 to 34.0 km/h. Other storm events occurred in March (twice), November 1979 (once) and February 1975 (once). Because of these high winds, the suspended sediment load in the river was greatly increased by shore erosion and bottom disturbance in the shallow and nearshore areas of eastern Lake Erie. This wind-induced increase in suspended sediment concentration resulted in high concentrations of total phosphorus, particulate organic carbon, total zinc, total iron and fecal coliform. Figure 3 shows the changes that occurred at range 20.5 in December 1979.

Nutrients

Summaries of the nutrient data parameters for each station are given in Table B-6 for 1975 and 1979 surveys.

Dissolved organic carbon and particulate organic carbon were significantly lower ($P \geq 0.05$) in 1979, while total Kjeldahl nitrogen and nitrite + nitrate nitrogen were significantly higher ($P \geq 0.05$).

Yearly mean values of particulate organic carbon for all stations decreased from 0.695 mg/L in 1975 to 0.511 mg/L in 1979. This represents an overall decrease of 26%. A similar decrease (29%) was observed in summer data (mean of June, July and August) for the Lake Ontario Open Lake Surveillance data (zone 9) just off the mouth of the Niagara River between 1974 and 1980 (R. Kwiatkowski, Water Quality Branch, communication).

Nitrate values for all stations were observed to increase from a yearly mean of 0.148 mg/L in 1975 to a yearly mean of 0.187 mg/L in 1979. This represents an overall increase of 26% or 9.7 µg N/L/yr. A similar increase of 10.1 µg N/L/yr in nitrate nitrogen was reported for Lake Ontario in the 1980 IJC annual report on Great Lakes Water Quality (11).

One-way analysis of variance tests were performed on 1979 yearly mean data to determine cross stream and downstream variability. In the Tonawanda Channel, total phosphorus (see Fig. 4), total filtered phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, particulate organic carbon, particulate nitrogen and reactive silicate all showed significant ($P \geq 0.05$) cross stream variability. In the Chippawa Channel, only cross stream variability of nitrate and downstream variability of total Kjeldahl nitrogen were significant.

High values of total nitrogen, total Kjeldahl nitrogen and particulate nitrogen on the December 1979 survey were caused by the effects of the storm during the three days before the survey.

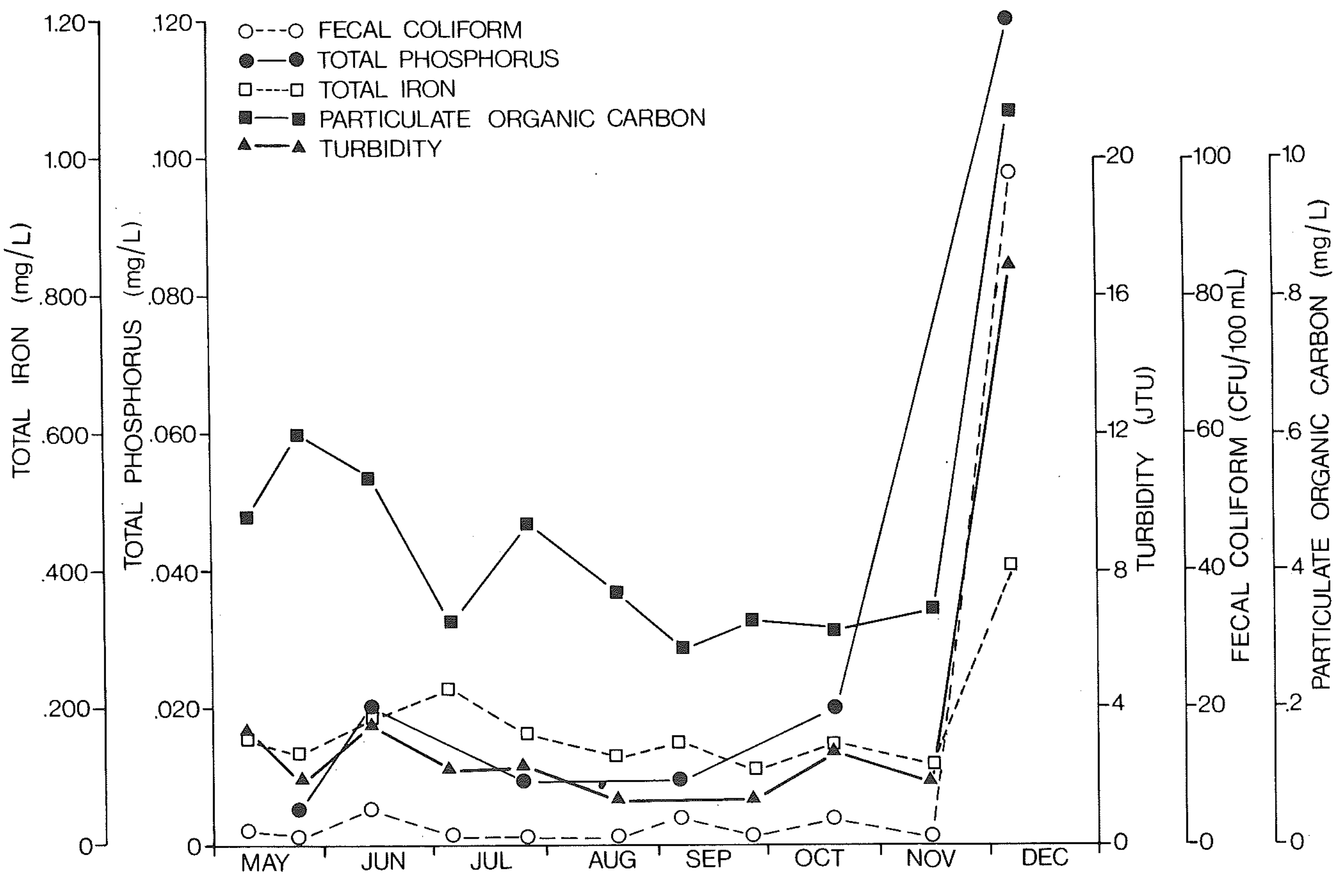

Figure 3. 1979 upper Niagara data, range 20.5, Station A, showing December storm effects.

