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Canadian Environmental Protection Act, 1999

PRIORITY SUBSTANCES LIST ASSESSMENT REPORT

Textile Mill Effluents

Canada

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Environment Canada
Health Canada

March 2001

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List of Acronyms and Abbreviations

AF	application factor
BOD	biological oxygen demand
CEPA	*Canadian Environmental Protection Act*
CEPA 1999	*Canadian Environmental Protection Act, 1999*
COD	chemical oxygen demand
CTV	Critical Toxicity Value
EC_{50}	median effective concentration
EEV	Estimated Exposure Value
EEV_{TEQ}	Estimated Toxic Exposure Value based on nonylphenol toxic equivalency quotients
ENEV	Estimated No-Effects Value
IC_{25}	inhibiting concentration estimated to cause a 25% effect
LC_{50}	median lethal concentration
LOEC	Lowest-Observed-Effect Concentration
MUC	Montreal Urban Community
MWWTP	municipal wastewater treatment plant
NOEC	No-Observed-Effect Concentration
NP	nonylphenol
NPE	nonylphenol ethoxylate or polyethoxylate (as a general class)
NPnEO	nonylphenol ethoxylate; where n = specific number of ethoxylate groups
PSL	Priority Substances List
SS	suspended solids
TEQ	toxic equivalency quotient
TL_{50}	time to 50% mortality (lethality)
TME	textile mill effluent
TU	toxic unit
YES	yeast estrogen screen

SYNOPSIS

Textile mill effluents (TMEs) are wastewater discharges from Canadian textile mills that are involved in wet processes such as scouring, neutralizing, desizing, mercerizing, carbonizing, fulling, bleaching, dyeing, printing and other wet finishing activities. They are not generated at facilities that conduct only dry processing (carding, spinning, weaving and knitting), laundering or manufacture of synthetic fibres through chemical processes. In the context of this report, TMEs do not include waste streams such as air emissions or solid waste.

As of 1999, there were 145 wet processing textile mills operating in Canada. Most wet processing mills were located in Quebec (58%), followed by Ontario (34%), Nova Scotia (3%), New Brunswick (2%), British Columbia (1%) and Prince Edward Island (1%). Most wet processing mills in Canada (96%) discharged to municipal wastewater collection systems, 99% of which had some form of wastewater treatment. The highest percentage of TMEs received secondary treatment (61%), followed by primary (28%), tertiary (9%) and none (1%). The dilution potential for TMEs varied principally according to the volume and flow of the receiving environment, and the total TMEs discharged ranged from 17% to 0.000 01% of the receiving environment.

TMEs contain a wide range of chemicals and are known to have a range of pH, temperature, colour and oxygen demand characteristics. The assessment did not attempt to determine the contribution of individual components of TMEs to toxicity or environmental effects and was based instead on the impacts of whole effluents.

However some effort was made to determine the environmental risk of nonylphenol and its ethoxylates in TMEs due to the availability of information produced by concurrent PSL2 Assessment for that substance.

In order to supplement the sparse database on the environmental effects of TMEs, a number of studies were undertaken in support of the assessment. The combined results of a battery of whole-effluent toxicity tests indicated a reduction in toxicity with increasing intensity of treatment of TMEs. The battery of tests used included rainbow trout (*Oncorhynchus mykiss*) acute lethal, *Daphnia magna* acute lethal, Microtox® (*Vibrio fischeri*) acute sublethal, Microtox® chronic sublethal, *Ceriodaphnia dubia* chronic (lethal and reproduction) and algal growth (*Selenastrum capricornutum*). All untreated TMEs had effects on all of the organisms tested. Primary-treated TMEs had slightly less toxicity than untreated effluents. Most of the secondary-treated effluents produced no effects on test organisms, with two exceptions, both of which discharged to municipal wastewater treatment systems. At one of those sites, where the treatment system was believed to be not operating optimally, aquatic toxicity was detected in all whole-effluent toxicity tests conducted. At the other site, significant inhibition of reproduction in *C. dubia* was detected; however, no aquatic toxicity was observed in the other three tests conducted. No tertiary-treated TMEs produced effects on test organisms.

There were limited data available on the aquatic toxicity of samples obtained from aquatic environments receiving TMEs. There were no data on the aquatic toxicity of environmental samples near untreated TME discharges, and only one site receiving primary-treated TMEs was studied. At that site, chronic toxicity (*C. dubia* survival and reproduction) was detected at 120 m below the outfall, and acute toxicity to the bacterium *V. fischeri* was detected 30 m from the outfall. No acute toxicity was measured in samples from environments receiving TMEs that were subject to secondary or tertiary treatment. At a single site receiving untreated TME, an *in situ* bioassay was conducted using caged clams (*Anodonta implicata*), and significant mortality occurred up to

120 m downstream of the outfall. Pore water from sediments taken from locations up to 80 m from an outfall discharging primary-treated TME inhibited fertilization in the white sea urchin (*Lytechninus pictus*). Toxicity was not detected using a variety of other sediment toxicity tests at sites receiving secondary-treated TMEs.

Studies measuring impacts on benthic invertebrate communities in aquatic environments receiving TMEs were conducted at single locations for each of untreated, secondary-treated and tertiary-treated effluents. Changes in community structure were detected 120 m below the outfall at the untreated site; however, no impacts were detected at the sites where secondary or tertiary treatment was provided by a municipal wastewater treatment system.

Estimated Toxic Exposure Values based on nonylphenol toxic equivalency quotients (EEV_{TEQ}) for nonylphenol (NP) and nonylphenol ethoxylates (NPEs) in untreated TMEs exceeded the chronic toxicity threshold for invertebrates in 90% of samples and the chronic toxicity threshold for fish in 86% of samples. Eighty-three percent of untreated samples had NP and NPE EEV_{TEQ}s falling within the range of acute toxicity to fish, invertebrates and algae. All five primary-treated TME samples had NP and NPE EEV_{TEQ}s falling within the range of acute toxicity to fish and invertebrates and exceeding chronic toxicity benchmarks for those organisms.

Based on the available data, it is concluded that textile mill effluents are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Thus, it is concluded that textile mill effluents should be considered "toxic" as defined in Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999) and that evaluation of options under CEPA 1999 to reduce exposure should be considered a priority at this time.

It is recommended that options to reduce environmental risk be examined on a site-specific basis. In addition, pollution prevention opportunities for the management of TMEs should be identified and evaluated, with particular attention to the use and release of NP and its ethoxylates. Given the fact that most textile mills in Canada have their wastewater treated at municipal wastewater treatment plants, it is recommended that discussions with the appropriate authorities (municipal and/or provincial) be undertaken to address the risks. This may require additional effects monitoring of TMEs and municipal effluents.

1.0 INTRODUCTION

The *Canadian Environmental Protection Act, 1999* (CEPA 1999) requires the federal Ministers of Environment and of Health to prepare and publish a Priority Substances List (PSL) that identifies substances, including chemicals, groups of chemicals, effluents and wastes, that may be harmful to the environment or constitute a danger to human health. The Act also requires both Ministers to assess those substances and determine whether they are "toxic" as defined in Section 64 of the Act, which states:

> ...a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that
>
> (a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity;
>
> (b) constitute or may constitute a danger to the environment on which life depends; or
>
> (c) constitute or may constitute a danger in Canada to human life or health.

Substances that are assessed as "toxic" as defined in Section 64 may be placed on Schedule I of the Act and considered for possible risk management measures, such as regulations, guidelines, pollution prevention plans or codes of practice to control any aspect of their life cycle, from the research and development stage through manufacture, use, storage, transport and ultimate disposal.

Based on an initial screening of readily accessible information, the rationale for assessing textile mill effluents (TMEs) provided by the Ministers' Expert Advisory Panel on the Second Priority Substances List (Ministers' Expert Advisory Panel, 1995) was as follows:

> Textile mill effluents are complex mixtures of chemicals, varying in composition over time and from mill to mill. They can include high concentrations of suspended solids and metals, extreme pH and elevated temperatures. Given the many mills across the country, exposure is widespread. Studies indicate that effluents have harmful effects on a wide variety of aquatic organisms. An assessment is needed to evaluate the widespread toxicity and biological impact of treated and untreated textile mill effluents on aquatic ecosystems. The assessment should include the examination of the fate and effects of dyes in aquatic environments downstream.

A description of the approaches to assessment of the effects of Priority Substances on the environment is available in a published companion document. The document, entitled "Environmental Assessments of Priority Substances under the *Canadian Environmental Protection Act*. Guidance Manual Version 1.0 — March 1997" (Environment Canada, 1997), provides guidance for conducting environmental assessments of Priority Substances in Canada. This document may be purchased from:

> Environmental Protection Publications
> Environmental Technology Advancement Directorate
> Environment Canada
> Ottawa, Ontario
> K1A 0H3

It is also available on the Internet at www.ec.gc.ca/cceb1/ese/eng/esehome.htm under the heading "Guidance Manual." It should be noted that the approach outlined therein has evolved to incorporate recent developments in risk assessment methodology, which will be addressed in future releases of the guidance manual for environmental assessments of Priority Substances.

The focus of the assessment was a determination of whether TMEs could be "toxic" under Paragraph 64(a) of CEPA 1999. The basis for inclusion of "Textile Mill Effluents" by the Ministers' Expert Advisory Panel on the Second Priority Substances List was limited to environmental effects (namely on aquatic ecosystems). Given their rationale (Ministers' Expert Advisory Panel, 1995), the focus of the assessment of TMEs was on liquid effluents discharged into aquatic systems and did not include other waste streams, such as air emissions or solid waste. Moreover, the general human population is unlikely to be directly exposed to TMEs. Based on information identified, it was determined that consideration of the effects of TMEs on the environment upon which life depends was not relevant to the assessment of TMEs. Therefore, detailed consideration of whether TMEs are "toxic" as defined under Paragraphs 64(b) and 64(c) of CEPA 1999 was not included in this assessment.

There were a number of textile-related industries that may have had some liquid discharges but were excluded from the assessment. Those included:

- dry processing mills that conduct only processes such as spinning, weaving and knitting that do not consume water and whose discharges are limited to domestic wastewater and equipment washing water (U.S. EPA, 1978; Chen, 1989);
- laundering facilities that are not involved in the production of textiles; however, some of the chemicals used during textile manufacturing may be released during the laundering process, along with detergents or other cleaning products (SNCI, 1997); and
- facilities involved with the manufacture of synthetic fibres through chemical processes that were determined through the characterization portion of the assessment not to have wet processing activities (Chen, 1989).

Due to the wide range of chemical and physical characteristics of TMEs that were suspected to vary from mill to mill as well as on a temporal basis at individual mills, a whole-effluent approach was taken for the assessment. Given the rationale of the Ministers' Expert Advisory Panel, a review of the effects of dyes released during textile processing was also conducted. Since it was also known that TMEs have various degrees of treatment prior to discharge, mills were evaluated by level of treatment to determine the effectiveness of those treatment types.

Two surveys of the Canadian textile industry were carried out to collect information for the TME assessment. A voluntary survey in association with the Canadian Textiles Institute was conducted in 1997 and was followed by a mandatory survey conducted in 1999 under the authority of Section 16 of the *Canadian Environmental Protection Act* (CEPA).

The search strategies employed in the identification of data relevant to the assessment of potential effects on the environment are presented in Appendix A. In summary, on-line databases were searched for relevant world literature and scientific and trade journals were monitored for the duration of the assessment. In addition, information on the effects of TMEs was solicited from the municipalities where textile mills were known to be located as well as from provincial environment departments. All original studies that form the basis for determining whether TMEs are "toxic" under CEPA 1999 have been critically evaluated by staff of Environment Canada.

An Environmental Resource Group was established by Environment Canada to assist in the preparation and review of the environmental sections of the Assessment Report and supporting documentation (Environment Canada, 2000). Members were selected based on their expertise, notably in the areas of toxicology, environmental effects and risk assessment, as well as their knowledge of the textile industry. Members included:

W. Belschner, Canadian Textiles Institute
R. Breton, Environment Canada
K. Doe, Environment Canada
E. Fédida, Environment Canada
J. Fraser, Water Technology International Corporation
C. Garron, Environment Canada
T. Helmes, Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers

K. Kennedy, Environment Canada
T. Leah, Environment Canada
J. Maguire, Environment Canada
D. Minns, National Research Council of Canada
D. Moore, The Cadmus Group
H. Motschi, Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers
L. Rutherford, Environment Canada
A. Schnell, Conor Pacific
J.-P. Thomé, *Université de Liège*
M. Weltrowski, Textile Technology Centre

The assessment was led by W.R. Ernst of Environment Canada.

Peer review of the report was provided by E. Barry (Canadian Textiles Institute), D. Bennie (National Water Research Institute), S. Courtenay (Fisheries and Oceans Canada) and K. Solomon (Centre for Toxicology/University of Guelph).

The Assessment Report was reviewed and approved by the Environment Canada/Health Canada CEPA Management Committee.

A draft of the Assessment Report was made available for a 60-day public comment period (July 1 to August 30, 2000) (Environment Canada and Health Canada, 2000b). Following consideration of comments received, the Assessment Report was revised as appropriate. A summary of the comments and responses is available on the Internet at:

www.ec.gc.ca/cceb1/eng/final/index_e.html

The text of the Assessment Report has been structured to address environmental effects relevant to determination of "toxic" under Paragraph 64(a) of CEPA 1999.

