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# ENDOCRINE-DISRUPTING CHEMICALS IN INDUSTRIAL WASTEWATER SAMPLES

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**NWRI Contribution No. 01-033**

# Endocrine-disrupting Chemicals in Industrial Wastewater Samples

By

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## MANAGEMENT PERSPECTIVE

In a collaborative research project by the National Water Research Institute and the City of Toronto on the quality of industrial wastewater, the occurrence of four selected endocrine-disrupting chemicals (EDCs), including bisphenol A, nonylphenol ethoxylates, and nonylphenol in these samples has been studied. While a wide range of concentrations were observed for each of the above chemicals, many of the samples were found to have much higher levels of one or more of the EDCs in question than those in sewage. Our results suggest that detergents based on nonylphenol ethoxylates have been extensively used and released to the sewage system by the commercial cleaners and the textile products and clothing industries. Major point sources of the above EDCs discharging into the Toronto sewer system have been identified.

## SOMMAIRE A L'INTENTION DE LA DIRECTION

Dans le cadre d'un projet de recherche portant sur la qualité des eaux usées industrielles, mené en collaboration par l'Institut national de recherche sur les eaux et la ville de Toronto, on a étudié l'occurrence, dans ces échantillons, de quatre perturbateurs du système endocrinien (PSE) choisis, notamment le bisphénol A, les éthoxylates de nonylphénol et le nonylphénol. Alors qu'on a observé une vaste gamme de concentrations pour chacun de ces produits chimiques, on a mesuré, dans bon nombre de ces échantillons, des concentrations très supérieures d'un ou plusieurs de ces PSE, par rapport à celles des eaux usées. Nos résultats semblent indiquer que les nettoyeurs commerciaux et les industries des produits textiles et des vêtements rejettent dans le réseau d'égout de grandes quantités de détergents à base d'éthoxylates de nonylphénol. On a donc identifié les principales sources ponctuelles des rejets de ces PSE dans le réseau d'égout de Toronto.

## ABSTRACT

The occurrence of endocrine-disrupting chemicals (EDCs) such as bisphenol A (BPA), 4-tert-octylphenol (OP), nonylphenol (NP) and its ethoxylates (NPEO) in wastewater generated in the Toronto area has been studied. In all, 97 samples from 40 facilities in ten different industry classes have been collected and analyzed. Widely divergent concentrations have been observed in these samples. They ranged from <0.01 to 195 µg/L for OP, from <0.1 to 253 µg/L for NP, from <2 to 117,570 µg/L for NPEO, and from <0.01 to 149 µg/L for BPA. The results show that the concentrations of NP and NPEO in these samples generally exceeded City of Toronto By-law (No. 457-2000) limits. The results also suggest that detergents based on NPEO are still extensively used by the commercial laundries, and also by the textile products and clothing industries. These facilities, together with several sources in the chemical and chemical products industries and the fabricated metal products industries are believed to be the major sources of NP and NPEO input into the sewer system in Toronto. In addition to the two facilities in the chemicals and chemical products sector, several commercial laundries also had significant on-site releases of BPA. Except for those collected from three facilities in the chemicals and chemical products industries, the levels of OP in these samples were generally low. Many industries in the Toronto area would have to take drastic actions to reduce releases of NPEO and NP if full compliance with the most recent City By-law regarding wastewater quality were to be achieved

## RESUME

On a étudié l'occurrence de perturbateurs du système endocrinien (PSE) comme le bisphénol A (BPA), le 4-tert-octylphénol (OP), le nonylphénol (NP) et ses éthoxylates (EONP) dans les eaux usées de la région de Toronto. On a prélevé et analysé un total de 97 échantillons dans 40 installations de 10 catégories différentes d'industries. Dans ces échantillons, on a mesuré des concentrations extrêmement variables, comprises entre moins de 0,01 et 195 µg/L pour l'OP, 0,1 et 253 µg/L pour le NP, moins de 2 et 117 570 µg/L pour l'EONP, et moins de 0,01 et 149 µg/L pour le BPA. Ces résultats montrent que les concentrations de NP et d'EONP dans ces échantillons dépassaient généralement les limites du *Règlement n° 457-2000* de la ville de Toronto. Ils semblent aussi indiquer que les détergents à base d'EONP sont encore fortement utilisés par les blanchisseries commerciales, ainsi que par les industries des produits textiles et des vêtements. On croit que ces installations, ainsi que plusieurs installations industrielles de produits chimiques, de produits dérivés et de produits métalliques ouvrés, sont les principales sources des apports de NP et d'EONP dans le réseau d'égout de Toronto. En plus des deux installations de l'industrie des produits chimiques et des produits qui en dérivent, plusieurs blanchisseries commerciales rejetaient aussi des quantités significatives de BPA. Sauf dans le cas des échantillons prélevés dans les trois installations industrielles de produits chimiques et de produits dérivés, les teneurs en OP de ces échantillons étaient généralement faibles. De nombreuses industries de la région de Toronto devraient donc prendre des mesures radicales pour réduire les rejets d'EONP et de NP pour l'application intégrale du règlement municipal le plus récent visant la qualité des eaux usées.

