PRELIMINARY TECHNICAL REPORT ON THE NIAGARA RIVER MUSSEL BIOMONITORING SURVEY 1993

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FOREWORD

This document is a preliminary technical report which summarizes the 1993 Niagara River Mussel Biomonitoring Survey. This report has been prepared for release to the scientific community and the public involved in the Niagara River Toxics Management Plan and the Niagara River Remedial Action Plan. Since this is a preliminary technical report, statistical analysis of the data has not been completed.

Caged mussels were placed in the Niagara River on the American and Canadian side for three weeks. The mussels were retrieved and the tissues were then analyzed for a variety of contaminants. The study was designed to identify sources of contamination by persistent organic chemicals along the Niagara River, assess the effectiveness of contaminant source reductions and U.S and Canadian cleanup efforts at previously identified contaminated sites (NRTC 1984). The results are useful to compare the relative contribution of contaminants to the river from individual point and non-point sources.

The data generated by the 1993 Niagara River Biomonitoring survey augments other Niagara River Toxics Management Plan programs by providing information on contaminant levels in the river between Fort Erie and Niagara-on-the-Lake. The Niagara River mussel biomonitoring survey is a biennial program which has been ongoing since 1981.

EXECUTIVE SUMMARY

This report presents the results of the 1993 mussel biomonitoring survey. Caged mussels *(Elliptio complanata)* were placed in the Niagara River for three weeks. The tissues were then analyzed for organochlorine pesticides, PCBs, chlorinated benzenes, polycyclic aromatic hydrocarbons (PAHs) and chlorinated dioxins and furans. The study was designed to identify sources of contamination along the Niagara River. The relative contribution of contaminants to the river from individual point and non-point sources was assessed using this data and, in general, broad temporal trends were evaluated. Analysis of contaminant loadings and detailed long term trend analysis is not possible due to the short (three week) exposure period of the mussels.

The success of remedial activities at hazardous waste sites was assessed by measuring contaminant concentrations in the tissue of mussels introduced at these sites to determine if the sites were still leaching contaminants into the river once remediation was complete.

With the exception of trace concentrations of *p,p'*-DDE, *p,p*'-DDD and γ-chlordane, organochlorine pesticides and PCBs were not detected in mussels introduced on the Canadian side of the river.

Organochlorine pesticides were detected in mussels at several stations on the American side of the Niagara river. α-BHC and β-BHC were detected in mussels exposed at Gill Creek, the 102nd Street landfill site, the site at the base of the Bloody Run Creek seeps and at Occidental's sewer outfall 003. The highest concentrations were detected in mussels placed at the 102nd St. landfill site.

Mirex was detected at two stations in 1993. The concentration of mirex in mussels at the Occidental Chemical Corporation's sewer 003 in Niagara Falls, New York has been fairly consistent since the first survey in 1983 (mean and standard deviation in 1993; 35 ng/g (SD 3.5 ng/g). Mirex was also detected at a storm sewer which receives run off from the area surrounding the Occidental Chemical Corporation.

PCBs were detected in mussels placed at 13 sites on the American side of the river. The highest concentrations of PCBs were detected in mussels placed at Occidental's 003 sewer (283 ng/g SD 34 ng/g), 102nd St landfill site (213 ng/g SD 21.7 ng/g), Pettit Flume (117 ng/g SD 47.8 ng/g), Two Mile Creek (129 ng/g SD 15.7 ng/g) and the upstream (control) site for Gill Creek (157 ng/g SD 27.7 ng/g). Concentrations in mussels at these sites were greater than the Canada-U.S. Great Lakes Water Quality Agreement specific objective for the protection of fish-eating wildlife, which is 100 ng/g.

Mussels placed immediately downstream of the remediated area in Gill Creek also had PCB concentrations that approached the Great Lakes Water Quality Agreement specific objective for the protection of fish-eating wildlife. It is unclear if the source of the PCBs in the mussels at this station is the area recently remediated, or if it is due to other PCB sources further upstream in Gill Creek. There were high PCB concentrations in mussels placed at the Gill Creek "upstream control" site above the remediated area.

Chlorinated benzenes were not detected in mussels at any stations sampled on the Canadian side of the Niagara River, however, they were detected at most sites sampled on the American side.

The highest concentrations of hexachlorobenzene were detected in mussels at the two sites in the Pettit Flume (124 ng/g SD 34 and 168 ng/g SD 32.4), at the base of the seeps from Bloody Run Creek (217 ng/g SD 101.1 ng/g) and at the 102nd Street landfill site (103 ng/g SD 17.3 ng/g).

Data for the 102nd Street landfill site in 1993 show an increase in mussel tissue concentrations for almost all the chlorinated benzenes detected, relative to data from 1991. For many of the compounds concentrations in mussels are at least two times greater in 1993 than in 1991.

The highest concentrations of 2,3,6-trichlorotoluene and 2,4,5-trichlorotoluene were detected in mussels placed at the base of the seeps at Bloody Run Creek (88 ng/g (SD 37.1) and 53 ng/g (SD 16.7) respectively).

The highest concentrations of hexachlorobutadiene were detected in mussels placed at Occidental's 003 sewer (67 ng/g SD 45.6 ng/g) and at the base of the seeps from Bloody Run Creek (61 ng/g SD 34.1 ng/g).

The highest concentration of dioxins and furans in general were found in mussels exposed at the Pettit Flume, the 102nd Street landfill site and at the base of the seeps from Bloody Run Creek. Of particular concern is the detection of high concentrations of 2,3,7,8 tetrachlorodibenzo-p-dioxin (TODD) in mussels introduced at the Bloody Run Creek site (260 pg/g - ppt). This compound is the most toxic form of dioxin. Sediment collected from the same site contained 110,000 pg/g T4CDD and up to 320,000 pg/g 08CDD. The sediment concentration of 2,3,7,8 TCDD was 100,000 pg/g. Because of the exceptionally high concentrations of dioxins and furans at the this site, Occidental Chemical Corporation has been required to remove some of the sediment in this area. Sediment remediation is expected to be completed this summer.

PAHs were present at low concentrations in the tissues of mussels exposed at most sites; including Niagara-on-the-Lake, and the Fort Erie and Thunder Bay, Lake Erie control sites. The highest tissue concentrations of PAHs were found in mussels placed at the two sites in the Pettit Flume and at Two Mile Creek. High concentrations of fluoranthene, pyrene, benzo(a)anthracene, phenanthrene and benzo(b)fluoranthene were found at these stations. Concentrations of these compounds in mussels at these two locations were about ten times greater than the concentrations found in mussels placed at other sites.

SUMMARY OF THE 1993 NIAGARA RIVER MUSSEL BIOMONITORING DATA

This report presents the results of the 1993 mussel biomonitoring survey. Caged mussels *(Elliptio complanata)* were placed in the Niagara River for three weeks. The tissues were then analyzed for organochlorine pesticides, PCBs, chlorinated benzenes, polycyclic aromatic hydrocarbons (PAHs) and chlorinated dioxins and furans. The study was designed to identify sources of contamination along the Niagara River. The relative contribution of contaminants to the river from individual point and non-point sources was assessed using this data and, in general, broad temporal trends were evaluated. Analysis of contaminant loadings and detailed long term trend analysis is not possible due to the short (three week) exposure period of the mussels.

The success of remedial activities at hazardous waste sites by containment of contaminants or contaminant removal can be assessed by measuring contaminant concentrations in the tissue of mussels introduced at these sites. This program is particularly useful for determining if the sites are still leaching contaminants into the river once remediation is complete.

