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Suspended Particulate Concentrations in the St.
Lawrence River (1985-1987) Determined by
Centrifugation and Filtration

By:

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**SUSPENDED PARTICULATE CONCENTRATIONS IN THE ST. LAWRENCE RIVER (1985 - 1987)
DETERMINED BY CENTRIFUGATION AND FILTRATION**

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Running Head: Suspended particulate determinations

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ABSTRACT

Suspended particulate concentrations were determined by centrifugation of water for four sampling periods at different seasonal conditions throughout the St. Lawrence River between May 1985 and June 1987. Average concentrations of 0.9 mg.L^{-1} were found to exit Lake Ontario with a nearly linear increase to 10 mg.L^{-1} at Quebec City. In 1987, raw and centrifuged water samples were also sequentially filtered through a set of membrane filters with pore sizes of 8.0, 0.4, and 0.2 μm . For most raw water samples, filtration resulted in a lower total particulate retention than centrifugation. Exceptions were water samples with high levels of humic substances, especially those from the Ottawa River tributary.

The divergence of filtration and centrifugation results is thought to reflect alterations of the suspended particles by the mechanical and gravitational forces acting on them during centrifugation. These effects may also produce changes in the contaminant partitioning between water and the particulates, especially in samples where such contaminants are not evenly distributed in the particulates. Our data indicate that the concentration of polychlorinated biphenyls (PCBs) in particulates of the size 0.2 to 0.4 μm are up to ten times higher than in the larger particles found in St. Lawrence River water.

The presence of high levels of humic substances in comparatively soft surface water will therefore lower the centrifuge efficiencies for the recovery of fine suspended particles. As a consequence, hydrophobic contaminants, such as PCBs, which tend to adsorb onto clay and organic particulates, may only incompletely be recovered with these particles and remain in the centrifugate from where they can be determined by extraction with suitable solvents. The determination of contaminant partitioning factors between aquatic compartments will also be influenced by these effects.

INTRODUCTION

In comparison to other large world rivers, the St. Lawrence River has extremely low concentrations of suspended solids. However, the known association of many organic contaminants with these particulates demands an accurate determination of their concentration for the correct measurement and interpretation of contaminant loadings and fluxes and their impact on the aquatic foodchain in the estuary (Gagnon et al., 1989). Water, fishes and mammals in the St. Lawrence River and Gulf are heavily contaminated with organochlorine compounds, particularly polychlorinated biphenyls and certain trace metals, such as cadmium (Masse et al., 1986; Lum and Kaiser, 1986; Dutil et al., 1985; Addison et al., 1973). Good management of these resources requires an in-depth knowledge of the contaminant sources and pathways.

One of the principal means for fluvial transport of hydrophobic organics is through association with suspended particulate matter. It is for this reason that these particles are intensely studied. Suspended particles do not take part in the process of permanent sedimentation due to such physical factors as size, origin or density. Hydrodynamic processes and events provide these particles with sufficient energy to sustain suspension in the water column such that they are transported or circulated in a horizontal direction. Some suspended particles may exist in a "colloidal state" as small solid particles or macro molecules, buoyed by small droplets of fluids or small gas bubbles. The continuous phase in which these units are dispersed may be liquid or gaseous and includes such formations as aerosols and foams. Suspended solids may also form flocculates when added to saline water or to water of high turbidity. Particles involved in such processes result from mechanical, chemical and biological action on organic and inorganic matter such as phytoplankton cells, fragmented plant material, marine detritus, mineral grains, metal oxides and hydroxides, clays and other silicates. These complexities of particulate composition, interaction, flocculation, or peptization together with the hydrodynamics of the system are the determining factors for contaminant association with particulate moieties.

Contaminant loadings are frequently estimated from the contaminant concentrations on the particulates and the water volume and flow rate. However, the knowledge of particulate composition and ~~the~~ in-situ physical process is usually not incorporated into the results, hence variations between observations using different test procedures are often encountered.

Present methods for the determination of suspended particulates are centrifugation and filtration. Both methods are known to influence the particle characteristics and therefore may influence the analytical results. One perceived problem with centrifugation is the shear stress effect. Large particles may rupture into smaller particles and pass through the centrifuge, or inversely, small particles may flocculate into larger aggregates. These processes can also affect both the thermodynamics and kinetics of contaminant adsorption. In some cases, adsorption may also become non-reversible. In comparison, filtration of highly humic waters containing fibrils can tend to clog filter paper pores, the retained particles causing precipitation of dissolved material which otherwise might have passed through the filter. This process is known as filter medium filtration or depth-filtration. In contrast, under reduced pressure or under saline filtration conditions, particles may undergo peptization and pass through the membrane into the solute.

This report provides new data which may offer insight into the causes of suspended sediment recovery problems and their effects on contaminant data interpretation on the basis of field observations in the St. Lawrence River.