## INTRODUCTION

Endocrine-disrupting chemicals (EDCs) are compounds that may interfere with the normal functions of the hormonal systems of humans, fish, and wildlife. At levels that can be found in the environment, many agrochemicals, industrial chemicals, natural and synthetic hormones have the potential to affect the growth, development, and reproduction of fish (Tyler et al., 1998, Jobling et al. 1998). Several reports have shown that municipal sewage effluents were sources of estrogenic activities (Sumpters 1995), causing the observation of eggs in the testes and the induction of vitellogenin in male fish downstream of sewage treatment plants (Harris et al. 1997). For these reasons, research on the occurrence and fate of EDCs and their effects on the aquatic ecosystem has been given a high priority by Environment Canada.

In the last few years, we have developed methods for the determination of a number of EDCs, including nonylphenol ethoxylates (NPEO) (Lee et al., 1997), their metabolites nonylphenol (NP) (Lee and Peart, 1995) and nonylphenol carboxylates (NPEC) (Lee et al., 1998), as well as bisphenol A (BPA) (Lee and Peart, 2000a) in sewage, wastewater, and sludge. NPEO, a major class of non-ionic surfactants still used in various formulations of detergents by many industries in Canada, are chemicals in the Priority Substances List 2, as are their metabolites. The occurrence and fate of NPEO and their more persistent and estrogenic metabolites, NP and NPEC, in samples from a Canadian sewage treatment plant have previously been reported (Lee and Peart, 1998). While BPA, a building block of many polycarbonate and epoxy resins, has been shown to be one of

the more potent anthropogenic estrogen receptors agonists (Reutledge and Sumpter 1996), information regarding its environmental levels in Canada was virtually non-existent until recently (Lee and Peart, 2000b).

To give citizens access to information on pollutant release by industrial facilities in their communities, the National Pollutant Release Inventory (NPRI) of Environment Canada has maintained searchable on-line databases of selected chemicals since 1994 (Environment Canada, 2000a). There were 245 reporting substances in 1999, including NPEO, NP, and BPA. 4-*tert*-Octylphenol (OP) was not a reporting substance until year 2000. Except for those organizations exempted from reporting, all facilities exceeding the employee and concentration thresholds and also emitting more than 10 tonnes of an NPRI substance are required to submit reports to the NPRI (Environment Canada, 2000b). In the Toronto area for the year 1999 (the most recent year for which data are available for this study), there were no facilities reporting on-site releases of NPEO and NP, and only one facility reporting 0.26 tonnes of on-site releases of BPA.

In 1998 and 1999, collaborative research by the National Water Research Institute and the City of Toronto was conducted to establish the levels of selected EDCs in sewage samples. Results indicated that BPA as well as NPEO and their metabolites were consistently detected in all effluent and sludge samples collected from the four sewage treatment plants located in metropolitan Toronto (Lee et al., unpublished results, 2000). The levels of these EDCs were always higher in the raw sewage samples collected from a treatment plant that had received a proportionally larger amount of industrial wastewater.

The latter was thus implicated in the elevated levels of these chemicals in municipal effluents. To better regulate the quality of wastewater, the City of Toronto has enacted a By-law (No. 457-2000) that sets the upper limits for certain chemicals in sanitary and combined sewage discharge. Among other stipulations, the limits given for NP and NPEO are 1 μg/L and 10 μg/L respectively (City of Toronto, 2000).

In an attempt to establish a database on the quality of industrial wastewater in Toronto with respect to the levels of NP and NPEO, a first-ever study on the occurrence of these EDCs in samples collected from 40 industrial facilities was initiated. The results were then sorted by the industrial classification of the facilities to determine if any trends could be observed for different industries. While BPA and OP were not included in the By-law, their occurrence in these samples was also documented in this survey.

## EXPERIMENTAL

### Materials

A calibrated mixture of nonylphenol ethoxylates (NPEO with 1 to 17 ethoxy units), in acetone, was a gift from C. Naylor of Huntsman Corp. (Austin, TX, USA). A calibration standard of NPEO, at 11.5 μg/mL, was prepared in isopropanol/hexane (2/98, v/v). NP, OP, 4-*n*-octylphenol (surrogate standard), BPA, BPA-$d_{16}$ (surrogate standard), triethylamine, and pentafluoropropionic acid anhydride (PFPA) were obtained from Aldrich (Milwaukee, MI, USA). Stock solutions of NP, OP, and BPA at 1, 10, 100, and

1000 µg/mL were prepared in acetone. Anhydrous sodium sulfate and silica gel were obtained from BDH and ICN, respectively. Sodium sulfate had been heated at 500°C for 16 h before use. A 5% deactivated silica gel for column cleanup was prepared by mixing 5 mL of water thoroughly with 95 g of the fully activated adsorbent.

Distilled-in-glass grade solvents were purchased from Caledon (Georgetown, ON, Canada). Solid phase extraction (SPE) cartridges (ENVI-18) and manifold were the products of Supelco.

Sampling

As stipulated in the City of Toronto By-law, every industrial facility connected to the municipal sewer system is required to maintain an access hole that allows sampling and flow measurements. Wastewater samples (2-4 L composites over a 24-h period), representative of the industrial activities at each facility, were collected using automated samplers during the weekdays in the period July 1999 - July 2000. After collection, a 1 L aliquot of the sample was placed in an amber bottle, kept at 4°C in the dark, and extracted the next day. Where a longer storage time was required, 10 mL of a 37% formalin solution was added to each sample.