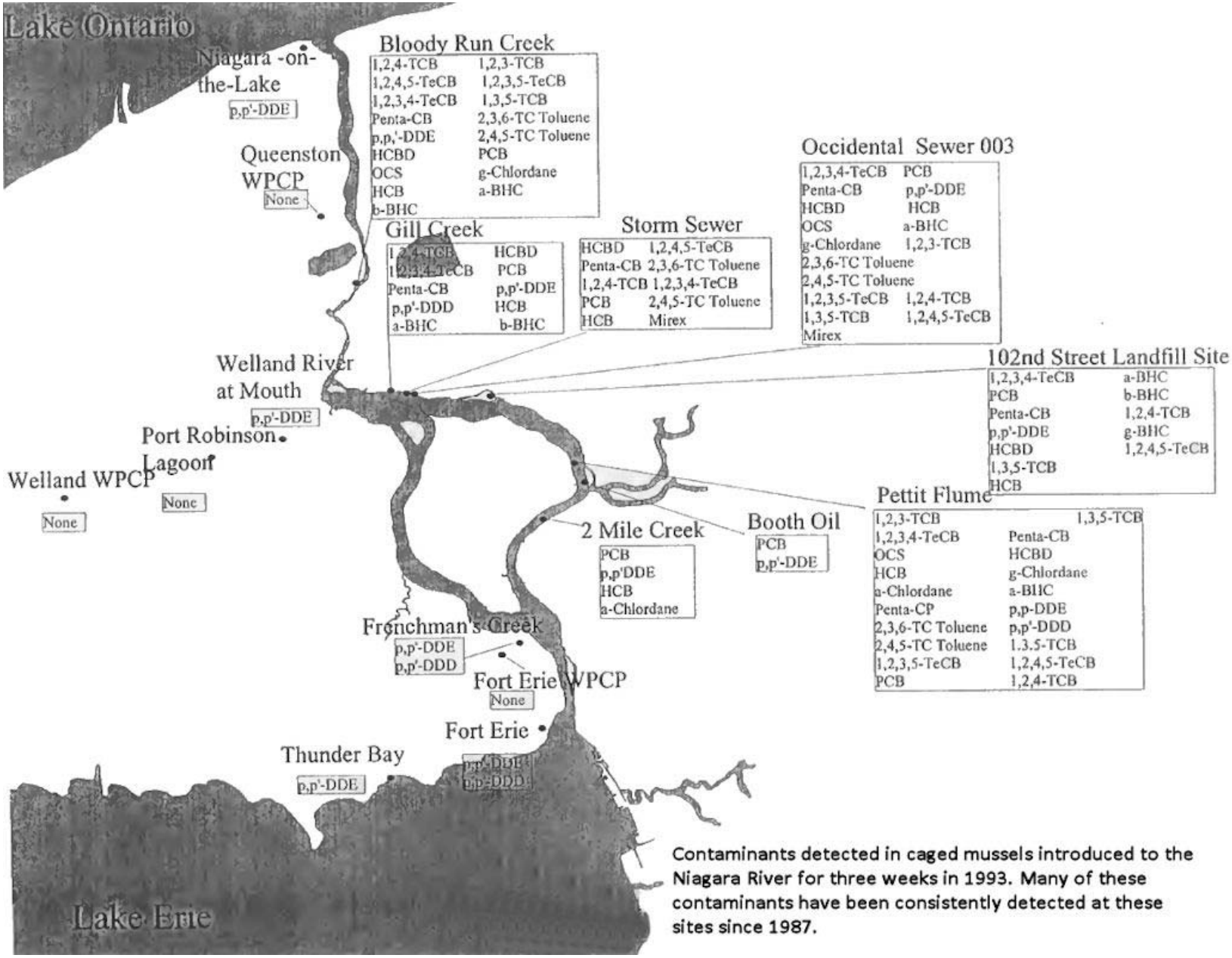
METHODS

Mussels originating from Balsam Lake (a relatively uncontaminated lake located in Victoria county, Ontario) were placed in the Niagara River at 28 sampling stations in June 1993 for three weeks (Figure 1-subset of the sampling stations). Sampling stations were located at the mouth of several tributaries and near known industries, Water Pollution Control Plants (WPCP) and hazardous waste sites on the Canadian and American side of the river.

Mussels were retrieved after 21 days. They were immediately shucked, excess water was drained and the soft tissues were individually wrapped in hexane-rinsed aluminum foil and placed in a plastic bag. Tissues were sent for analysis of organic compounds including organochlorine pesticides, PCBs, chlorinated benzenes and PAHs.

Caged mussels and surficial sediment were collected from seven of the stations for analysis for polychlorinated dioxins and furans. The stations included; the Pettit Flume (2) sites, 102nd Street landfill site, base of the seeps from Bloody Run Creek, Thunder Bay - Lake Erie, Niagara-on-the-Lake and at the Atlas Steel landfill in the Welland River. Some of these stations had high dioxin and furan concentrations in mussels and sediment in previous surveys.

Analysis for PAHs was completed by Environment Canada at the Wastewater Technology Centre. Analysis of the organochlorine pesticides, chlorinated benzenes and dioxins and furans was completed by the Ministry of Environment and Energy's Rexdale laboratory.



Contaminants detected in caged mussels introduced to the Niagara River for three weeks in 1993. Many of these contaminants have been consistently detected at these sites since 1987.

RESULTS

BALSAM LAKE CONTROL MUSSELS

Analysis of the Balsam Lake mussels (control mussels) for organochlorine pesticides, PCBs, mirex and chlorinated benzenes showed that all compounds tested were below the method detection limits (Appendix 1). This means that the contaminants detected in mussels exposed to sites along the Niagara River were present because of the release or deposition of these compounds into the river from point and non-point sources.

ORGANOCHLORINE PESTICIDES

With the exception of trace concentrations of *p,p'*-DDE, *p,p'*-DDD and γ-chlordane, organochlorine pesticides and PCBs were not detected in mussels introduced on the Canadian side of the river (Appendix 1, Figure 1).

Organochlorine pesticides were detected in mussels at several stations on the American side of the Niagara river (Appendix 1, Figure 1). α-BHC (the most ubiquitous isomer of technical grade BHC (hexachlorocyclohexane) from which the pesticide lindane is extracted), was detected in all the mussels exposed at Gill Creek, the 102nd Street landfill site, the site at the base of the Bloody Run Creek seeps and at Occidental's sewer outfall 003. Trace concentrations were found with the exception of the 102nd Street landfill and Bloody Run Creek where the mean concentration and standard deviation (SD) were 71 ng/g (11.2) and 18 ng/g (11.1) respectively. This compound has been identified as a Priority Toxic Chemical of Concern for surveillance in the Niagara River by the NRTC (NRTC 1984).

Trace concentrations of β-BHC were detected in mussels collected from the same stations listed above, in addition to a station located downstream of the Occidental Chemical Corporation, Niagara Falls plant. The highest concentration was detected in mussels placed at the 102nd St. landfill site where the mean concentration was 23 ng/g (SD 4.6). γ-BHC was also detected in mussels placed at the 102nd Street landfill site (29 ng/g SD 4.6). Trace concentrations were also found in one of the three mussels placed at the Niagara Falls water pollution control plant (3 ng/g).

Low concentrations of α- and γ-chlordane were each detected in mussels at only one station; Two Mile Creek and, at the base of the seeps from Bloody Run Creek respectively.

Trace concentrations of *p,p'*-DDD and *p,p'*-DDE were detected in mussels placed at several stations on the American and Canadian side of the river. *p,p'*-DDD was detected at low concentrations in mussels placed at the Pettit Flume, Occidental Sewer 003 and 4 at Fort Erie where the highest concentrations were found (15 ng/g (SD 4.7). *p,p'*-DDE was

detected at low concentrations in mussels at almost all of the sites on the American side and on the Canadian side at the mouth of Frenchman's Creek and the Welland River, at Niagara-on-the-Lake and at the Fort Erie and Niagara Falls water pollution control plants (Appendix 1). The presence of DDT metabolites is believed to be due to historical use of the pesticide resulting in a widespread distribution.

MIREX

Mirex was detected at two stations in 1993. The Occidental sewer 003 upstream control station is of particular interest. Concentrations of mirex, as well as several other compounds were higher in mussels placed at the upstream control site when compared with the site located immediately downstream of the outfall. It is possible that a back eddy existed at the outfall which pushed the contaminants upstream initially, thereby exposing the mussels to the effluent. The upstream site was located fairly close to the outfall. The movement of the contaminant plume once discharged into the river may have then bypassed the downstream station.

The concentration of mirex in mussels at the Occidental Chemical Corporation's sewer 003 in Niagara Falls, New York has been fairly consistent since the first survey in 1983. Mean concentrations in 1983 were low (16 ng/g SD 14 ng/g). In 1987, mirex concentrations in mussels were higher than in 1983, however, concentrations in 1989 and 1991 were again consistent with the 1983 survey; 9 ng/g (SD 4 ng/g) in 1989 and ranging from non detect to 40 ng/g in 1991. Concentrations of mirex remain fairly consistent with previous years in 1993 with a mean of 35 ng/g (SD 3.5 ng/g). In 1993 mirex was also detected at trace concentrations in two of the three mussels placed at a storm sewer downstream of the sewer 003. Mussels placed at this sewer in 1991 also accumulated similar concentrations of mirex.

Occidental Chemical Corporation (formerly Hooker Chemical and Plastics Corporation) was the sole producer of mirex in 1959 (Interagency Task Force on Hazardous Waste 1979). Since the use of mirex was limited in 1976 by Canadian and U.S. legislation because of its environmental impacts, its presence in the Niagara River downstream of the 003 outfall and the storm sewer suggests that residues from previous operations at the facility are still leaching into the river, either from surrounding landfills, or from historically-contaminated equipment. Contaminants in mussels placed at the storm sewer may be originating from the fill or bedding surrounding the sewer since this outfall is not connected to the Occidental facility or surrounding waste sites.

Previously, trace concentrations of mirex were also detected in mussels and in spottail shiners (Suns and Hitchin 1994) at the 102nd Street landfill site and in mussels at the base of the seeps from Bloody Run Creek, however, mirex was not detected in mussels placed at

those sites in 1993. Spottail shiners were not collected from these sites in 1993, however, mirex was found in spottail shiners collected in 1993 from Niagara-on-the-Lake (Suns and Hitchin 1994).

The length of time that the mussels are exposed to the river and the variability in the mussel data within a site precludes any trend through time analysis; however, the presence of mirex at these locations confirms that the Niagara River is still a source of mirex to Lake Ontario. Mirex is a priority toxic chemical of concern in the Niagara River Toxic Management Plan and has been targeted for a 50% source loadings reduction by 1996 compared with 1986 levels.

PCBs

PCBs were detected in mussels placed at 13 sites on the American side of the river. The highest concentrations of PCBs were detected in mussels placed at Occidental's 003 sewer (283 ng/g SD 34 ng/g), 102nd St. landfill site (213 ng/g SD 21.7 ng/g), Pettit Flume (117 ng/g SD 47.8 ng/g), Two Mile Creek (129 ng/g SD 15.7 ng/g) and the upstream (control) site for Gill Creek (157 ng/g SD 27.7 ng/g). Concentrations in mussels at these sites were greater than the Canada-U.S. Great Lakes Water Quality Agreement specific objective for the protection of fish-eating wildlife, which is 100 ng/g.