Copies of this Assessment Report are available upon request from:

Inquiry Centre
Environment Canada
Main Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 0H3

or on the Internet at:

www.ec.gc.ca/cceb1/eng/final/index_e.html

Unpublished supporting documentation (Environment Canada, 2000); which presents additional information, is available upon request from:

Commercial Chemicals Evaluation Branch
Environment Canada
14th Floor, Place Vincent Massey
351 St. Joseph Blvd.
Hull, Quebec
K1A 0H3

2.0 SUMMARY OF INFORMATION CRITICAL TO ASSESSMENT OF "TOXIC" UNDER CEPA 1999

2.1 Identity and physical/chemical properties

2.1.1 Identity

A TME is defined in this assessment as a wastewater discharge that results from wet processing activities. Wet processing activities have traditionally been defined as those including any of the following: scouring, neutralizing, desizing, mercerizing, carbonizing, fulling, bleaching, dyeing, printing or finishing (Chen, 1989). Crechem Technologies Inc. (1998) and Environment Canada (2000) provide descriptions of each of those processes. An untreated TME is the combined raw process wastewater from a facility. A primary-, secondary- or tertiary-treated TME receives wastewater treatment on-site or at a municipal wastewater treatment plant (MWWTP). Definitions of each type of treatment, with some examples, are provided in Appendix B.

Textile mills have traditionally been categorized according to manufacturing operations (IEC Ltd., 1982; Chen, 1989). In order to ensure that the categories used in the assessment reflected the industry in Canada today, an evaluation of the Canadian textile industry was commissioned. In that evaluation, six major categories of wet processing mills were identified, based on mill operations and finished textile products. Those categories were knit fabric finishing mills, woven fabric finishing mills, wool finishing mills, carpet finishing mills, stock/yarn finishing mills and non-woven fabric finishing mills. Those mill types are described in supporting documentation (Crechem Technologies Inc., 1998; Environment Canada, 2000).

2.1.2 Chemicals present in TMEs

Textile mills use a wide variety of chemicals to conduct wet processing operations. Those chemicals include acids, bases, salts, wetting agents, retardants, accelerators, detergents, oxidizing agents, reducing agents, developers, stripping agents and finishes (Chen, 1989; Crechem Technologies Inc., 1998). Many chemicals are not retained in the final product and are discarded in TMEs.

Based on Environment Canada surveys of the textile industry conducted in 1973–74, 1981–82, 1985–86 and 1998–99, organic pollutants expected to be found in untreated TMEs in Canada include substituted alkylphenolics (e.g., 4-nonylphenol [4-NP], nonylphenol ethoxylates [NPEs] and nonylphenol carboxylates), benzenes (e.g., toluene, ethylbenzene and chlorobenzenes), naphthalene, phenol, substituted phenols (e.g., chlorophenols, methylphenol and nitrophenol), chloroethylenes, chloroethanes and phthalates (Chen, 1989; Bennie, 1998; Rutherford, 1999). Organic pollutants identified in untreated TMEs from three mills in Atlantic Canada generally fell into one of five groups:

- detergents/surfactants (e.g., ethoxy- and phenoxyethanols, ethylhexanol, NP, ethoxylated acylphenoxyethanols);
- plasticizers (e.g., diethylphthalate, bis(ethylhexyl)phthalate);
- dye carriers (e.g., alkylated benzenes, mono-, di- and trimethylnaphthalenes, biphenyl and methylbiphenyls, benzoic acid, napthalenol);
- mineral oils (C_{10}–C_{32} n-alkanes); and
- miscellaneous chemicals (e.g., methylpyrolidinone, caprolactam) (Rutherford *et al.*, 1992).

Sampling conducted by Environment Canada in 1985–86 measured the following metals in effluent discharges from Canadian textile mills: arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc (Chen, 1989). Inorganic chemicals identified by 26 textile mills in response to the 1997 Environment Canada–Canadian Textiles Institute voluntary survey included those above as well as calcium, iron and manganese (Environment Canada, 1999a).

Data on concentrations of those organic and inorganic chemicals in TMEs are provided in the supporting documentation (Environment Canada, 2000).

Dyes are used extensively in the textile industry (U.S. EPA, 1997). A substantial quantity of the dye used in textile mills is not fixed to fabric in dye baths; the degree of fixation is largely dependent on the type of dye used. For commonly used dyes, typical unfixed levels are as follows: disperse, 1–12%; direct, 4–36%; reactive, 3–45%; vat, 5–30%; sulphur, 5–40%; acid, 2–15%; basic, 1–4%; and metal complex, 2–18% (European Commission, 1996). In addition to residual dyes, process waters also typically contain auxiliary chemicals such as salts, surfactants, spent solvents, acids and bases (U.S. EPA, 1997).

2.1.3 *Physical properties of TMEs*

Untreated TMEs are known to have extremes of pH (either alkaline or acidic, depending on the processes used) and temperature, high biological oxygen demand (BOD), high chemical oxygen demand (COD) and high concentrations of suspended solids (SS) (Porter *et al*., 1971; Thompson, 1974; Kothandaraman, 1976; U.S. EPA, 1978; IEC Ltd., 1982; Vaidya and Datye, 1982; Chen, 1989; Watson, 1991; Rao *et al*., 1992; Rutherford *et al*., 1992; Mohapatra *et al*., 1993; UNEP, 1993; Correia *et al*., 1994). TMEs are also characterized by high levels of colour caused by residual dyes that were not fixed to fibres in the dyeing process. Physical properties of untreated TMEs are described quantitatively in the supporting documentation (Environment Canada, 2000).

2.2 Entry characterization

The primary sources of information on the characterization of TME entry into the Canadian environment were the results of a voluntary industry survey conducted by Environment Canada and the Canadian Textiles Institute in 1997 and a mandatory CEPA Section 16 notice issued by Environment Canada in 1999. Results of both surveys were compiled into a single database (Environment Canada, 1999a). The rate of response to the voluntary survey was low (35%), but the mandatory notice, sent to all mills that did not respond to the voluntary questionnaire, increased the total response rate from wet processing textile mills to 100%. Gaps in information remain, however, due to the fact that all mills that responded to the voluntary survey did not provide all requested information. Where data gaps exist (e.g., discharge volume and mill type) available data were extrapolated to represent the total number of wet processing mills in Canada.

2.2.1 *Sources*

The presence of TMEs in the environment is solely a consequence of anthropogenic activity, and all TMEs are ultimately released to the environment either prior to or after wastewater treatment.

FIGURE 1 Wet processing mills in Canada, by mill type

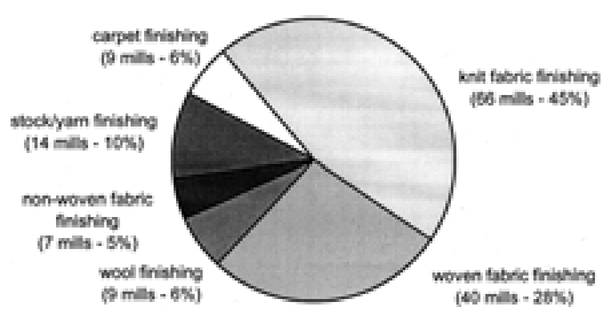


TABLE 1 Distribution of wet processing textile mills in Canada

Province	Number of mills	Percentage of total [1]
Quebec	84	58
Ontario	50	34
Nova Scotia	5	3
New Brunswick	3	2
British Columbia	2	1
Prince Edward Island	1	1

[1] Percentages do not add to 100 because of rounding.

In 1999, there were 145 wet processing textile mills operating in Canada. Figure 1 depicts the number of wet processing mills in Canada by mill type (Environment Canada, 1999a). Data on mill type were available only for 135 of the 145 existing wet processing mills, so the numbers provided in the figure are the result of extrapolation.

2.2.2 Releases of TMEs in Canada

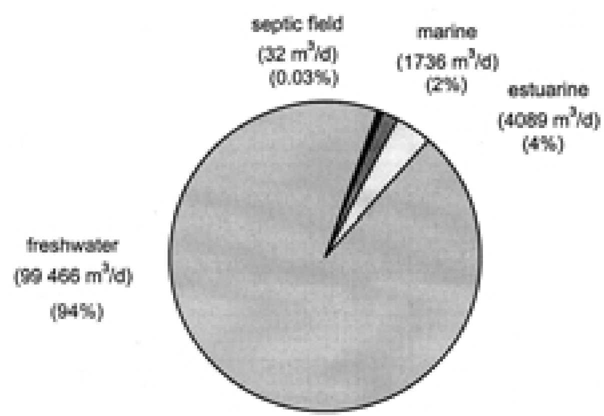
In 1996, approximately 105 000 m^3 of TMEs were discharged daily to the Canadian environment (Environment Canada, 1999a). As indicated in Figure 2, TMEs were discharged primarily to freshwater ecosystems (94% of discharges). Five mills discharged to estuarine environments, and three discharged to marine environments. There is one case of septic field disposal of TMEs in Canada.

Most wet processing mills were located in Quebec (58%) and Ontario (34%) (Table 1).

2.2.3 Treatment of TMEs in Canada

Only six mills (4%) relied completely on on-site treatment systems, and those were either primary (one mill) or secondary (five mills). The remaining 139 mills (96%) discharged to municipal wastewater collection systems, and 137 of those have some form of wastewater treatment. There were only two mills in Canada that were known to discharge untreated TMEs to the environment, both through municipal wastewater collection systems without wastewater treatment. The highest percentage of TMEs received secondary treatment (61%), followed by primary (28%), tertiary (9%) and none (1%).[1]

FIGURE 2 Distribution of TME releases to the environment

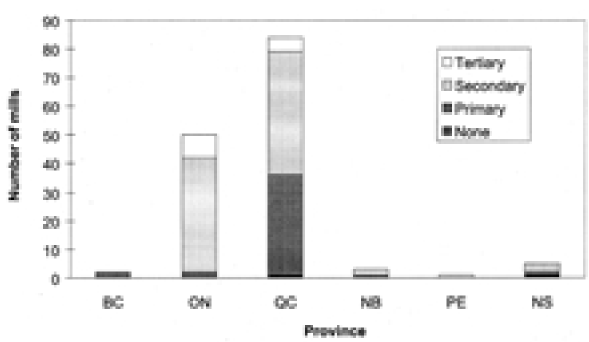


[1] Percentages do not add to 100 because of rounding.

Discharges of TMEs into the Canadian environment are for the most part continuous. That is due primarily to retention times in MWWTPs, which act to equalize the batch discharge practices of some textile mills. However, many textile mills that have batch wet processes also have some type of on-site flow equalization before discharge to MWWTPs. In the case of textile mills that do not conduct wet processing operations on weekends, particularly where there is no on-site equalization, biological treatment plants may not be able to perform at design performance levels at the beginning of each week until the bacterial population in the treatment system is re-established (Belschner, 2000).

Figure 3 presents the degree of treatment applied to TMEs in each province. The high number of mills with primary treatment in Quebec is largely due to the 33 mills in the city of Montréal that discharge to the Montreal Urban Community (MUC) primary MWWTP. The two mills with no wastewater treatment were Tricots Godin in Ste-Anne-de-la-Pérade, Quebec, and Nova Scotia Textiles in Windsor, Nova Scotia.

FIGURE 3 Degree of treatment applied to TMEs by province in 1996–1999



Of the total 105 000 m³ of TMEs released per day to the Canadian environment in 1996, 137 m³/day (0.1%) were discharged with no wastewater treatment, 31 600 m³/day (30%) with primary treatment, 62 800 m³/day (60%) with secondary treatment and 10 800 m³/day (10%) with tertiary treatment (Environment Canada, 1999a).

2.3 Exposure characterization

2.3.1 Environmental fate of TMEs

Little work has been done to quantify the degree of environmental partitioning of TMEs. Information on physical characteristics (i.e., pH, temperature, BOD, COD, SS concentrations and colour) in aquatic environments that receive TMEs in Canada is lacking. Colour has been observed in Canadian water bodies receiving untreated TMEs at distances several hundred metres downstream of outfalls (Chen, 1989; Rutherford *et al*., 1992).

2.3.2 Dyes in TMEs

Little is known of the environmental occurrence, persistence or fate of dyes used in textile wet processing due to difficulties in the determination of different classes of dyes at trace levels in environmental samples (Maguire and Tkacz, 1991). In the only published investigation of the occurrence of dyes in the Canadian environment, Maguire and Tkacz (1991) detected concentrations of three disperse dyes in water samples and of two disperse dyes in sediments downstream of TME discharges in the Yamaska River, Quebec, in 1985–86. In addition, a mutagenic degradation product of a disperse dye was detected in sediments 6 km downstream from Granby, Quebec, a town with a large concentration of textile mills. In 1987, following the installation of MWWTPs in the major cities and towns in the river basin, no disperse dyes were detected in water samples from that river. No disperse dyes were detected in over 100 samples of fish from the river.