EXPERIMENTAL

Sample Collection

Westfalia Separator

Suspended particulates were collected at the locations shown in Figure 1 from the separation bowl of a Westfalia separator. The centrifuge was operated at 9,800 rpm with the water sample passing through at a rate of 6 L/min. The contents of the separation bowl were removed by slurring retained sample water with the particulate film using a nylon toothbrush or small nylon bristle paint brush. The sample was poured and rinsed into a 500 mL wide-mouth glass jar and stored at 4 °C until processing at the laboratory. In May 1985, these samples were obtained by filling a 600-L polyethylene tub with the aid of a March pump at a rate of 6 L/min from a depth of 2 m with river water and centrifuging the entire tub contents. In October 1985 samples were taken in a similar manner, with two 600-L tubs being used. In 1986, the samples were taken in-situ over a period of 25 to 36 hours at a depth of 3m. In 1987 samples were collected at a depth of 5 m for time periods of 100 min each and total station times of 9 to 23 hours. Samples were collected with the research vessels *CSS Limnos* and *Advent*. Additional information on sampling can be obtained from concurrent project reports (Comba et al., 1988, 1989) and detailed information from the cruise reports (TOD, 1985 to 1987). Table 1 gives the station locations and descriptions for the 1987 samples.

Sorvall Centrifuge

A Sorvall SS-2 centrifuge with a KSB continuous-flow rotor operating at 19,000 rpm was used to recentrifuge Westfalia centrifugate. A constant flow of centrifugate water was fed to the Sorvall from a stream splitter manifold (4:1) from which a valve manifold provided a regulated flow of 1L/minute. In 1987, this system was replaced with a peristaltic pump drawing water from a common reservoir receiving three separate Westfalia centrifuge effluents. This system provided greater flexibility in drawing off other water samples compared to the 1986 procedure. The suspended particulates collected were transferred to 500 ml glass jars and stored at 4°C, as described above.

Sample Preparation

Sample Drying

The samples in 500 mL jars were allowed to settle for one day prior to removal of the surface water above the particulate by suction through a water aspirator using a disposable pipette. The supernatant water was removed to approximately 1 cm above the suspended particulate layer which was then covered with a Medi-Wipe (McGaw Supply Ltd., Mississauga, Ontario), secured with an elastic, frozen and then freeze dried.

Freeze drying was performed in a Virtis 100-SRC Sublimator with a shelf temperature of 20°C and a vacuum of 15 to 30 Torr. Samples were prepared in batches using drying periods of 72 to 100 hours.

Membrane Filtration

In 1987, four litres each of raw and centrifuged water were collected in glass bottles from each of the sampling stations in the upper river (stations 27 to 41) and one litre each from the stations in the lower river. Each water sample was sequentially filtered through three different pore sized filter papers using a Millipore filtering apparatus and a vacuum

pump. Nucleopore polycarbonate filters were pre-weighed to 10^{-6} g on a Mettler Micro Gram Atic Balance (Model MS). An alpha-emitter was placed alongside the weighing pan to eliminate static interference. A set of control filter papers for each pore size was weighed eleven times over 30 days under the prevailing laboratory conditions of temperature (23 to 24 C) and relative humidity, (67 to 83%). The greatest deviation observed between the highest and lowest weight for any of the 33 weighings of new membranes was 0.000234 g with a standard deviation of 0.00010 g. A confidence level of 0.0002 g was therefore chosen for the filter paper weighings. The weighed papers were stored individually in Petri dishes until use.

Each water sample was filtered first through an 8.0 um filter, next through a 0.4 um filter and last through a 0.2 um filter. After filtering, each filter was returned to the Petri dish. In the laboratory all filter papers were air-dried simultaneously in a closed cupboard. The lids of the Petri dishes were removed and the filter papers covered with AHS "Mediwipes" for two weeks before being reweighed.

Dissolved Organic Carbon and Dissolved Organic Matter Analysis

A 250 ml portion of final filtrate (0.2 um filter) from the previously described filtration process for both raw and centrifuged water was kept in glass bottles for dissolved organic carbon (DOC) and dissolved organic matter (DOM) analyses. A 10 ml portion of sample was brought to pH 4 to 5 with nitric acid and 30 uL injected into a Beckman, Industrial Model 915 B, total organic carbon analyzer.

Dissolved organic matter was estimated (Hanya and Ogura, 1962) by UV absorbance measurements at a wavelength of 220 nm with a 10 mm UV silica autocell on a Pye Unicam P4 8600 series spectrophotometer.

RESULTS AND DISCUSSION

Particle Concentrations, Size Characteristics and Centrifuge Efficiencies

Capture of suspended particulate matter from fluvial systems by centrifugation for subsequent determination of contaminant identification and concentration has been a routine operation at this research institute for the past decade. Recovery efficiencies of the Westfalia continuous flow centrifuges were reported to be above 85%. (Nriagu, et al., 1981; Churchland et al., 1988). Capture efficiencies, however, are dependent on sampling conditions, particle concentration, type and size as well as seasonal influences. Recovery rates as low as 45% for organic-rich suspended sediments were reported by Ongley and Blachford (1982). Also, substantial seasonal fluctuations were described by Ongley et al. (1981) and were associated with the particulate composition and concentration, particularly during the summer months (with one recovery as low as 15%).