Although the mean concentration of PCBs in mussels placed at Bloody Run Creek (86 ng/g SD 34 ng/g) was below 100 ng/g, there was, however, one mussel that accumulated 133 ng/g PCB. Furthermore, mussels placed immediately downstream of Gill Creek also had PCB concentrations that approached the Great Lakes Water Quality Agreement specific objective for the protection of fish-eating wildlife. This is particularly interesting because a major clean up of PCB contaminated sediment was recently completed in Gill Creek. Gill Creek had received contaminants from chemical operations at Olin and Dupont and was historically a known PCB "hot spot" (Interagency Task Force on Hazardous Waste 1979; Raven 1991) and a significant source of PCBs to the Niagara River and subsequently Lake Ontario. Although the concentration of PCBs in the introduced mussels are significantly lower in 1993 than they were in 1991, the presence of PCBs in mussels placed at this site indicates that this compound, despite completion of remedial activities, is still migrating from Gill Creek and is bioavailable. It is unclear if the source of the PCBs in the mussels at this station is the area recently remediated or if it is due to other PCB sources further upstream in Gill Creek. There were high PCB concentrations in mussels placed at the Gill Creek "upstream control" site above the remediated area. The presence of PCBs at this upstream site suggests that there are other sources of PCBs to Gill Creek.

PCBs were found in some mussels at several stations on the U.S. side of the river in the vicinity of Occidental Chemical Corp. (range from non detect to 93 ng/g),and Booth Oil (range from non detect to 58 ng/g).

Bloody Run Creek was contaminated by the Hyde Park Waste site which contained PCBs, as did the 102nd Street landfill site (Raven 1991). Both these sites have a history of health and environmental problems (Interagency Task Force on Hazardous Waste 1979). Plant effluent, contaminated groundwater and soil and several waste sites are known to contribute contaminants (including PCBs) to Occidental's sewer 003 (Geologic Testing Consultants 1989) and the surrounding area. Concentrations of PCBs in the introduced mussels at these sites in 1993 are consistent with past results (Anderson *et al* 1991; Richman 1992; Richman 1993).

CHLORINATED BENZENES AND INDUSTRIAL CHLORINATED COMPOUNDS

Chlorinated benzenes were not detected in mussels at any stations sampled on the Canadian side of the Niagara River (Appendix 2, Figure 1).

Chlorinated benzenes were detected at all the sites sampled on the American side of the river with the exception of the Booth Oil site, Two Mile Creek and the Gill Creek upstream control site. Low concentrations of several chlorinated benzenes were detected in mussels placed at Gill Creek, however, it is clear that these sites are not important sources of chlorinated benzenes to the river.

Mussels placed at Occidental's 003 sewer and the other stations downstream of the 003 sewer in the vicinity of the Occidental Buffalo Avenue Plant, Niagara Falls also had low concentrations of most chlorinated benzene compounds. Concentrations of chlorinated benzenes in mussels were consistent with previous survey results.

The highest concentrations of hexachlorobenzene were detected in mussels at the two sites in the Pettit Flume (124 ng/g SD 34 and 168 ng/g SD 32.4), at the base of the seeps from Bloody Run Creek (217 ng/g SD 101.1 ng/g) and at the 102nd Street landfill site (103 ng/g SD 17.3 ng/g) (Appendix 2).

Historically, the Pettit Flume was the most significant source of chlorinated benzenes to the Niagara River relative to the other sites sampled in this survey. In particular, in 1991 concentrations of hexachlorobenzene, pentachlorobenzene and several other chlorinated benzenes in mussels were in the part per million range, far exceeding concentrations in mussels exposed at other sites and significantly higher than concentrations reported in previous years of this survey (in some cases concentrations in mussels were 10 or 100 times higher in 1991 compared with previous years). In 1993, concentrations in mussels at Pettit Flume were considerably lower than the 1991 values and were consistent with the 1989 data. The cause for the increase in concentrations of chlorinated benzenes in mussels in 1991 is presently unknown. Since the caged mussels are in the river for only three weeks detailed trend through time analysis would be inappropriate.

Mussels placed at the Pettit Flume downstream station to determine if contaminants were migrating out of the enclosed inlet, accumulated trace concentrations of most chlorinated benzenes and 60 ng/g (SD 0.6) of hexachlorobenzene, confirming that the Pettit Flume is a source of chlorinated benzenes to the Niagara River. The Pettit Flume was a storm sewer which received waste water from the Occidental Chemical Corp. Durez division and surrounding hazardous waste sites (Geologic Testing Consultants LTD. 1984). The sites were filled with waste products which included chlorinated phenols, chlorotoluene, other organic and inorganic compounds and phenol tar containing chlorinated benzenes (Interagency Task Force on Hazardous Waste 1979; Raven 1991). This site is presently under extensive remediation which is expected to be completed within the next few years.

Data for the 102nd Street landfill site in 1993 show an increase in mussel tissue concentrations for almost all the chlorinated benzenes detected, relative to data from 1991. For many of the compounds, concentrations in mussels are at least two times greater in 1993 than in 1991. The mussels placed at the 102nd Street landfill site had a high concentration of pentachlorobenzene (627 ng/g, SD 118.6 ng/g), 1,2,3,4 tetrachlorobenzene (575 ng/g, SD 108.3 ng/g), 1,2,4,5 tetrachlorobenzene (71 ng/g SD 15.1 ng/g) and 1,2,4 trichlorobenzene (71 ng/g SD 12.6 ng/g). This increase should not necessarily be interpreted as a trend since it is not known if the high tissue concentrations would be detected if the area was sampled at a different time, however, it is a sign that monitoring of this site should continue and the cause of this increase investigated. Remedial activities at the site may have affected the leaching or movement of the contaminants.

Mussels were placed at several outfalls in the vicinity of the Occidental Chemical Corporation's Buffalo Avenue plant to identify the contaminants released from surrounding landfills and plant operations. These sites have typically been a source of 2,3,6-trichlorotoluene and 2,4,5-trichlorotoluene to the Niagara River. Concentrations of 2,3,6-trichlorotoluene and 2,4,5-trichlorotoluene in mussels at the 003 sewer were 18 ng/g (SD 7.3) and 34 ng/g (SD 17.9) respectively. Trace concentrations of these compounds were detected at the other sites in the area. The highest concentration of these compounds was detected in mussels placed at the base of the seeps at Bloody Run Creek. Concentrations for 2,3,6 trichlorotoluene and 2,4,5 trichlorotoluene were 88 ng/g (SD 37.1) and 53 ng/g (SD 16.7) respectively. Bloody Run Creek had relatively high concentrations of 1,2,3,4 tetrachlorobenzene (76 ng/g SD 18.1 ng/g) when compared with the remaining sites.

The highest concentrations of hexachlorobutadiene were detected in mussels placed at Occidental's 003 sewer (67 ng/g SD 45.6 ng/g) and at the base of the seeps from Bloody Run Creek (61 ng/g SD 34.1 ng/g). The Pettit Flume and the remaining stations in the area of Occidental Chemical Corporation all had low concentrations. Low concentrations of octachlorostyrene were detected in some mussels placed at 102nd Street landfill site, Pettit Flume and at the base of the seeps from Bloody Run Creek (Appendix 2).

POLYCHLORINATED DIBENZO-p-DIOXINS AND POLYCHLORINATED DIBENZO-FURANS IN MUSSELS AND SEDIMENT

Mussels

Dioxins and Furans were analyzed in mussels from seven stations (Appendix 3). They were not detected in the Balsam Lake control mussels or the mussels placed at the Thunder Bay, Lake Erie control site.

The highest concentration of dioxins and furans in general were found in mussels exposed at the Pettit Flume, the 102nd Street landfill site and at the base of the seeps from Bloody Run Creek (Figure 2). Of particular concern is the detection of high concentrations of 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD) in mussels introduced at the base of the seeps from Bloody Run Creek (260 pg/g - ppt). This compound is the most toxic form of dioxin. The drainage from the Hyde Park landfill through Bloody Run Creek was historically a major source of dioxin contamination to the Niagara River (U.S. EPA and NYDEC 1993). The results from this survey suggest that the seeps may still an important source of chlorinated dioxins and furans. Mussels at the Pettit Flume contained 15 pg/g of 2,3,7,8 TCDD while mussels at the 102nd Street landfill site contained 74 pg/g 2,3,7,8 TCDD. Concentrations in mussels at all three sites exceeded the New York State fish flesh criterion of 3 pg/g for "total TCDDs" to protect fish-eating birds and mammals (Newell *et al* 1987).

The mussels at Pettit Flume accumulated the highest concentration of furan congeners when compared with other sites (1800 pg/g T4CDF, 1500 pg/g P5CDF and 1000 pg/g H6CDF, 390 pg/g H7CDF and 240 pg/g O8CDF). These mussels tended to bioaccumulate polychlorinated dibenzofurans in preference to dioxins. As well, there were higher concentrations of the lower chlorinated dioxins and furans relative to the higher chlorinated compounds. This preference for the lower chlorinated compounds has been observed in fish and birds in the Great Lakes and is believed to be the result of the lower water solubility of the higher chlorinated congeners such as the octa and hepta dioxins and furans (Laycock 1986).