2.3.3 Dilution of TMEs in Canada

The rate of dilution by receiving waters is largely controlled by the volume and flow rate of the receiving water body. Initial dilution is affected by a number of factors, including temperature or density differences between effluent and receiving environment, bathymetry and diffuser location (U.S. EPA, 1991).

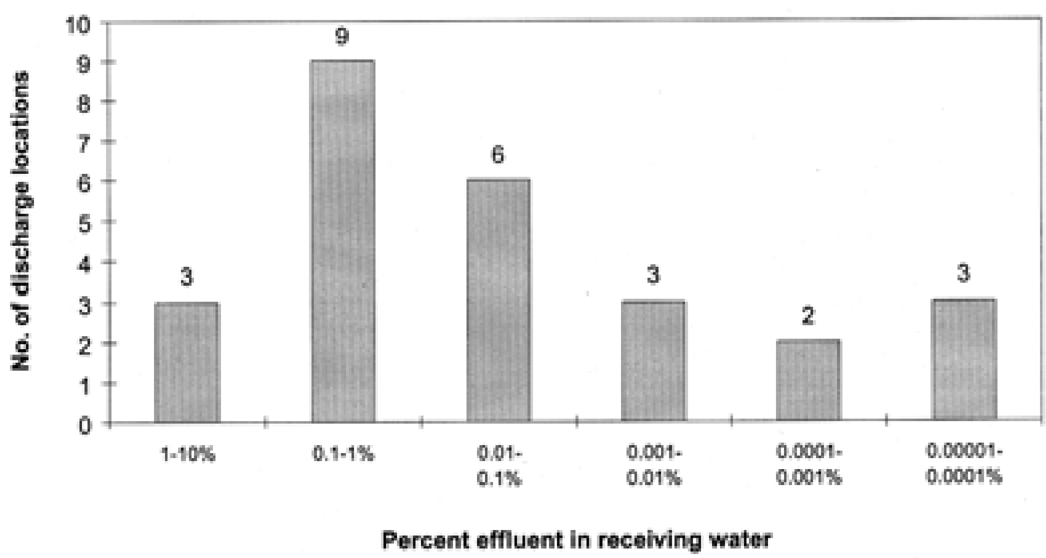
Since most TMEs in Canada are discharged to freshwater rivers, lowest mean monthly river flow rates were compared with TME discharge rates in the estimation of the dilution potential of various receiving environments. Discharges of TMEs, either directly or through MWWTPs, occurred to rivers that had lowest mean monthly flows ranging from 15 500 to 782 784 000 m^3/day.

Cumulative TME discharges (i.e., the combined flow of all mills discharged to the same point in a water body) were divided by river flow rates at discharge locations and multiplied by 100 to derive the percentage of effluent in the receiving water at full dilution (Figure 4). Only rivers were considered for this calculation, as other aquatic discharges were to marine environments or very large lakes (e.g., Lake Ontario). Those dilutions were calculated using the lowest mean monthly flow rates, over the last 5 years, of rivers receiving TMEs. Lowest mean monthly flow data were used rather than 7Q2 flow data (consecutive 7-day average low flow with an average recurrence interval of once in 2 years), which account for infrequent ultra-low flow rates that may occur during exceptionally dry periods, because the data set was more comprehensive for mean monthly flows and those values are more realistic. The most conservative dilution using 7Q2 flow data in Canada is 17% effluent in receiving water, or 83% dilution of TME for the Bourbon River, Quebec.

Although there are only 26 discharge points presented in Figure 4, those 26 points included discharges from 71 textile mills. For the remaining 74 mills in Canada, either the mills discharged to marine areas or large lakes or lowest mean monthly flow data were not available. Where TMEs were discharged through MWWTPs, only the TME volume was considered in the calculation, rather than the total volume discharged from the MWWTP. Some dilution would occur in the MWWTP before the TME reaches the receiving environment, but the use of TME volume only in dilution calculations is more conservative and therefore more appropriate for the assessment. Dilutions of TMEs within MWWTPs in Canada range from 67% to 99.9999%. Eighty-eight percent were diluted by more than 90% within the MWWTP.

In order to determine the zone of influence of TMEs in receiving environments, a number of site-specific as well as hypothetical dispersion calculations were made and are presented in Section 3.1.2.4.

FIGURE 4 Full dilution potential of cumulative TME discharges to rivers in Canada (Environment Canada, 1996, 1999a)



2.4 Effects characterization

The environmental effects of complex substances such as TMEs can be difficult to ascertain. Factors such as the partitioning and persistence of individual substances in the mixture, as well as additive and interactive effects and effects on organisms, make the environmental assessment of complex substances problematic. In order to characterize the environmental effects of whole-effluent TME discharges in Canada, the results of a number of types of studies that are preferred methods for characterizing complex substances in PSL assessments (Environment Canada, 1997) were used, including:

- laboratory toxicity tests using whole-effluent samples (i.e., acute and chronic whole-effluent aquatic toxicity, Ames testing, endocrine disruption assays);
- laboratory ambient toxicity tests (i.e., ambient aquatic toxicity, sediment toxicity, endocrine disruption assays); and
- field toxicity tests (i.e., benthic macroinvertebrate community surveys, *in situ* aquatic toxicity).

Most of these data were produced by studies that were conducted specifically to support the assessment. In addition, due to the availability of a comprehensive set of data on concentrations of NP and NPEs in TMEs, a comparison was made between calculated Estimated Toxic Exposure Values relative to nonylphenol (EEV_{TEQ}s) for NP and NPEs in untreated and primary-treated TMEs and known toxicity thresholds for those substances.

2.4.1 Whole-effluent aquatic toxicity

Whole-effluent toxicity measures the total toxic effect of an effluent directly with a toxicity test on a sample of effluent that has not been treated to separate the toxic components. Aquatic toxicity can be measured using effluent samples obtained at the point of discharge and by conducting either short-term (acute) or long-term (chronic) toxicity tests on those samples. Results of such aquatic toxicity testing are often expressed as volumetric concentrations. For example, a reported 96-hour LC_{50} for rainbow trout (*Oncorhynchus mykiss*) of 5% means that a test solution of 5% of the effluent being tested plus 95% dilution water was estimated to cause 50% of the test organisms (rainbow trout) to die after 96 hours of exposure. This method of reporting was used for this assessment.

The aquatic toxicity of untreated TMEs is generally assumed because of the wide range of chemicals known to be in such effluents, many of which are known to individually cause environmental harm (Thompson, 1974; U.S. EPA, 1978; Delée *et al*., 1998; Vandevivere *et al*., 1998), but surprisingly few published studies exist detailing results of acute and chronic aquatic toxicity testing of TMEs. In Canada, studies of the aquatic toxicity of TMEs are sparse, being primarily the results of a number of Environment Canada investigations (Chen, 1989; Rutherford *et al*., 1992, 1998; Costan *et al*., 1993; Rutherford, 1999).

Chen (1989) reported on the acute toxicity of seven individual TMEs, representing different mill types and processes, to rainbow trout (*O. mykiss*) and common guppy (*Lebistes reticulatus*). The reported 96-hour LC_{50}s, expressed as volumetric concentrations of untreated (screened) TMEs from the rainbow trout tests (conditions unstated), were 6.9 ± 1.0% and 8.8 ± 0.4% for two carpet mills and 14.0 ± 4.0% for a wool finishing mill. The reported 96-hour LC_{50}s for rainbow trout for secondary-treated TMEs were 80 ± 16% and 100% for two woven fabric finishing mills and 100% for a knit fabric finishing mill. Four of those mills were tested 4 years later using the common guppy bioassay, and the effluents were found to be much less toxic (96-hour LC_{50}s 70–100%). However, that reduction in toxicity could not be clearly related to improvements in wastewater treatment due to the possibility that rainbow trout and common guppy have different sensitivities to toxicants.

Rutherford *et al*. (1992) tested untreated TMEs from three textile mills in Atlantic Canada using a battery of toxicity tests. All samples tested were acutely lethal to rainbow trout (*O. mykiss*), with 96-hour LC_{50}s of 8.2–35% (n = 8) for two woven fabric finishing mills and 35–71% (n = 4) for a knit fabric finishing mill. Likewise, all samples were acutely lethal to the water flea (*Daphnia magna*), with 48-hour LC_{50}s of 6.8–46% (n = 16) for two woven fabric finishing mills and 8.8–35% (n = 8) for a knit fabric finishing mill. At a woven fabric finishing mill, all samples were acutely lethal to threespine stickleback (*Gasterosteus aculeatus*), with 96-hour LC_{50}s of <6.3–62% (n = 4). All samples but one exhibited acute toxicity to the marine bacterium, *Vibrio fischeri*, in the Microtox® test, with 15-minute EC_{50}s of 2.9–61% (n = 21). All samples had sublethal effects, which included reproductive impairment in the cladoceran, *Ceriodaphnia dubia* (7-day IC_{50}s of 1.8–8.7%; n = 6), and growth impairment in the alga, *Selenastrum capricornutum* (72-hour EC_{50}s of 0.10–27%; n = 6).

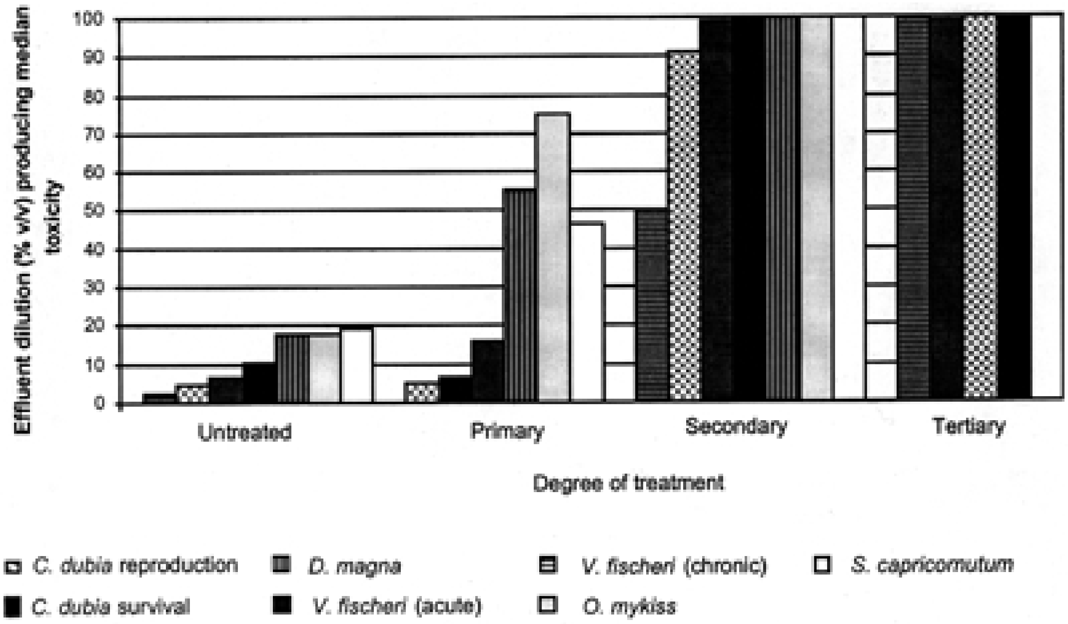
Costan *et al*. (1993) found that an untreated TME ranked second in toxicity to pulp and paper effluent, among eight industrial sectors represented (pulp and paper, petroleum refining, inorganic chemical production, organic chemical production, metallurgy, mining, metal plating and textile production), by using an index based on the results of a series of bioassays assessing the acute, sublethal and chronic toxicity at various trophic levels.

In 1998 and 1999, Environment Canada conducted an assessment of the aquatic toxicity of untreated and/or treated TMEs from 14 textile mills in eastern Canada (Rutherford *et al*., 1998; Rutherford, 1999). Most untreated TMEs exhibited acute toxicity to *V. fischeri*, with 15-minute EC_{50}s ranging from 1.9% to 61% (n = 26), and all untreated TMEs were acutely lethal to *C. dubia* (7-day LC_{50}s ranged from 3.2% to 67%; n = 20) and exhibited sublethal effects that included reproductive impairment in *C. dubia* (7-day IC_{25}s ranged from 1.1% to 21%; n = 20) and growth inhibition in *S. capricornutum* (72-hour IC_{50}s ranged from 6.0% to 80%; n = 20). On-site primary wastewater treatment did not alleviate acute aquatic toxicity, with 15-minute EC_{50}s for *V. fischeri* ranging from 1.3% to 18% (n = 6) and 7-day LC_{50}s for *C. dubia* ranging from 6.5% to 18% (n = 4), or sublethal toxicity, with 7-day IC_{25}s for *C. dubia* ranging from 2.2% to 13% (n = 4) and 72-hour IC_{50}s for *S. capricornutum* ranging from 35% to 58% (n = 2). In most cases, on-site secondary treatment, secondary treatment at an MWWTP or tertiary treatment at an MWWTP eliminated aquatic toxicity. Two exceptions were at MWWTPs with secondary treatment, one of which was believed not to be functioning optimally, thereby providing a relatively poor degree of treatment.

Appendices C and D provide a summary of all published and unpublished Environment Canada and company-generated aquatic toxicity data for untreated and treated TMEs, respectively. Those data are presented in the CEPA 1999 supporting document for the TME assessment (Environment Canada, 2000).