Suspended particulate concentrations were determined throughout the St. Lawrence River, during May 1985, October 1985, June 1986 (Kaiser et al., 1989a). The June/July 1987 particulate concentrations determined by continuous flow centrifuge are given in Table 2. Seasonal fluctuations in particle concentrations were observed, with higher sediment concentrations in May (1985) as a result of the spring runoff and lower concentrations during the summer and fall surveys (Figure 2). We find an average of 0.9 mg.L^{-1} to leave Lake Ontario with a nearly linear increase to approximately 10 mg.L^{-1} at Quebec City. Repetitive sampling of up to 11 samples of 600 L water each at 11 river stations between Kingston and Quebec City in June,

1987, shows only small variations in particle load at each sampling station, indicating a steady downstream flux of suspended material. Additional single (600 L) water samples taken at other stations in the river, are therefore assumed to have an equally low variation, hence to be quite representative of those other sites.

GOOD POINT

Particle size distribution as determined by filtration of raw water in the upper St. Lawrence River (Figure 3 and Table 3) indicates a predominance of smaller particles of less than 0.2 μm , a reflection of Lake Ontario's retention of much of the larger size particulates. The first observable change in particle composition occurs below Cornwall/Massena (stn. 41), an area which receives major hydro-electric power plant, chemical and pulp and paper industry effluents in addition to municipal discharges. Downstream of Cornwall, a general pattern of increasing particle size in easterly (downstream) direction is evident. In terms of mass, the size fraction $> 8.0 \mu\text{m}$ (Fa) dominates the suspended particulate concentration in raw water, except at station 243 and - to a lesser degree - at station 255 (Figure 3 and Table 3). The different particle size distribution at site 243 is most likely due to the large volume of Ottawa River water entering at Montreal. Compared to the Lake Ontario derived water, that of the Ottawa River is high in humic substances and other organic matter added to it by pulp and paper industry effluents. A similar large increase in the 0.4 to 8.0 μm fraction (Fb) at station 255 is probably resulting from the pulping operations at Trois Rivières. The dominance of the larger particle fraction (Fa) at station 253, just above the Quebec City, can be derived from the influence of tidal flow disturbances in the upper St. Lawrence River estuary, which are regularly observed as far upstream as Trois Rivières (Pocklington and Tan, 1987; SD, 1985).

GOOD

Efficiency of the Westfalia centrifuge units as determined by membrane filtration of the centrifugates was between 75 and 100%, except for station 22, where it was 46% only (Table 4). These values are similar to those from other observations where centrifuge efficiencies generally were in the 90% range for mineral-rich suspended sediments but only 55% to 80% for organic-rich sediments (Ongley and Blachford, 1982).

The high shear forces experienced by particles in the centrifuge may also result in the alteration or breakup of some particles. This effect should be particularly strong on organic particles and our data support this possibility by the observation of increased levels of dissolved organic carbon (mean dDOC = 3.2 +/- 1.4 mg/L) after centrifugation (Table 5).

Determination of Particle Concentrations: Centrifugation vs Filtration

Contrary to our expectations, the suspended material retained by centrifugation was higher than that of the corresponding observations using membrane filters (Table 6 and Figure 3). In quantitative terms, the membrane filters retained only between 4 and 89% of the amounts of the centrifugation tests. The only and notable exception was at station 22, where the membrane filter recovered a significantly higher amount than the centrifuge. This station is in Lac des deux Montagnes, at the mouth of the Ottawa River, a major St. Lawrence River tributary. It has a much higher level of dissolved organic matter than the St. Lawrence River (Table 5). The membrane filter (Fc) of station 22 showed also a comparatively heavy coverage, indicating retention of large amounts of particulate matter.

GOOD POINT

Waters rich in organic matter can produce considerable errors in cascade filtration systems by "fibril matting" and retention of suspended organic material that would normally pass through the membrane filtration scheme (Leppard, 1985). This effect is commonly known as depth filtration or filter medium filtration. If occurring here during filtration of the centrifuged

water, it would artificially lower the calculated centrifuge efficiency because of the additional material retained by the filtration. In addition, other filtration-caused phenomena, such as particle flocculation may occur in cases where industrial wastewaters, rich in surfactants have entered the river (Graham, 1988).

The filtration measurements in the upper St. Lawrence River are subject to a greater relative error due to the lower absolute suspended particulate concentrations in each of the three fractions. However, even if the material was distributed equally between the three size ranges chosen, their combined values (FTR) would still exceed the lower confidence level of 0.0002g. The particulate concentrations for most stations are well above this error level and considered accurate for comparative purposes.

Except for stations 22 (Ottawa River), the membrane filtrations recovered fewer particles than the centrifugation (Table 5). At the downstream stations (112 to 253), where the suspended sediment levels were highest (in the 8 to 10 mg/L range), the membrane filtration recovered typically between 53% and 63% of the material obtained by centrifugation. Therefore, one must conclude that the filtration system passed appreciable amounts of material below the 0.2 μ m size, or conversely, that organic matter of that size or smaller (possibly including dissolved matter) is retained by the centrifuge. This conclusion is investigated in more detail further on.

