

**ORGANIC TRACE CONTAMINANTS IN
ST LAWRENCE RIVER WATER AND
SUSPENDED SEDIMENTS, 1985-1987**

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MANAGEMENT PERSPECTIVE

Title: Organic trace contaminants in St. Lawrence River water and suspended sediments, 1985 -1987

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Perspective: Reported here are the concentrations of organic contaminants in water and suspended sediments of the St. Lawrence River for four sampling periods covering three seasonal regimes in 1985 to 1987.

The results indicate:

- (i) low levels of suspended sediments at the head of the river which increase approximately ten-fold towards the river mouth;
- (ii) significant loadings of PCB and other organochlorine compounds from Lake Ontario;
- (iii) significant inputs of PCB along certain river sections;
- (iv) low levels of mirex in suspended sediments throughout the river;
- (v) little long-term retention of contaminants in the riverine lakes of the St. Lawrence system.

RÉSUMÉ

On a mesuré dans des échantillons d'eau et de sédiments en suspension prélevés dans le fleuve Saint-Laurent, la concentration de contaminants organiques à l'état de traces, notamment des congénères de chlorobenzène, des isomères d'hexachlorocyclohexane, des pesticides du groupe DDT, des polychlorobiphényles (PCB) ainsi que plusieurs autres biocides comme le mirex, la dieldrine et l'endosulfan. Les résultats couvrent d'importantes sections du fleuve entre Kingston et la ville de Québec pour quatre périodes d'échantillonnage, soit mai 1985, octobre 1985, juin/juillet 1986 et juin 1987. On a également analysé, pour la période couvrant 1986, des échantillons d'eau et de sédiments en suspension provenant de plusieurs stations dans le haut estuaire du Saint-Laurent entre la ville de Québec et Tadoussac.

Les résultats indiquent que: i) les faibles concentrations de sédiments en suspension dans le cours supérieur du fleuve (environ 1 mg/L) augmentent jusqu'à environ 10 mg/L (25 mg/L en octobre 1985) près du golfe; ii) certaines sections du fleuve reçoivent des charges considérables de PCB; iii) partout dans le fleuve, les sédiments en suspension contiennent de faibles concentrations de mirex; et iv) les lacs fluviaux du Saint-Laurent (lacs Saint-François, Saint-Louis et Saint-Pierre) semblent être des bassins de contamination à court terme seulement.

Perspective:

Ce document présente les concentrations des contaminants organiques dans l'eau et les sédiments en suspension dans le fleuve Saint-Laurent pour quatre périodes d'échantillonnage couvrant trois régimes saisonniers de 1985 à 1987.

Les résultats indiquent:

- i) la présence de faibles concentrations dans les sédiments du cours supérieur du fleuve, lesquelles sont environ dix fois plus élevées vers l'embouchure;
- ii) la présence de charges considérables de PCB et d'autres composés organochlorés provenant du lac Ontario.
- iii) le déversement dans certaines sections du fleuve de quantités importantes de PCB;
- iv) la présence de faibles concentrations de mirex dans les sédiments en suspension dans tout le fleuve;
- v) une faible rétention à long terme des contaminants dans les lacs fluviaux du réseau du Saint-Laurent.

ORGANIC TRACE CONTAMINANTS IN ST. LAWRENCE RIVER WATER AND SUSPENDED SEDIMENTS, 1985 - 1987

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ABSTRACT

The concentrations of organic trace contaminants including chlorobenzene congeners, hexachlorocyclohexane isomers, DDT group pesticides, polychlorobiphenyls (PCB) and several other biocides, such as mirex, dieldrin and endosulfan have been determined in water and suspended sediments of the St. Lawrence River. The data cover important areas of the river between Kingston and Quebec City for four sampling periods, i.e. May 1985, October 1985, June/July 1986 and June 1987. Water and suspended sediment samples from several stations in the upper St. Lawrence River estuary between Quebec City and Tadoussac were also analyzed for the 1986 period.

The results indicate: (i) low levels of suspended sediments at the head of the river (approximately 1 mg/L) which increase towards the river mouth to approximately 10 mg/L (up to 25 mg/L in October 1985), (ii) significant inputs of PCB along certain river sections, (iii) low levels of mirex in suspended sediments throughout the river, (iv) the riverine lakes in the St. Lawrence (Lakes St. Francis, St. Louis and St. Pierre) appear to be short-term contaminant sinks only.

INTRODUCTION

The Great Lakes - St. Lawrence River system is the Earth's largest freshwater reservoir containing some 20% of the planet's freshwater volume. The Great Lakes drainage basin alone covers over 500,000 km² and the whole system supports approximately 50 million residents, who are engaged in agriculture, industry and commerce. The major part of the system is subject to the *Boundary Waters Treaty* of 1911 between the United States of America and Canada. In addition, a multitude of other federal, provincial and state legislations pertain to activities involving the Great Lakes ecosystem.

Since the recognition of polychlorobiphenyls (PCB) as ubiquitous contaminants in aquatic systems (Jensen, 1972) and the observation of mirex as an important trace contaminant in Lake Ontario (Kaiser, 1974, 1978), research into the environmental sources, pathways and effects of such persistent chemicals greatly intensified. While this contaminant research on the Great Lakes has documented their effects for nearly two decades, comparatively little knowledge has been collected on the St. Lawrence River system. In part, this may have been a result of the large flow and geographic extension of the river, which requires considerable resources for an adequate temporal and spatial coverage.

With an average flow of 7,700 m³/s at the head and 12,750 m³/s at its mouth (Pocklington and Tan, 1987), the St. Lawrence River is Canada's largest river. Toxic organic contaminants enter its water primarily from three sources: (i) Lake Ontario, the source of the river; (ii) point sources along the river including inflowing tributaries, and (iii) by desorption and solubilization from particulates and sediments. Figure 1 shows the St. Lawrence River between Kingston, Ontario and Quebec City, Quebec.

Most of the St. Lawrence River is a fast flowing deep river - current velocity approximately 0.5 to 1.5 m/s - (SD, 1985) with little deposition of suspended particulate matter. Consequently, both dissolved and particulate adsorbed contaminants are quickly flushed through the system with limited time for desorption and bioaccumulation via benthic organisms to occur, relative to large lake and oceanic systems. In contrast, the three riverine lakes in the St. Lawrence River system, namely Lake St. Francis, Lake St. Louis and Lake St. Pierre, are large shallow basins with bathymetric and current conditions conducive to temporary particle settling and burial, and to wind-driven resuspension, resulting in chemical and biological contaminant transfer.

This paper describes results of PCB and selected organochlorine (OC) analyses of river water and suspended sediments collected from up to 26 stations for four sampling periods in the St. Lawrence River. It explores the dynamics of contaminant transport in and through this system and complements other simultaneous investigations on inorganic contaminants (Lum et al., 1989; Lum and Kaiser, 1986), on biota (Gagnon et al., 1989) and biological effects (Kaiser et al., 1988).