Figure 5 presents the median toxicity of TMEs for the whole-effluent toxicity database. Medians are used because the toxicity data were not normally distributed (Gad, 1999). The whole-effluent toxicity database was compiled from the results of aquatic toxicity testing of untreated, primary-treated, secondary-treated or tertiary-treated TME samples. Untreated TMEs were collected at individual mills and represent the combined process wastewater from those facilities prior to any subsequent treatment or direct discharge to the environment. Primary- and secondary-treated TME samples were collected either from on-site wastewater treatment systems or at MWWTPs prior to discharge to the environment. Tertiary-treated TMEs were collected at MWWTPs prior to discharge to the environment. All untreated TME samples exhibited lethal or sublethal effects on all of the organisms tested. Primary-treated TMEs had slightly less toxicity. Most of the secondary-treated MWWTP samples containing TMEs, with the exception of samples from two MWWTPs with secondary treatment, and all of the tertiary-treated wastewater containing TMEs did not exhibit acute or sublethal toxicity. It would appear that well-designed and properly functioning aerobic biological process-based secondary or tertiary treatment can eliminate the acute and

FIGURE 5 Median toxicity of TMEs



Note: Medians represented as 100% effluent exhibited no detectable toxicity.

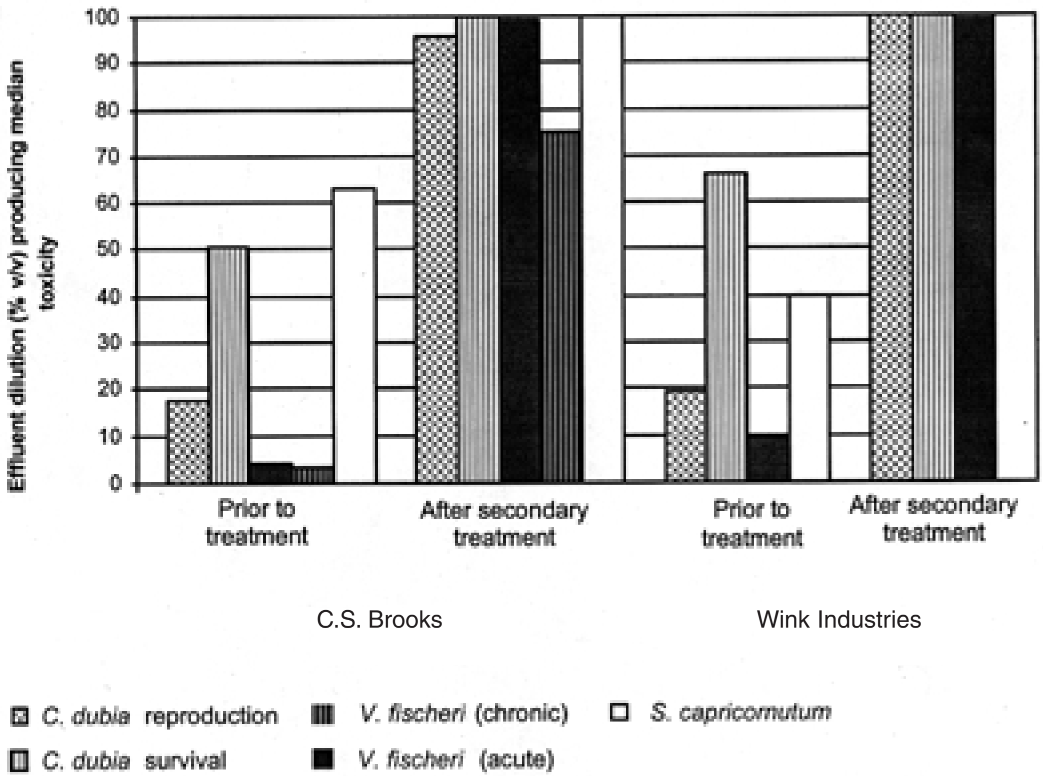
chronic aquatic toxicity of TMEs according to the tests used.

Statistical analyses for differences in toxicity between the different types of TMEs using the Kruskal-Wallis test indicated that untreated and primary-treated TMEs had significantly ($p < 0.05$) greater toxicity than either secondary- or tertiary-treated TMEs. Significant differences between untreated and primary-treated TMEs were detected in rainbow trout (*O. mykiss*) and *D. magna* acute toxicity tests (Kruskal-Wallis test, $p < 0.05$); however, no significant differences were detected in sublethal *C. dubia* and *S. capricornutum* tests or in Microtox® acute tests ($p > 0.05$), indicating that primary-treated TMEs have toxicity characteristics similar to those of untreated TMEs.

Figure 6 presents the median toxicity of TMEs from on-site secondary wastewater treatment systems at two sites, C.S. Brooks and Wink Industries, compared with the toxicity of the TMEs prior to treatment. Untreated TMEs exhibited lethal or sublethal effects on all organisms tested, and secondary treatment removed almost all of those effects. The data provide a direct indication of the relative benefits of biological wastewater treatment of TMEs, as the toxicity results from those locations would not be influenced by dilution effects and other possible confounding factors present at MWWTPs. Zaloum (1987) and Chen (1989) both reported that TMEs following secondary treatment in Canada did not cause acute lethality in fish.

Figure 7 presents the median toxicity of untreated TMEs from five different mill types. The non-woven fabric finishing sector was not tested, as it produces significantly lower volumes of wastewater than the other five mill types. All untreated TME samples were acutely lethal to or had sublethal effects on all of the test organisms, regardless of mill type. Statistical analysis of the data indicated no significant differences in toxicity of untreated TMEs between any of the mill types (Kruskal-Wallis test, $p > 0.05$), with the exception of the lower degree of acute toxicity of woven fabric finishing effluents using Microtox®

FIGURE 6 Median toxicity of TMEs from on-site secondary wastewater treatment systems



Note: Medians represented as 100% effluent exhibited no detectable toxicity.

tests. That statistically significant difference was determined using post-hoc Mann-Whitney U-tests. The data indicated that although TMEs may be chemically complex and may vary in constituents from one mill to another or at one mill over a period of time, the high toxicity of those untreated TMEs is consistent.

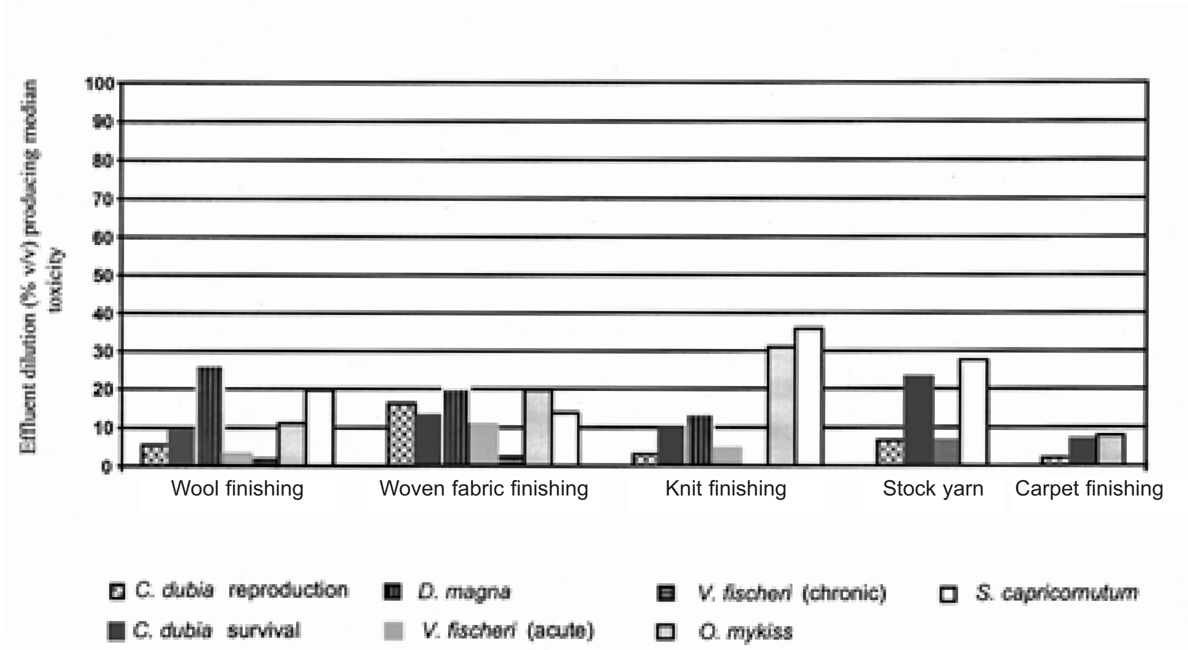
Pearson Product Moment Correlation analyses were conducted on the whole-effluent toxicity data for sites where a battery of toxicity tests were conducted on samples (Rutherford *et al*., 1998; Rutherford, 1999). The tests indicated that Microtox® acute, *C. dubia* survival and reproduction and *S. capricornutum* growth inhibition were all strongly and positively correlated (R values 0.81–0.95; $p < 0.05$; n = 34), indicating that the tests could be used interchangeably as predictors of toxicity (Environment Canada, 2000). The Microtox® chronic assay was the most sensitive test (lowest Lowest-Observed-Effect Concentration [LOEC], 0.06%), closely followed by the *C. dubia* reproduction test (lowest 7-day IC_{25}, 1.1%). Other studies of untreated TMEs have found *S. capricornutum* to be the test organism most sensitive to TMEs (Walsh *et al*., 1980; Rutherford *et al*., 1992).

2.4.2 Ambient aquatic toxicity

The Canadian data set for toxicity testing of samples from aquatic environments receiving TME discharges is small; there are no data from environments receiving untreated TME discharges.

Rutherford (1999) collected ambient river water samples in the effluent plume at various distances downstream from the outfalls of five TME discharges, one with on-site primary treatment (Britex, Bridgetown, Nova Scotia), three with secondary treatment at an MWWTP

FIGURE 7 Median toxicity of untreated TMEs from various mill types



(CookshireTex, Cookshire, Quebec; Les Industries Troie, St. Pamphile, Quebec; and Lainages Victor, St-Victor, Quebec) and one with tertiary treatment at an MWWTP (Coats Bell, Arthur, Ontario). The samples were tested for acute toxicity using the marine bacterium, *V. fischeri*, in the Microtox® test. At one of the sites where ambient toxicity was encountered, additional samples were collected at later dates for testing with both Microtox® and *C. dubia* (survival and reproduction).

Rutherford (1999) reported that 15-minute EC_{50}s for *V. fischeri* ranged from 23% to 32% (n = 3) on two dates in samples from the Annapolis River, Nova Scotia, 30 m from the outfall of an on-site primary-treated TME discharge. No acute toxicity was detected in samples 60, 120 or 240 m from the outfall or at an upstream control station at that site. Chronic aquatic toxicity was also detected up to 120 m from the outfall (*C. dubia* survival 7-day LC_{50}s ranged from 61% to >100%, n = 2; *C. dubia* reproduction 7-day IC_{25}s ranged from 30% to 40%, n = 2). No acute toxicity was detected in samples of TMEs in receiving waters from three sites involving secondary treatment and one site utilizing tertiary treatment of wastewater containing TMEs.

2.4.3 In situ *aquatic toxicity*

Only one Canadian study was identified that included *in situ* toxicity testing of an untreated TME discharge in a receiving environment, although the objective of that work was to measure the uptake of contaminants in the exposed organisms. In October 1990, freshwater clams, *Anodonta implicata*, suffered 100% mortality during 1-month exposure periods up to 120 m downstream of Stanfield's in the Salmon River, Nova Scotia. All clams died at three stations (30, 50, 100 m) and 60% died at 120 m below the outfall in June 1991. All of the clams survived in the upstream control station for a month during surveys in both October 1990 and June 1991.

2.4.4 *Sediment toxicity*

Only one study in Canada has examined sediment toxicity in receiving environments near textile mills. In a study of the environmental occurrence and toxicity of chlorobenzenes in freshwater and marine sediments, Rutherford *et al*. (1995) collected sediments in the receiving environments near three textile mills with their own treatment systems. At Britex, Bridgetown, Nova Scotia, a woven fabric finishing mill with primary treatment, sediment samples from approximately 10 m from the plant's outfall were toxic to *V. fischeri* in the solid-phase Microtox® test (10-minute IC_{50} was 790 mg/kg), while sediments from approximately 40 and 80 m from the outfall were not toxic. However, pore water from sediments collected at those locations was toxic to the white sea urchin (*Lytechinus pictus*) in the sea urchin fertilization test (20-minute IC_{25}s were 29% and 51%, respectively). No toxicity was detected with the marine amphipod, *Corophium volutator*, at any sampling station, the closest of which was 10 m from the outfall. At C.S. Brooks, Magog, Quebec, a woven fabric finishing plant with secondary treatment discharging to a freshwater river, no effect on survival was detected in downstream sediment samples in tests on the midges *Chironomus riparius* and *C. tentans*, the amphipod *Hyalella azteca*, the mayfly *Hexagenia limbata* and the oligochaete worm *Tubifex tubifex*. At Wink Industries, Caraquet, New Brunswick, a woven fabric finishing plant with secondary treatment discharging to the marine environment, sediment samples collected were not toxic to *V. fischeri* (Microtox® test), the white sea urchin (*L. pictus*) or the marine amphipod *Amphiporeia virginiana*; the closest station at which sediment samples were collected was 8 m from the outfall.