Particulate Integrity and Contaminant Association

It is commonly thought that suspended particulates subjected to high centrifugal forces and shear stress undergo alteration, yet documentation of such effects is very limited. In order to elucidate such changes, we have also determined the distribution of particles in the raw and centrifuged water by both membrane filtration (Table 6) and centrifugation with the continuous-flow Sorvall centrifuge (Table 7). A comparison of particle size distributions in the raw and centrifuged water examined here indicates a considerable particle structure change from the (Westfalia) centrifugation process (Table 3). Alteration of particle aggregation by shear force effect has been noted by other investigators (e.g., Ongley and Blachford, 1982).

Flocculation of particles was reported under various stress and concentration conditions that yielded larger diameter aggregates with greater density and mass (Tsai et al., 1987). Furthermore, dissolved organic matter such as fulvic acids are known to aggregate under certain conditions, such as high localized concentrations and interactions with other surfaces (Leppard et al., 1986). Such conditions may possibly exist during high speed centrifugation. As stated before, organic rich waters with colloidal/fibril constituents have also a high potential to form flocculates with aggregates of larger particle size. This effect is most likely the reason that organic rich waters have been previously cited for poor centrifuge recoveries. As observed here too, poor centrifuge efficiencies appear to be a function of the organic matrix of the water. In particular, high levels of dissolved organic matter, such as in the brown Ottawa River water result in significantly lower centrifuge recoveries of suspended sediments. As dissolved humic acids are carriers of dissolved PCBs and other contaminants (Landrum et al., 1984), their passage through the filtration and centrifugation process may also lead to a poor PCB recovery

Lacustrine fibrils are reported to account for up to 33% of carbon content in the conventional dissolved organic carbon (DOC) fraction (Burnison and Leppard, 1983; Leppard, 1985). Also, suspended particulates in marine environments have been shown to take on coatings of DOC materials (Neihof and Loeb, 1974; Hunter, 1980). Measurements of the DOC fraction in the raw and centrifuged water samples gave increased DOC values for the

centrifugates compared to the raw water (Table 5). This would imply that DOC bound material is released within the centrifuge, another indication of structure alteration, or that DOC material bound to fibril/colloidal matrices are retained on the filter papers. Either way, the implication of sampling process controlled changes in particulate concentrations and their consequent effects on the partitioning relationships of contaminants is of considerable importance.

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Effects on Contaminant Partitioning

Our study of this phenomenon was by attempt to capture particulate matter from the Westfalia centrifugate with ultra-centrifugation using a second stage continuous flow centrifuge (Sorvall). The retention of particulate material in this second stage centrifuge was quite reproducible over two sampling periods and in a range of 2.6 to 7.9% of the total particulate matter in the raw water, as determined by centrifugation with the Westfalia system (Table 7).

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Contaminant analyses of these particulates revealed a strong increase of polychlorinated biphenyl concentrations (PCB) in the Sorvall captured particles over those retained in the Westfalia centrifuge (Table 7). This increase (of up to ten-fold) indicates that PCB are not uniformly distributed in the suspended solids but are present at relatively higher concentrations in the finer (mostly <1 um size) particles. If, as our results above appear to indicate, the fraction of these smaller particulates depends on the sampling mechanics, then the found contaminant levels in the suspended sediments may also vary with these sampling parameters. As the suspended sediments are the major carriers of the organochlorine contaminant load, particularly in the lower St. Lawrence River (Kaiser et al., 1989a, 1989b) loadings and flux calculations may also be affected by these factors. This is in agreement with observations by Baker et al. (1986) who found that the presence of colloidal matter has a dominating influence on the distribution of hydrophobic compounds and their water/sediment partitioning.

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The quantitative changes introduced by sampling methods such as centrifugation on contaminant partitioning relationships between colloids, fibrils, water and chemical speciation is unknown. Such influences, however, should be a concern and need to be determined. Clearly, the conclusions drawn from such data without consideration of the potential artifacts arising from certain methods of particle separation should be examined in greater detail.

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ACKNOWLEDGEMENT

We thank the crews of the C.S.S. *Limnos* and *Advent* for assistance in the sample collections and processing and Virginia S. Palabrica and Julie Wassien for much of the analytical work.

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Role of
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LIST OF FIGURES

Figure 1. Sampling Locations on the St. Lawrence River, 1985 to 1987.

Figure 2. Suspended sediment concentrations in the St. Lawrence River, 1985 to 1987.

Figure 3. Suspended particulate concentrations by Westfalia centrifugation (CA) and filtration ($FT = Fa + Fb + Fc$) and particle size distribution ($Fa > 8.0 \text{ } \mu\text{m}$; $0.4 < Fb < 8.0 \text{ } \mu\text{m}$; $0.2 < Fc < 0.4 \text{ } \mu\text{m}$) for St. Lawrence River water, June 1987.

Table 1. St. Lawrence River station locations^a and descriptions, 1987 sampling.

Station No.	Latitude (N)	Longitude (W)	Description
28	44.1208	76.3689	Kingston, Wolfe Isld., north channel
27	44.2417	76.3219	Kingston, Wolfe Isld., south channel
29	44.6386	75.5975	Prescott, mid-channel
41	45.0442	74.5806	Lake St. Francis, western end
524	45.2331	74.2311	Lake St. Francis, eastern end
51	45.2306	74.1436	Beauharnois Canal, upper end
56	45.3692	73.8264	Lake St. Louis, center
252	44.4086	73.7717	Lake St. Louis, eastern end
251	45.6411	73.4783	Montreal
243	45.9789	73.1922	Sorel
112	46.2364	72.7606	Lake St. Pierre, center
255	46.6236	71.9539	Portneuf
253	46.7161	71.3783	Quebec City
22	45.4572	74.1000	Ottawa River, Lac des deux Montagnes

^a Longitude and latitude given in degrees and decimal degrees.