EXPERIMENTAL

Sample Collection

General

The sample collections took place in the periods of May 6 to 17, 1985, September 30 to October 18, 1985, June 16 to July 9, 1986 and June 15 to July 11, 1987, with the research vessels *CSS Advent* and *CSS Limnos* or small craft launched from the ship. Details of the chronology of events can be found in the respective cruise reports published by the Technical Operations Division of the National Water Research Institute (TOD, 1985 to 1987). Details of the procedures used to collect and process the samples have been described elsewhere (Comba et al., 1985, 1988, 1989). Briefly, the methods and procedures are given below.

Suspended particulates, (i) Westfalia centrifuge

Suspended particulates were collected from the separation bowl of a Westfalia centrifuge. The centrifuge was operated at 9,800 rpm (g force approximately 10,000) with the water sample passing through at a rate of 6 L/min. The contents of the separation bowl were obtained by slurrying the thin film of retained particles with water in the centrifuge bowl using a nylon toothbrush or small nylon bristle paint brush. The slurry was rinsed into a 500 mL wide-mouth glass jar and stored at 4 C. In May 1985, samples were obtained by filling a 600 L polyethylene tub from a depth of 2 m with river water and centrifuging the tub to dryness. In October 1985, samples were taken in a similar manner, with two 600-L tubs being used to acquire the samples. 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 5m at discrete intervals every 100 minutes for a period of 20 to 26 hours. Samples were collected with the research vessels *CSS Advent* and *CSS Limnos*. Details on the sampling can be found in the data reports (Comba et al., 1985, 1988, 1989) and the vessels' cruise reports (TOD, 1985 to 1987).

Suspended particulates, (ii) Sorvall centrifuge

A Sorvall SS-2 centrifuge with a KSB continuous-flow rotor operated at 19,000 rpm (g force approximately 40,000) 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 1 L/min. 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 over the 1986 procedure. The suspended particulates collected were transferred to 500 mL glass jars and stored at 4 C.

Water samples for polychlorinated biphenyl and organochlorine analysis

Centrifuged water samples of 200 L each were extracted onboard with an aquatic phase liquid/liquid extractor (APLE). The APLE (McCrea and Fisher, 1984) is used in conjunction with a Westfalia continuous flow centrifuge and is designed to extract contaminants from centrifuged water. The solvent, dichloromethane, is continuously pumped from the bottom of the extraction drum to the spray bar, where it is dispersed over the entire surface of the water sample.

Eight litres of pesticide grade dichloromethane are added to the extraction drum which is then filled with 200 litres of centrifuged water and 10 mL of a 'spiking' solution for determination of the recovery. The dichloromethane is recirculated by means of a small pump for 60 min. at a rate of approximately 12 L/min. The pump is then turned off to allow the solvent to settle out of the sample water; 40 minutes later, the solvent is drained back into the original amber solvent bottles. For occupational health reasons, a layer of sample water is included during the draining process to minimize volatilization of the solvent.

Sample Preparation

Suspended particulates

The samples in 500 mL jars were allowed to settle for one day prior to sucking off the supernatant using a disposable glass pipette attached to a water aspirator. The sample water was removed to approximately 1 cm above the suspended particulate layer; covered with a Medi-Wipe (McGaw Supply Ltd., Mississauga, Ontario), secured with an elastic, frozen and then freeze dried. Freeze drying was done in a Virtis 100-SRC Sublimator with a shelf temperature of 2 C and a vacuum of 15 to 30 Torr for 72 to 100 hours.

Sub-samples of homogenized freeze-dried suspended particulates were extracted with 3 x 50 mL portions of dichloromethane using an Ultra-Turrax homogenizer. Each sample was placed in a 300 mL Erlenmeyer flask which coupled to a ground glass adapter on the homogenizer probe, positioning the probe 1 mm above the flask bottom. Each 50 mL extraction was performed for five minutes. The three combined extracts were passed through sodium sulfate and rinsed with 50 mL of hexane. The sample extracts were concentrated to 8 mL with a rotary evaporator. An additional 20 mL of hexane was added to the concentrated sample and reduced to 8 mL again. The extract was transferred to a 15 mL centrifuge tube with 2 x 2 mL hexane rinses. The samples were concentrated to approximately 1 mL by evaporation prior to column chromatographic fractionation.

Water samples

Methylene chloride extracts from the 200 L water samples were concentrated to 200 mL with 12 stage Synder condensers and further concentrated to 50 mL by rotary evaporation. The extracts were passed through sodium sulfate and rinsed with 50 mL of hexane. Samples were reduced to 8 to 10 mL of hexane solution as described for suspended particulates and concentrated to a final volume of 1 to 2 mL in hexane as above.

Sample clean-up

Column chromatography

Glass columns 300 x 1 cm prewashed with acetone, toluene, and hexane were prepared by gravity settling through hexane to a height of 20 cm with activated silica gel. An acid silica gel column was prepared by placing a teflon wool plug into a 5 x 0.2 cm column with a 24/40 female ground glass fitting reservoir. The teflon plug was prewashed with toluene and hexane before the column portion was filled with 4 cm of 44% (by weight H_2SO_4) acid silica gel and rinsed with 25 mL hexane. The acid silica gel column was placed in a 250 mL round-bottom flask and positioned beneath the silica gel column, which previously had the hexane layer drained to the top of the silica gel bed.

The prepared sample was added to the top of the silica gel column and eluted to the top of the bed. The sample container was rinsed twice with 2 mL of hexane and the above procedure repeated for each addition. Another 46 mL of hexane was then added to the column and the eluant allowed to chromatograph through the acid silica gel column beneath the silica gel column. The flask was removed and the acid reservoir rinsed with 10 mL of hexane and labelled fraction A. Another 250 mL round bottom flask was placed beneath the silica gel column, and eluted with 50 mL of (1:1) methylene chloride and hexane. The chromatographic eluant was labelled fraction B.

To each fraction, 0.5 mL of toluene was added and the fraction concentrated to between 2 and 3 mL on a rotary evaporator. The samples were transferred to centrifuge tubes with two 1 mL hexane rinses. The samples were allowed to evaporate to 1 mL and quantitatively adjusted to 1 mL with toluene, then transferred to autosampler vials, capped with an aluminum foil liner and autosampler crimp cap and the liquid level recorded on the vial.

Mercury treatment of silica gel (A) fractions

Sample extracts of suspended particulates were treated with mercury to remove organic sulphur. To each autosampler vial, 0.5 mL of triple distilled mercury was added. The vial was capped and agitated on a vortex stirrer for five minutes. The extracts were allowed to stand overnight and the samples transferred to another autosampler vial, recapped and the liquid level recorded.

Silica gel (activated)

Kiesel gel 60, 70-230 mesh, ASTM as supplied by Merck, was activated by heating for 24 hours at 500 C and used without further treatment.