Analytical Procedure

Wastewater samples were analyzed for the various EDCs by several previously published methods. After filtration (GF/C filter), NPEO in a 50-mL aliquot of a wastewater sample was pre-concentrated with a 3-mL (500 mg) ENVI-18 SPE cartridge. The methanol eluate, after a solvent exchange and volume adjustment, was analyzed for NPEO by high-performance liquid chromatography using a Hewlett-Packard 1100 HPLC equipped with a normal phase column (APS Hypersil $NH_2$) and a fluorescence detector operating at 230 nm (excitation) and 300 nm (emission) (Lee et al., 1997).

After a pH adjustment to 3 and the addition of 4-*n*-octylphenol and BPA-$d_{16}$ (surrogates), NP, OP, and BPA in a second 50-mL filtered sample were extracted similarly. When the extraction was complete, the cartridge was rinsed with 5 mL of 1:4 (v/v) acetone /water mixture to remove polar coextractives. The elution was followed by 3 mL of acetone and 3 mL of methanol. The combined extract was concentrated and then reacted with PFPA to form the pentafluoropropionyl (PFP) derivatives, which were then analyzed by GC/MS in an SIM mode using a Hewlett-Packard 5890 Series II gas chromatograph equipped with a Model 7673 autosampler, a Model 5972 Mass Selective Detector, and a 30 m x 0.25 mm i.d. x 0.25 μ HP-5-MS column (Lee and Peart, 2000a). The ions being monitored were m/z 253, 267, 281, 295, 309, 352, 366 for the PFP derivatives of OP, NP, and 4-*n*-OP, as well as m/z 505, 516, 520, and 534 for the PFP derivatives of BPA and BPA-$d_{16}$.

## RESULTS

## Industrial Facilities

The 40 industrial facilities included in this survey are listed in Table 1. For the 26 facilities that had reported to the NPRI, information regarding their standard industrial classification, i.e. their two-digit SIC, and their NPRI ID numbers, was retrieved from the database. For the other facilities that had not reported to the NPRI, the classifications were assigned by us, to the best of our knowledge on their industrial activities. Facilities from the chemical and chemical products industries (SIC 37), commercial laundries or personal and household industries (SIC 97), textile products industries (SIC 19), clothing industries (SIC 24), fabricated metal products industries (SIC 30), paper and allied products industries (SIC 27), plastic products industries (SIC 16), and several other industries were included. With the exception of Valspar Inc. which had reported on-site releases of BPA, none of the other 39 facilities included in this study had reported to the NPRI releases of NPEO, NP, or BPA in 1999.

The following is a summary of the EDC results sorted by industry class for the 97 wastewater samples.

## Chemical and Chemical Products Industries (SIC 37)

Results of OP, NP, NPEO, and BPA in the 37 samples collected from 12 facilities in this industry class are tabulated in Table 2. Extremely wide concentration ranges were

observed for all these chemicals in these samples. For instance, NP and NPEO were detected in all samples, with concentration ranges from 0.51 to 253 (median 6.49) μg/L for NP and from 3 to 117,520 (median 767) μg/L for NPEO. In contrast, OP was detected in all but two samples, with concentrations ranging from 0.02 to 195 (median 0.72) μg/L. BPA was detected in 34 out of the 37 samples, with levels ranging from 0.08 to 91.3 (median 1.50) μg/L. For some facilities, widely fluctuating concentrations of OP, NP, and NPEO were observed in samples collected on different days. These results imply that NPEO and NP were used in large quantities in the manufacturing and/or packaging processes by only some facilities in the chemical and chemical products industries and their releases into the sewer system were time-dependent as well. Significant levels of OP were observed in samples from only three facilities, and BPA from only two, in this industry class.

**Commercial Laundries -- Personal and Household Service Industries (SIC 97)**

A total of 17 samples were collected from six commercial laundries. In general, the levels of OP in these samples were low, with a range from 0.06 to 1.53 μg/L (Table 3). However, the concentrations of NP and NPEO in wastewaters collected from facilities in this industry class were consistently high, with ranges from 3.38 to 80.4 (median 21.69) μg/L for NP, and from 1610 to 108,937 (median 11736) μg/L for NPEO. The results suggest that detergents based on nonylphenol ethoxylates were extensively used by this industry. For unknown reasons, the levels of BPA in the samples of this industry class

were surprisingly high too, with a median concentration of 6.56 μg/L and five of the concentrations well over 10 μg/L.

**Textile Products (SIC 19) and Clothing Industries (SIC 24)**

Wastewaters from the textile products and clothing industries had NP/NPEO profiles similar to those from the commercial laundries, except that the levels were lower. In the 10 samples collected, the concentrations ranged from 1.39 to 41.1 (median 5.93) μg/L for NP and from 155 to 43626 (median 5137) μg/L for NPEO (Table 4). These numbers again suggest that NPEO based detergents were also widely used by these industries in the washing processes. Levels of OP were low, with concentration ranging from 0.08 to 0.47 (median 0.11) μg/L. In contrast to wastewaters from the commercial laundries, very low levels of BPA (<0.5 μg/L) were observed in these samples.