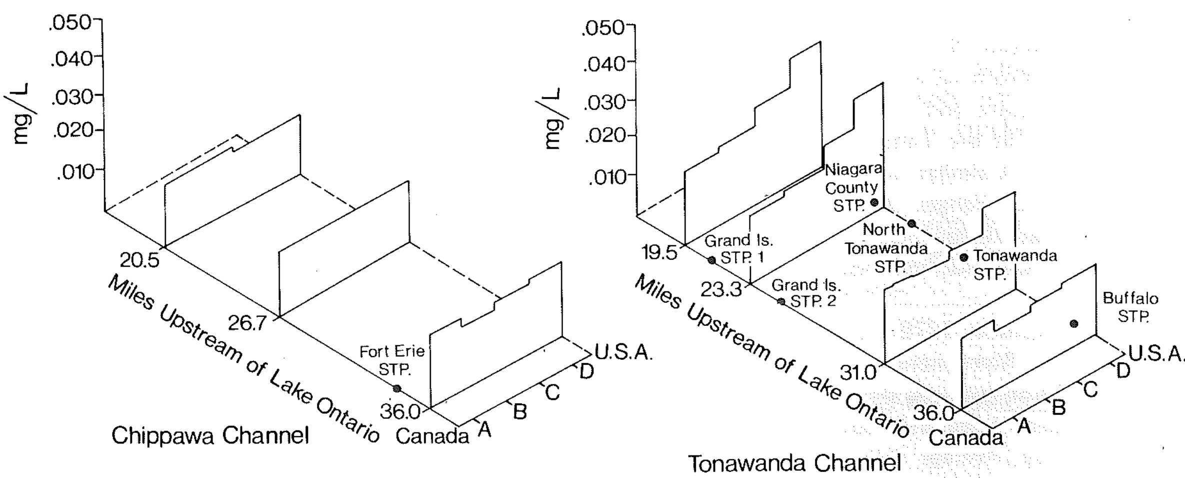

Figure 4. 1979 upper Niagara River, mean total phosphorus (mg/L). STP = sewage treatment plant.

Major Ions

Mean concentrations of major ions measured in the upper Niagara River during 1975 and 1979 are given in Table B-7. The Student's t-test indicated that calcium and sulphate were significantly lower ($P \geqslant 0.05$) in 1979 than in 1975. These differences cannot be explained by changes in flow, since the flow has decreased from a mean annual flow of 239 000 to 222 000 cfs as measured at Queenston during this period (1).

One-way analysis of variance, using annual mean values for each station as measured in 1979, indicated that cross stream chloride, sodium, magnesium and sulphate concentrations were significantly different ($P \geqslant 0.05$) between stations in the Tonawanda Channel, with higher values observed on the U.S. mainland side of the Tonawanda Channel. No significant ($P \geqslant 0.05$) differences were noted in major ion parameters measured in the Chippawa Channel.

Data from Sibley and Stewart (12) collected in the upper Niagara River in 1967-68 indicated the following mean values: alkalinity (89 mg/L), calcium (38.5 mg/L), magnesium (9.5 mg/L), sodium (13.5 mg/L), potassium (1.6 mg/L), and chloride (25.7 mg/L). Their results, with the exception of alkalinity, are higher than the present data. These differences could be due to different analytical techniques or flow increases in the river from 194 000 cfs in 1967 to 238 000 cfs in 1975 (1).

Trace Metals

During four surveys on the upper Niagara River in 1975, a full range of extractable filtered and total trace metals were analyzed. In 1979, total trace metal analyses were completed on six surveys of the upper Niagara River. Data are summarized in Table B-8. Values of zero were used in mean calculations for sample results below the detection limit.

Data for both 1975 and 1979 indicated that values for dissolved arsenic and selenium, extractable Hg, Cd, Cr, Pb, Cu, Mn, Zn and Ni and total Cd, Cu, Cr, Pb, As and Ni were at or near the detection limits of the analytical methods. In 1975 mercury and extractable chromium were never detected. Other metals measured, such as total manganese and total iron, were above the detection limits. Extractable filtered iron values were much lower than total iron levels, indicating that a large percentage of the total iron present is in the particulate form.

The Student t-test run on 1975 and 1979 means indicated that total iron concentrations were significantly ($P \geqslant 0.05$) higher in 1979.

One-way analysis of variance of 1979 data in the Tonawanda Channel (ranges 31.0, 23.3 and 19.5) indicated that cross stream differences in total iron (see Fig. 5), total manganese and total zinc concentrations were significant at the 95% confidence level.

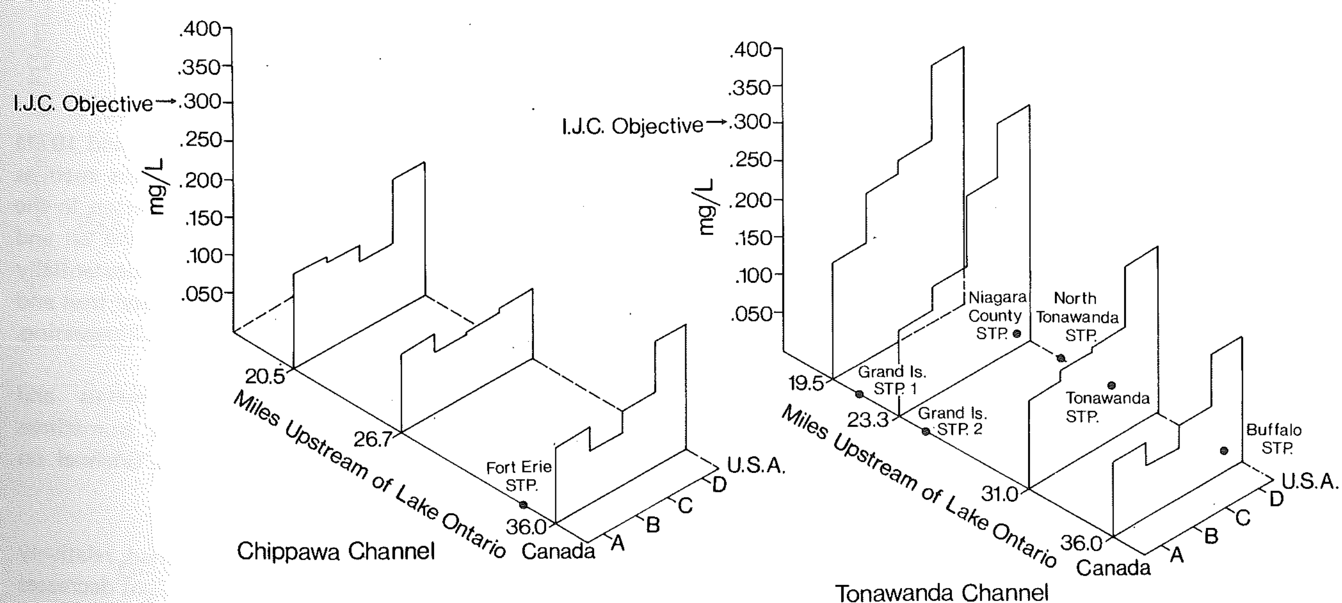

Figure 5. 1979 upper Niagara River, mean total iron (mg/L). STP = sewage treatment plant.