Sample Quantitation and Quality Assurance

Procedures used for quantitation, previously described by Comba et al.(1985, 1988), were used with the following modification. The DB-1 column was replaced with an OV-1 column with similar chromatographic properties.

Spiking solution

Each large volume water sample was 'spiked' with 10 mL of spiking solution prior to extraction. The spiking solution contained the 1,3; 1,3,5 and 1,2,4,5 brominated benzene congeners as well as 2,3,5,6 tetrachlorobiphenyl and octachloronaphthalene. The 10 mL of spiking mixture provided final extract concentrations of 100 pg/ul, which were used to monitor extraction recoveries.

RESULTS

A total of 41 stations was sampled during the four research cruises on the St. Lawrence River, their locations are given in Table 1. Of these, approximately 50% were sampled at each cruise while the remainder was sampled at one or two cruises only. Not all of the stations reflect mixed St. Lawrence River water, some stations are located in or close to the mouths of tributaries, others near significant local municipal or industrial effluent outfalls. In fact, lateral mixing in the St. Lawrence River is for most parts quite low and larger tributary and/or effluents plumes may be found to extend for significant river stretches. For example, the Ottawa River tributary has significantly higher concentrations of humic substances, resulting in visibly darker water which can be found to extent along the St. Lawrence River north shore from its confluence above Montreal downstream through Lake St. Pierre to Trois Rivières and even further. These observations have been made repeatedly by both visual and chemical/physical means (Bruton et al., 1988; Sloterdijk, 1987; Roy et al., 1989; Kaiser et al., 1989). No doubt, similar slow mixing could be observed for tributary and effluent waters entering the St. Lawrence River along its southern shore, particularly in those areas where the river bed is relative uniform and without embayments, lakes or islands which cause eddies and counter currents.

Given the fast water flow in the river, namely 0.25 to 0.50 m/s in the area between Kingston and Montreal and 0.50 to 1.0 m/s from there to Quebec City (Kaiser, unpublished data), a given water mass will pass through the river in approximately five to seven days. For example, radioactive spills in the Ottawa River traversed the Montreal to Quebec corridor of the St. Lawrence River in three days (Roy et al., 1989). Consequently, our observations, which typically span a two-week period cannot be considered to provide a synoptic picture. Furthermore, episodic events, whether spills, discontinuous discharges or natural variations related to flow, wind and wave action are superimposed on this time scale. Therefore, the interpretation of the results must, where possible and known, consider any such variations.

Suspended sediments in the river

Suspended sediment (SS) concentrations were determined for each station during each cruise and are shown in Figure 2. As evident from Figure 2, SS values increase during each sampling period from the head of the river to its mouth. Except for the October 1985 period, the SS concentrations increase from approximately 1 mg/L at the outflow of Lake Ontario to approximately 10 mg/L near Quebec City, indicating a tenfold increase from river head to mouth. In October 1985, SS values in the Lake St. Pierre to Quebec stretch rose to approximately 20 mg/L as a result of a storm event in Lake St. Pierre.

The above data indicate a general increase in SS concentrations along the river, an observation which is common to most large rivers of the world. However, in contrast to most other rivers, the concentrations of suspended solids in the St. Lawrence River are well below those found elsewhere, in fact they are two to three orders of magnitude lower than at the mouths

of other world rivers. Obviously, these low SS concentrations are the result of particle settling in the Laurentian Great Lakes, particularly Lake Ontario, which effectively filters out all but the finest clay materials. In addition, much of the St. Lawrence River drainage basin below Kingston is situated in the Canadian shield area, where erosion-resistant granitic bedrock predominates.

In the context of organic trace contaminant pathway dynamics and kinetics, the low suspended sediment concentration in the St. Lawrence River is a critical parameter. This will become more evident from the discussion of our results on the major contaminant groups.

Organochlorine contaminants of suspended sediments

PCB

Suspended sediments, obtained from centrifugation with the Westfalia separators, were analyzed for organochlorine trace contaminants for each of the four research cruises. Table 2 gives the polychlorinated biphenyl (PCB) concentrations for each station, except stn. 59 in May 1985, where the amount of particulates collected (0.33 mg/L) was insufficient for analysis. In Figure 3, the PCB values in the SS are plotted versus the station locations by decreasing longitude.

The data indicate generally decreasing PCB concentrations in suspended particulates in downstream direction. At the outflow of Lake Ontario (stations 28, 27 and 29), the values range from approximately 500 to 1500 ng/g while the concentrations at the river mouth (stations 253, 19, 17 and 18) were found to be in the range of 100 to 200 ng/g. This approximately five-fold decrease in PCB concentration on suspended sediments, of course, has to be viewed in connection with the approximately ten-fold increase in the SS concentration along the river. As this dilution of PCB on the particulates is larger by a factor of approximately two than the decrease in PCB values, the overall loading or flux of PCB on the suspended particles more or less doubles within the St. Lawrence River. This increased load of PCB at Quebec City can be attributed to inputs along the river as atmospheric additions can be regarded as insignificant. This interpretation is supported by the detection of high concentrations of PCB at specific inshore stations, some of which are apparent from Figure 3. Sharp increases in PCB on SS values are apparent for station 30 (May 1985), station 32 (Oct. 1985) and station 66 (Oct. 1985). Other, less distinct increases appear to be evident from the values at station 254 (1986) and station 51 (1987).

Pesticides

PCB comprise approximately 80% of the total organochlorine residue burden in St. Lawrence River bottom sediments (Kaiser et al., 1989). In the suspended sediments, our observations indicate a similar distribution. Figure 4 shows the concentrations of total DDT (consisting of the ortho-para and para-para isomers of DDT, DDE and DDD), total BHC (consisting of the alpha, beta and gamma isomers) and dieldrin in SS. As evident from these data, a significant portion of these low level contaminants is contributed by Lake Ontario with levels of 30 to 50 ng/g for each of these groups. Additional sources for some of these substances appear to exist in Lake St. Francis, as evident from the higher levels at station 574 (location as station 254) and station 51 (Beauharnois Canal). This appears consistent with the recent use of DDT by farmers in Quebec (Keating, 1985). From there on, all downstream locations show levels in the 5 to 10 ng/g range only. This finding is consistent with a five to ten-fold dilution of the contaminant burden by the increasing levels of suspended solids.