**Metal Finishing Industries (SIC 30)**

Concentrations of the EDCs in the 11 samples collected from eight facilities in the fabricated metal industries are shown in Table 5. With the exception of two samples coming from the same facility, the levels of NP and NPEO were in general moderate to low, as suggested by their medians of 1.10 and 869 μg/L, respectively. As in samples collected from other industries, the concentrations of OP and BPA in the 11 samples were mostly low.

**Paper and Allied Products Industries (SIC 27)**

With one or two exceptions, the levels of OP, NP, and NPEO in the samples from the four facilities in the paper and packaging industries were very low (Table 6). This observation was borne out by the relatively low median concentrations of 0.28, 2.63, and 148 μg/L for OP, NP, NPEO, respectively. In contrast, a wide range of BPA concentrations, ranging from <0.01 (undetected) to 149 μg/L, were observed for the 8 samples. Large fluctuations in BPA levels were also observed for samples collected from the same facility on different days.

**Plastic Products Industries (SIC 16)**

A total of 9 samples were collected from 3 facilities in the plastic products industries. The levels for the four chemicals, including BPA, were also very low in these samples (Table 7). The concentration ranges observed for these samples were from <0.01 to 0.18 (median 0.04) μg/L for OP, from <0.1 to 7.90 (median 0.54) μg/L for NP, from 16 to 241 (median 30) μg/L for NPEO, and from 0.05 to 2.12 (median 0.63) μg/L for BPA.

**Miscellaneous – Food, beverages, refined petroleum and coal products industries (SIC 10, 11, and 36)**

Only one facility from each of these industry classes was included in this survey and five samples were collected. Insignificant levels of NPEO, NP, OP, and BPA were observed in all samples in this group also (Table 8).

## DISCUSSION

Table 9 tabulates the median concentrations, by industrial class, of OP, NP, NPEO, and BPA in wastewater samples. Also given in the same table are the overall medians for these EDCs in all 97 samples. They were 0.22, 5.55, 1056, and 1.38 μg/L for OP, NP, NPEO, and BPA, respectively. Out of all wastewater samples tested in this study, only 3 samples were below 10 μg/L in NPEO and 18 were below 1 μg/L in NP. In other words, over 82% of the samples would have failed to meet either one or both of the limits as required by the City of Toronto By-law No. 457-2000.

Wastewater samples coming from the commercial laundries, as a class, were the most contaminated with respect to nonylphenol and its ethoxylates. The median levels of NPEO and NP in those samples, at 11,736 and 21.7 μg/L respectively, were not only the highest among all industrial groups but were also four to 10 times higher than the overall medians. These samples were followed by those from the textile and clothing industries, which had the second and the third highest median concentrations for NPEO and NP at 5,137 and 5.93 μg/L, respectively. This observation suggests that detergents based on nonylphenol ethoxylates were extensively used in the cleaning and washing processes by the commercial laundries as well as the textile products and clothing industries. Certain

facilities in the chemical and chemical products industries and metal finishers were also the sources of significant releases of NPEO and NP, although their levels could be quite varying with time. It seems that, collectively, these five industry sectors are the major contributors of the NP and NPEO input to the sewage system in Toronto.

As demonstrated by their overall median concentrations noted above, OP generally occurred at much lower levels in wastewaters than NP. However, in this study, three facilities in the chemical and chemical products industries and perhaps one in the paper and packaging industries have been identified as possibly the major point sources of OP in the Toronto area.

Of the two facilities in the chemical and chemical products industries that showed elevated levels of BPA in the samples, only one reported on-site releases of this chemical in 1999. In addition, significant BPA contamination was also observed in the samples collected from three commercial laundries and two facilities in the paper and packaging industries in this area. The relatively low BPA concentrations observed for the wastewater samples from the plastic products industries in the Toronto area suggested that this chemical was not heavily involved in their manufacturing processes.

Our data suggested that industrial facilities routinely discharge various amounts of NPEO, NP, OP, and BPA into the sewage system in the Toronto area. We have also identified some major industrial point sources of such pollutants in this area. It is noteworthy that none of the facilities with significant on-site releases of NPEO or NP

have reported to the NPRI. Until these industries take drastic measures to reduce releases of NPEO and NP voluntarily, it is unlikely that they can be in full compliance with the Toronto By-law in regard to wastewater quality. Based on the results of this study, the City of Toronto can set priorities for future action on the releases of OP and BPA.

## ACKNOWLEDGEMENTS

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Table 1. List of industrial facilities in the Toronto area included in this study.