The distribution of congeners in mussels at 102nd Street landfill site and Bloody Run Creek were similar to the Pettit Flume for the furans, where concentrations of the lower chlorinated compounds were greater than the higher chlorinated compounds. The concentration of the dioxin congeners in the mussels were more evenly distributed than the furans, however, at the 102nd Street site the mussels tended to bioaccumulate higher concentrations of the higher chlorinated dioxins.

Low concentrations of dioxins and furans were found in mussels placed at Niagara-on-the-Lake and at the Welland River Atlas Steel landfill. At Niagara-on-the-Lake 6.8 pg/g of octachlorodibenzo-p-dioxin (O8CDD) and 1.1 pg/g of octachlorodibenzofuran (O8CDF) was detected in the mussels. Tetrachlorodibenzo-p-dioxin (T4CDD) (3.8 pg/g),

O8CDD (26 pg/g) and tetrachlorodibenzofuran (T4CDF) (4.3 pg/g) was detected in mussels at the landfill. The T4CDD did not contain any 2,3,7,8 TODD.

Sediment

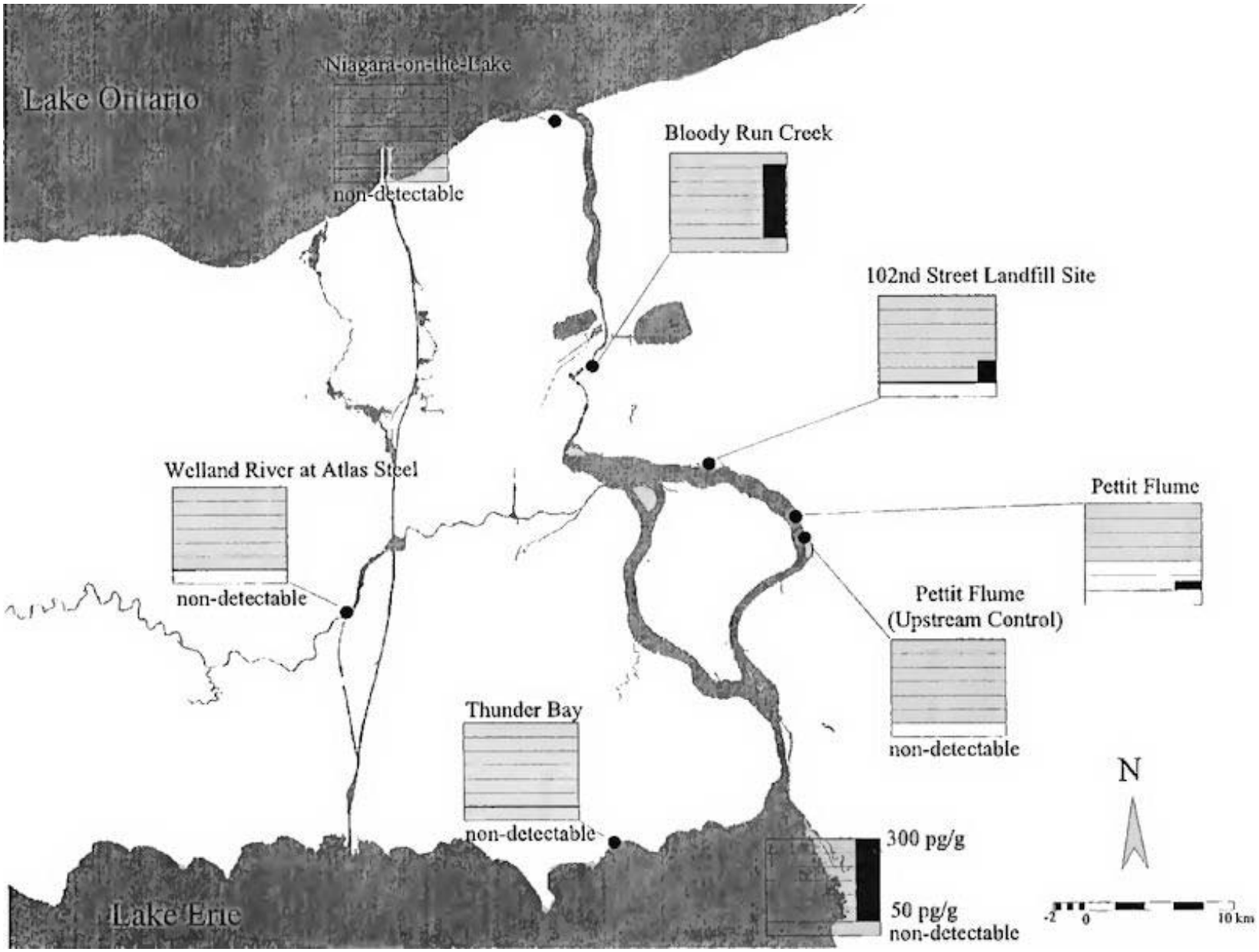
The highest concentration of dioxins and furans in the sediment were found at the Pettit Flume and at the base of the seeps of Bloody Run Creek (Appendix 3). This data is consistent with the mussel data. Sediment concentration for dioxins and furans at 102nd Street were high as well, however, they tended to be 100 to 1000 times lower than concentrations found at the Pettit Flume and Bloody Run Creek.

Dioxins and furans were not detected in sediment at the Thunder Bay, Lake Erie site and low concentrations were present at Niagara-on-the-Lake, the Pettit Flume upstream control site and at the Welland River Atlas Steel landfill. Concentrations at these sites tended to be about 10 or 20 times lower than sediment concentrations at the 102nd Street landfill site.

Sediment concentrations of dioxins at the Pettit Flume ranged from 36,000 pg/g for T4CDD to 40,000 pg/g for O8CDD. Furan concentrations were at least ten times greater and ranged from 100,000 pg/g T4CDF to 1,100,000 pg/g O8CDF. The sediment concentration of 2,3,7,8 TODD was 740 pg/g. In comparison, sediment concentration at the base of the seeps from Bloody Run Creek contained 110,000 pg/g T4CDD and up to 320,000 pg/g O8CDD. The sediment concentration of 2,3,7,8 TODD was 100,000 pg/g. Furan concentrations were lower at Bloody Run Creek than at the Pettit Flume but were still the same order of magnitude.

Because of the exceptionally high concentrations of dioxins and furans at the base of the seeps from Bloody Run Creek (in particular the concentration of 2,3,7,8 TCDD), Occidental Chemical Corporation (owner of the Hyde Park landfill site which was the source of the contaminants) has been required to remove some of the sediment in this area. Sediment remediation is expected to be completed this summer.

Levels of 2,3,7,8-TCDD in Mussels 1993



POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Several PAHs were present in the Balsam Lake mussels at trace concentrations (Appendix 4). Benzo(a)anthracene concentrations ranged from 8 to 20 ng/g. Benzo(b)fluoranthene ranged from 9 to 27 ng/g and Benzo(a)pyrene from 11 to 32 ng/g. Fluoranthene concentrations ranged from 6 to 33 ng/g, fluorene from 6 to 20 ng/g, pyrene from 7 to 22 ng/g while naphthalene and phenanthrene concentrations ranged from 8 to 22 ng/g and 12 to 56 ng/g respectively. The presence of PAHs in control mussels should be noted when reviewing the data for the mussels placed at sites in the Niagara River. There were analytical difficulties distinguishing between total benzo(b)fluoranthene and benzo(k)fluoranthene and between total chrysene and benzo(a)anthracene. Values reported for these compounds should be considered at the sum of the two compounds.

PAHs were present at low concentrations in the tissues of mussels exposed at most sites; including Niagara-on-the-Lake, and the Fort Erie and Thunder Bay, Lake Erie control sites.

In general, with only a few exceptions, low concentrations of acenaphthene, acenanphthylene, anthracene, benzo(a)pyrene. benzo(b)fluorene, benzo(g,h,i)perylene, dibenzo(a,h,)anthracene, fluorene and indeno(1,2,3-c,d)pyrene were present in mussels exposed in the Niagara River. In many cases body burdens may not be due to uptake but rather the background concentrations in the Balsam Lake control mussels. Possible exceptions for the compounds listed above were: higher concentrations of benzo(b)fluorene in mussels placed at Two Mile Creek (23 ng/g SD 6) relative to other stations and the Balsam Lake control mussels, and similarly benzo(g,h,i)perylene and Indeno(1,2,3-c,d) pyrene concentrations appeared higher in mussels placed at Two Mile Creek (35 ng/g SD 8.1 and 19 ng/g SD 3.1 respectively), at the Gill Creek control site (23 ng/g SD 9.6 and 15 ng/g SD 8.4 respectively) and at the two Pettit Flume sites where concentrations were similar to the Two Mile Creek and Gill Creek control site.

Slightly higher concentrations of fluorene were also found in the mussels placed at Two Mile Creek and the Pettit Flume relative to other sites and the Balsam Lake mussels. Further statistical analysis will determine if any of these contaminant concentrations in the mussels are in fact significantly different from the other sites.

In the case of phenanthrene and naphthalene concentrations present in mussels introduced into the river are all within the range of the Balsam Lake control mussels with only few exceptions.