Mirex

The pesticide and flame retardant mirex has been observed in fish, sediments and suspended particulates in Lake Ontario (Kaiser, 1978), where its major sources were the Niagara and Oswego Rivers. Due to its high persistence and lipophilic nature, mirex is expected to be found on sediments leaving Lake Ontario. Our results indicate the presence of mirex in SS at approximately 5 ng/g at the St. Lawrence River stations near Kingston, declining to approximately 1 ng/g near Quebec City (Figure 5). Trace levels of mirex were also observed in several of the centrifuge samples throughout the river. As found for the PCB compounds, the approximately five-fold decrease in mirex concentration represents dilution of the suspended particles load by tributary and erosion derived sediments. As for PCB, it would appear that, because of the ten-fold increase in SS along the river, there is a doubling of the mirex load as well. So far however, no sources of mirex have been found on the river or its tributaries and, due to the much lower absolute concentrations, the analytical limitations create a higher uncertainty. Also, there is a possibility that, even though the majority of sediments are not permanently deposited in the St. Lawrence riverine lakes (Kaiser et al., 1989; Mudroch et al., 1989), resuspension of mirex contaminated sediments could contribute to this apparent increase. In terms of contaminant transport, the particle adsorbed mirex flux is in the order of 1 to 2 kg/yr, which is less than that transported by eels migrating from Lake Ontario to the St. Lawrence estuary (Lum et al., 1987).

The results indicate that the values of PCB, mirex and other organochlorine compounds in suspended sediments decline along the river. Significant sources of PCB in some areas are clearly evident, but these zones disappear through dilution and mixing. Overall, this can be interpreted as showing a dynamic process of suspended particulate and/or contaminant mixing in the river.

Centrifugate samples

In 1986 and 1987, centrifugates leaving the Westfalia centrifuges used for the collection of the suspended particles, were analyzed for major organochlorine contaminants as well. Results of these determinations are given in Table 2 and are shown for both years in Figure 6. As apparent from this figure, there is a considerable difference between the centrifugate PCB concentrations in these two years. In 1986, concentrations at the river head and mouth are in the order of 0.5 to 1 ng/L with several river stations in the 1 to 2 ng/L range. In contrast, the 1987 samples indicate a much smaller variation with virtually all samples in the 0.5 to 0.8 ng/L range. Furthermore, the relative standard deviations observed for the repetitive samples at most stations in 1987 were smaller than in 1986 (Table 2). It appears quite possible then that the apparent absence of significant PCB point sources in 1987 compared to the previous year indicates a positive step towards waste treatment and reduction of PCB loadings from such point sources, particularly in the Cornwall/Massena (stations 32, 31 and 41 in 1986), Montreal (station 252) and Sorel (station 243) areas in 1986. However, as mentioned above, caution must be exercised in the interpretation due to the natural variations and episodic events and, therefore, additional sampling will be necessary to confirm or refute this interpretation.

Mirex was also found in eight of 14 centrifugate samples in 1986 and in 17 of 18 samples in 1987. The highest value observed was 0.013 ng/L (or 13 ng/m³) at station 243 in 1986. This compares with 7 ng/m³ mirex in the suspended sediments and a total load of 20 ng/m³ at this location. For the eight stations where mirex was found in both the suspended sediment and centrifugate phases, the total mirex load was very constant at 15±3 ng/m³. The ratio of mirex in SS to mirex in centrifugate appears to increase from river head to mouth, similar to that observed for PCB (*vide infra*), but the data are too limited for a statistical treatment.

Contaminant Loads and Dynamics

It is of considerable interest to review the loads of PCB in suspended particulates and in water and their relative importance to the total amount of PCB in the water column. Figure 7 shows these loads, separated into SS and centrifugate portions, expressed as ng/m^3 for 1986. It is interesting to note that the ratio of PCB in particulates versus PCB in centrifugate water changes significantly between river head and mouth. As mentioned above and shown in Figure 6, in 1986, strong PCB sources were apparent from the increase in PCB concentrations in the Cornwall/Massena area (stations 32, 31 and 41). In terms of the PCB ratio in SS and water (Figure 7), these sources are equally apparent from the sharp increase in the percentage of PCB in the centrifugate relative to that in SS. At the river head, a significant part of the total PCB load is found in the centrifugate portion, i.e. either truly dissolved or adsorbed to particles of less than 1 μm in size. A more detailed discussion of contaminant-particle association and centrifuge recoveries is given by Comba and Kaiser (1989). Additions of PCB along the river result initially in high levels of PCB in centrifugate water, such as at stations 32, 31, 441, 243). With the passage of the river, however, PCB become adsorbed onto the increasing concentrations of suspended particles (Figure 2), and at the river mouth (station 253), the ratio of PCB on particulates to that in water has completely reversed.

It appears that a high ratio of dissolved (water) to adsorbed (SS) PCB is a clear indicator of fresh contaminant input to the river (Figure 7). As the adsorption of PCB is thermodynamically favoured over their dissolved state, the transit of a water mass through the river system appears to provide both sufficient time and mixing to approach this thermodynamically preferred, but kinetically controlled equilibrium. In principle, similar observations are made for the 1987 survey, however, the changes are less pronounced due to generally lower PCB levels and apparently also smaller inputs of PCB along the river.

SUMMARY and CONCLUSIONS

1. Our observations show approximately ten-fold increases of the suspended sediment concentrations between the head of the St. Lawrence River at Kingston and its mouth at Quebec City. Superimposed on this increase, which is substantially derived from the primary production within the river during the summer period, are sharp sediment resuspension derived increases downstream of the riverine lakes subsequent to storm events.
2. The concentrations of PCB and mirex on suspended particulates decrease approximately five-fold within the river. Despite strong local sources of PCB in some areas and lateral striation of water masses for significant portions of the river, mixing of the appears to result in spatially uniform concentrations at the river mouth.
3. Loads of PCB near the river head are in the order of 1 ug/m^3 and increase to around 2 ug/m^3 near the river mouth, indicating that approximately one half of the total PCB load at the river mouth is contributed each from Lake Ontario and sources along the river.
4. The ratio of dissolved to particle-adsorbed PCB varies strongly. Near point sources, the dissolved fraction is generally high (70% or more) and it declines with the course of the river to less than 30%, indicating increased thermodynamical control of the ratio. These particle-adsorbed contaminants may be contributing to food-chain contamination in the upper St. Lawrence estuary.

5. Low levels of other organochlorine contaminants, including DDT group pesticides, BHC isomers and dieldrin in suspended sediments at the river head are between five and ten-fold lower at the river mouth. Sources of some of these compounds appear to exist in areas upstream of Montreal. Lake Ontario appears to be the sole source for mirex in the river and the total mirex load (in suspended sediments and centrifugates) remains quite constant at approximately 15 ng/m³ throughout the river in 1986.