| Facility name | Industrial classification | SIC* | NAICS** | NPRI ID*** |
|---|---|---|---|---|
| | | | | |
| 1265104 Ontario Inc. | Textile Products Industries | 19 | 2269 | NA |
| A.G. Simpson Co. Ltd. | Fabricated Metal Products Industries | 30 | 3011, 3465 | 2640 |
| Acadian Platers Co. Ltd. | Fabricated Metal Products Industries | 30 | 3471 | 2541 |
| Atlantic Packaging Products Ltd. | Paper and Allied Products Industries | 27 | 2631, 2676 | 5688 |
| BASF Canada Ltd. | Chemical and Chemical Products Ind. | 37 | 5065 | 0034 |
| Cadet Cleaners Ltd. | Personal and Household Service Ind. | 97 | 7218 | NA |
| Campbell Soup Co. Ltd. | Food Industries | 10 | 2032 | NA |
| Canadian Linen Supply Co. Ltd. | Personal and Household Service Ind. | 97 | 7213 | 4476 |
| CCL Custom Manufacturing | Chemical and Chemical Products Ind. | 37 | 2842, 2841 | 0181 |
| Centennial Hospital Linen Services | Personal and Household Service Ind. | 97 | 7213 | NA |
| Crown Cork & Seal Canada Inc. | Fabricated Metal Products Industries | 30 | 3411 | 0538 |
| Dominion Colour Corporation | Chemical and Chemical Products Ind. | 37 | 2865 | 1497 |
| Dovercourt Electroplating Co. Ltd. | Fabricated Metal Products Industries | 30 | 3471 | 2602 |
| Foamex Canada Inc. | Plastic Products Industries | 16 | 1611 | 2422 |
| Gibson Textile Dyers Ltd. | Textile Products Industries | 19 | 2261, 2262 | NA |
| Halltech Inc. | Chemical and Chemical Products Ind. | 37 | 3792, 3731 | 0374 |
| Henkel Canada Ltd. | Chemical and Chemical Products Ind. | 37 | 2899, 2841, 2869 | 0384 |
| Image Pac Merchandising | Paper and Allied Products Industries | 27 | 2653 | NA |
| IPEX | Plastic Products Industries | 16 | 3089 | 4712 |
| Lever Brothers Ltd. | Chemical and Chemical Products Ind. | 37 | 2844, 2841, 2842 | 3658 |
| M & M Plating Inc. | Fabricated Metal Products Industries | 30 | 3471 | 4639 |
| McGregor Hosiery Mills Co. | Clothing Industries | 24 | 2252 | NA |
| Mirolin Industries Inc. | Plastic Products Industries | 16 | 3088 | 3573 |
| Molson Breweries | Beverages Industries | 11 | 2082 | 3245 |
| Paperboard Industries Corp. | Paper and Allied Products Industries | 27 | 2675 | 1870 |
| Phantom Industries Inc. | Clothing Industries | 24 | 2251 | NA |

| | | | | |
|---|---|---|---|---|
| Reichhold Ltd. | Chemical and Chemical Products Ind. | 37 | 2821, 2851 | 2022 |
| Rohm and Haas Canada Inc. | Chemical and Chemical Products Ind. | 37 | 3731 | 2065 |
| Schenectady Canada Ltd. | Chemical and Chemical Products Ind. | 37 | 3731, 3751, 3792 | 4175 |
| Shield Plating Inc. | Fabricated Metal Products Industries | 30 | 3471 | NA |
| Sunchemical Ltd. | Chemical and Chemical Products Ind. | 37 | 2851 | NA |
| Top Coat Metal Finishers Inc. | Fabricated Metal Products Industries | 30 | 3471 | NA |
| Topper Linen Supply Ltd. Plant | Personal and Household Service Ind. | 97 | 7218 | NA |
| Torcad Ltd. | Fabricated Metal Products Industries | 30 | 3471 | 2281 |
| Total Uniform Services | Personal and Household Service Ind. | 97 | 7213 | NA |
| Valspar Inc. | Chemical and Chemical Products Ind. | 37 | 3751, 2851 | 2331 |
| Winpak Technologies Inc. | Paper and Allied Products Industries | 27 | 2671 | 2878 |
| Witco Canada Inc. | Refined Petroleum & Coal Products Ind. | 36 | 3712 | 3553 |
| Wood Wyant Inc. | Chemical and Chemical Products Ind. | 37 | 3711 | 4433 |
| Work Wear Corp. of Canada Ltd. | Personal and Household Service Ind. | 97 | 7218 | NA |

* Two-digit Canadian Standard Industrial Classification
** Four-digit North American Industry Classification System
*** National Pollutant Release Inventory identification number