Table 2. Concentration and variation of suspended particulate material in the St. Lawrence River, June, 1987; values in mg/L.

Station ^a Number	Concentration ^b			Number of Samples (n)	Station Time ^c (hours)
	Mean	Stand. Dev.	Relative Dev.		
28	0.38	0.04	11	7	18
27	0.60	0.11	18	8	17
29	0.94	0.26	28	8	17
41	1.6	0.06	4	8	17
51	0.98	0.06	6	6	9
252	2.6	0.10	4	6	12
251	3.3	0.19	6	5	12
243	6.6	0.37	6	11	23
112	8.2	1.1	13	11	23
255	8.0	0.85	11	11	22
253	10.	1.3	13	10	23
22 ^d	5.1	0.45	9	12	60

^a See Figure 1 and Table 1 for locations.

^b Mean Value based on n measurements of 600 L of centrifuged water from a depth of 5m.

^c Total station time, includes sampling and non-sampling time.

^d Station 22 is in the Ottawa River tributary.

Table 3. Particle size distribution in raw and centrifuged (Westfalia system) St. Lawrence River water as determined by filtration through membrane filters in 1987.

Station	Concentration in raw water (mg/L)				Concentration in centrifuged water (mg/L)				
	Fa ^a	Fb	Fc	Ft ₁ ^b	Fa	Fb	Fc	Ft ₂	Ft ₁ -Ft ₂
28	0	0.035	0.025	0.060	0	0	0	0	0.06
27	0	0	0	0	0	0	0	0	0
29	0	0	0.043	0.043	0	0	0.042	0.042	0
41	0.51	0.17	0.053	0.73	0.14	0	0.24	0.38	0.35
51	0.21	0	0.20	0.41	0	0	0.085	0.085	0.32
252	1.1	0.39	0.16	1.7	0.58	0	0.20	0.78	0.9
251	0.54	0.39	0	0.93	0.20	0.44	0	0.64	0.3
243	1.2	1.5	3.2	5.9	0.11	0	0	0.11	5.8
112	3.2	0.24	0.81	4.3	0.16	1.1	0	1.3	3.0
255	1.3	3.3	0.14	4.7	0.60	0.99	0.26	1.9	2.8
253	5.2	0	0.037	5.2	0	0.62	0.19	0.81	4.4
22 ^c	1.1	4.8	3.0	8.9	0.12	5.0	0.86	5.9	3.0

^a Filter pore sizes: Fa: 8 um; Fb: 0.4 um; Fc: 0.2 um.

^b Ft = Sum of Fa, Fb and Fc.

^c Station 22 is in the Ottawa River tributary.

Table 4. Concentrations of suspended particulates as determined by centrifugation (CA) and filtration of the centrifugate (Ft_c). Centrifuge efficiencies calculated as:
Efficiency = 100 CA/(CA + Ft_c).

Station Number	Concentration CA ^a (mg/L)	Concentration Ft _c ^b (mg/L)	Centrifuge Efficiency 100 CA/CA+Ft _c
28	0.38	0	100
27	0.60	0	100
29	0.94	0.042	96
41	1.6	0.38	80
51	0.98	0.085	92
252	2.6	0.78	76
251	3.3	0.44	89
243	6.6	0.11	94
112	8.2	1.3	79
255	8.0	1.9	75
253	10.0	0.81	93
22 ^c	5.1	5.86	46

^a CA: Suspended material retained by centrifugation of raw water.

^b Ft_c: Suspended material retained by filtration of centrifugate.

^c Station 22 is in the Ottawa River tributary.

Table 5. UV absorption values as measure for dissolved organic matter (DOM) and dissolved organic carbon (DOC) values for St. Lawrence River water, 1987.

Station Number	Filtered Raw Water (Fc) ^a		Filtered Centrifuged Water (CA _f) ^b		d(DOC) ^d
	E ₂₂₀ ^c	DOC (mg/L)	E ₂₂₀	DOC (mg/L)	
27	0.15	6.3	0.16	5.6	-0.7
28	0.14	8.6	0.15	10.9	+2.3
29	0.16	6.1	0.16	10.1	+4.0
41	0.17	5.8	0.17	5.7	-0.1
51	0.17	6.7	0.17	11.9	+5.2
252	0.17	5.7	0.18	11.1	+5.4
251	0.19	11.2	0.17	5.0	-6.2 ^e
243	0.25	12.8	0.25	16.2	+3.4
112	0.14	7.6	0.14	10.4	+2.8
255	0.19	7.0	0.19	8.7	+1.7
253	0.18	6.1	0.17	10.6	+5.5
22f	0.41	7.9	0.46	7.6	-0.3

^a Filtrate after membrane filtration through 0.2 um filter.

^b Westfalia centrifugate water after membrane filtration through 0.2 um filter.