The highest tissue concentrations of PAHs were found in mussels placed at the two sites in the Pettit Flume and at Two Mile Creek. High concentrations of fluoranthene, pyrene, benzo(a)anthracene, phenanthrene and benzo(b)fluoranthene were found at these stations. Concentrations of these compounds in mussels at these two locations were about ten times

greater than the concentrations found in mussels placed at other sites.

The Gill Creek upstream control site also had high concentrations of pyrene, benzo(a)anthracene and benzo(b)fluoranthene relative to other stations sampled in the survey, however, concentrations were lower than those found at the Pettit Flume and Two Mile Creek. On the Canadian side only pyrene present in mussels at the Welland WPCP was detected at high concentrations (179 ng/g SD 15.2).

CONCLUSIONS AND RECOMMENDATIONS

The detection of contaminants in introduced mussels placed at specific sites on the Canadian and American side of the Niagara river suggests the presence of point and non-point sources at these locations. Contaminant sources of chlorinated benzenes, chlorinated dioxins and furans, PCBs and mirex are present on the American side of the river. These compounds were not detected in mussels placed on the Canadian side of the river.

Organochlorine pesticides were detected in mussel on both sides of the river, in particular the metabolites of DDT. This reflects the general distribution of these compounds in the Great Lakes basin and for some compounds is the result of historical practices.

PAHs were also present in mussels introduced on both sides of the river. Without statistical evaluation it is difficult to determine if concentrations of several compounds present in mussels was a result of uptake or due to background concentrations in the Balsam Lake control mussels. However, concentrations of several PAH compounds appear to be significantly higher in mussels placed at the Pettit Flume, Two Mile Creek and the Gill Creek upstream control station.

This survey meets the objectives of identifying point and non point sources of contaminants to the Niagara River and of evaluating the success of remedial activities at known hazardous waste sites. It is recommended that this program be continued in the future to assess the effectiveness of clean up plans in the Niagara River and the reduction of contaminant loadings from point and non point sources.

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Appendix 1. Mean (± Standard Deviation) Concentrations (ng/g wet weight) of Organochlorine Pesticides and PCBs in Mussels Introduced to the Niagara River for Three Weeks, 1993. If one or more samples were below the detection Omit the range was provided in place of the mean.

Sampling Station	α BHC	β BHC	γ BHC	α Chlordane ◆	γ Chlordane ◆	Mirex ◆
Detection Limit	1	1	1	2	2	5
Canadian Sites						
Fort Erie	.	.	.	.	.	.
Thunder Bay, Lake Erie	.	.	.	.	.	.
Frenchmans Creek	.	.	.	.	.	.
NOTL	.	.	.	.	.	.
Welland River (Mouth)	.	.	.	.	.	.
Welland River Slag Dump	.	.	.	.	.	.
Welland WPCP	.	.	.	.	.	.
Port Robinson Lagoon	.	.	.	.	.	.
Stevensville-Douglastown WPCP	.	.	.	.	.	.
Niagara Falls WPCP	.	.	(.) - 3	.	.	.
Queenston WPCP	.	.	.	.	.	.
Fort Erie WPCP	.	.	.	.	.	.
Burlington WPCP	.	.	.	.	.	.
American Sites						
Two Mile Creek	.	.	.	(.) - 3	.	.
Booth Oil	.	.	.	.	.	.

Sampling Station	α BHC	β BHC	γ BHC	α Chlordane ◆	γ Chlordane ◆	Mirex ◆
Detection Limit	1	1	1	2	2	5
Pettit Flume (upstream control)	.	.	.	.	.	.
Pettit Flume (site A)	.	.	.	.	.	.
Pettit Flume (site B)	.	.	.	.	.	.
Pettit Flume (downstream)	.	.	.	.	.	.
102nd Street	71 ± 11.2	23 ± 4.6	29 ± 4.6	.	.	.
Occidental 003 (upstream control)	.	4 ± 1.1	.	.	.	35 ± 3.5
Occidental 003	(.) - 3	.	.	.	.	.
Storm Sewer (S & N area)	.	.	.	.	.	(.) - 13
Occidental 002	.	.	.	.	.	.
S&N area near wall	.	(.) - 4	.	.	.	.
Gill Creek (upstream control)	7 ± 1	5 ± 1.1	.	.	.	.
Gill Creek	(.) - 5	2 ± 0.6	.	.	.	.
Bloody Run Creek	18 ± 11.1	4 ± 1	.	.	(.) - 4	.
Balsam Lake Control Mussels	.	.	.	.	.	.

Appendix 1 continued

Sampling Station	*p,p'*-DDD ◆	*p,p'*-DDE ◆	*p,p'*-DDT ◆	Octachlorostyrene ◆	Total PCBs ◆	% Lipid
Detection Limit	5	1	5	1	20	
Canadian Sites						
Fort Erie	15 ± 4.7	22 ± 4.9	·	·	·	0.8 ± 0.3
Thunder Bay, Lake Erie	·	·	·	·	·	1.1 ± 0.2
Frenchmans Creek	·	5 ± 1.5	·	·	·	0.8 ± 0.1
NOTL	·	(.) -3	·	·	·	0.4 ± 0.1
Welland River (Mouth)	·	(.) -3	·	·	·	0.6 ± 0.2
Welland River Slag Dump	·	·	·	·	·	0.7 ± 0.3
Welland WPCP	·	·	·	·	·	1 ± 0.4
Port Robinson Lagoon	·	·	·	·	·	0.6 ± 0.2
Stevensville-Douglastown WPCP	·	·	·	·	·	0.8 ± 0.1
Niagara Falls WPCP		(.) - 3	·	·	·	0.7 ± 0.2
Queenston WPCP		(.) - 2	·	·	·	0.9 ± 0.1
Fort Erie WPCP	·	·	·	·	·	0.7 ± 0.1
Burlington WPCP	·	·	·	·	·	0.6 ± 0.2
American Sites						
Two Mile Creek	·	2 ± 0.6	·	·	129 ± 15.7	0.7 ± 0.06
Booth Oil	·	(.) -3	·	·	(.) -58	0.9 ± 0.1
Pettit Flume (upstream control)	·	·	·	·	·	1.0 ± 0.1

Sampling Station	*p,p'*-DDD ◆	*p,p'*-DDE ◆	*p,p'*-DDT ◆	Octachlorostyrene ◆	Total PCBs ◆	% Lipid
Detection Limit	5	1	5	1	20	
Pettit Flume (site A)	(.) - 14	(.) - 3	·	·	117 ± 47.8	0.8 ± 0.2
Pettit Flume (site B)	·	·	·	(.) - 2	(.) - 100	1 ± 0.1
Pettit Flume (downstream)	·	·	·	(.) - 2	(.) - 87	0.8 ± 0.1
102nd Street	·	3 ± 1.1	·	(.) - 5	213 ± 21.7	0.7 ± 0.1
Occidental 003 (upstream control)	·	6 ± 1.1	·	·	283 ± 34.1	0.6 ± 0.1
Occidental 003	·	(.) - 3	·	·	·	0.8 ± 0.2
Storm Sewer (S & N area)	·	·	·	·	(.) - 60	0.5 ± 0.1
Occidental 002	·	(.) - 2	·	·	(.) - 90	0.5 ± 0.1
S&N area near wall	·	2	·	·	79 ± 13.2	0.4 ± 0.0
Gill Creek (upstream control)	(.) - 7	(.) - 3	·	·	157 ± 27.7	0.5 ± 0.1
Gill Creek	·	·	·	·	81 ± 18.9	0.4 ± 0.1
Bloody Run Creek	·	11 ± 8.3	·	5 ± 2.9	86 ± 34.3	0.6 ± 0.2
Balsam Lake Control Mussels	.	.	.	.	.	.

"·" Compound was below the detection limit.

For all sampling sites n = 3, with the exception of Occidental's Sewer 003 (n=20), Pettit Flume site A (n=14), Bloody Run Creek (n=4). Site A = Near the culvert Site B = Further into the middle of the cove.

◆ Priority Toxic Chemicals of Concern - Niagara River Toxics Management Plan.
NOTL : Niagara-on-the-Lake

Aldrin, Heptachlor, Toxaphene and *o,p'*-DDT were not detected in any samples analysed.

Appendix 2. Mean (± Standard Deviations) Concentrations (ng/g wet weight) of Chlorinated Benzenes and Chlorinated Industrial Compounds in Mussels Introduced to the Niagara River for Three Weeks, 1993. If one or more samples were below the detection limit the range was provided in place of the mean.

Sampling Station	Hexachlorobutadiene	Hexa-chlorobenzene ◆	Penta-chlorobenzene	2,3,6 - Trichlorotoluene	2,4,5 - Trichlorotoluene
Detection Limit	1	1	1	1	1
Canadian Sites					
Fort Erie	.	.	.	.	.
Thunder Bay, Lake Erie	.	.	.	.	.
Frenchmans Creek	.	.	.	.	.
NOTL	.	.	.	.	.
Welland River (Mouth)	.	.	.	.	.
Welland River Slag Dump	.	.	.	.	.
Welland WPCP	.	.	.	.	.
Port Robinson Lagoon	.	.	.	.	.
Stevensville - Douglastown WPCP	.	.	.	.	.
Niagara Falls WPCP	.	.	.	.	.
Queenston WPCP	.	.	.	.	.
Fort Erie WPCP	.	.	.	.	.
Burlington WPCP	.	(.) - 3	.	.	.
American Sites					
Two Mile Creek	.	(.) - 4	.	.	.
Booth Oil	.	.	.	.	.