Table 2. Levels of EDCs (µg/L) in wastewater samples collected from the chemical and chemical products industries (SIC 37)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| A-1 | Oct 7/99 | 0.40 | 98.38 | 32033 | 5.32 |
| A-2 | Jan 19/00 | 0.09 | 20.09 | 41714 | 2.23 |
| B-1 | Sep 29/99 | 1.19 | 2.88 | 93 | 1.38 |
| B-2 | Jan 10/00 | 19.30 | 253.31 | 111 | 2.93 |
| B-3 | Jun 30/00 | 103.40 | 41.86 | 1252 | 2.86 |
| C-1 | Oct 6/99 | 0.16 | 2.38 | 937 | 0.13 |
| C-2 | Jan 10/00 | <0.01 | 38.98 | 117520 | <0.01 |
| D-1 | Oct 5/99 | 0.13 | 0.66 | 41 | 1.68 |
| D-2 | Jan 11/00 | <0.01 | 2.39 | 3 | 1.45 |
| E-1 | Jul 6/99 | 0.02 | 0.93 | NA* | 0.08 |
| E-2 | Jul 13/99 | 1.82 | 34.12 | 1542 | 1.29 |
| E-3 | Jul 20/99 | 0.16 | 5.87 | 722 | 1.09 |
| E-4 | Sep 30/99 | 1.00 | 9.10 | 8733 | 0.15 |
| E-5 | Sep 29/99 | 1.22 | 7.91 | 6393 | 5.38 |
| E-6 | Oct 1/99 | 0.22 | 2.89 | 1101 | 0.12 |
| E-7 | Jan 17/00 | 0.25 | 3.31 | 1178 | 0.33 |
| F-1 | Jan 24/00 | 0.02 | 0.62 | 49 | 2.97 |
| G-1 | Sep 28/99 | 0.09 | 9.92 | 916 | 0.17 |
| G-2 | Sep 29/99 | 0.17 | 30.42 | 767 | 0.27 |
| H-1 | Sep 28/99 | 11.80 | 16.11 | 1580 | 1.56 |
| H-2 | Jan 13/00 | 147.66 | 148.38 | 917 | 0.10 |
| H-3 | Jul 4/00 | 11.74 | 6.49 | 1136 | 0.31 |
| I-1 | Jul 6/99 | 21.50 | 20.80 | NA | 0.08 |
| I-2 | Jul 14/99 | 195.10 | 52.96 | 614 | 0.57 |
| I-3 | Sep 29/99 | 44.18 | 20.68 | 647 | 0.52 |
| I-4 | Jan 10/00 | 6.11 | 10.42 | 1052 | <0.01 |
| I-5 | Jul 19/00 | 16.04 | 8.44 | 2701 | <0.01 |
| J-1 | Jul 6/99 | 0.72 | 2.15 | NA | 3.71 |
| J-2 | Jul 14/99 | 0.43 | 3.27 | 34 | 10.92 |
| J-3 | Sep 22/99 | 0.43 | 1.45 | 14 | 11.64 |
| J-4 | Jan 10/00 | 2.08 | 5.15 | 114 | 91.27 |
| K-1 | Feb 10/00 | 0.08 | 0.51 | 229 | 0.12 |
| L-1 | Jul 6/99 | 0.72 | 2.63 | NA | 4.60 |
| L-2 | Jul 14/99 | 0.64 | 4.98 | 44 | 23.36 |
| L-3 | Sep 30/99 | 0.67 | 5.61 | 51 | 39.09 |
| L-4 | Oct 1/99 | 0.86 | 2.05 | 572 | 84.53 |
| L-5 | Jan 10/00 | 1.00 | 8.78 | 112 | 74.71 |
| | | | | | |
| | No. of results | 37 | 37 | 33 | 37 |
| | Minimum | <0.01 | 0.51 | 3 | 0.08 |
| | Maximum | 195.10 | 253.31 | 117520 | 91.27 |
| | Median | 0.72 | 6.49 | 767 | 1.50 |

* NA = not analyzed

Table 3. Levels of EDCs (μg/L) in wastewater samples collected from commercial laundries (SIC 97)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| M-1 | Jul 6/99 | 0.49 | 8.55 | NA | 7.76 |
| M-2 | Jul 12/99 | 1.53 | 26.77 | 11119 | 43.45 |
| M-3 | Sep 28/99 | 0.40 | 3.38 | 5419 | 34.88 |
| M-4 | Jan 10/00 | 0.48 | 10.47 | 9017 | 28.96 |
| M-5 | Jan 11/00 | 0.50 | 15.24 | 8125 | 32.33 |
| N-1 | Sep 28/99 | 0.44 | 75.41 | 108937 | 6.56 |
| N-2 | Feb 21/00 | 0.40 | 64.46 | 32543 | 10.33 |
| O-1 | Jan 27/00 | 0.17 | 15.85 | 4031 | 2.58 |
| O-2 | Jul 21/00 | 0.19 | 18.61 | 58110 | 2.35 |
| O-3 | Jul 26/00 | 0.93 | 21.69 | 45804 | 3.00 |
| P-1 | Oct 6/99 | 0.22 | 39.10 | 2594 | 0.92 |
| P-2 | Oct 7/99 | 0.18 | 34.77 | 1610 | 0.80 |
| P-3 | Jan 11/00 | 0.09 | 18.86 | 12353 | 0.75 |
| Q-1 | Oct 5/99 | 0.06 | 10.62 | 27585 | 1.47 |
| Q-2 | Jul 19/00 | 0.50 | 59.20 | 34341 | 2.29 |
| R-1 | Oct 5/99 | 1.26 | 80.42 | 72355 | 31.37 |
| R-2 | Jan 18/00 | 0.41 | 41.20 | 3542 | 9.29 |
| | | | | | |
| | No. of results | 17 | 17 | 16 | 17 |
| | Minimum | 0.06 | 3.38 | 1610 | 0.75 |
| | Maximum | 1.53 | 80.42 | 108937 | 43.45 |
| | Median | 0.41 | 21.69 | 11736 | 6.56 |