A summary of percentage of violations of the 1978 Water Quality Agreement's specific objectives is given in Table B-9. These data indicate that violations occur infrequently except for iron. Although violations for total iron occurred 24% of the time in 1979, when data for the last survey were eliminated this was reduced to 12%. All 24 samples collected during the December 1979 survey were above the 1978 Agreement specific objective for total iron. As mentioned previously, these high values were believed to have been caused by the high winds measured in the area and in eastern Lake Erie during the three days prior to the survey.

Organic Contaminants

During 1975 surveys on the upper Niagara River, analyses were completed for an extensive list of organic contaminants. Detection limits of analytical methods, however, were not low enough to permit detection of many of the compounds sought. Only phenols (9% of the time) and cyanides (always) were detected in the upper Niagara River.

Since 1975, however, detection limits of analytical methods have been reduced significantly. As a result, in 1979 considerably more compounds were detected. As in 1975, phenols were sometimes detected and cyanides were nearly always detected. Also, α-BHC in the 0.005-0.007 μg/L range was always detected. Other organic contaminants detected in order of their decreasing frequency of detection were γ-BHC (lindane), dieldrin, PCBs, p,p-DDE, hexachlorobenzene, β-endosulfan, and p,p-DDT. Other compounds analyzed for but never detected were heptachlor, aldrin, heptachlor epoxide, α- and γ-chlordane, α-endosulfan, endrin, o,p-DDT, p,p-TDE, mirex and p,p-methoxychlor. These data for 1979 represent a total of 72 samples collected, 12 per range. Table B-10 summarizes the detection limit, percentage of time detected, 1978 Agreement specific objective, percentage of time above Agreement specific objective and mean value for those parameters detected during 1979 surveys. Only phenols were observed to be above the Agreement specific objective (4% of the time). It should be noted, however, that many of these contaminants do not have Agreement specific objectives.

Microbiological Data

During both 1975 and 1979, total coliform, fecal coliform, fecal streptococci and aerobic heterotrophic analyses were completed on the upper Niagara River. In 1979, *Pseudomonas aeruginosa* was also analyzed for. Yearly summaries for each station are given in Table B-11. No significant changes were observed between 1975 and 1979. Values reported here are similar to those reported in the 1967 IJC report (3) on the Niagara River.

The most obvious pattern in these data was the large difference in almost all parameters between the Chippawa (ranges 20.5 and 26.7) and the Tonawanda Channels (ranges 19.5, 23.3 and 31.0). In addition, significant ($P \geqslant 0.05$) cross stream differences were observed between stations in the Tonawanda Channel for fecal coliform, fecal streptococci and *Pseudomonas aeruginosa*. In the Chippawa Channel, cross stream total coliform and fecal streptococci counts were significantly ($P \geqslant 0.05$) different, while heterotrophs were significantly ($P \geqslant 0.05$) different in a downstream direction. Large increases, observed in both cross stream and downstream directions in the Tonawanda Channel, are shown in a three-dimensional plot of total coliform data (see Fig. 6). These data are indicative of sources of bacteriological and organic pollution along the U.S. mainland side of the river. The relatively low levels of contamination in the Chippawa Channel indicate little or no contamination from Canadian sources.

The 1972 Agreement objectives for bathing and swimming (i.e. contact recreational uses) for total coliform (1000/100 mL) and fecal coliform (200/100 mL) were often exceeded at ranges 19.5 and 23.3 in the Tonawanda Channel.

These data are compared with those collected by the Ontario Ministry of the Environment in 1980 (P. Kauss, MOE, personal communication) in Figure 7. Total coliform data for ranges 19.3 (19.5) and 23.3 show excellent agreement between the two years and suggest no reduction in the magnitude of the bacteriological contamination problem.

SUMMARY

Previous reports by the IJC (1951, 1967 and 1971) have documented numerous pollution problems such as oil, phenol, bacteriological and iron contamination in the upper Niagara River. From our observations, the oil and phenol contamination problems have been substantially reduced between 1971 and 1979, although total iron and nitrate + nitrite nitrogen concentrations are still increasing.

Concentrations of nutrients, trace metals and bacteriological parameters are always higher (sometimes up to five times higher) in the Tonawanda Channel on the U.S. side than in the Chippawa Channel.

Major ion concentrations have remained relatively constant between 1975 and 1979, with only slight decreases observed for calcium and sulphate.