Sampling Station	Hexachlorobutadiene	Hexa-chlorobenzene ◆	Penta-chlorobenzene	2,3,6 - Trichlorotoluene	2,4,5 - Trichlorotoluene
Detection Limit	1	1	1	1	1
Pettit Flume (upstream control)	.	.	.	.	.
Pettit Flume (site A)	3 ± 0.9	124 ± 34	77 ± 19.1	(.) - 2	.
Pettit Flume (site B)	7 ± 5.9	168 ± 32.5	81 ± 9.5	(.) - 7	(.) - 8
Pettit Flume (downstream)	(.) - 2	60 ± 0.6	18 ± 3.8	.	.
102nd Street	1.3 ± 0.6	103 ± 17.3	627 ± 118.6	5 ± 2	4 ± 0.6
Occidental 003 (upstream control)	49 ± 13.2	31 ± 6.0	70 ± 20.8	8± 3.0	14 ± 8.7
Occidental 003	67 ± 45.6	7 ± 1.6	24 ± 7.9	18 ± 7.3	34 ± 17.9
Storm Sewer (S & N area)	19 ± 4.5	10 ± 1.5	20 ± 2.5	7 ± 1.7	10 ± 2.5
Occidental 002	4 ± 1.5	5 ± 2.0	(.) - 7	4 ± 2.0	4 ± 1.7
S&N area near wall	2 ± 0.6	4 ± 0.6	6 ± 1.0	(.) - 2	(.) - 2
Gill Creek. (upstream control)	.	.	.	.	.
Gill Creek	9 ± 1	2	(.) - 6	.	.
Bloody Run Creek	61 ± 34.1	217 ± 101.1	253 ± 100.2	88 ± 37.2	53 ± 16.7
Balsam Lake Control Mussels	.	.	.	.	.

Appendix 2 continued

Sampling Station	1,2,3 - Trichlorobenzene	1,2,3,4 - Tetrachlorobenzene	1,2,4 - Trichlorobenzene	1,2,4,5 - Tetrachlorobenzene	1,3,5 - Trichlorobenzene
Detection Limit	2	1	2	1	2
Canadian Sites					
Fort Erie	.	.	.	.	.
Thunder Bay, Lake Erie	.	.	.	.	.
Frenchmans Creek	.	.	.	.	.
NOTL	.	.	.	.	.
Welland River (Mouth)	.	.	.	.	.
Welland River Slag Dump	.	.	.	.	.
Welland WPCP	.	.	.	.	.
Port Robinson Lagoon	.	.	.	.	.
Stevensville-Douglastown WPCP	.	.	.	.	.
Niagara Falls WPCP	.	.	.	.	.
Queenston WPCP	.	.	.	.	.
Fort Erie WPCP	.	.	.	.	.
Burlington WPCP	.	.	.	.	.
American Sites					
Two Mile Creek	.	.	.	.	.
Booth Oil	.	.	.	.	.

Sampling Station	1,2,3 - Trichlorobenzene	1,2,3,4 - Tetrachlorobenzene	1,2,4 - Trichlorobenzene	1,2,4,5 - Tetrachlorobenzene	1,3,5 - Trichlorobenzene
Detection Limit	2	1	2	1	2
Pettit Flume (upstream control)	.	.	.	.	.
Pettit Flume (site A)	30 ± 16.4	51 ± 11.6	46 ± 33.3	9 ± 3.5	15 ± 14.2
Pettit Flume (site B)	26 ± 4.7	44 ± 3.6	55 ± 39.6	21 ± 15.9	66 ± 66.8
Pettit Flume (downstream)	4 ± 0.6	3.3 ± 0.6	10 ± 1		3
102nd Street	22 ± 4	575 ± 108.3	71 ± 12.6	71 ± 15.1	19 ± 2.9
Occidental 003 (upstream control)	(.) - 3	39 ± 13.7	14 ± 7.6	9 ± 3.0	(.) - 10
Occidental 003	(.) - 5	42 ± 19.8	17 ± 5.3	7 ± 3.2	(.) - 6
Storm Sewer (S & N area)	.	19 ± 0.2	7 ± 5.5	3 ± 0.6	(.) - 3
Occidental 002	.	9 ± 3.5	(.) - 5	(.) - 2	.
S&N area near wall	.	6 ± 1	(.) -3	(.) - 2	.
Gill Creek (upstream control)	.	.	.	.	.
Gill Creek	.	(.) - 2	(.) - 5	.	.
Bloody Run Creek	(.) - 4	76 ± 18.1	17 ± 8.2	27 ± 6.5	(.) - 16
Balsam Lake Control Mussels	.	.	.	.	.

"." Compound was below the detection limit.

For all sampling sites n = 3, with the exception of Occidental's sewer 003 (n=20), Pettit Flume (site A) (n=14), Bloody Run Creek (n=4)

Site A = Near the culvert Site B = Further into the middle of the cove.

◆ Priority Toxic Chemicals of Concern - Niagara River Toxics Management Plan

NOTL; Niagara-on-the-Lake

Appendix 3. Polychlorinated Dioxin and Furan Concentrations (pg/g wet weight) in Mussels Introduced to the Niagara River for Three Weeks, 1993. Concentrations represent a composite of four mussels.

CONGENER	Sampling station							
	Balsam Lake (Control Mussels)	Thunder Bay Lake Erie	Pettit Flume (Upstream)	Pettit Flume (Site A)	102nd Street Landfill	Niagara-On-The-lake	Bloody Run Creek	Atlas Steel Land Fill
T4CDD	ND(1)	ND(1)	2.5	780	100	ND(1)	280	3.8
P5CDD	ND(1)	ND(1)	ND(1)	360	41	ND(1)	57	ND(1)
H6CDD	ND(1)	ND(1)	ND(1)	120	110	ND(1)	150	ND(2)
H7CDD	ND(1)	ND(1)	1.3	24	160	ND(1)	110	ND(3)
O8CDD	ND(1)	ND(1)	7	21	190	6.8	54	26
T4CDF	ND(1)	ND(1)	ND(1)	1800	270	ND(1)	280	4.3
P5CDF	ND(1)	ND(1)	1.4	1500	180	1.1	120	ND(1)
H6CDF	ND(1)	ND(1)	ND(1)	1000	120	ND(1)	63	ND(1)
H7CDF	ND(1)	ND(1)	ND(1)	390	41	ND(2)	17	ND(2)
O8CDF	ND(1)	ND(1)	ND(1)	240	29	ND(4)	29	ND(6)
2,3,7,8-T4CDD	ND(1)	ND(1)	ND(1)	15	74	ND(1)	260	ND(1)
1,2,3,7,8-P5CDD	ND(1)	ND(1)	ND(1)	20	4.9	ND(1)	3.1	ND(1)
1,2,3,4,7,8-H6CDD	ND(1)	ND(1)	ND(1)	5.8	ND(2)	ND(1)	3.1	ND(2)
1,2,3,6,7,8-H6CDD	ND(1)	ND(1)	ND(1)	15	28	ND(1)	41	ND(2)
1,2,3,7,8,9-H6CDD	ND(1)	ND(1)	ND(1)	7.1	9.3	ND(1)	18	ND(2)
1,2,3,4,6,7,8-H7CDD	ND(1)	ND(1)	1.3	15	9.4	ND(1)	79	ND(3)
2,3,7,8-T4CDF	ND(1)	ND(1)	ND(1)	110	18	ND(1)	7.5	ND(1)
1,2,3,7,8-P5CDF	ND(1)	ND(1)	ND(1)	62	9.1	ND(1)	2.4	ND(1)
2,3,4,7,8-P5CDF	ND(1)	ND(1)	ND(1)	170	18	ND(1)	8.4	ND(1)
1,2,3,4,7,8-H6CDF	ND(1)	ND(1)	ND(1)	460	49	ND(1)	22	ND(1)

1,2,3,6,7,8-H6CDF	ND(1)	ND(1)	ND(1)	96	10	ND(1)	4.2	ND(1)
2,3,4,6,7,8-H6CDF	ND(1)	ND(1)	ND(1)	39	4.2	ND(1)	2.7	ND(1)
1,2,3,7,8,9-H6CDF	ND(1)	ND(1)	ND(1)	1.2	ND(1)	ND(1)	ND(1)	ND(1)
1,2,3,4,6,7,8-H7CDF	ND(1)	ND(1)	ND(1)	340	22	ND(2)	7.5	ND(2)
1,2,3,4,7,8,9-H7CDF	ND(1)	ND(1)	ND(1)	14	6.5	ND(1)	2.4	ND(1)

ND = NON DETECT
DETECTION LEVEL IN PARENTHESES

Concentrations of Polychlorinated Dioxin and Furans (pg/g dry weight) in Surficial Sediment Collected During the Niagara River Biomonitoring Survey, 1993.