Table 4. Levels of EDCs (µg/L) in wastewater samples collected from the textile products and clothing industries (SIC 19 and 24)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| S-1 | Sep 28/99 | 0.21 | 25.17 | 16644 | 0.11 |
| S-2 | Feb 16/00 | 0.09 | 6.36 | 4021 | 0.17 |
| T-1 | Sep 16/99 | 0.17 | 1.43 | 155 | 0.26 |
| T-2 | Jan 10/00 | 0.08 | 3.13 | 1059 | 0.45 |
| U-1 | Sep 28/99 | 0.40 | 41.10 | 43626 | 0.26 |
| U-2 | Sep 29/99 | 0.08 | 1.39 | 2390 | 0.13 |
| U-3 | Feb 8/00 | 0.47 | 9.42 | 3059 | 0.48 |
| V-1 | Sep 28/99 | 0.12 | 10.72 | 7117 | 0.13 |
| V-2 | Sep 29/99 | 0.10 | 3.81 | 6803 | 0.10 |
| V-3 | Jan 25/00 | 0.08 | 5.49 | 6253 | 0.31 |
| | | | | | |
| | No. of results | 10 | 10 | 10 | 10 |
| | Minimum | 0.08 | 1.39 | 155 | 0.10 |
| | Maximum | 0.47 | 41.10 | 43626 | 0.48 |
| | Median | 0.11 | 5.93 | 5137 | 0.21 |

Table 5. Levels of EDCs (μg/L) in wastewater samples collected from the fabricated metal products industries (SIC 30)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| W-1 | Jan 12/00 | 0.09 | 0.76 | 3772 | 0.39 |
| X-1 | Feb 8/00 | 4.54 | 2.48 | 1125 | 6.51 |
| Y-1 | Jan 11/00 | 0.09 | 0.80 | 1347 | 0.42 |
| Z-1 | Jan 18/00 | 0.13 | 1.50 | 869 | 3.80 |
| AA-1 | Oct 6/99 | 0.90 | 195.30 | 48649 | 1.10 |
| AA-2 | Jan 11/00 | 0.16 | 20.86 | 9920 | 0.98 |
| AB-1 | Jan 21/00 | 0.07 | 1.10 | 828 | 0.09 |
| AC-1 | Jan 18/00 | <0.01 | 1.46 | 130 | 1.89 |
| AD-1 | Sep 24/99 | <0.01 | 0.23 | 665 | <0.01 |
| AD-2 | Jan 18/00 | 0.04 | 1.08 | 224 | 0.10 |
| AD-3 | Jan 20/00 | 0.01 | 0.68 | 123 | 0.09 |
| | | | | | |
| | No. of results | 11 | 11 | 11 | 11 |
| | Minimum | 0.01 | 0.23 | 123 | <0.01 |
| | Maximum | 4.54 | 195.30 | 48649 | 6.51 |
| | Median | 0.09 | 1.10 | 869 | 0.70 |

Table 6. Levels of EDCs (µg/L) in wastewater samples collected from the paper and allied products industries (SIC 27)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| AE-1 | Oct 7/99 | 0.36 | 1.42 | 19 | 149.23 |
| AE-2 | Jul 5/00 | 0.16 | 0.97 | 201 | 0.34 |
| AF-1 | July 20/00 | 39.05 | 10.38 | 79 | <0.01 |
| AG-1 | Sep 28/99 | 0.12 | 2.63 | 341 | 28.20 |
| AG-2 | Jan 17/00 | 0.09 | 1.56 | 45 | 89.43 |
| AG-3 | Jul 6/00 | 0.19 | 6.70 | 96 | 8.72 |
| AH-1 | Oct 6/99 | 2.45 | 11.07 | 4015 | 2.97 |
| AH-2 | Jan 18/00 | 0.36 | 2.62 | 1302 | 0.49 |
| | | | | | |
| | No. of results | 8 | 8 | 8 | 8 |
| | Minimum | 0.09 | 0.97 | 19 | <0.01 |
| | Maximum | 39.05 | 11.07 | 4015 | 149.23 |
| | Median | 0.28 | 2.63 | 148 | 8.72 |

Table 7. Levels of EDCs (μg/L) in wastewater samples collected from the plastic products industries (SIC 16)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| AI-1 | Sep 29/99 | <0.01 | 7.90 | 112 | 2.12 |
| AI-2 | Feb 8/00 | 0.06 | 0.59 | 241 | 0.15 |
| AJ-1 | Jul 3/99 | 0.04 | 0.35 | NA | 0.05 |
| AJ-2 | Sep 28/99 | <0.01 | <0.1 | 16 | 0.23 |
| AJ-3 | Sep 29/99 | 0.06 | 0.54 | 72 | 1.89 |
| AJ-4 | Feb 9/00 | 0.18 | 0.54 | 21 | 0.15 |
| AK-1 | Jul 13/99 | 0.01 | 0.20 | NA | 0.63 |
| AK-2 | Sep 23/99 | 0.15 | 0.44 | 20 | 1.74 |
| AK-3 | Jan 17/00 | <0.01 | 0.75 | 30 | 1.03 |
| | | | | | |
| No. of results | | 9 | 9 | 7 | 9 |
| Minimum | | <0.01 | <0.1 | 16 | 0.05 |
| Maximum | | 0.18 | 7.90 | 241 | 2.12 |
| Median | | 0.04 | 0.54 | 30 | 0.63 |