^c Absorbance at 220 nm wavelength.

^d dDOC = DOC (raw water) - DOC (centrifuged water).

^e Montreal Harbour station, omitted from calculation of mean dDOC; mean dDOC = 3.2 +/- 1.4; n = 11.

^f Station 22: Lac des deux Montagnes (Ottawa River).

Table 6. Comparison of suspended particulate material obtained by filtration (Ft) and centrifugation (CA, Westfalia centrifuge) of St. Lawrence River water, June 1987

Station	Concentration (mg/L)		
	CA ^a	Ft ^b	%Ft/CA
28	0.38	0.060	17
27	0.60	no value	no value
29	1.01	0.043	4
41	1.58	0.73	46
51	0.98	0.41	41
252	2.6	1.7	65
251	3.9	0.93	24
243	6.6	5.9	89
112	6.8	4.3	63
255	7.9	4.7	59
253	9.9	5.2	53
22 ^c	5.5	8.9	162

^a Concentrations given are those of the same individual centrifugation of 600 L water, during which the water sample for the filtration experiment was taken, except for stations 28, 27 and 51, where the means (Table 2) are given due to the low levels.

^b Concentrations (Ft) are combined amounts obtained from three filters, Fa > 8 um; 0.4 < Fb < 8 um; 0.2 < Fc < 0.4 um.

^c Station 22 is in the Ottawa River tributary.

Table 7. Particulate concentrations in Westfalia separator centrifugate as determined by centrifugation with the Sorvall centrifuge and their PCB concentrations.

Station	Particulates ^a				PCB Concentration in particulates (ug/g)			
	Concentration CB (mg/L)		Retention (% CB/CA)		CA		CB	
	1986 (volume) ^b	1987 (volume) ^b	1986	1987	1986	1986	1987	1987
27	- (0)	0.025 (820)	-	5.3	0.39	-	1.28	3.1
28	- (0)	0.032 (930)	-	6.9	0.27	-	0.92	4.7
29	0.12 (690)	0.032 (930)	7.9	3.1	0.13	2.3	1.50	3.8
41	0.08 (960)	0.043 (930)	3.0	2.6	0.16	2.4	0.87	6.4
254	0.07 (1220)	- (0)	2.6	-	0.19	2.0	-	-
51	- (0)	0.029 (690)	-	3.0	-	-	0.96	9.8
56	0.11 (1100)	- (0)	2.9	-	0.19	4.5	-	-
252	0.17 (1200)	0.12 (690)	4.7	4.6	0.12	6.8	0.58	2.7
251	0.14 (1200)	- (0)	3.1	-	0.10	2.2	-	-
243	0.45 (1200)	0.42 (1300)	6.2	6.4	0.07	2.1	0.16	1.1
112	0.51 (1200)	0.25 (1260)	5.3	3.0	0.07	1.5	0.14	1.1
255	- (0)	0.44 (160)	-	5.5	-	-	0.15	1.2
253	0.38 (450)	0.66 (60)	3.8	6.7	0.21	2.3	0.12	1.8
22 ^c	- (0)	0.12 (400)	-	7.5	-	-	0.10	1.4

^a CA: Material retained by Westfalia centrifuge, CB: material retained by Sorvall centrifuge.

^b Volume of water processed by Sorvall centrifuge at 19,000 rpm; volume in L.

^c Water from this station was collected on 24 Oct. 1987, trucked to the laboratory and then processed.