	Sampling Station						
CONGENER	Balsam Lake (Control Mussels)	Thunder Bay Lake Erie	Pettit Flume (Site A)	Pettit Flume (Upstream)	102nd Street Landfill	Bloody Run Creek	Niagara On-the-lake
T4CDD	ND(1)	29	36000	110	15	110000	ND(4)
P5CDD	ND(1)	36	32000	120	8.7	77000	ND(7)
H6CDD	ND(2)	95	45000	1200	56	420000	110
H7CDD	ND(2)	320	32000	3600	120	560000	810
08CDD	ND(6)	1400	40000	7300	390	320000	8200
T4CDF	ND(2)	74	110000	360	21	63000	22
P5CDF	ND(2)	83	180000	600	29	130000	28
H6CDF	ND(3)	180	450000	1500	39	140000	47
H7CDF	ND(4)	370	800000	1500	75	67000	230
O8CDF	ND(7)	480	1100000	1600	120	250000	200
2,3,7,8-T4CDD	ND(1)	ND(2)	740	65	8.2	100000	ND(4)
1,2,3,7,8 P5CDD	ND(1)	3.6	1870	9.1	ND(2)	3400	ND(3)
1,2,3,4,7,8-H6CDD	ND(2)	4.2	2300	23	ND(2)	10000	ND(8)
1,2,3,6,7,8-H6CDD	ND(2)	9.9	3000	250	11	90000	28
1,2,3,7,8,9-H6CDD	ND(2)	9.8	2700	130	5.7	57000	ND(20)
1,2,3,4,6,7,8-H7CDD	ND(2)	160	19000	2300	67	390000	440
2,3,7,8-T4CDF	ND(2)	12	20000	ND(3)	ND(1)	7300	11
1,2,3,7,8-PSCDF	ND(2)	4.9	9400	58	ND(2)	3700	ND(5)
2,3,4,7,8-P5CDF	ND(2)	8.9	15000	55	3.1	9500	ND(5)
1,2,3,4,7,8-H6CDF	ND(3)	85	230000	720	21	55000	ND(10)

1,2,3,6,7,8-H6CDF	ND(2)	119	48000	150	ND(4)	13000	ND(8)
2,3,4,6,7,8-H6CDF	ND(3)	12	ND(15000)	73	ND(2)	5000	ND(9)
1,2,3,7,8,9- H6CDF	ND(2)	ND(1)	ND(500)	43	ND(2)	1600	ND(7)
1,2,3,4,6,7,8-H7CDF	ND(4)	290	700000	1100	56	24000	65
1,2,3,4,7,8,9-H7CDF	ND(1)	11	26000	160	4	12000	ND(9)

ND = NON DETECT
Detection Level In Parentheses

APPENDIX 4: Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River for Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Balsam Lake Control	Thunder Bay/ L. Erie Control	Fort Erie	Frenchmans Creek
Acenaphthene	ng/g	(.) - 2	5.0 ± 4.0	(.)	(.)
Acenaphthylene	ng/g	(.)	12.0 ± 11.0	(.) - 2	(.) - 2
Anthracene	ng/g	(.) - 2	(.) - 11	(.) - 2	(.) - 3
Benzo(a)anthracene	ng/g	13.3 ± 5.0	18.5 ± 13.5	7.3 ± 4.8	10.7 ± 3.1
Benzo(a)pyrene	ng/g	(.) - 32	(.) - 39	(.)	(.)
Benzo(b)fluoranthene	ng/g	(.) - 27	40.5 ± 38.5	7.3 ± 4.4	10.7 ± 8.1
Benzo(b)fluorene	ng/g	(.) - 4	(.) - 4	(.)	(.) - 4
Benzo(g,h,i)perylene	ng/g	(.) - 8	(.) - 46	(.)	(.) - 8
Benzo(k)fluoranthene	ng/g	(.) - *	*		
Chrysene	ng/g	** - 15	** - 30	**	** - 14
Dibenzo(a,h)anthracene	ng/g	(.)	(.) - 16	(.)	(.)
Fluoranthene	ng/g	16 ± 12.1	19.5 ± 13.5	15.7 ± 1.9	15.3 ± 2.4
Fluorene	ng/g	(.) - 20	3.5 ± 1.5	5 ± 2.5	(.) - 3
Indeno(1,2,3-c,d)pyrene	ng/g	(.) - 7	(.) - 42	(.)	(.) - 4
Naphthalene	ng/g	13.3 ± 6.2	7.0 ± 1.0	32.3 ± 25.4	11.0 ± 8.5
Phenanthrene	ng/g	29.7 ± 19.0	17.5 ± 0.5	17.3 ± 1.7	15.3 ± 0.9
Pyrene	ng/g	12.3 ± 6.9	21.5 ± 17.5	11.7 ± 0.5	11.0 ± 0.8

If one or more samples were below the MDL, the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River For Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Niagara-on-the-Lake	Welland River Mouth	Welland River Atlas Steel	Niagara Falls STP
Acenaphthene	ng/g	(.) - 7	(-) - 3	(.) - 3	3 ± 0.8
Acenaphthylene	ng/g	6.7 ± 5.4	(.) - 2	(.)	(.) - 2
Anthracene	ng/g	(.) - 28	(.) - 4	(.)	(.) - 15
Benzo(a)anthracene	ng/g	14.3 ± 9.0	31.0 ± 3.7	27.3 ± 8.2	19.3 ± 6.9
Benzo(a)pyrene	ng/g	(.) - 20	(.) - 34	(.) - 25	(.)
Benzo(b)fluoranthene	ng/g	17.7 ± 14.8	17.3 ± 7.7	20.3 ± 12.5	6.7 ± 2.4
Benzo(b)fluorene	ng/g	(.)	(.)	(.)	(.) - 6
Benzo(g,h,i)perylene	ng/g	(.) - 18	(.)	(.)	(.) - 2
Benzo(k)fluoranthene	ng/g	*	*	*	*
Chrysene	ng/g	** - 15	**	**	** - 8
Dibenzo(a,h)anthracene	ng/g	(.)	(.)	(.)	(.)
Fluoranthene	ng/g	18.0 ± 13.4	18.3 ± 4.9	21.0 ± 5.4	36.3 ± 9.0
Fluorene	ng/g	(.) - 7	(.) - 9	6.0 ± 2.5	8.0 ± 3.6
Indeno(1,2,3-c,d)pyrene	ng/g	(.) - 15	(.)	(.)	(.)
Naphthalene	ng/g	13.0 ± 3.7	15.3 ± 2.6	14.0 ±- 3.7	6.0 ± 2.5
Phenanthrene	ng/g	12.3 ± 7.6	24.3 ± 13.6	30.0 ± 13.7	43.3 ± 7.7
Pyrene	ng/g	18.0 ± 17.1	20.7 ± 5.4	25.0 ± 3.6	33.3 ± 8.3

If one or more samples were below the MDL the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River for Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Queenston STP	Fort Erie STP	Stevensville STP	Welland STP
Acenaphthene	ng/g	(.) - 2	(.)	(.) - 10	(.) - 16
Acenaphthylene	ng/g	(.) - 4	(-) - 3	(.) - 1	(.) - 4
Anthracene	ng/g	(.) - 2	(.) - 4	(.) - 3	(.) - 1
Benzo(a)anthracene	ng/g	10.0 ± 0.8	10.0 ± 2.2	8.3 ± 3.4	46.7 ± 9.5
Benzo(a)pyrene	ng/g	(.)	(.) - 3	(.)	(-)
Benzo(b)fluoranthene	ng/g	(.) - 7	6.3 ± 0.9	(.) - 14	20.3 ± 4.5
Benzo(b)fluorene	ng/g	(.)	(.)	(.)	11.0 ± 9.2
Benzo(g,h,i)perylene	ng/g	(.) - 2	(.) - 4	(.) - 2	(.) - 13
Benzo(k)fluoranthene	ng/g	(.) - *	*	(-) - *	*
Chrysene	ng/g	**	**	**	** - 35
Dibenzo(a,h)anthracene	ng/g	(.)	(.)	(-)	(.)
Fluoranthene	ng/g	8.3 ± 4.5	6.0 ± 1.4	15.0 ± 8.6	25.3 ± 8.4
Fluorene	ng/g	0 - 4	(.) - 4	3.0 ± 1.4	3 ± 0
Indeno(1,2,3-c,d)pyrene	ng/g	(.) - 2	(.)	(.) - 2	(.)
Naphthalene	ng/g	10.7 ± 5.7	27.3 ± 21.5	10.0 ± 5.0	11.3 ± 6.3
Phenanthrene	ng/g	15.7 ± 3.1	10.0 ± 3.6	16.7 ± 3.7	18.3 ± 5.9
Pyrene	ng/g	6.3 ± 1.3	11.0 ± 2.9	10.0 ± 7.1	179.4 ± 15.2

If one or more samples were below the MDL the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River for Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Burlington STP	Port Robinson STP
Acenaphthene	ng/g	(.) - 3	(.) - 8
Acenaphthylene	ng/g	(.) - 2	(.) - 5
Anthracene	ng/g	(.) - 8	(.) - 4
Benzo(a)anthracene	ng/g	11.7 ± 1.9	7.3 ± 2.6
Benzo(a)pyrene	ng/g	(.) - 25	(.)
Benzo(b)fluoranthene	ng/g	(.) - 15	(.) - 4
Benzo(b)fluorene	ng/g	(.)	(.) - 3
Benzo(g,h,l)perylene	ng/g	(.)	(.) - 3
Benzo(k)fluoranthene	ng/g	(.) - 4	(.) - 4
Chrysene	ng/g	**	3.0 ± 0.8
Dibenzo(a,h)anthracene	ng/g	(.)	(.) - 5
Fluoranthene	ng/g	13.0 ± 3.3	9.7 ± 3.9
Fluorene	ng/g	(.) - 9	(.) - 6
Indeno(1,2,3-c,d)pyrene	ng/g	(.)	(-)
Naphthalene	ng/g	15.0 ± 2.9	13.3 ± 0.9
Phenanthrene	ng/g	20.0 ± 2.2	26.0 ± 9.4
Pyrene	ng/g	18.0 ± 3.7	5.0 ± 1.4