2.4.5 *Benthic macroinvertebrate community impacts*

In Canada, only one study reported on the effects of untreated TME discharges on aquatic communities in receiving waters. Rutherford *et al.* (1992) reported a statistically significant decrease in the abundance and diversity of benthic macroinvertebrates at sampling stations in the effluent plume of a knit fabric finishing mill discharging untreated TME to a freshwater river. In October 1990, the abundance of 13 of 14 taxa was significantly lower at four stations up to 120 m downstream compared with the control station (Dunnett's T test, $p < 0.05$). During a June 1991 survey, 5 of 7 taxa were significantly less abundant at impacted stations than at the control station (Dunnett's T test, $p < 0.05$). During both surveys, the mean number of taxa was significantly lower at all impacted stations than at the upstream control station (Dunnett's T test, $p < 0.05$). In both instances, the biological impact of the effluent discharge was not specific to one group of organisms, as aquatic insects (caddisflies, mayflies, beetles and chironomids), snails and leeches were all negatively impacted by the untreated TME discharge. The impacts were a classic community response to toxic pollution rather than to nutrient enrichment, as a decrease in both diversity and abundance of benthic macroinvertebrates was observed as a gradient with distance from the outfall.

There were no Canadian studies found on the impact of primary-treated TME discharges on benthic macroinvertebrate communities.

In St-Victor, Quebec, benthic invertebrate samples were collected in the Lebras River in July 1999, downstream of an MWWTP with secondary treatment (Rutherford, 1999). That plant received approximately 75% of its influent from Lainages Victor, a wool finishing mill, the largest industry in town. Surber sampling indicated no significant differences in taxa diversity from 2 m to 300 m downstream compared with control stations above the outfall (Kruskal-Wallis test, $p > 0.05$). Benthic invertebrate abundance was not significantly different between downstream and upstream control stations, with the exception of abundance 20 m downstream compared with the control station located 10 m upstream (Kruskal-Wallis test, $p < 0.05$). In that case, an increase in numbers of chironomids (tolerant organisms often associated with nutrient enrichment in receiving environments) at the station 20 m downstream appeared to be responsible for the increased abundance downstream of the outfall.

In Arthur, Ontario, benthic invertebrate Surber samples were collected in the Conestogo River in April 1999, downstream of the MWWTP with tertiary treatment (Rutherford, 1999) that receives approximately 30% of its influent from Coats Bell, a stock yarn finishing mill (Letson, 1999). No significant differences in diversity or abundance of benthic macroinvertebrates between downstream (2, 15, 80 and 280 m) and control stations were detected (Kruskal-Wallis test, $p > 0.05$).

2.4.6 Endocrine disruption effects

To determine whether TMEs have the potential to induce endocrine disruption effects in the environment, samples of untreated and treated TMEs, as well as samples from TMEs in receiving environments, were collected in 1999 and analysed for endocrine disrupting activity with the yeast estrogen screen (YES) assay (Burnison *et al.*, 1999).

Results indicated that some untreated TMEs (three of six samples from six sites) and on-site primary-treated TMEs (one of two samples from two sites) have estrogenic properties, while others do not. Estrogenic activity was also detected in receiving environment samples from TME discharges from an on-site primary treatment system. While some estrogenic activity was detected in effluents from MWWTPs receiving TME discharges, there is uncertainty whether other sources may have contributed to those estrogenic responses (e.g., estrogenic hormones in raw sewage). Given the considerable scientific debate regarding the significance of estrogenic responses to individual organisms or populations, the environmental effects produced by estrogenic compounds in TME samples is currently unknown.

2.4.7 Mutagenicity of TMEs

Rutherford *et al.* (1992) tested the mutagenic properties of untreated TME samples from three textile mills in Atlantic Canada. Ames testing of six untreated TME samples indicated that all samples were slightly to highly mutagenic using the spot test or the plate incorporation test with the TA97, TA98, TA100 and TA102 strains of *Salmonella typhimurium*. There were differences in the apparent types of mutagenicity associated with each sample; some samples showed mutagenicity to a specific tester strain, while other samples were mutagenic to one or more other tester strains. The results suggest that more than one mutagen was present in the samples. Other studies have demonstrated the mutagenic activity of TMEs (Brookman, 1980a,b).

2.4.8 Effects of dyes in TMEs

No Canadian studies were found on the effects of dyes in the aquatic environment.

While most textile dyes have low aquatic toxicity (U.S. EPA, 1997), the discharge of highly coloured untreated or partially treated TMEs can impair the aesthetic value of receiving waters as well as having the potential to affect water transparency and gas solubility, which may in turn negatively affect aquatic biota (Banat *et al.*, 1996; Kennedy *et al.*, 1999). Conventional wastewater treatment based on activated sludge systems is not adequate for the treatment of colour in TMEs, neither on-site nor after dilution with domestic wastewater at MWWTPs (Vandevivere *et al.*, 1998). Colour has been observed in Canadian water bodies receiving untreated and partially treated TMEs (Chen, 1989; Rutherford *et al.*, 1992; Rutherford, 1999).

While the lack of data on dyes in the Canadian environment makes it difficult to determine specifically whether dyes from the textile industry are an environmental problem in aquatic ecosystems, the whole-effluent approach used in this assessment should ensure that any toxic effects of dyes, as a constituent of TMEs, are considered in the risk characterization of that substance.

3.0 Assessment of "Toxic" under CEPA 1999

3.1 CEPA 1999 64(a): Environment

The methods used to estimate risk were based primarily on the procedures outlined in Environment Canada (1997). Analysis of exposure pathways and subsequent identification of sensitive receptors were used to select environmental assessment endpoints. Assessment endpoints are explicit expressions of the actual environmental value that is to be protected. They reflect social and ecological priorities and are expressed in a manner that can be evaluated through an objective scientific process (Menzie *et al*., 1996). A tiered approach for estimating risks of adverse effects of Priority Substances on assessment endpoints was then employed. For complex substances such as TMEs, the tiered approach used for assessments of individual substances was modified as required, and a weight-of-evidence approach was taken (Environment Canada, 1997).

In the approach utilized, a quotient was derived by dividing an Estimated Exposure Value (EEV) by an Estimated No-Effects Value (ENEV). The ENEV was derived by dividing a Critical Toxicity Value (CTV) by an application factor. In that analysis, if the quotients were less than one, it was concluded that the substance posed no significant risk to the environment in Canada, and no additional risk quantification was undertaken. If, however, the quotient was greater than or equal to one for a particular assessment endpoint, then the risk assessment for that endpoint proceeded to an analysis that more precisely quantified the magnitude of risk. To do that, plume dispersion predictions were calculated to determine the spatial influence of TME discharges in aquatic environments, and a weight-of-evidence analysis was conducted according to the methods of Menzie *et al*. (1996).

3.1.1 Assessment endpoints

Since the scope of the assessment is confined to the aquatic environment, only aquatic endpoints were chosen. Given the chemical complexity of TMEs and the likelihood that their constituents could partition to both sediment and water in aquatic environments, several assessment endpoints were required to ensure that risks to aquatic biota were evaluated as completely as possible.

The assessment endpoints included the following:

- at the community level — biodiversity of benthic macroinvertebrates as a measure of ecological integrity;
- at the population level — abundance of sensitive aquatic species; and
- at the individual level — physiological, reproductive, growth and endocrine effects.

The measurement endpoint, or line of evidence, used to evaluate the assessment endpoint on the biodiversity of benthic macroinvertebrates was field studies on the abundance and diversity of benthic macroinvertebrates in aquatic environments receiving TMEs. Potential population effects were evaluated using measurement endpoints such as acute and chronic toxicity tests of whole effluents and receiving environment water samples, acute and sublethal toxicity tests of receiving environment sediment samples, *in situ* toxicity tests, and whole-effluent as well as receiving environment measurements of the EEV_{TEQ}s of NP and NPEs. Physiological and biochemical effects were assessed using measurement endpoints such as YES assays of whole effluents and receiving environment samples and mutagenicity tests of whole effluents.

3.1.2 Environmental risk characterization

TMEs enter the Canadian environment in substantial quantities; however, there is a wide range of discharge volumes from individual mills, and there is a great deal of variability in the volume and dilution characteristics of the aquatic environments to which the TMEs discharge. Although batch processes are employed in most mills, the retention times in MWWTPs receiving TMEs tend to moderate the effect of the batch discharge practices of textile mills. In addition, many textile mills have on-site flow equalization, which also reduces the effect of batch discharges of TMEs to MWWTPs. The dilution capacity of receiving environments does vary significantly with season, however, altering the spatial influence of the discharge. In 1999, most TMEs (99%) received some level of treatment before they were discharged, primarily through MWWTPs, although some mills (4%) had dedicated treatment systems. A small number of mills (1%) discharged untreated TMEs directly to aquatic environments.

The exposure of aquatic organisms to TMEs was estimated using the results of whole-effluent and ambient toxicity tests and EEV_{TEQ}s for NP and NPEs in ambient samples taken at various locations in receiving environments. Predictive plume dispersion calculations were also made for a limited number of sites in order to better define the "zone of influence" for exposure of aquatic organisms to TMEs.

Analysis of the whole-effluent aquatic toxicity data from seven different kinds of lethal and sublethal toxicity tests for different mill types indicated that generally there were no significant differences in the toxicity of untreated TMEs between mill types. The one exception was that of woven fabric finishing mills, which had significantly less toxicity according to the results of one acute Microtox® test. Therefore, the risk characterization was not conducted for individual mill types. Since analysis of the data did reveal a significant difference in the toxicity of effluents from mills that had different types of wastewater treatment, risk estimates were derived for the four categories of treatment — namely, untreated, primary, secondary and tertiary.

3.1.2.1 Overview of approach for determination of risk quotients

Since the assessment of TMEs was based on a whole-effluent approach, an EEV was established, for the purpose of developing risk quotients, on the basis of the percent dilution of the whole effluent. ENEVs were derived on the basis of selecting an appropriate sensitive toxicity endpoint or CTV and applying an application factor to account for uncertainties such as extrapolation from laboratory to field conditions, variations in interspecies and intraspecies sensitivities and uncertainties of ecological relevance of the chosen endpoint.

For the Tier 1 assessment, the EEV was taken to be 17% effluent in the receiving environment. That value was derived from the lowest river flow to cumulative mill flow ratio for all TME discharges in Canada. The river flow data used for that calculation were the 7Q2 (consecutive 7-day average low flow with an average recurrence interval of once in 2 years), as those data were considered to be the most conservative for risk characterization. Unlike lowest mean monthly flow rates, 7Q2s do account for infrequent ultra-low flow rates that may occur within exceptionally dry periods. The 7Q2 data value used was that for the Bourbon River, Quebec, because that represented the lowest dilution situation in all of Canada. That river received secondary-treated wastewater from the Plessisville MWWTP that treated TME discharges from three textile mills.

The ENEV used was derived using a CTV that was one of the most sensitive sublethal toxicity endpoints for whole effluents, the 7-day IC_{25} for *C. dubia* reproduction. Tests using those organisms were observed to be sensitive to the effects of TMEs, having a median 7-day IC_{25} of 4.7%. In fact, Microtox® chronic bioassays were slightly more sensitive than the *C. dubia*

TABLE 2 Results of Tier 1 risk quotient calculations using whole-effluent toxicity endpoints

	Untreated	Primary	Secondary	Tertiary
EEV (dilution rate 83%)	17	17	17	17
C. dubia 7-day IC_{25} (CTV) (% v/v)	1.1	2.2	56	100
ENEV (CTV/AF[1]) (% v/v)	0.42	0.85	22	38
Quotient (EEV/ENEV)	40	20	0.77	0.45

[1] AF (application factor) = 2.6 = upper 95% confidence interval of the mean 7-day IC_{25}/7-day IC_{10}.

reproduction bioassays; however, the *C. dubia* reproductive test was selected because it was a more comprehensive data set and is representative of organisms important in aquatic food chains in freshwater receiving environments in Canada. The 7-day IC_{25} for each treatment type that demonstrated the greatest toxicity was selected with the belief that such tests approximated a threshold for sublethal effects. An application factor of 2.6 was used for converting CTVs to ENEVs. That value was derived by calculating the upper 95% confidence interval of the mean ratio of 7-day IC_{25}/7-day IC_{10} results for each *C. dubia* bioassay (n = 27). A similar method was used by Chapman *et al.* (1998) in calculating application factors using LOECs and No-Observed-Effect Concentrations (NOECs). While a maximum application factor of 10 is recommended by Environment Canada (1997) for converting CTVs to ENEVs for Tier 1 assessments, it was believed that the use of a smaller application factor in this case was warranted, since toxicity tests were conducted directly on whole-effluent samples, thereby reducing the uncertainty associated with correlating laboratory-generated toxicity values with environmental measurements of the stressor substance.

3.1.2.2 Results of Tier 1 assessment

The results of the Tier 1 assessment using whole-effluent toxicity endpoints (Table 2) demonstrated that untreated and primary-treated TMEs had risk quotients greater than one. Therefore, further risk assessment was required for those treatment types.