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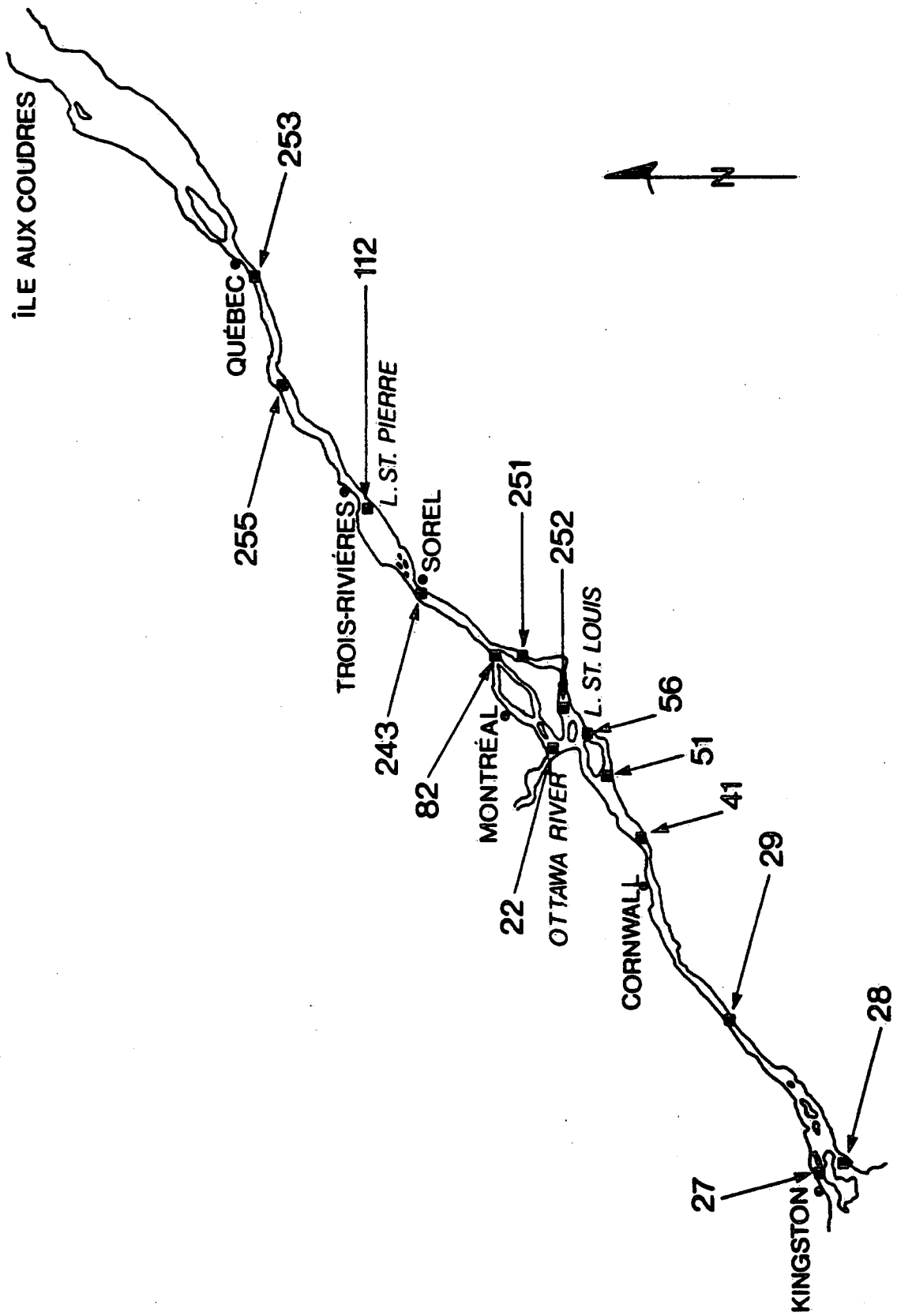
Table 1. St. Lawrence River station locations^a and descriptions

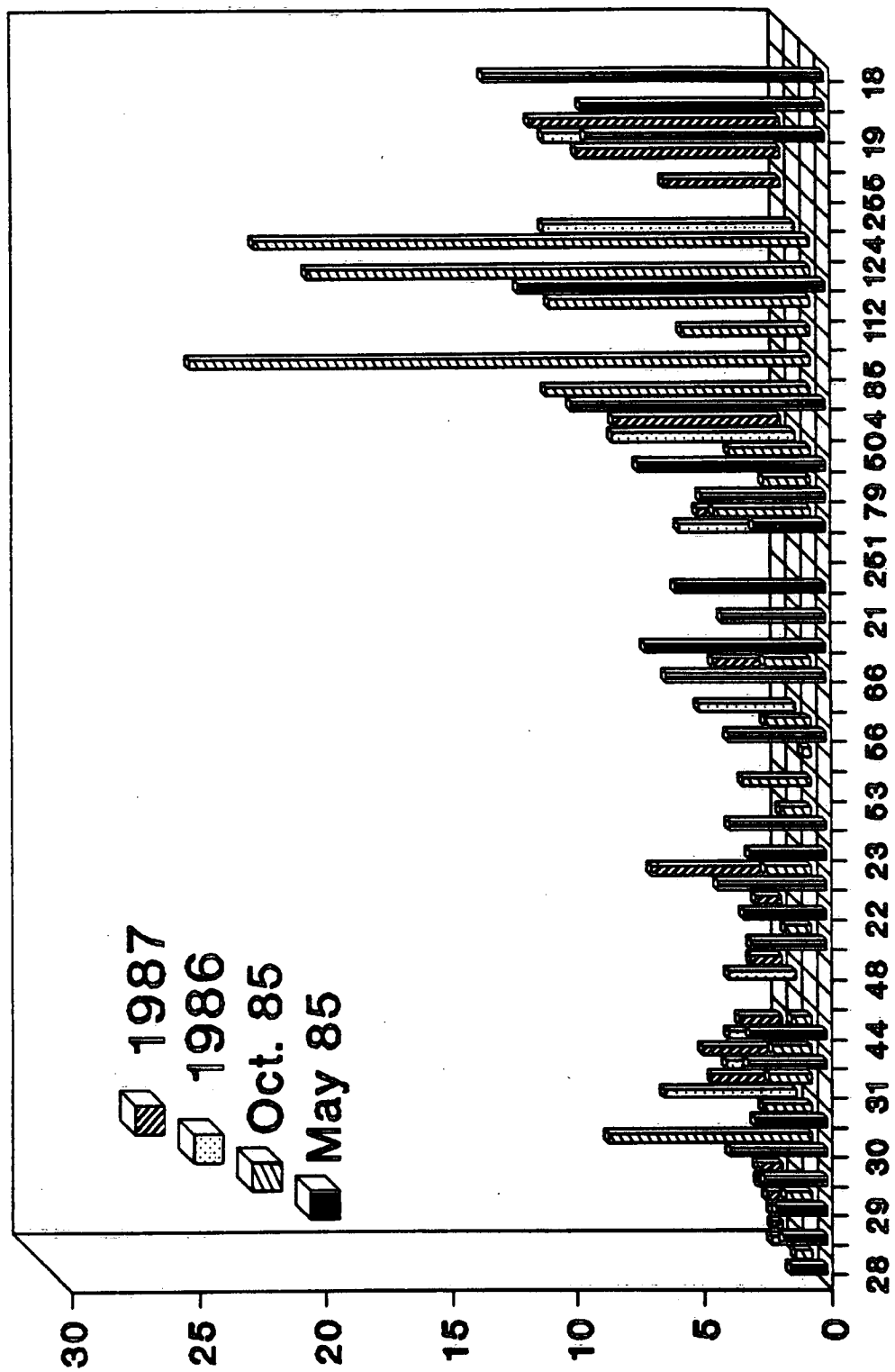
Station No.	Latitude (N)	Longitude (W)	Description
28	44.1208	76.3689	Kingston, Wolfe Isld., north channel
27	44.2417	76.3219	Kingston, Wolfe Isld., south channel
29	44.6386	75.5975	Prescott, mid-channel
4	44.7147	75.4728	Prescott,
30	44.9875	74.7708	Massena, mouth of Grass River
32	45.0231	74.6806	Cornwall, north channel
31	45.0047	74.6597	Cornwall, south channel
41	45.0442	74.5806	Lake St. Francis, western end
44	45.1886	74.3242	Lake St. Francis, center
254	45.2331	74.2311	Lake St. Francis, eastern end
48	45.2208	74.2044	Lake St. Francis, eastern end
51	45.2306	74.1436	Beauharnois Canal, upper end
22	45.4572	74.1000	Ottawa River, Lac des deux Mont.
62	45.4478	74.0506	Lac des deux Montagnes
23	45.4908	73.9572	Lac des deux Montagnes
54	45.3372	73.9289	Lake St. Louis, western end
53	45.3239	73.9017	Lake St. Louis, western end
59	45.4119	73.8275	Lake St. Louis, north
56	45.3692	73.8264	Lake St. Louis, center
252	44.4086	73.7717	Lake St. Louis, eastern end
66	45.4056	73.7289	Lake St. Louis, eastern end
9	45.4044	73.7275	Lake St. Louis, eastern end
21	45.5261	73.5589	Montreal
20	45.5975	73.5083	Montreal
251	45.6411	73.4783	Montreal
82	45.7317	73.4383	Montreal, north
79	45.7228	73.2523	Montreal, south
243	45.9789	73.1922	Sorel
504	46.1578	72.9444	Lake St. Pierre, western end
95	46.1281	72.9497	Lake St. Pierre, western end
85	46.1192	72.9339	Lake St. Pierre, Yamaska River
104	46.1892	72.8964	Lake St. Pierre, western end
112	46.2364	72.7606	Lake St. Pierre, center
123	46.2719	72.6286	Lake St. Pierre, eastern end
124	46.3767	72.4806	Trois Rivières
515	46.3764	72.4792	Lake St. Pierre, north east
255	46.6236	71.9539	Portneuf
253	46.7161	71.3783	Quebec City
19	46.7422	71.3347	Quebec City
17	46.8517	71.1519	Quebec City, north side
18	46.8433	71.0881	Quebec City, south side