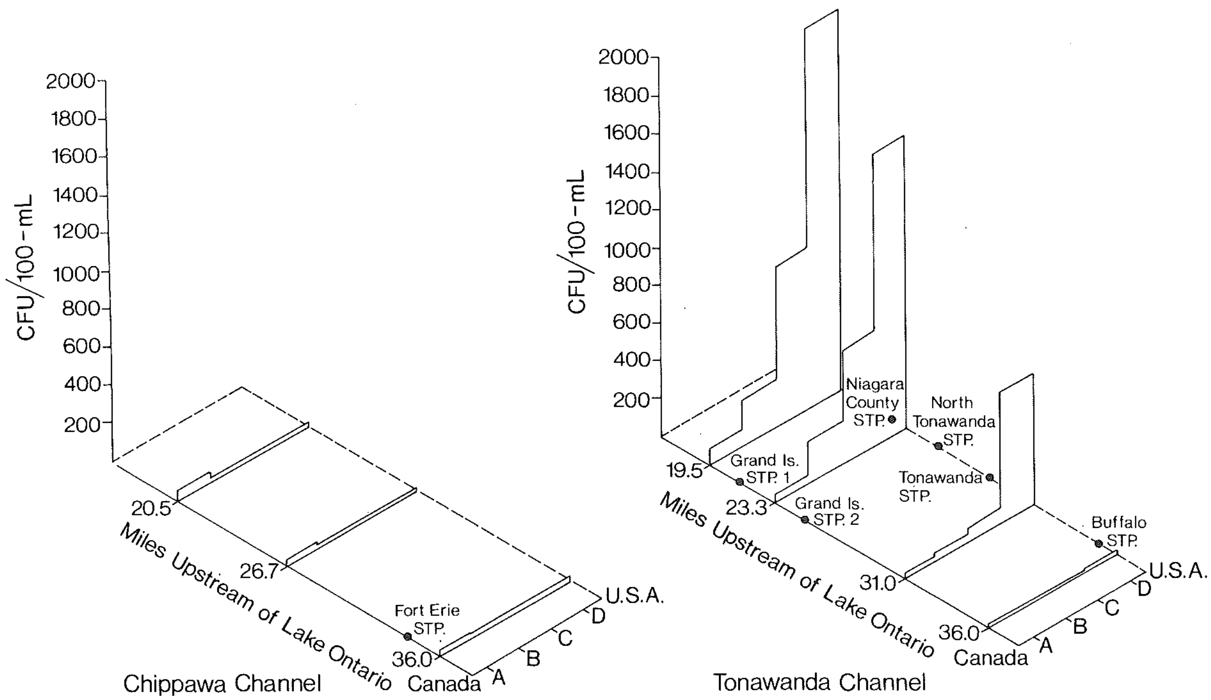

Figure 6. 1979 upper Niagara River, geometric mean total coliform (CFU/100 mL). STP = sewage treatment plant.

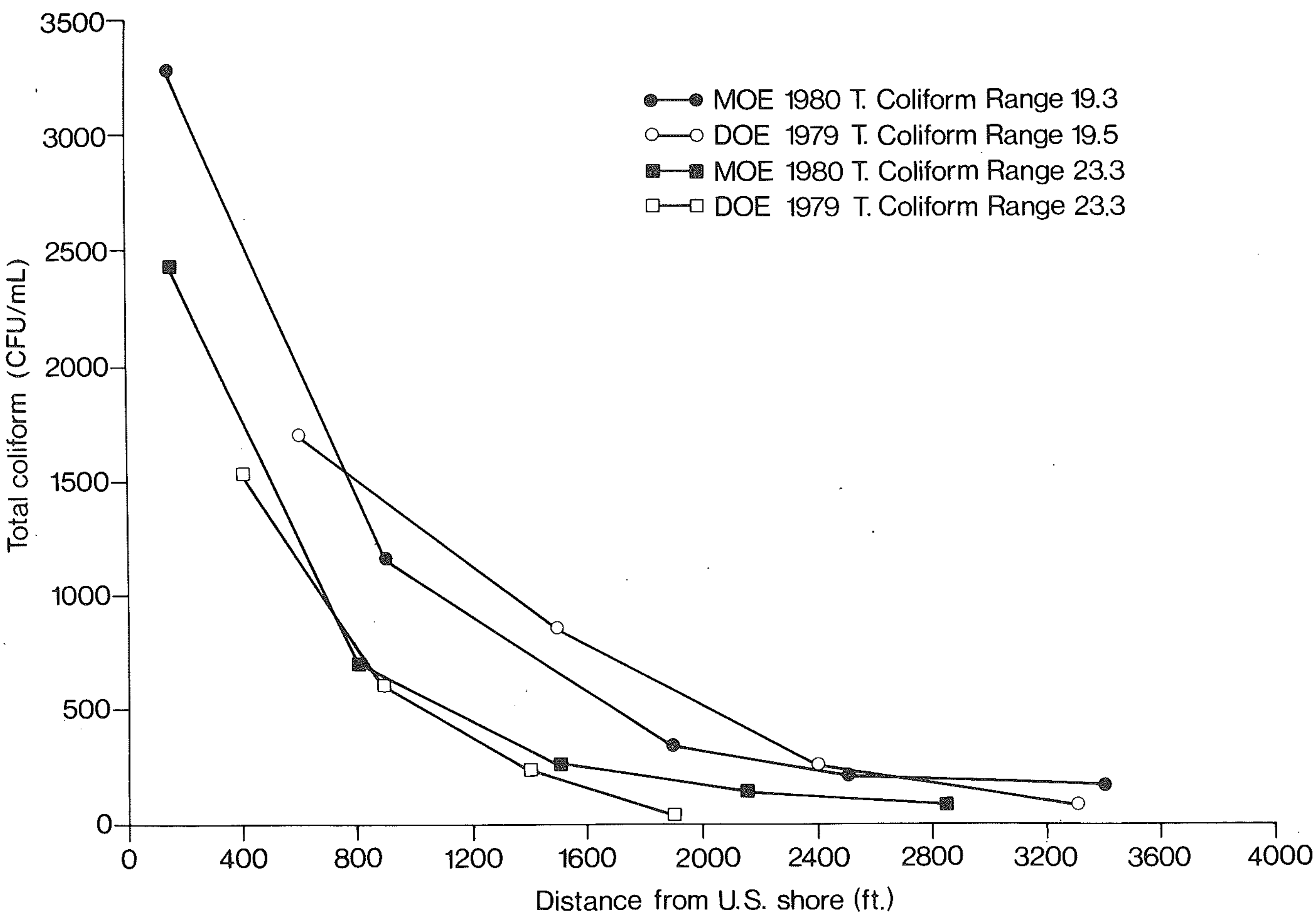

Figure 7. DOE and MOE total coliform measurements in Tonawanda Channel in 1979–80.

Nutrients data for 1975 and 1979 appear to be similar except for an increase of 26% in nitrate nitrogen and a decrease of 26% in particulate organic carbon.

Many of the trace metals and organic contaminants measured were at or near the detection limits of the analytical method except for total iron, which was above the 1978 Agreement specific objective of 0.3 mg/L more than 20% of the time in 1979 (12% when December survey eliminated).

Bacteriological contamination of the Tonawanda Channel poses a problem for contact recreational activities, since 1972 Agreement special objectives were often exceeded at ranges 19.5 and 23.3 for total and fecal coliforms.