TMEs that were subject to secondary treatment on-site or at MWWTPs produced a risk quotient of less than one. The available whole-effluent toxicity information for secondary-treated wastewater containing TMEs indicated that virtually all such effluents did not produce lethal or sublethal effects, using *C. dubia* reproduction, *C. dubia* chronic survival, *D. magna* acute mortality, Microtox® acute, rainbow trout (*O. mykiss*) acute mortality and algal growth inhibition tests. One mill of six sampled had secondary-treated TMEs that produced acute toxicity in Microtox® tests and chronic toxicity in *C. dubia* survival and algal growth inhibition tests. At that site (CookshireTex), the discharge was being treated by an MWWTP that was believed not to be functioning properly. However, acute aquatic toxicity to Microtox® was not detected in the receiving environment at that site. Two of the three mill effluents receiving secondary treatment at MWWTPs exhibited chronic toxicity to Microtox® (three of five samples, median 50%). However, samples obtained from those receiving environments demonstrated no acute aquatic toxicity. In addition, impacts on the benthic macroinvertebrate community were not detected at a single site receiving secondary-treated wastewaters containing TMEs from an MWWTP.

Available data did not indicate any receiving environment ambient toxicity, benthic macroinvertebrate community impacts or endocrine disrupting activity in aquatic environments at any of the sites receiving tertiary-treated wastewaters containing TMEs. The above evidence indicates that TMEs that receive adequate secondary treatment do not represent a substantial risk to the environment. It should be cautioned, however, that the analysis was based on a limited data set, and it must be acknowledged that treatment systems do not always perform optimally. The quotient analysis also indicated that tertiary-treated TMEs do not represent a substantial risk to the environment. A more rigorous assessment was not required for mills having either secondary or tertiary treatment processes.

3.1.2.3 Overview of approach for the Tier 2 or weight-of-evidence assessment

For untreated and primary-treated TMEs, a further risk determination was made using a weight-of-evidence approach. Weight-of-evidence methods have been suggested as appropriate for higher-level risk assessments of complex mixtures (Environment Canada, 1997).

Weight-of-evidence approaches, simply stated, attempt to integrate the results of multiple measurements into ecological risk assessments. A weight-of-evidence evaluation takes into account the strengths and weaknesses of different measurement endpoints when determining whether the results show that a stressor has caused, or could cause, a harmful ecological effect. The procedure outlined by Menzie *et al.* (1996) was used to evaluate the multiple lines of evidence related to the ecological risk of untreated and primary-treated TMEs. That approach includes methods for (a) weighing the individual measurement endpoints by evaluating how well they score against a set of attributes related to the strength of association between measurement and assessment endpoints, data quality and study design and execution, (b) determining whether environmental harm or lack of environmental harm is indicated and, if so, the magnitude of response, and (c) graphically displaying the measurement endpoints in a matrix so that concurrence can be examined. Detailed results of those analyses are presented in Environment Canada (2000).

Untreated TMEs contain high concentrations of NP and NPEs, especially those with high ethoxylate chain lengths, and it is known that those chemicals have toxicological effects on aquatic biota (Servos, 1999).

Given the presence of NP and NPEs in TMEs, samples of untreated TMEs prior to subsequent treatment and samples of on-site primary-treated TMEs were collected and analysed for concentrations of those substances (Bennie, 1998; Rutherford, 1999). It has been assumed that the lower-chain-length NPEs have a mode of action similar to that of NP and that their effects are additive. Therefore, a toxic equivalency approach was applied that factored in the contribution of NP as well as those of the lower-chain-length NPEs. An EEV_{TEQ} was calculated by multiplying the exposure concentration (C_X) of each of the NPEs (NP1EO, NP2EO, NP3–17EO) by each compound's relative potency (RP_X) value (Environment Canada, 1999b) and then adding them together, as in the following:

$$EEV_{TEQ} = \sum (\text{4-NP } \mu g/L)(1) + (\text{NP1EO } \mu g/L)(0.5) + (\text{NP2EO } \mu g/L)(0.5) + (\text{NP3–17EO } \mu g/L)(0.005)$$

This provides a total exposure value in terms of NP that can then be compared with a toxic threshold of NP. Results of the NP and NPE analyses and the calculated EEV_{TEQ}s are presented in Appendix E.

To determine the spatial influence of TME discharges for the Tier 2 assessment, TME plume dispersion calculations were conducted for sites in Canada discharging untreated TMEs directly to receiving environments and primary-treated TMEs to receiving environments via on-site treatment systems or MWWTPs. The sites are presented in Appendix F. In addition, dispersion predictions were made by Coastal Ocean Associates (COA) for several hypothetical "worst-case" situations. Dispersion predictions were used due to a lack of site-specific field data for many of the locations where untreated and primary-treated TMEs are discharged into the environment.

In order to estimate toxicity dispersion, toxicity levels were converted to toxic units (TU) by dividing the toxicity into 100 (i.e., TU = $100/IC_{25}$) (U.S. EPA, 1991). Since toxicity involves an inverse relationship with effects concentrations of substances (the lower the effects concentration, the greater the toxicity of the effluent), it is more understandable when concentration-based toxicity measurements are translated into TUs. For example, an effluent with a reported IC_{25} of 5% is an effluent containing 20 TUs. Any effluent that has a TU value of 1 would produce a 25 percent effect at full strength (IC_{25} = 100%). Therefore, the higher the TU value, the higher the potential for aquatic toxicity. In areas influenced by TME plumes with TU values greater than 1, environmental harm to populations of resident aquatic organisms would be predicted based on the TU value.

For the TME plume dispersion calculations, a point-of-discharge CTV of 20 TUs was derived using the median value of *C. dubia* reproduction measured for all effluents subject to either primary treatment (7-day IC_{25} 5.0%) or no treatment (7-day IC_{25} 4.7%). The median value was used, as it is believed to be a more representative measure of risk than the lowest *C. dubia* reproduction value used in the Tier 1 assessment.

In many cases, TMEs are discharged to an MWWTP as a minor component of the total flow by volume. Those MWWTPs often discharge to large bodies of water, usually through a diffuser designed to provide good dispersion of the effluent in the receiving waters. Dispersion from such outfalls has been described extensively both theoretically (Csanady, 1973; Fischer *et al.*, 1979) and practically (Bowie *et al.*, 1985; Baumgartner *et al.*, 1994). An initial assessment was made of chronic aquatic toxicity in the receiving environment for such cases by considering the treatment and dilution effect of the MWWTP. In cases where there remained a high chronic aquatic toxicity or where there was no treatment, the reduction in aquatic toxicity due to turbulent dilution in the environment was estimated using the following calculation for horizontal dispersion from a steady source in a uniform current (Baumgartner *et al.*, 1994):

$$T = T_o \mathrm{erf}(\mathrm{sqrt}[1.5/(1 + 8*a*b^{2/3}*t)^3 - 1])$$

where T is the toxicity, T_O is the initial toxicity, erf is the error function, "b" is the initial width of the discharge, "t" is time and "a" is an effective dispersion coefficient parameter. The parameter "a" is typically assumed to be in the range 0.0001–0.0005. A conservative value of 0.0001 was assumed for "a." The parameter "b," the initial width of the plume, was assumed to be 1 m based on field observations (Rutherford, 1999). The equation predicts the time required for an effluent to not meet measurable IC_{25} concentrations for the related endpoint. To determine the distance or "zone of influence" of a plume exhibiting aquatic toxicity, the time is multiplied by the current (u) of the receiving environment (i.e., d = u*t, where d = distance).

3.1.2.4 Results of Tier 2 assessment

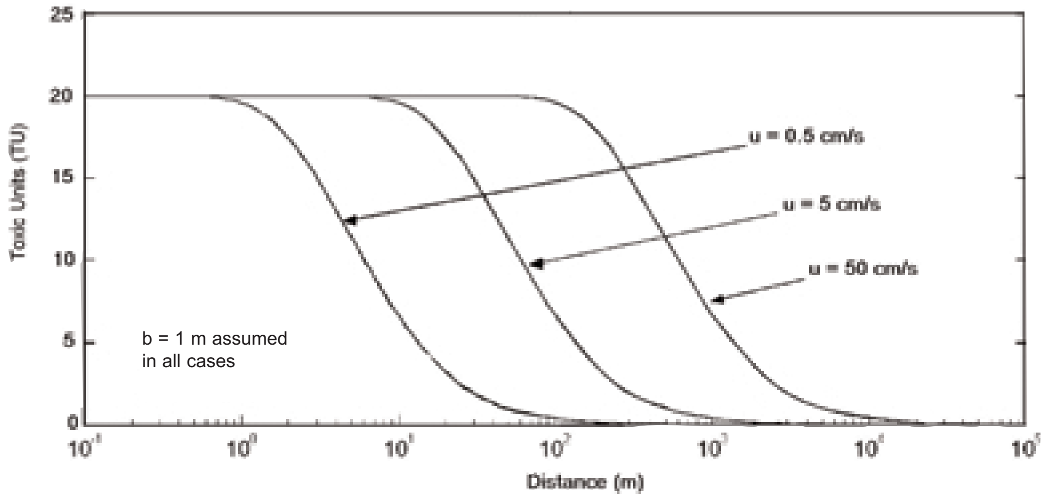
3.1.2.4.1 Untreated TMEs

Sufficient data were available for a number of locations to allow site-specific untreated TME plume dispersion calculations to be made.

Ste-Anne-de-la-Pérade, Quebec

In 1999, untreated TMEs from Les Tricots Godin were discharged to a tributary of the St. Lawrence River (Ste. Anne River) at Ste-Anne-de-la-Pérade, Quebec, at a rate of 0.00018 m^3/s. The effluent toxicity was estimated at 20 TUs. The mill effluent was collected by the municipal wastewater collection system and discharged via several simple pipe outfalls without treatment. Assuming that the discharge was via a simple pipe at the shoreline (one of the municipal discharge pipes) with no initial dilution, toxicity of greater than 1 TU could occur for up to about 10^4 seconds (167 minutes) after discharge. The lowest mean monthly flow rate for the Ste. Anne River (76 m^3/s) is expected to generate shoreline currents of the order of a few cm/s. Therefore, the toxicity threshold (1 TU) in the plume would

FIGURE 8 Theoretical toxicity reduction in untreated and primary-treated TMEs with varying river currents



not be reached for a distance of several hundred metres along the shoreline downstream of the outfall if it is conservatively assumed that there is no initial dilution associated with buoyant rise from a subsurface plume.

Windsor, Nova Scotia

In 1999, Nova Scotia Textiles discharged untreated TMEs through the Town of Windsor's wastewater collection system to the St. Croix River at a rate of 0.0014 m^3/s. The St. Croix River is tidal, with a downstream tidal range of over 10 m. The outfall is located above the water surface during a part of the tidal cycle. The area between the outfall and the water's edge at low tide is expected to be exposed to effluent concentrations of greater than 1 TU. After initial mixing, the plume will diminish in size until the spatial influence is negligible. This may occur for up to 100 m from the outfall.

Hypothetical untreated TME plume dispersions

Plume dispersion calculations were also made to predict the spatial extent of hypothetical untreated TME discharges. The process wastewater flows of textile mills obtained from surveys of the textile industry (Environment Canada, 1999a) showed that the flow from existing textile mills in Canada is small on a volume basis when compared with typical river flows or municipal collection flows (Appendix F). Under continuous low-flow conditions in relatively well flushed systems (e.g., no potential for toxicants to accumulate in a given area), it is appropriate to ignore many of the details of aquatic dispersion, including effects of bathymetry, coastlines and background buildup. In those cases, the equation presented in Section 3.1.2.3 was used to estimate dilution and hence toxicity reduction in the environment after discharge. The results of several scenarios are plotted in Figure 8, assuming initial discharge plume widths of 1 m. The figure shows that at an ambient current of 5 cm/s, toxicity levels from untreated TME discharges that are undiluted by MWWTP additions will be reduced to 1 TU from 100 m to approximately 1000 m downstream of the outfall. The current determines the distance travelled in a particular time period; the stronger the current, the farther the plume will travel.

Weight of evidence for other untreated TME discharges

Rutherford *et al*. (1992) reported a significant decrease in the abundance and diversity of benthic macroinvertebrates at sampling stations in the effluent plume of a knit fabric finishing mill discharging untreated TMEs to the Salmon River, Nova Scotia. That ecological impact was observed during sampling programs in both the fall of 1990 and the spring of 1991 and was not specific to one group of organisms, as aquatic insects, snails and leeches were all negatively impacted. The impacts were observed up to 120 m downstream of the TME outfall. *In situ* toxicity testing, using freshwater clams, during that study clearly showed a biological impact from the untreated TME discharge. While all clams survived at the upstream control station for a month during both fall and spring surveys, all clams died at stations 30, 50, 100 and 120 m downstream during the 1990 survey, and all but 4 of 10 clams died at the station 120 m from the TME outfall in 1991.