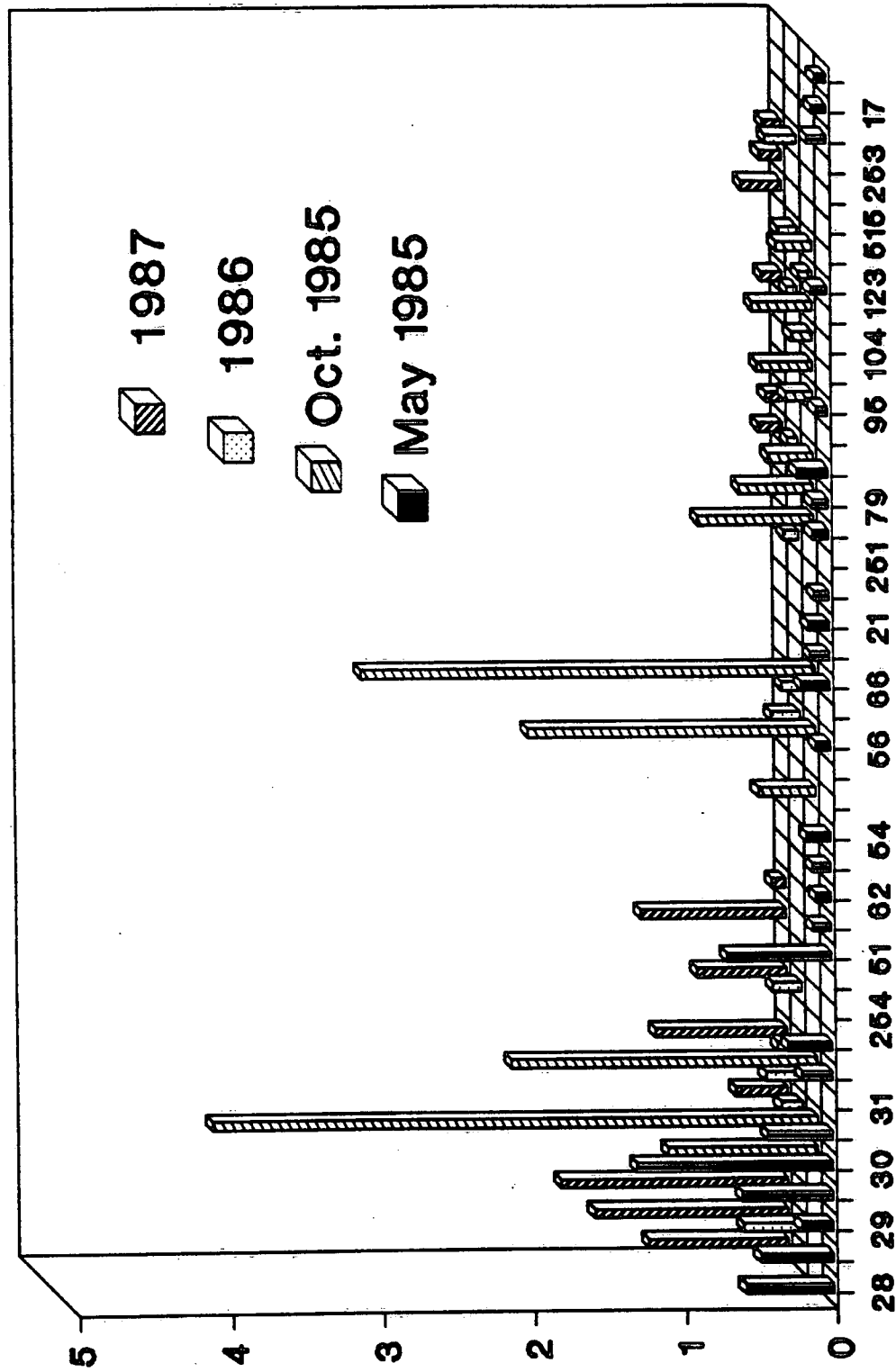
^a Latitude and longitude in degrees and decimal degrees

Table 2. PCB concentrations in suspended sediments (ng/g) and in centrifugate water samples (ng/L) of the St. Lawrence River.