ACKNOWLEDGMENTS

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REFERENCES

1. Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, "Lake Erie Outflow; 1860–1964 with addendum 1965–1975," Environment Canada, Water Planning and Management Branch, Cornwall, Ontario and U.S. Army Corps of Engineers, North Central Div., Chicago, Ill. 1976.
2. International Joint Commission. 1951. Report of the International Joint Commission of the United States and Canada on the Pollution of Boundary Waters. U.S. Government Printing Office, Washington, D.C.
3. International Joint Commission. 1967. Summary Report on Pollution of the Niagara River. U.S. Government Printing Office, Washington, D.C.
4. International Joint Commission. 1971. Summary Report on Pollution Abatement Progress in the Niagara River Area. U.S. Government Printing Office, Washington, D.C.
5. Environment Canada. 1974. Analytical Methods Manual. Water Quality Branch, Inland Waters Directorate, Ottawa.
6. Environment Canada. 1979. Analytical Methods Manual. Water Quality Branch, Inland Waters Directorate, Ottawa.
7. American Public Health Association. 1965. Standard Methods for the Examination of Water and Wastewater, 12th Edition. American Public Health Association, New York.
8. Dutka, B.J. 1977. Methods for Microbiological Analysis of Waters, Wastewaters and Sediments. Inland Waters Directorate, Canada Centre for Inland Waters, Burlington, Ontario.
9. Kim, J.O. and F.J. Kohout. 1975. Analysis of Variance and Covariance: Subprograms ANOVA and ONEWAY. *In* Statistical Package for the Social Sciences. N.H. Nie *et al*. McGraw-Hill Book Company.
10. National Oceanic and Atmospheric Administration Data, Climatological Data. 1975 and 1979. Buffalo, N.Y.
11. International Joint Commission, 1980 Great Lakes Water Quality Board Report to the International Joint Commission, 1980 Report on Great Lakes Water Quality.
12. Sibley, T.H. and K.M. Stewart. 1969. Some Variation in the Quality of Water from the Source and Mouth of the Niagara River, Proc. 12th Conf. Great Lakes Research 1969. pp. 774–785.

APPENDIX A

QUALITY CONTROL

A summary of blank or control values measured during both 1975 and 1979 is given in Table A-1. Generally these blank values were at or near the detection limits of the respective analytical methods and were much lower than the values observed in the samples. Detection limits were used for mean calculations when values were below detection limits, however, for some parameters such as selenium, phenol, cadmium, chromium, copper, lead, manganese, nickel and zinc these blank values could be as high as the values observed in the environmental samples.

A summary of data for consecutive samples collected during 1975 and 1979 on the upper Niagara River is given in Table A-2. Consecutive samples are defined here as two separate samples collected one after the other and treated separately throughout analysis. Hence, there is a possibility that short-term variations in the river water quality could have caused the observed differences. Other sources of variation are bottle contamination or method variation during analysis. It is expected that these observed differences in consecutive samples represent maximum differences expected owing to the sampling and analytical variations at any one station at any one time.

Consecutive samples analyzed generally showed good agreement. Data shown in Table A-2 are the mean differences observed between consecutive samples during each year. The higher values observed are usually for those parameters involving an analysis which includes particulates, such as particulate nitrogen and carbon, total alkalinity, and total iron. These parameters show larger errors because the presence of particulates makes sampling and division into aliquots both in the field and the laboratories more susceptible to error.

The magnitude of the observed differences is also dependent on the magnitude of each particular parameter in each separate analysis.

A matched pairs t-test was used to check whether analyses of consecutive samples were statistically different. No statistically significant difference at the $(P \geqslant 0.05)$ was found between consecutive sets of data.

Table A–1. Summary of Blank Values During 1975 and 1979 (mg/L)

Parameter	1975 Number of observations	1975 Mean	1975 Standard deviation	1979 Number of observations	1979 Mean	1979 Standard deviation
Total phosphorus	18	.0016	.0015	19	.0014	.0018
Total phosphorus (filt.)	18	.0017	.0014	12	.0029	.0014
Soluble reactive phosphorus	–	–	–	16	.0004	.0003
Total Kjeldahl nitrogen	22	.021	.008	15	.022	.017
Ammonia nitrogen	–	–	–	16	.003	.010
Nitrate nitrogen	–	–	–	16	.003	.002
Particulate nitrogen	18	.001	.001	12	.002	.003
Particulate organic carbon	18	.054	.080	12	.029	.011
Dissolved organic carbon	24	.33	.29	16	L.20	–
Total alkalinity	9	.77	.61	10	L.10	–
Calcium	9	.42	.11	10	L.10	–
Magnesium	9	.11	.04	10	L.10	–
Potassium	9	L.10	–	10	L.10	–
Sodium	9	L.10	–	10	L.10	–
Chloride	9	L.10	–	10	L.10	–
Sulphate	9	L.50	–	10	L.50	–
Reactive SiO_2	–	–	–	10	L.05	–
Arsenic	9	L.0001	–	6	L.0001	–
Selenium	9	L.0001	–	6	L.0001	–
Cyanide	21	.001	.0008	10	L.001	–
Mercury, extractable	8	L.00005	–	10	.00006	.00012
Phenol	–	–	–	9	.0009	.0012
Cadmium, total	5	L.001	–	12	L.001	–
Chromium, total	5	.004	.008	12	L.001	–
Copper, total	5	.003	.001	10	.001	.001
Iron, total	5	.019	.001	10	.012	.009
Lead, total	5	.002	.001	12	.001	L.001
Manganese, total	5	L.001	–	12	.001	L.001
Nickel, total	5	.001	L.001	12	.001	L.001
Zinc, total	5	.005	.004	12	.001	.001
Aluminum, extractable	4	.005	.004			
Aluminum, dissolved	7	.004	.004			
Cadmium, dissolved	7	L.001	–			
Chromium, dissolved	7	L.001	–			
Copper, dissolved	7	.002	L.001			
Iron, dissolved	7	.003	.002			
Manganese, dissolved	7	L.001	–			
Nickel, dissolved	7	L.001	–			
Zinc, dissolved	6	.004	.003			