The whole-effluent toxicity data for Canada indicated that all untreated TME samples tested were acutely lethal to fish (96-hour LC_{50}s 3.9–71%) and invertebrates (48-hour or 7-day LC_{50}s 0.80–67%). Sublethal effects of untreated TMEs include reproductive impairment in invertebrates (7-day IC_{25}s 1.1–21%) and growth impairment in algae (72-hour IC_{50}s 0.10–80%) (Environment Canada, 1988, 1989, 1991a,b,c,d,e, 1992d, 1994, 1995; Chen, 1989; Harris Industrial Testing Service, 1992, 1997, 1998, 1999; Rutherford *et al*., 1992, 1998; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995; Rutherford, 1999).

Untreated TMEs contain very high concentrations of NP and NPEs, especially those with high ethoxylate chain lengths (Bennie, 1999). EEV_{TEQ}s were calculated for untreated TMEs based on data collected by Environment Canada in 1998 and 1999 (Bennie, 1998; Rutherford, 1999). For untreated TME samples, EEV_{TEQ}s for NP and NPEs ranged widely between 0.94 and 1200 µg/L (n = 29; 14 sites). Eighty-three percent of those samples fell within the range of acute toxicity to fish (LC_{50}s 17–1400 µg/L), invertebrates (LC_{50}s 20–3000 µg/L) and algae (EC_{50}s 27–2500 µg/L) reported by Environment Canada (1999b). Eighty-six percent of those samples exceeded the chronic toxicity threshold for fish of 6 µg/L (NOEC), and 90% of those samples exceeded the chronic toxicity benchmark for invertebrates of 3.9 µg/L (NOEC) (Servos, 1999).

Some untreated TMEs exhibited estrogenic properties using the YES assay (three of six sites) (Burnison *et al*., 1999).

Rutherford *et al*. (1992) tested the mutagenic properties of untreated TME samples from three textile mills in Atlantic Canada. Ames testing of six untreated samples indicated that all samples were slightly to highly mutagenic using the spot test or the plate incorporation test. The results suggested that more than one mutagen was present in the samples.

3.1.2.4.2 Primary-treated TMEs

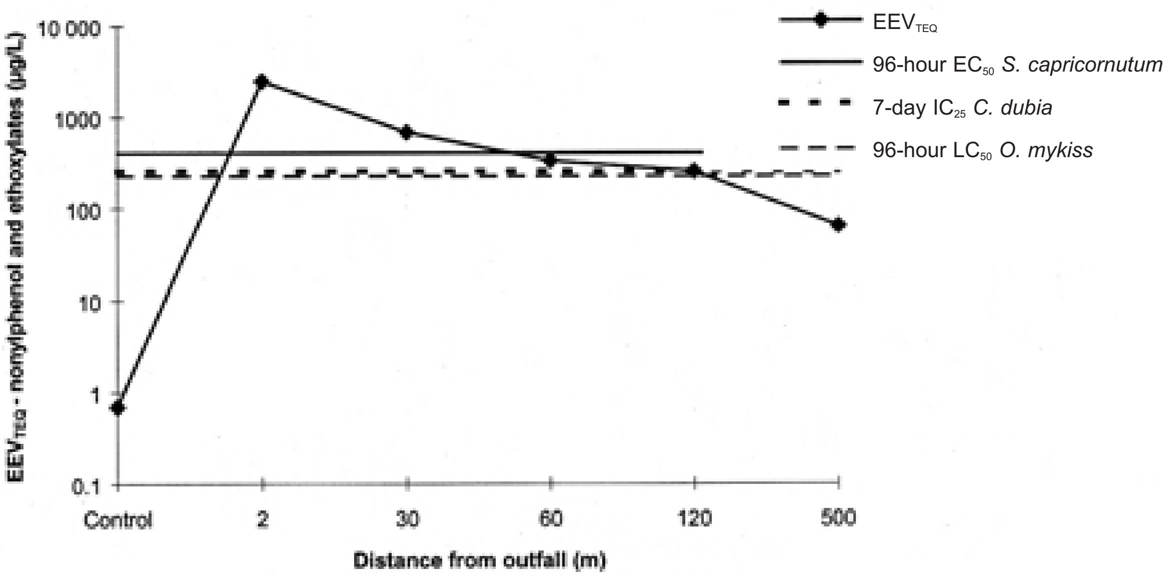
Sufficient data were available for a number of locations to allow site-specific dispersion calculations to be made.

Bridgetown, Nova Scotia

In 1999, Britex discharged on-site primary-treated effluent at a rate of 0.013 m^3/s to the Annapolis River from a simple shoreline outfall at Bridgetown, Nova Scotia. Treatment was assumed to reduce toxicity to about 20 TUs. The lowest mean monthly flow was about 8 m^3/s though a cross-sectional area at the outfall site of about 300 m^2. Thus, a typical current was about 2–3 cm/s. Assuming an initial plume width of 1 m, plume dispersion calculations estimated that the chronic toxicity to *C. dubia* in the river will be reduced to 1 TU at a distance of a few hundred metres downstream of the outfall.

At Britex, Rutherford (1999) detected chronic aquatic toxicity to *C. dubia* up to 120 m from the outfall, with a 7-day LC_{50} of 61% for *C. dubia* survival on one date and 7-day IC_{25}s of 30% and 40% for *C. dubia* reproduction on two dates. Those results are consistent with the findings of the plume dispersion modelling, as chronic toxicity was detected in an area in the Annapolis River influenced by the TME plume, within a few hundred metres of the outfall. In

FIGURE 9 NP and NPE EEV_{TEQ}s in the Annapolis River, 1999



Notes:

1. NP and NPEs are undetected at control sites and are presented as the method detection limit (MDL)/2.
2. Straight lines represent the toxicity thresholds for selected endpoints.
3. 96-hour EC_{50} *S. capricornutum* threshold is 410 µg/L (Ward and Boeri, 1990; Naylor, 1995).
4. 7-day IC_{25} *C. dubia* threshold is 258 µg/L (England, 1995a,b; Weeks *et al*., 1996).
5. 96-hour LC_{50} *O. mykiss* threshold is 230 µg/L (Naylor, 1995).

addition, acute Microtox® toxicity was detected 30 m from the outfall of that primary-treated TME discharge, with 15-minute EC_{50}s for *V. fischeri* ranging from 24% to 32% on three dates.

Rutherford (1999) also measured the concentrations of NP and NPEs in the Annapolis River downstream of that site. Since 4-NP is known to be more toxic and has a larger database than the ethoxylates (Servos, 1999), EEV_{TEQ}s were calculated to normalize the concentration of the ethoxylates to that of 4-NP. EEV_{TEQ}s for NP and NPE concentrations in the Annapolis River exceeded the 96-hour EC_{50} toxicity threshold of 410 µg/L for *S. capricornutum* (Ward and Boeri, 1990; Naylor, 1995) up to 30 m downstream of the textile plant (Figure 9). The *C. dubia* 7-day IC_{25} threshold of 260 µg/L (England, 1995a,b; Weeks *et al*., 1996) and the rainbow trout (*O. mykiss*) 96-hour LC_{50} threshold of 230 µg/L (Naylor 1995) were exceeded 120 m downstream from the outfall.

Pore water from sediments obtained from the Annapolis River (Rutherford *et al*., 1995) produced sublethal toxicity to the white sea urchin (*L. pictus*) at 40 m and 80 m from the Britex outfall (20-minute IC_{25}s were 29% and 51%, respectively). In addition, sediment samples collected 10 m from that plant's outfall exhibited acute toxicity to *V. fischeri* in the solid-phase Microtox® test.

Montréal, Quebec

In 1999, there were 33 textile mills that discharged TMEs to the MUC MWWTP, contributing 0.381 m^3/s or about 6% of the industrial input. The MUC flow was 32 m^3/s, resulting in a dilution of 84:1 before the end of pipe of the MUC discharge into the St. Lawrence River. The assumed toxicity level after treatment of 20 TUs would be reduced to about 0.24 TU by in-plant dilution. Therefore, the TME component of the effluent would not exhibit sublethal toxicity to *C. dubia* prior to discharge.

Cornwall, Ontario

In 1999, Richelieu Hosiery International discharged 0.00084 m^3/s into the St. Lawrence River via the Cornwall MWWTP. That plant provides a primary level of treatment with a total discharge of 0.5 m^3/s. The assumed toxicity level after treatment of 20 TUs will be reduced to 0.03 TU before the end of pipe at the MWWTP discharge. The TME component of the effluent would therefore not exhibit sublethal toxicity to *C. dubia* at the point of discharge.

Prescott, Ontario

In 1999, Prescott Finishing discharged 0.0033 m^3/s into the St. Lawrence River via the Prescott MWWTP. That small wastewater treatment plant provided a primary level of treatment with a total discharge of 0.04 m^3/s. The assumed toxicity level after treatment of 20 TUs will be reduced to about 1.7 TUs before the end of pipe at the MWWTP discharge. The flow conditions of that river are such that a further reduction to levels of less than 1 TU would be expected to occur within several metres of the discharge entering the river.

St-Jean-sur-Richelieu, Quebec

In 1999, the combined discharge from J.B. Martin and Textiles Novacolor constituted an inflow of 0.0089 m^3/s to the Haut-Richelieu MWWTP. That plant provided primary wastewater treatment with a total discharge of 0.80 m^3/s. The assumed toxicity level after treatment of 20 TUs will be reduced to 0.22 TU before the end of pipe of the MWWTP discharge; therefore, the TME component of the effluent would not exhibit sublethal toxicity to *C. dubia* at the point of discharge.

Moncton, New Brunswick

In 1999, Tandem Fabrics discharged TMEs at a rate of 0.0046 m^3/s to the Peticodiac River via the Moncton MWWTP. That plant provided a primary level of treatment with a total discharge estimated at 1 m^3/s. The assumed toxicity level after treatment of 20 TUs will be reduced to 0.092 TU before the end of pipe at the MWWTP; therefore, the TME component of the effluent would not exhibit sublethal toxicity to *C. dubia* at the point of discharge.

Vancouver, British Columbia

In 1999, the combined discharge from E.F.A. Hosiery Manufacturing and West Coast Woolen Mills 1986 constituted an inflow of 0.0020 m^3/s to the Vancouver regional MWWTP. That plant provided a primary level of treatment with a total discharge estimated at 4 m^3/s. The assumed toxicity level after treatment of 20 TUs will be reduced to 0.01 TU before the end of pipe at the MWWTP; therefore, the TME component of the effluent would not exhibit sublethal toxicity to *C. dubia* at the point of discharge.

Hypothetical primary-treated TME plume dispersions

Plume dispersion calculations were conducted to predict the spatial extent of hypothetical primary-treated TME discharges. An initial toxicity value of 20 TUs was used for those calculations, based on the median of all 7-day IC_{25}s for *C. dubia* reproduction that were available for primary-treated effluents. The results of several scenarios are plotted in Figure 8, assuming initial discharge plume widths of 1 m. That figure shows that with an ambient current of 5 cm/s, chronic toxicity levels from primary-treated TME discharges that are undiluted by any MWWTP additions will be reduced to 1 TU from 100 m to approximately 1000 m downstream of the outfall.

Weight of evidence for other primary-treated TME discharges

The whole-effluent toxicity data for Canada indicated that most primary-treated TME samples tested were acutely lethal to fish (96-hour LC_{50}s 18 –>100%) and invertebrates (48-hour and 7-day LC_{50}s 6.5–71%). Sublethal effects of primary-treated TMEs include reproductive impairment in invertebrates (7-day IC_{25}s 2.2–6.8%) and growth impairment in algae (72-hour IC_{50}s 35–58%) (Environment Canada, 1988, 1989, 1991a,b,c,d,e, 1992d, 1994, 1995; Chen, 1989; Harris Industrial Testing Service, 1992, 1997, 1998, 1999; Rutherford *et al*., 1992, 1998; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995; Rutherford, 1999).

Primary-treated TMEs can contain very high concentrations of NP and NPEs (Bennie, 1999). For primary-treated TME samples in Canada, EEV_{TEQ}s for NP and NPEs ranged widely between 48 and 2260 µg/L (n = 5; 2 sites) (Rutherford, 1999). All samples fell within the range of acute toxicity thresholds for fish and invertebrates reported by Servos (1999) and exceeded NOEC benchmarks for chronic toxicity to fish and invertebrates.

One of two primary-treated TME samples exhibited estrogenic properties using the YES assay (Burnison *et al*., 1999).

3.1.3 Summary of risk characterization

TMEs are entering the Canadian environment at an estimated total volume of 105 000 m^3/day. The geographic locations of textile mills in Canada and estimates of volumes of effluent that they discharge to the Canadian environment have been identified. A wide variety of chemicals are used in wet processing operations, many of which are discharged in TMEs. While TMEs may vary substantially in their chemical and physical characteristics according to wet processes conducted, the toxicity and environmental effects seem to be quite consistent for mills employing different treatment processes. The toxicity and environmental effects of TMEs vary substantially according to the level of treatment that they receive prior to discharge. In 1999, most mills in Canada (95%) discharged to MWWTPs; however, some (4%) had dedicated treatment systems. In 1999, there were 2 mills in Canada that discharged untreated TMEs to the aquatic environment, while the effluents from 41 mills had primary treatment, 89 mill effluents had secondary wastewater treatment and 13 mill effluents had tertiary wastewater treatment.