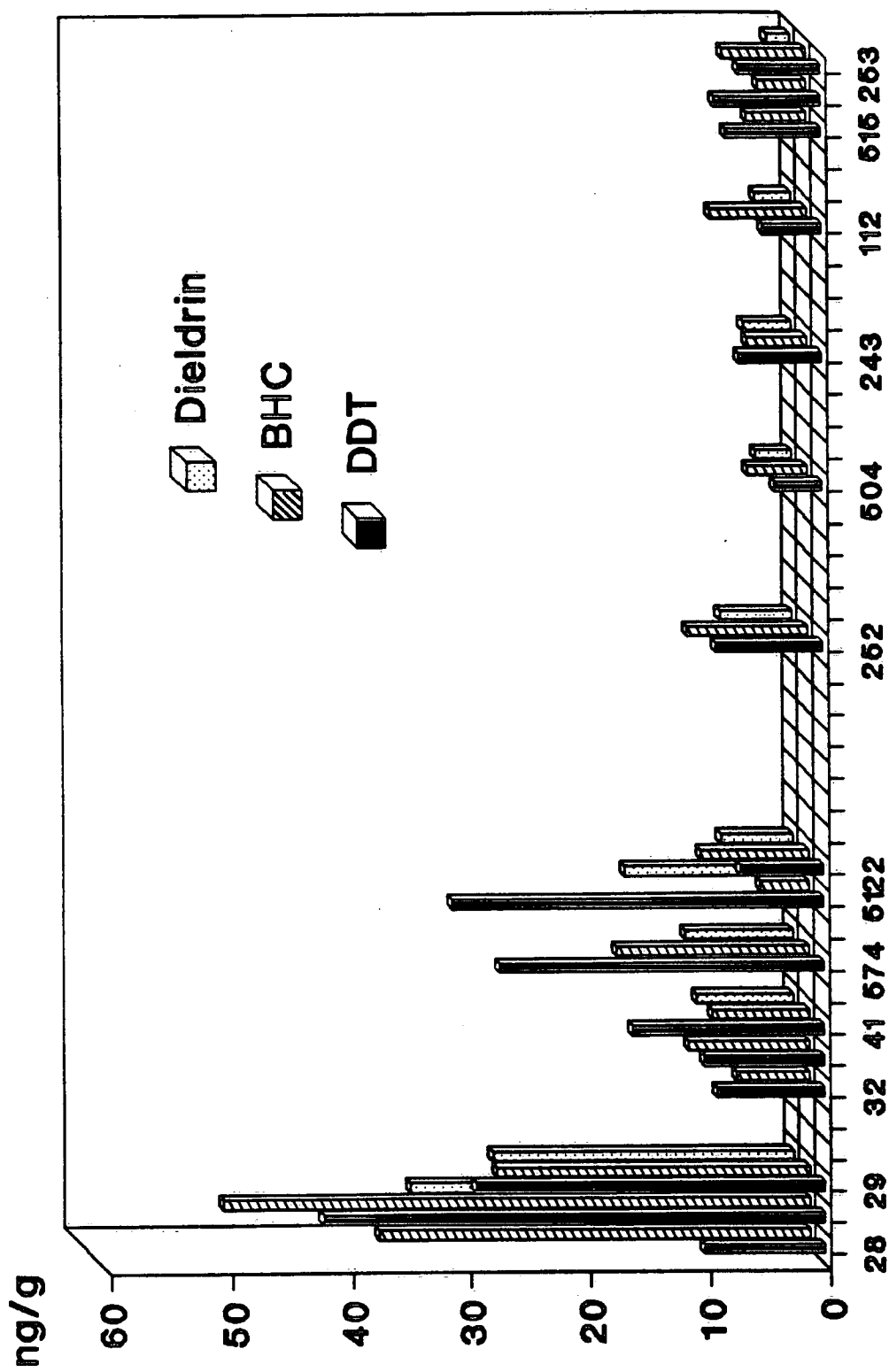
Station	Suspended Sediments				Centrifugate	
	May 85	Oct.85	June 86	June 87	June 86	June 87
28	580	-	270	920	1.30	0.79
27	480	-	390	1280	0.47	0.44
29	210	-	130	1500	0.68	0.65
4	600	-	-	-	-	-
30	1300	990	-	-	-	-
32	430	4000	140	340	1.90	0.62
31	-	-	240	300	1.70	0.84
41	200	2020	160	870	1.90	0.87
44	290	-	-	-	-	-
254	-	-	190	590	0.69	0.53
48	-	-	-	-	-	-
51	690	-	-	960	-	0.84
22	120	-	-	92	-	0.55
62	100	-	-	-	-	-
23	120	-	-	-	-	-
54	160	-	-	-	-	-
53	-	380	-	-	-	-
56	100	1900	190	-	1.10	-
252	-	-	120	580	0.69	0.70
66	190	3000	-	-	-	-
9	130	-	-	-	-	-
21	140	-	-	-	-	-
20	100	-	-	-	-	-
251	-	-	100	400	0.73	0.75
82	110	770	-	-	-	-
79	110	490	-	-	-	-
243	210	300	70	160	1.40	0.90
504	-	-	-	110	-	0.69
95	80	180	-	-	-	-
85	-	370	-	-	-	-
104	-	140	-	-	-	-
112	-	400	70	140	0.73	0.86
123	110	90	-	-	-	-
124	-	240	130	-	1.10	-
515	-	-	-	270	-	0.75
255	-	-	-	150	-	0.76
253	-	-	205	120	0.39	0.65
19	130	-	-	-	-	-
17	100	-	-	-	-	-
18	80	-	-	-	-	-