L = Less than detection limit

Table A-2. Summary of 1975 and 1979 Upper Niagara River Consecutive Samples

Parameter	1975 Mean value of consecutive samples	1975 Mean difference	1979 Mean value of consecutive samples	1979 Mean difference
pH	8.4	0.7	8.4	0.01
Conductance	306.	6.0	307.	2.0
Dissolved organic carbon	2.6	0.2	2.1	0.02
Total alkalinity	91.0	0.5	92.0	1.8
Ca	37.2	0.2	35.8	0.3
Mg	8.1	L0.1	8.0	L0.1
Particulate organic carbon	0.70	0.094	0.52	0.037
NH_3	0.015	0.002	0.031	0.003
K	1.27	L0.1	1.3	L0.1
Na	9.9	L0.1	10.1	0.1
Total Kjeldahl nitrogen	0.275	0.020	0.239	0.021
Particulate nitrogen	0.095	0.008	0.074	0.006
Cl	20.4	0.2	20.6	0.2
Reactive SiO_2	0.139	0.022	0.145	0.008
SO_4	25.4	0.2	24.0	0.2
NO_3	0.161	0.002	0.184	0.003
Total dissolved phosphorus	0.007	0.002	0.012	0.002
Total phosphorus	0.020	0.002	0.021	0.002
Soluble reactive phosphorus	0.003	0.0008	0.004	0.001
Al, extractable	0.017	0.001	—	—
Al, dissolved	0.008	0.004	—	—
Fe, dissolved	0.005	0.002	—	—
Zn, dissolved	0.002	0.001	—	—
Cu, total	0.003	0.001	0.002	0.001
Fe, total	0.267	0.026	0.265	0.032
CN	0.003	0.001	—	—
Pb, total	—	—	0.002	L0.001
Mn, total	—	—	0.006	L0.001
Ni, total	—	—	0.003	0.001
Zn, total	—	—	0.003	0.002

Appendix B

APPENDIX B

Table B-1. Sampling Locations in Upper Niagara River

Range	Station	Distance from left bank looking downstream (feet)	Landmark
19.5 E	A	500	Upstream from North Grand Island Bridge
width 3800 ft	B	1400	
	C	2300	
	D	3200	
20.5 W	A	500	2000 ft upstream from Navy Island
width 2500 ft	B	1000	
	C	1500	
	D	2200	
23.3 E	A	600	Off Stoney Pt. Road, Grand Island, N.Y.
width 2500 ft	B	1100	
	C	1600	
	D	2100	
26.7 W	A	440	6000 ft downstream from Niagara Parks Comm. Marina
width 2200 ft	B	880	
	C	1320	
	D	1760	
31.0 E	A	500	Off Blue Water Marina, Grand Island, N.Y.
width 2500 ft	B	1000	
	C	1500	
	D	2000	
36.0	A	500	Under tower transmission line downstream from Peace Bridge, Fort Erie
width 2600 ft	B	1000	
	C	1500	
	D	2000	

Table B-2. Summary of Survey Dates and Parameters Measured During 1975 and 1979 in Upper Niagara River

Year	Survey dates	Parameters measured					
		Physical	Nutrients	Major ions	Trace metals	Organics	Microbacteriology
1975	May 22-24	X	X	X	X	X	X
	July 31-Aug. 1	X	X	X	X	X	X
	Sept. 22-24	X	X	X	X	X	X
	Dec. 3-5	X	X	X	X		X
1979	May 10	X	X	X	X	*	X
	May 24	X	X		X		X
	June 13	X	X	X	X	*	X
	July 5	X	X				X
	July 26	X	X	X	X	*	X
	Aug. 20	X	X				X
	Sept. 6	X	X	X	X	*	X
	Sept. 26	X	X				X
	Oct. 18	X	X	X	X	*	X
	Nov. 14	X	X				X
	Dec. 6	X	X	X	X	*	X

*only sampled at selected stations

Table B-3. Summary of Preservatives and Cleaning Techniques for Water Sampling Bottles

Parameter	Bottle type	Preservative used	Cleaning techniques
Major Ions (Ca, Mg, Na, K, SO_4 Cl, total alk., SiO_2, As, Se)	Polyethylene	none	Rinse once with high pressure tap water, then 10% HCl, then high pressure tap water, then twice with deionized water.
Nutrients (NO_3, NH_3, soluble reactive P, total N, total Kjeldahl N, dissolved organic C)	Glass	none	Wash with 10% H_2SO_4, rinse with high pressure jet, rinse twice with deionized water.
Total P, total Kjeldahl N	Glass	1 mL 30% H_2SO_4/100 mL sample	Same as for Nutrients above.
Trace Metals	Polyethylene	4 mL 50% HNO_3/L	Wash with high pressure jet, 10% HNO_3, high pressure jet, twice with deionized water (in 1979, bottles were soaked with deionized water spiked with 4 mL of 50% HNO_3/L prior to use).
Mercury	Polypropylene	1 mL conc. H_2SO_4 + 1 mL 5% $K_2Cr_2O_7$ (dithizone extracted) per 100 mL sample	Wash with high pressure jet 10% H_2SO_4, high pressure jet and then twice with deionized water.
Cyanide	Polypropylene	1 mL 10% NaOH per 100 mL sample	Same as for major ion bottles above.
Phenols	Glass	0.1 g $CuSO_4 \cdot 5H_2O$ and 1 mL H_3PO_4 per 100 mL sample and stored at 4°C	Same as for major ion bottles above.
Organics	Glass	none	Wash with soap and hot water, then rinse out soap with hot water and distilled water. Rinse two or three times with pesticide grade ethyl acetate and then with pesticide grade hexane. The bottle should then be drained and dried in oven at 130°C overnight. Clean bottles capped with solvent-washed aluminum foil inside the plastic caps.
Microbiological Samples	Glass-75 Polyethylene-79	iced	Sterilized.

Table B-4. Upper Niagara River Mean Temperature Data (°C)

Year	Survey dates	Ranges					
		19.5	20.5	23.3	26.7	31.0	36.0
1975	May 22-24	–	12.2	14.9	11.7	14.9	12.7
	July 31-Aug. 1	–	23.5	24.0	23.5	23.6	23.0
	Sept. 22-24	–	17.0	17.0	17.0	17.0	16.5
	Dec. 1-2	–	6.5	6.5	6.5	6.5	6.5
1979	May 10	9.7	6.4	9.6	7.2	8.7	6.7
	May 24	12.4	9.8	12.0	9.7	11.6	11.0
	June 13	16.3	15.3	16.0	15.5	16.0	15.0
	July 5	17.9	17.5	17.7	17.5	17.7	16.8
	July 26	23.8	23.2	23.9	23.3	23.7	23.4
	Aug. 20	21.3	20.8	21.2	20.8	21.0	20.9
	Sept. 6	22.3	22.0	22.2	21.8	21.9	21.7
	Sept. 26	17.9	17.8	17.9	17.8	17.8	17.7
	Oct. 18	13.3	13.5	13.2	13.4	13.3	13.1
	Nov. 14	8.9	9.0	8.9	9.0	9.1	9.0
	Dec. 6	5.6	5.8	5.7	5.6	6.2	5.3

Table B-5. Summary of Upper Niagara River Physical Parameters During 1975 and 1979