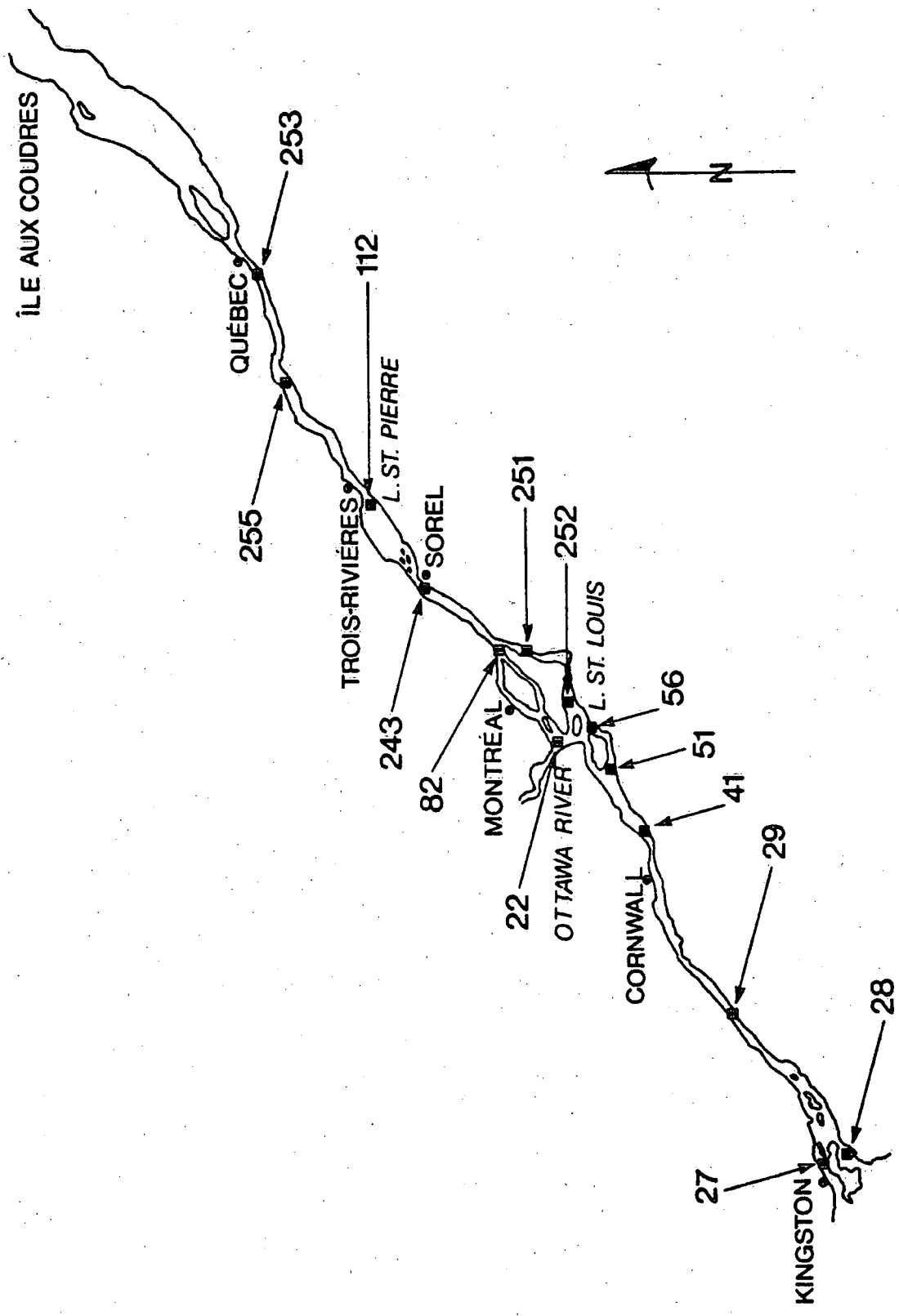


Figure 1. Sampling locations on the St. Lawrence River, 1985-1987.