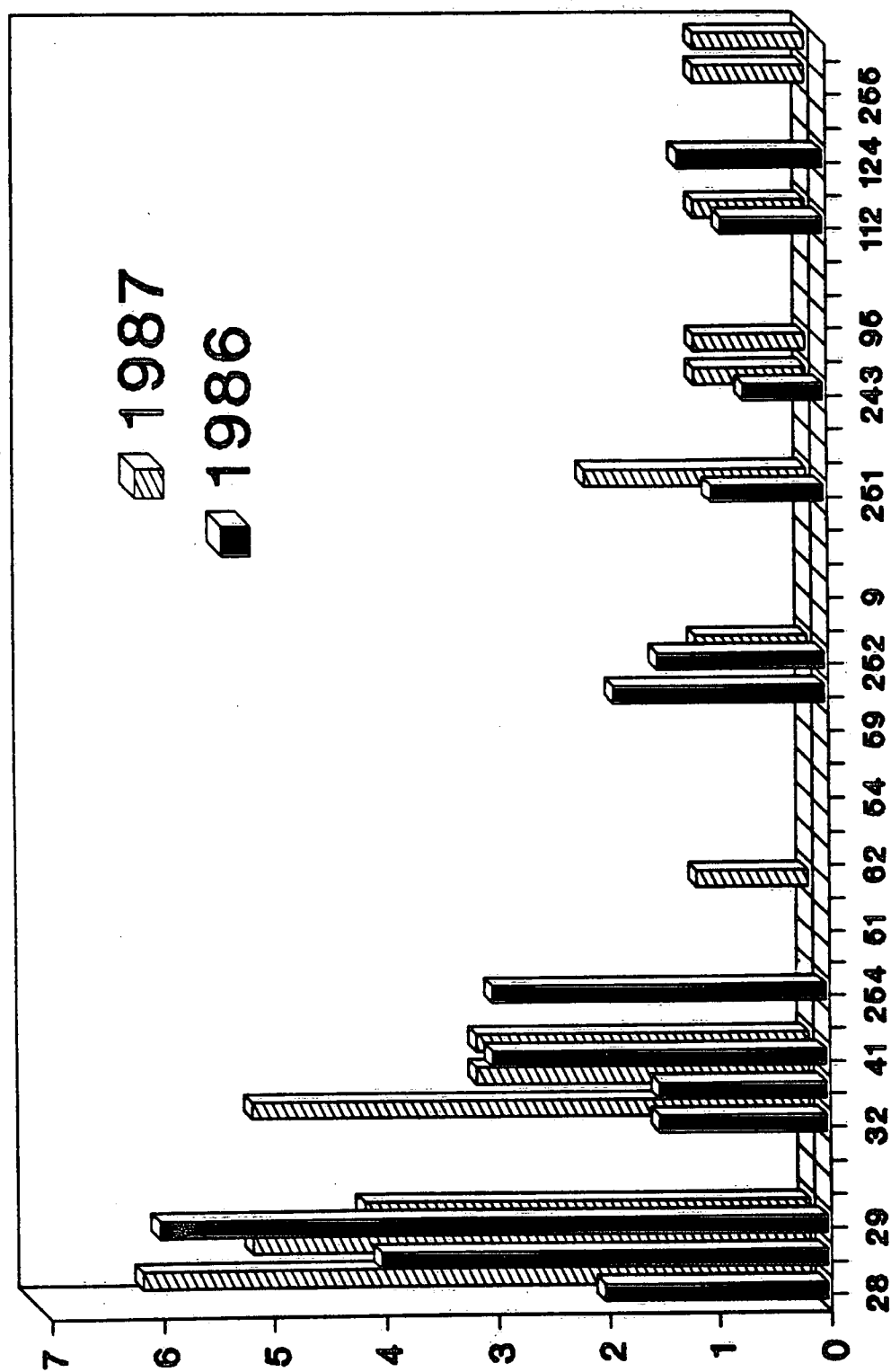




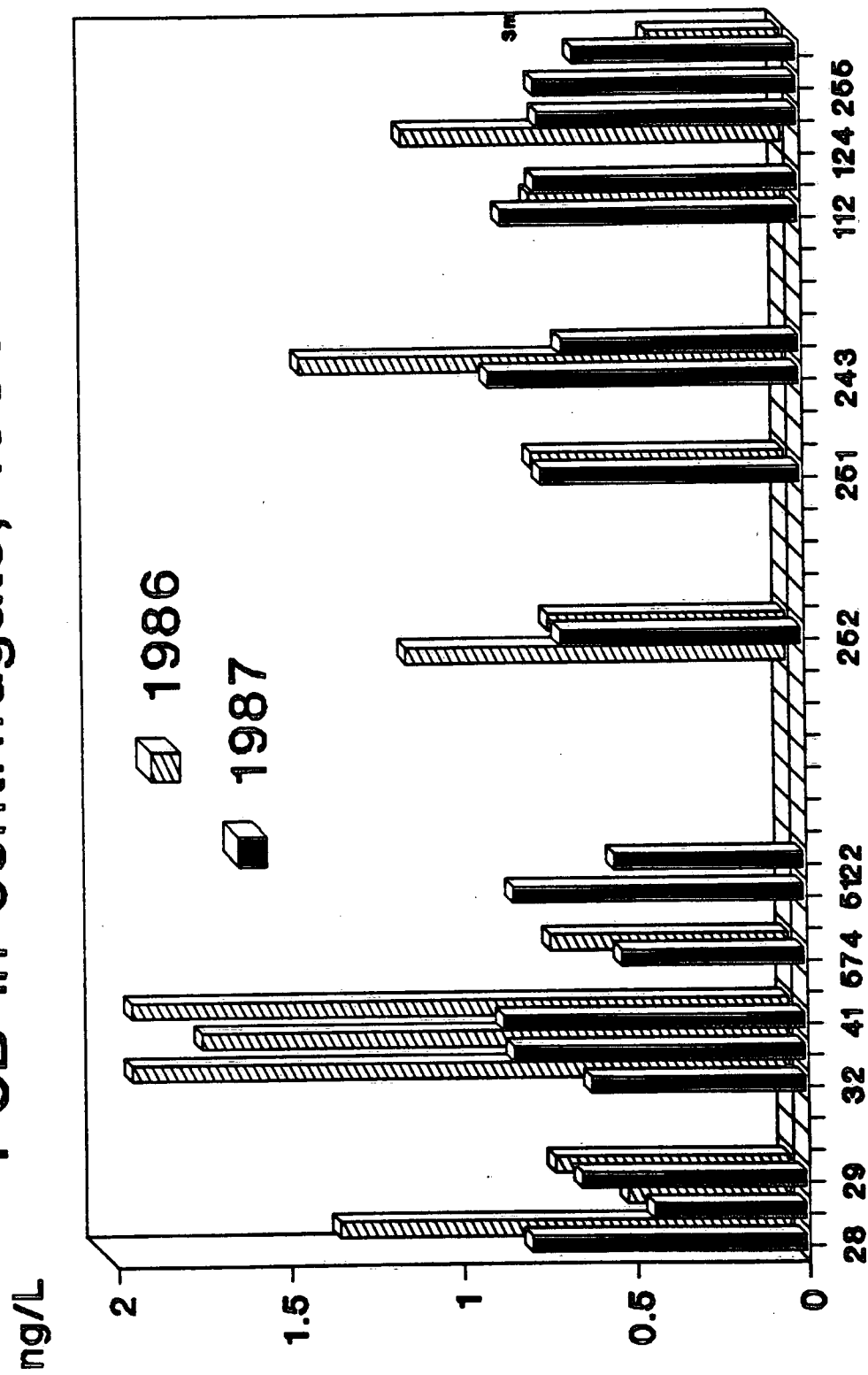


DDT, BHC, Dieldrin in susp. sed., 1987





PCB in centrifugate, 1986/1987



PCB Load in June 1986, ng/m³