Table 8. Levels of EDCs (µg/L) in wastewater samples collected from miscellaneous industries (SIC 10, 11, and 36)

| Sample | Sampling date | OP | NP | NPEO | BPA |
|---|---|---|---|---|---|
| | | | | | |
| AL-1 | Jan 24/00 | 0.02 | 1.02 | 49 | 1.61 |
| AM-1 | Sep 28/99 | 0.05 | 1.50 | 23 | 0.67 |
| AM-2 | Jan 10/00 | 0.10 | 1.47 | 40 | 0.67 |
| AN-1 | Jul 19/99 | 0.09 | 0.21 | <2 | 1.70 |
| AN-2 | Jan 17/00 | <0.01 | 1.84 | <2 | 0.20 |
| | | | | | |
| | No. of results | 5 | 5 | 5 | 5 |
| | Minimum | <0.01 | 0.21 | <2 | 0.20 |
| | Maximum | 0.10 | 1.84 | 49 | 1.70 |
| | Median | 0.05 | 1.47 | 23 | 0.67 |

Table 9. Median EDC levels (μg/L) in wastewater by industry class.

| Industrial classification | OP | NP | NPEO | BPA |
|---|---|---|---|---|
| | | | | |
| Chemical/chemical products | 0.72 | 6.49 | 767 | 1.50 |
| Commercial laundries | 0.41 | 21.69 | 11736 | 6.56 |
| Textile products/clothing | 0.11 | 5.93 | 5137 | 0.21 |
| Fabricated metal products | 0.09 | 1.10 | 869 | 0.70 |
| Paper/allied products | 0.28 | 2.63 | 148 | 8.72 |
| Plastic products | 0.04 | 0.54 | 30 | 0.63 |
| Miscellaneous | 0.05 | 1.47 | 23 | 0.67 |
| All industries | 0.22 | 5.55 | 1056 | 1.38 |

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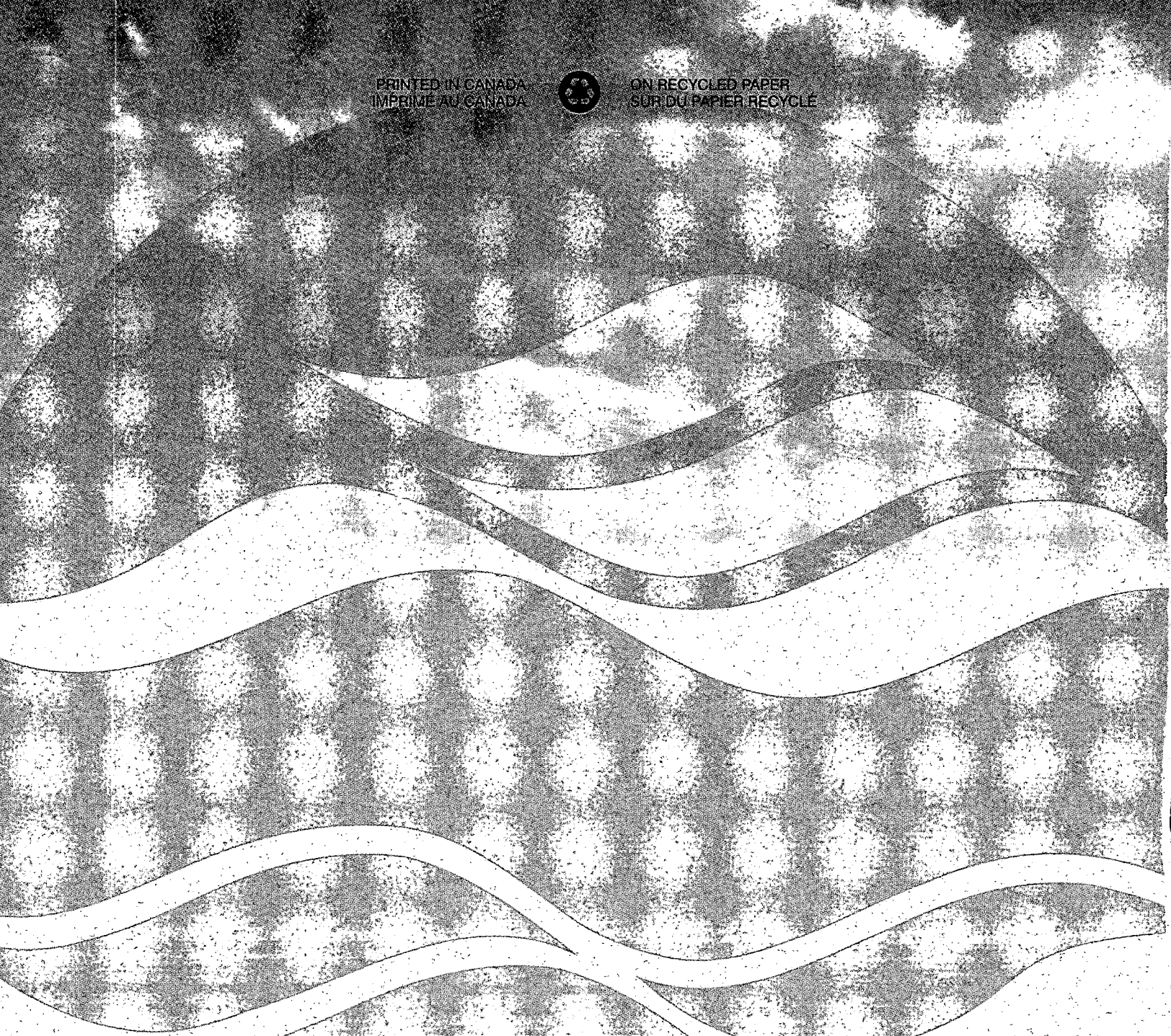

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