Year	Range	Spec. cond. at 25° C (μS/cm)	pH	Turbidity (JTU)	Secchi depth (m)
1975	20.5	317	8.5	–	2.2
	23.3	318	8.5	–	1.9
	26.7	316	8.5	–	2.3
	31.0	318	8.5	–	1.7
	36.0	317	8.5	–	–
1979	19.5	308	8.4	4.6	–
	20.5	306	8.4	3.4	–
	23.3	309	8.4	4.6	–
	26.7	306	8.4	3.6	–
	31.0	307	8.4	4.3	–
	36.0	308	8.4	3.8	–

Table B-6. Summary of 1975 and 1979 Upper Niagara River Annual Mean Nutrients Data (mg/L)

		Station A		Station B		Station C		Station D	
Range	Parameter	1975	1979	1975	1979	1975	1979	1975	1979
19.5	Total P	–	.019	–	.021	–	.026	–	.034
	Total filtered P	–	.009	–	.009	–	.011	–	.014
	Soluble reactive P	–	.003	–	.003	–	.004	–	.007
	Total N	–	.508	–	.529	–	.555	–	.631
	Total Kjeldahl N	–	.317	–	.332	–	.344	–	.400
	NO_3	–	.191	–	.197	–	.211	–	.222
	NH_3	–	.018	–	.025	–	.039	–	.068
	Particulate N	–	.074	–	.078	–	.086	–	.097
	Dissolved organic N	–	2.1	–	2.1	–	2.4	–	2.2
	Particulate organic carbon	–	.427	–	.452	–	.521	–	.645
	SiO_2	–	.168	–	.210	–	.273	–	.400
20.5	Total P	.017	.017	.017	.017	.020	.016	.019	.016
	Total filtered P	.007	.008	.007	.009	.008	.008	.007	.008
	Soluble reactive P	.002	.002	.002	.002	.001	.002	.002	.003
	Total N	.392	.449	.393	.452	.396	.473	.400	.484
	Total Kjeldahl N	.254	.286	.255	.281	.258	.298	.261	.302
	NO_3	.138	.163	.138	.171	.137	.175	.139	.182
	NH_3	.013	.014	.014	.014	.013	.014	.016	.011
	Particulate N	.065	.067	.072	.067	.076	.068	.080	.076
	Dissolved organic N	2.5	2.1	2.7	2.1	2.6	2.1	2.6	2.1
	Particulate organic carbon	.536	.404	.593	.386	.597	.394	.634	.444
	SiO_2	.195	.132	.179	.142	.189	.132	.227	.143
23.3	Total P	.019	.018	.020	.019	.023	.025	.031	.033
	Total filtered P	.008	.007	.007	.009	.009	.010	.014	.015
	Soluble reactive P	.002	.002	.002	.003	.003	.004	.005	.007
	Total N	.413	.472	.433	.502	.445	.539	.512	.633
	Total Kjeldahl N	.261	.288	.277	.307	.286	.332	.343	.404
	NO_3	.152	.184	.155	.195	.159	.207	.169	.229
	NH_3	.016	.015	.021	.021	.033	.032	.084	.067
	Particulate N	.092	.071	.104	.079	.096	.082	.113	.093
	Dissolved organic N	2.8	2.1	2.6	2.1	2.5	2.1	2.8	2.2
	Particulate organic carbon	.699	.424	.715	.461	.756	.509	.877	.606
	SiO_2	.220	.173	.228	.218	.267	.275	.339	.278

Table B-6. (cont'd)

Range	Parameter	Station A 1975	Station A 1979	Station B 1975	Station B 1979	Station C 1975	Station C 1979	Station D 1975	Station D 1979
26.7	Total P	.016	.017	.015	.017	.016	.017	.015	.017
	Total filtered P	.008	.007	.007	.009	.006	.007	.006	.008
	Soluble reactive P	.003	.002	.003	.002	.003	.002	.002	.002
	Total N	.383	.441	.382	.437	.401	.449	.389	.458
	Total Kjeldahl N	.248	.280	.247	.269	.261	.276	.253	.278
	NO_3	.134	.161	.135	.168	.140	.173	.136	.180
	NH_3	.015	.012	.013	.011	.012	.010	.013	.013
	Particulate N	.077	.068	.073	.065	.078	.065	.084	.068
	Dissolved organic N	3.0	2.1	2.6	2.1	2.5	2.1	2.6	2.1
	Particulate organic carbon	.629	.386	.579	.383	.632	.376	.610	.393
	SiO_2	.184	.138	.170	.145	.180	.143	.193	.142
31.0	Total P	.017	.018	.019	.017	.022	.018	.027	.025
	Total filtered P	.006	.007	.007	.007	.008	.008	.009	.011
	Soluble reactive P	.003	.002	.002	.002	.002	.002	.003	.004
	Total N	.408	.470	.414	.491	.432	.508	.484	.554
	Total Kjeldahl N	.265	.288	.265	.304	.281	.310	.323	.337
	NO_3	.143	.182	.148	.187	.152	.198	.161	.217
	NH_3	.012	.012	.014	.019	.024	.023	.062	.039
	Particulate N	.088	.078	.090	.076	.091	.078	.111	.086
	Dissolved organic N	2.7	2.1	2.5	2.1	2.6	2.1	2.9	2.1
	Particulate organic carbon	.693	.436	.649	.413	.640	.438	.769	.508
	SiO_2	.210	.170	.200	.192	.251	.272	.315	.312
36.0	Total P	.017	.019	.018	.016	.016	.018	.017	.019
	Total filtered P	.006	.007	.007	.007	.008	.007	.006	.008
	Soluble reactive P	.002	.002	.002	.002	.002	.002	.002	.002
	Total N	.385	.453	.381	.474	.400	.467	.427	.507
	Total Kjeldahl N	.250	.294	.250	.294	.260	.290	.277	.311
	NO_3	.135	.159	.131	.166	.140	.177	.150	.196
	NH_3	.010	.013	.010	.015	.010	.015	.012	.017
	Particulate N	.079	.068	.086	.077	.084	.078	.098	.086
	Dissolved organic N	2.6	2.1	2.6	2.1	2.6	2.1	2.6	2.2
	Particulate organic carbon	.736	.377	.720	.471	.647	.422	.692	.468
	SiO_2	.151	.158	.163	.168	.175	.205	.205	.183

NOTE: 1975 and 1979 data consist of about 44 observations per range.