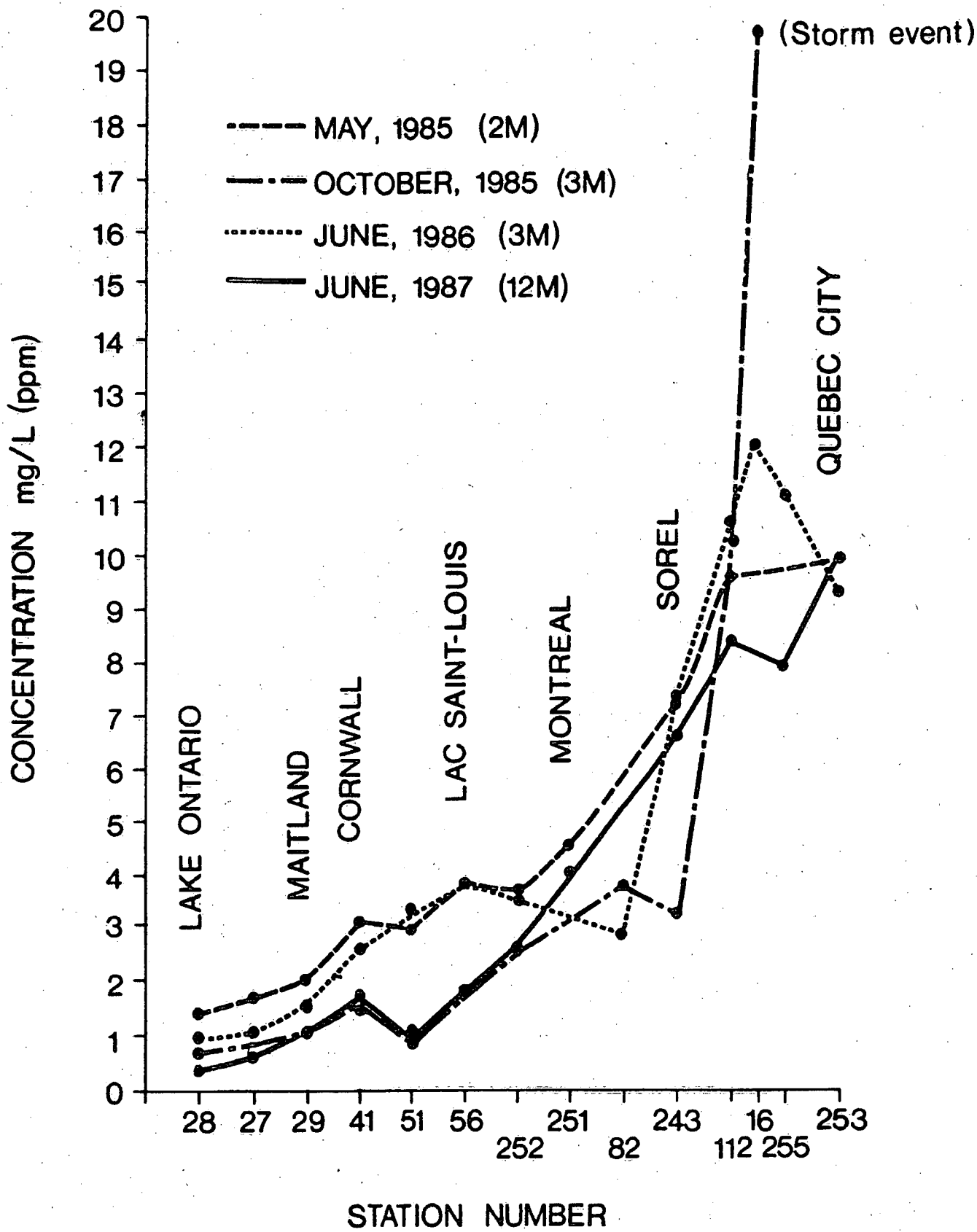


Figure 2. Suspended sediment concentrations in the St. Lawrence River, 1985 to 1987.

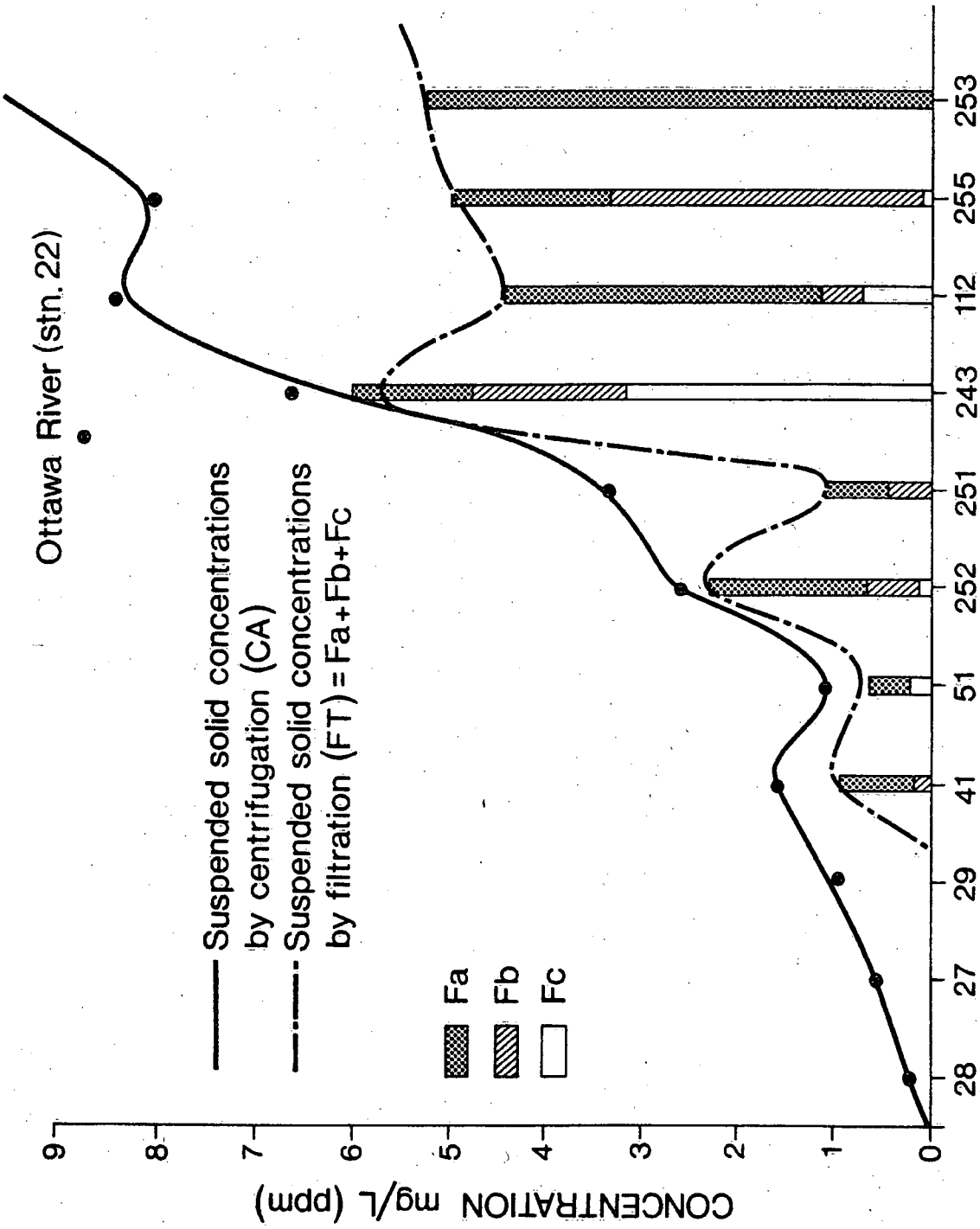


Figure 3. Suspended particulate concentrations by centrifugation (CA) and filtration (FT) = (Fa + Fb + Fc) and particle size distributions (Fa = < 8.0 um; Fb = 8.0 - 0.4 um and Fc = 0.4 - 0.2 um) for St. Lawrence River water, June 1987.

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