If one or more samples were below the MDL, the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River for Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Two Mile Creek	Booth Oil	Pettit flume Upstream	Pettit flume Site 'A'
Acenaphthene	ng/g	6.0 ± 2.5	(.) - 8	(.) - 1	(.) - 3
Acenaphthylene	ng/g	(.) - 15	(.) - 1	(.) - 3	4.0 ± 1.0
Anthracene	ng/g	(.) - 27	(.) - 4	(.) - 3	(.) - 8
Benzo(a)anthracene	ng/g	292.7 ± 201.7	30.0 ± 2.9	27.0 ± 6.5	332.0 ±116.0
Benzo(a)pyrene	ng/g	(.) - 31	(.) - 24	(.)	26.0 ± 16.0
Benzo(b)fluoranthene	ng/g	177.7 ± 52.8	18.7 ± 3.3	18.0 ± 7.0	172.5 ± 162.5
Benzo(b)fluorene	ng/g	22.7 ± 6.0	(.) - 4	(.) - 3	16.5 ± 10.5
Benzo(g,h,i)perylene	ng/g	34.7 ± 8.1	(.) - 10	7.3 ± 3.7	26.0 ± 12.0
Benzo(k)fluoranthene	ng/g	*	*	*	*
Chrysene	ng/g	**	**	**	**
Dibenzo(a,h)anthracene	ng/g	(.) - 9	(-) - 5	(.) - 9	13.5 ± 8.5
Fluoranthene	ng/g	455.7 ± 146.9	24.3 ± 4.5	24.0 ± 5.1	320.0 ± 83.0
Fluorene	ng/g	12.0 ± 2.8	2.7 ± 1.3	(.) - 8	9.5 ± 0.5
Indeno(1,2,3-c,d)pyrene	ng/g	19.3 ± 3.9	(.) - 8	(.) - 10	25.5 ± 16.5
Naphthalene	ng/g	7.3 ± 4.2	9.0 ± 5.0	10.0 ± 2.8	9.5 ± 1.5
Phenanthrene	ng/g	113.3 ± 30.3	16.0 ± 3.3	20.7 ± 6.3	50.0 ± 4.0
Pyrene	ng/g	352.3 ± 111.1	23.7 ± 2.5	21.3 ± 1.3	262.5 ± 60.5

If one or more samples were below the MDL, the range was provided In place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River for Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Pettit flume Site 'B'	Pettit flume Downstream	102 Street Landfill Site	Occidental Sewer 003
Acenaphthene	ng/g	6.7 ± 3.9	4.3 ± 3.4	4.7 ± 3.3	(.) - 7
Acenaphthylene	ng/g	(.) - 14	(.) - 9	3.0 ± 2.2	(.) - 12
Anthracene	ng/g	(.) - 15	(.) - 3	(.) - 2	(.) - 6
Benzo(a)anthracene	ng/g	305.3 ± 55.4	45.7 ± 13.3	25.0 ± 2.2	14.3 ± 6.6
Benzo(a)pyrene	ng/g	(.) - 39	(.) - 8	(.) - 8	(.) - 8
Benzo(b)fluoranthene	ng/g	181.3 ± 52.4	30.7 ± 14.9	15.7 ± 4.6	11.7 ± 11.6
Benzo(b)fluorene	ng/g	(.) - 26	(.) - 4	(.) - 3	(.) - 1
Benzo(g,h,i)perylene	ng/g	25.0 ± 9.4	8.7 ± 3.9	(.) - 12	(.) - 14
Benzo(k)fluoranthene	ng/g	*	*	*	*
Chrysene	ng/g	**	**	**	**
Dibenzo(a,h)anthracene	ng/g	(.) - 12	(.) - 9	(.) - 9	(.) - 8
Fluoranthene	ng/g	396.0 ± 23.3	39.7 ± 5.8	25.7 ± 1.3	31.7 ± 2.6
Fluorene	ng/g	16.7 ± 2.6	3.0 ± 0.8	3.0 ± 1.4	3.0 ± 1.4
Indeno(1,2,3-c,d)pyrene	ng/g	17.3 ± 8.7	(.) - 8	(.) - 10	(.) - 12
Naphthalene	ng/g	17.7 ± 10.3	12.0 ± 3.6	10.0 ± 5.7	9.0 ± 2.9
Phenanthrene	ng/g	99.0 ± 1.6	22.3 ± 8.3	19.3 ± 5.4	15.7 ± 3.9
Pyrene	ng/g	305.7 ± 13.1	30.3 ± 2.6	18.3 ± 4.5	22.0 ± 4.2

If one or more samples were below the MDL, the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River For Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Occidental Upstream Control	Occidental Storm Sewer	Occidental Sewer 002	Occidental Downstream
Acenaphthene	ng/g	(.) - 7	(.) - 7	(.) - 8	(.) - 9
Acenaphthylene	ng/g	(.) - 6	(.) - 16	(.) - 1	(.) - 3
Anthracene	ng/g	(.) - 2	(.) - 5	(.) - 2	(.) - 6
Benzo(a)anthracene	ng/g	41.7 ± 2.4	15.7 ± 2.1	26.7 ± 5.7	39.0 ± 6.7
Benzo(a)pyrene	ng/g	(.)	(.) - 9	(.) - 21	(.) - 8
Benzo(b)fluoranthene	ng/g	24.7 ± 4.5	4.7 ± 1.7	19.3 ± 7.4	28.3 ± 4.2
Benzo(b)fluorene	ng/g	(.) - 3	(.) - 3	(.) - 2	(.) - 4
Benzo(g,h,i)perylene	ng/g	9.0 ± 7.3	(.)	(.) - 14	10.3 ± 5.3
Benzo(k)fluoranthene	ng/g	*	*	*	*
Chrysene	ng/g	**	**	**	**
Dibenzo(a,h)anthracene	ng/g	(.) - 10	(.)	(.) - 13	(.) - 9
Fluoranthene	ng/g	32.7 ± 2.9	28.7 ± 2.1	22.3 ± 5.8	26.3 ± 7.1
Fluorene	ng/g	(.) - 4	5.0 ± 3.6	(.) - 2	5.7 ± 1.3
Indeno(1,2,3-c,d)pyrene	ng/g	(.) - 12	(.)	(.) - 11	(.) - 11
Naphthalene	ng/g	10.3 ± 2.5	15.3 ± 7.6	13.3 ± 6.1	14.7 ± 5.3
Phenanthrene	ng/g	13.0 ± 7.8	16.0 ± 6.7	10.3 ± 2.4	24.0 ± 11.2
Pyrene	ng/g	30.0 ± 1.6	21.7 ± 5.4	18.7 ± 3.4	22.0 ± 2.2

If one or more samples were below the MDL, the range was provided in place of the mean.

Concentrations (ng/g wet weight) of Polycyclic Aromatic Hydrocarbons in Mussels Introduced to the Niagara River For Three Weeks, 1993.

Mean ± Standard Deviation Results

Parameter	Unit	Gill Creek	Gill Creek Control	Bloody Run Creek
Acenaphthene	ng/g	(.) - 2	(.) - 12	(.) - 2
Acenaphthylene	ng/g	11.3 ± 12.5	8.7 ± 6.2	(.) - 5
Anthracene	ng/g	0 - 10	8.0 ± 3.7	(.) - 7
Benzo(a)anthracene	ng/g	19.0 ± 6.4	101.0 ± 19.3	17.7 ± 2.5
Benzo(a)pyrene	ng/g	(.) - 33	(.) - 18	(.) - 37
Benzo(b)fluoranthene	ng/g	29.7 ± 28.1	88.0 ± 17.9	39.7 ± 31.5
Benzo(b)fluorene	ng/g	(.) - 3	(.) - 18	(.)
Benzo(g,h,i)perylene	ng/g	(.) - 38	23.0 ± 9.6	(.) - 21
Benzo(k)fluoranthene	ng/g	(.) - 6	*	* - 8
Chrysene	ng/g	** - 26	**	** - 16
Dibenzo(a,h)anthracene	ng/g	(.) - 14	(.) - 17	(.)
Fluoranthene	ng/g	22.7 ± 11.5	74.7 ± 11.6	28.3 ± 22.7
Fluorene	ng/g	(.) - 5	7.0 ± 4.1	(.) - 10
Indeno(1,2,3-c,d)pyrene	ng/g	(.) - 32	15.3 ± 8.4	(.) - 9
Naphthalene	ng/g	14.0 ± 3.6	13.0 ± 1.6	13.0 ± 2.2
Phenanthrene	ng/g	14.3 ± 6.9	22.3 ± 7.1	21.0 ± 9.2
Pyrene	ng/g	24.3 ± 17.0	76.7 ± 10.9	25.7 ± 19.4

If one or more samples were below the MDL, the range was provided in place of the mean.