Table B-7. Summary of 1975 and 1979 Upper Niagara River Annual Mean Major Ions Data (mg/L)

Year	Range	Parameter: Total alk.	Ca	Mg	K	Na	Cl	SO_4
1975	20.5	91.9	37.3	8.1	1.3	10.0	20.6	25.1
	23.3	91.2	37.2	8.1	1.3	10.1	20.7	25.6
	26.7	92.2	37.4	8.1	1.3	10.0	20.6	25.3
	31.0	91.9	37.1	8.1	1.3	10.1	20.8	23.9
	36.0	92.0	37.1	8.1	1.3	9.9	20.6	25.0
1979	19.5	91.9	35.8	8.1	1.4	10.6	21.2	24.5
	20.5	91.8	35.8	8.0	1.3	10.0	20.3	23.7
	23.3	92.9	36.2	8.0	1.3	10.5	21.0	24.7
	26.7	91.5	35.8	8.0	1.3	9.9	20.4	23.8
	31.0	91.9	35.9	8.0	1.3	10.3	21.0	23.9
	36.0	91.8	35.8	8.0	1.3	9.9	20.5	23.3

Table B-8. Summary of 1975 and 1979 Upper Niagara River Mean Trace Metal Data (mg/L)

Parameter	1975 Number of observations	1975 Mean	1979 Number of observations	1979 Mean
As, dissolved	81	.0004 (81)	94	.0004 (94)
Se, dissolved	81	.0001 (73)	95	.0001 (65)
Hg, extractable	81	L.00005 (0)	144	.00001 (21)
Cd, total	81	L.001 (2)	165	L.001 (4)
Cr, total	81	.001 (44)	164	.001 (63)
Cu, total	80	.003 (80)	142	.003 (138)
Fe, total	81	.216 (81)	165	.343 (165)
Pb, total	81	.002 (71)	168	.001 (129)
Mn, total	81	.010 (69)	144	.008 (143)
Ni, total	81	.002 (81)	167	.003 (152)
Zn, total	81	.004 (81)	168	.006 (149)
Al, dissolved	81	.007 (77)		
Al, extractable, unfiltered	81	.087 (81)		
Cd, extractable, filtered	81	L.001 (3)		
Cr, extractable, filtered	81	L.001 (0)		
Cu, extractable, filtered	80	.002 (80)		
Fe, extractable, filtered	81	.005 (81)		
Pb, extractable, filtered	81	L.001 (28)		
Mn, extractable, filtered	81	L.001 (14)		
Ni, extractable, filtered	81	.001 (60)		
Zn, extractable, filtered	60	.002 (60)		

( ) No. of samples above detection limits
— Detection limit values entered as zero for mean calculations
L = Less than detection limit

Table B-9. Percentage of Trace Metal Values Above IJC Objectives

Parameter	IJC Objectives (mg/L)	1975 (%)	1979 (%)
Cadmium, total	.0002	2*	2*
Copper, total	.005	2	7
Iron, total	.300	22	24 (12)†
Lead, total	.025	0	0
Zinc, total	.030	0	1
Mercury, extractable	.0002	0	0

*Detection limit of analytical method above IJC objective
†Last survey data eliminated

Table B-10. Summary of 1979 Organic Contaminants Data in Upper Niagara River Water Samples

Parameter	Detection limit (μg/L)	% of time detected	1978 IJC objective (μg/L)	% of time above IJC objective	Mean value (μg/L) (det. limits = 0)
α-BHC	.001	100	—	—	.007
Cyanide	1.	90	—	—	.002
γ-BHC (lindane)	.001	84	.010	0	.001
Dieldrin	.001	32	.001	0	L.001
PCB	.020	19	—	—	.005
Phenol	1.	9	1.	4	L.001
p,p-DDE	.001	6	—	—	L.001
Hexachlorobenzene	.001	3	—	—	L.001
β-Endosulfan	.01	3	—	—	L.001
p,p-DDT	.001	1	.003	0	L.001

Detection limit values entered as zero for mean calculation
L = Less than detection limit

Table B-11. Summary of 1975 and 1979 Upper Niagara River Geometric Mean Bacteriological Data (CFU/100 mL)

Range	Parameter	A 1975	A 1979	B 1975	B 1979	C 1975	C 1979	D 1975	D 1979
19.5	Total coliform	–	85	–	256	–	863	–	1716†
	Fecal coliform	–	6	–	9	–	31	–	65
	Fecal streptococcus	–	11	–	13	–	32	–	47
	Pseudomonas	–	1	–	2	–	3	–	6
	*Heterotrophs	–	1637	–	2997	–	11866	–	23761
20.5	Total coliform	40	47	13	17	22	15	23	10
	Fecal coliform	4	3	2	2	2	2	2	2
	Fecal streptococcus	2	4	1	2	2	2	2	3
	Pseudomonas	–	L 1	–	L 1	–	L 1	–	L 1
	*Heterotrophs	895	854	620	619	808	744	1047	729
23.3	Total coliform	171	45	770	232	1060†	613	1994†	1540†
	Fecal coliform	7	8	20	8	47	25	152†	48
	Fecal streptococcus	3	8	8	17	18	23	32	33
	Pseudomonas	–	1	–	1	–	2	–	3
	*Heterotrophs	1172	1251	2284	2737	4876	5720	34211	10016
26.7	Total coliform	127	31	47	10	23	8	42	9
	Fecal coliform	8	4	3	1	3	2	4	2
	Fecal streptococcus	4	3	2	2	2	2	3	3
	Pseudomonas	–	L 1	–	L 1	–	L 1	–	L 1
	*Heterotrophs	1915	654	590	504	671	648	823	508
31.0	Total coliform	45	16	35	26	215	65	635	689
	Fecal coliform	4	4	4	3	20	10	55	22
	Fecal streptococcus	2	4	4	4	10	7	27	29
	Pseudomonas	–	1	–	1	–	1	–	3
	*Heterotrophs	1555	6632	904	739	2526	2185	12198	4655
36.0	Total coliform	16	9	10	4	10	6	18	12
	Fecal coliform	2	1	2	2	2	2	3	3
	Fecal streptococcus	2	1	1	1	2	2	4	2
	Pseudomonas	–	L 1	–	L 1	–	L 1	–	L 1
	*Heterotrophs	692	392	586	343	600	526	799	708

NOTE: All values are yearly geometric mean
*Heterotrophic units are in counts/mL
L = Less than detection limit
†Values exceed 1978 Ontario Ministry of the Environment swimming and bathing guidelines