The risk characterization was conducted according to the level of wastewater treatment provided prior to discharge. There was no evidence that the effluents of mills that were subject to tertiary treatment at MWWTPs were causing environmental harm; based on a conservative risk assessment, it was determined that such mills do not represent a significant threat to the environment. Although some secondary-treated wastewaters containing TMEs produced sublethal toxicity in whole-effluent toxicity testing, there was no evidence of environmental impacts, and a conservative risk assessment indicated that such effluents did not represent a significant threat to the environment. A weight-of-evidence assessment of the data available for untreated TMEs indicated that untreated effluents were likely to produce significant environmental impacts. That conclusion was weighted heavily on the data that indicated that an untreated TME discharge produced changes in the benthic macroinvertebrate community for several hundred metres below the outfall that would alter ecological processes. Plume dispersion predictions for untreated TME discharges indicated that chronic aquatic toxicity could be expected in receiving environments hundreds of metres downstream from outfalls, depending on the strength of the ambient river current. The whole-effluent toxicity, *in situ* toxicity and NP and NPE EEV_{TEQ} data indicated that untreated TMEs would produce environmental harm at the population level. Although mutagenicity and potential endocrine disrupting effects were measured in untreated TMEs, little weight could be placed on those endpoints because of uncertainties regarding their effects on individuals.

Data were not available that could be used to assess whether primary-treated TMEs have an impact on benthic macroinvertebrate communities; however, whole-effluent toxicity data, combined with predicted TME plume dispersion rates and ambient toxicity data, supported the conclusion that such effluents would have a significant impact on aquatic populations. There were also some sediment toxicity data that supported such a conclusion; however, not much weight was placed on that information, as the spatial extent of environmental harm was deemed low. It was judged that the evidence for endocrine disrupting potential of primary-treated effluents was not strong enough to allow the derivation of conclusions regarding impacts on individuals.

In summary, the weight of evidence indicated that untreated TMEs have an ecological impact at the community and population level, while primary-treated TMEs can be assumed to have effects at the population level. It is our opinion that discharges of untreated TMEs have been demonstrated to have a detrimental effect on the Canadian environment, while there is sufficient reason to believe that discharges of primary-treated TMEs will also negatively affect the Canadian environment. Similar conclusions were derived for TMEs in the PSL assessment of NP and its ethoxylates. In that risk assessment, it was concluded that concentrations of NP and its ethoxylates in untreated and partially treated TMEs discharged to the aquatic environment occur at levels that are likely to be causing harmful effects on aquatic organisms (Environment Canada and Health Canada, 2000a).

3.1.4 Uncertainties in the environmental risk characterization

There are a number of uncertainties associated with the environmental risk characterization that are due to knowledge and data gaps in the current literature on TMEs:

- The dilution of TMEs by ambient freshwater or marine water bodies was assumed to be a factor of 17 (17% effluent in the receiving environment) in the Tier 1 assessment, but that is likely to vary considerably both spatially and temporally. Mean annual dilution factors of water bodies receiving TMEs range from 19 to 9.7 million and vary with seasonal flow conditions. The dilution factor can play a large role in the calculation of risk quotients in the Tier 1 assessment. However, it is believed that a dilution factor of 17 was an appropriate conservative value to represent the areas near TME outfalls, as it represented the lowest river flow to cumulative mill flow ratio for all TME discharges in Canada.

- To derive the CTV, or low toxic effect, for the Tier 1 assessments, the 7-day IC_{25}s for *C. dubia* were used. That test was found to be sensitive to the effects of TMEs. While the database for *C. dubia* reproduction effects from untreated TMEs was sufficient (20 samples from 12 mills), there were limited data for primary-treated TMEs (3 samples from 3 sites), secondary-treated wastewaters containing TMEs (7 samples from 4 sites) and tertiary-treated wastewaters containing TMEs (4 samples from 4 sites). Although there were a limited number of bioassay results for some treatment types, the results of those tests were similar for primary-treated TMEs (7-day IC_{25}s ranged from 2.2% to 6.8%) and for tertiary-treated wastewaters containing TMEs (7-day IC_{25}s >100%), with the only variability observed being in secondary-treated wastewaters containing TMEs (7-day IC_{25}s ranged from 56.% to >100%).

- To derive the CTV for the Tier 1 assessment, as well as in the evaluation of the whole-effluent toxicity data in the weight-of-evidence assessment, a large proportion of the toxicity data used were collected from MWWTPs, since only two mills in Canada have on-site secondary wastewater treatment, and no mills have on-site tertiary treatment systems. TMEs represent only a fraction of the wastewater volume at MWWTPs, and factors such as dilution within the treatment plant or the influence of contaminants from other sources could have altered the measured toxicity characteristics of MWWTP effluents containing TMEs. In the field studies conducted in support of this assessment, efforts were made to select study sites where textile mills were the major industrial input to the MWWTP.

- Some constituents of TMEs likely partition to sediment in the environment; however, limited data on the impact of TMEs on sediment-dwelling organisms were found. Few studies have been conducted in Canada on the impact of TME discharges on benthic macroinvertebrate communities or on the toxicity of sediments near TME outfalls. That is likely because few textile mills have on-site treatment systems where studies of effects on sediment-dwelling organisms can be conducted without confounding effects from other contaminant discharges (i.e., from MWWTPs). In addition, receiving environments adjacent to mills with their own wastewater treatment systems were not conducive to those types of field investigations (i.e., other pollutant sources in the receiving environments, lack of sediment for sediment bioassays, etc.). Data on the impact of primary-treated TMEs on benthic macroinvertebrate communities in receiving environments, if available, would have contributed significantly to the determination of environmental risk for those effluent discharges.

- While the assessment attempted to examine the impact of TMEs on individuals in the environment, particularly endocrine disruption-related effects of untreated and treated TMEs demonstrated by YES assays, much of that information is still evolving and needs to be validated. The YES assay measures only one mechanism of action, estrogenic activity, and not other endocrine-related endpoints. A significant amount of method development was required to utilize the YES assays in testing highly coloured and toxic untreated TMEs. Those methods have not been standardized or published. While it was deemed important to consider endocrine-mediated mechanisms of toxicity in the assessment, the lack of confidence and uncertainty in the interpretation of the data were seen as limitations in using those data in the weight-of-evidence assessment.

- The TME plume dispersion calculations were designed to be as simple as possible to derive reasonable "ballpark" estimates of spatial influence of TME discharges. Those calculations were based on assumptions of watercourse characteristics and velocity that, if measured on a site-specific basis, would provide a more accurate estimate of the zone of influence of individual TME discharges.

- Much of the risk assessment was based on the results of toxicity testing of either whole-effluent samples or ambient water samples. Although application factors were used to compensate for the uncertainty in extrapolating laboratory toxicity test results to field effects, it is believed that such factors still provide a substantial level of uncertainty in the risk calculations.

- The risk assessment depended heavily on aquatic toxicity tests that were relatively short term. Whole-effluent toxicity testing cannot predict the potential for longer-term effects that may be due to the persistence and possible bioaccumulation of certain components of TMEs. It is believed that those effects would likely increase the level of environmental risk associated with TMEs.

3.1.5 Conclusions

CEPA 1999 64(a): Based on the available data, it is concluded that textile mill effluents are entering the environment in a quantity or

	concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Thus, it is concluded that textile mill effluents should be considered "toxic" as defined in Section 64 of CEPA 1999 and that the evaluation of options under CEPA 1999 to reduce exposure should be considered a priority at this time.
CEPA 1999 64(b) and 64(c):	No conclusions can be made, as TMEs were not evaluated for impacts on the environment on which life depends or for impacts on human health.
Overall conclusion:	Based on critical assessment of relevant information, textile mill effluents are considered to be "toxic" as defined in Section 64 of CEPA 1999.

3.1.6 Considerations for follow-up (further action)

It is recommended that options to reduce environmental risk be examined on a site-specific basis.

In addition, it is recommended that pollution prevention opportunities and control technologies for the management of TMEs be identified and evaluated. Pollution prevention opportunities to be examined should include, but not be limited to, reducing material inputs, re-engineering processes to reuse by-products, improving process management practices and employing substitution of less-polluting chemicals. Control technologies to be examined should include, but not be limited to, secondary and tertiary treatment and improving the performance of existing treatment systems through modifications and technological upgrades.

It is recommended that particular attention be paid to the use and release of NP and its ethoxylates from textile mills, as high concentrations of those substances exceeding acute and chronic toxicity thresholds were observed in untreated or primary-treated TMEs.

Given the fact that most textile mills in Canada have their wastewater treated at MWWTPs, it is recommended that discussions with the appropriate authorities (municipal and/or provincial) be undertaken to address the risks. This may require additional effects monitoring of TMEs and municipal effluents.

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Appendix A Search Strategies Employed for Identification of Relevant Data

Data relevant to the assessment of whether TMEs are “toxic” to the environment under CEPA 1999 were identified from existing review documents, published reference texts and on-line searches of the following databases for the period 1965–1999: Aqualine (Water Research Centre, Buckinghamshire), Aquasci, ASFA (Aquatic Sciences and Fisheries Abstracts, Cambridge Scientific Abstracts), BIOSIS (Biosciences Information Services), CAB Abstracts (Commonwealth Agriculture Bureaux), Current Contents (Institute for Scientific Information), Datalog (Syracuse Research Corp.), Desk References, Dunn & Bradstreet Canada Database of Canadian Manufacturers, ELIAS (Environmental Library Integrated Automated System, Environment Canada library), ENVIRODAT (Environment Canada), Environmental Abstracts, Envirosource (Environment Canada), ETAD (Ecological and Toxicological Association of Dyes and Organic Pigment Manufacturers, Basel), Hazardous Substances Database (Province of Quebec), HCA, HYDAT (Hydrological Database, Environment Canada), Life Sciences (Cambridge Scientific Abstracts), MUD (Municipal Water Use Data, Environment Canada), National Emission Inventory (Canadian Chemical Producers Association), National Registry of Toxic Chemical Residues (National Wildlife Research Centre, Environment Canada), NPRI (National Pollutant Release Inventory, Environment Canada), NTIS (National Technical Information Service, U.S. Department of Commerce), Pollution Abstracts (Cambridge Scientific Abstracts, U.S. National Library of Medicine), POLTOX (Cambridge Scientific Abstracts, U.S. National Library of Medicine), RTECS (Registry of Toxic Effects of Chemical Substances, U.S. National Institute of Occupational Safety and Health), Statistics Canada, Toxic Chemical Release Inventory (Office of Toxic Substances, U.S. Environmental Protection Agency) and Toxline (U.S. National Library of Medicine).

Two surveys of the Canadian textile industry were carried out to collect information for the TME assessment. A voluntary survey in association with the Canadian Textiles Institute was conducted in 1997 and was followed by a mandatory survey conducted in 1999 under the authority of Section 16 of CEPA (Environment Canada, 1999a).

Data obtained after January 2000 were not considered in this assessment unless they were critical data received during the 60-day public review of the report (July 1 to August 30, 2000).

Appendix B Wastewater Treatment Processes Applied to Textile Mill Effluents[1]

Degree of treatment	Definition
Untreated	The combined, raw process water from a facility (may have preliminary treatment such as screening, grit removal, flow equalization and/or pH neutralization).
Primary treatment	Primary treatment removes from wastewater those pollutants that will either settle out or float. It includes sedimentation with or without chemical addition, gas flotation with or without chemical addition and filtration.
Secondary treatment	Secondary treatment is generally biological treatment and includes activated sludge, trickling filter, lagoons of many types and rotating biological contractors.
Tertiary treatment	Tertiary treatments that may be applied to TMEs include activated carbon adsorption, chemical oxidation, air stripping, ion exchange, polymeric adsorption, reverse osmosis, ozonation and chemical reduction.

[1] U.S. EPA (1976); Klaamas (1997).

APPENDIX C AQUATIC TOXICITY DATA FOR UNTREATED TMEs[1]

Test	Toxicity (% v/v)			n	No. of sites	References
	Range	Median	Mean			
Oncorhynchus mykiss 96-hour LC_{50}	3.90–71.0	17.7	24.4	26	14	Environment Canada, 1988, 1989, 1991a,b,c,d,e, 1992d, 1994, 1995; Chen, 1989; Harris Industrial Testing Service, 1992, 1997, 1998, 1999; Rutherford *et al*., 1992; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995
Daphnia magna 48-hour LC_{50}	0.80–46.0	17.7	18.8	29	8	Environment Canada, 1991a,b,c,d,e; Rutherford *et al*., 1992; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995
Vibrio fischeri 15-minute EC_{50}	1.50–91	6.40	11.7	50	17	Environment Canada, 1991a,b,c,d,e; Rutherford *et al*., 1992, 1998; Rutherford, 1999
Vibrio fischeri LOEC	0.06–5.0	2.25	2.19	10	7	Rutherford *et al*., 1998
Ceriodaphnia dubia 7-day LC_{50}	3.22–66.7	10.5	18.7	26	15	Rutherford *et al*., 1992, 1998; Rutherford, 1999
Ceriodaphnia dubia 7-day IC_{25}	1.10–20.8	4.69	7.20	20	12	Rutherford *et al*., 1992, 1998; Rutherford, 1999
Selenastrum capricornutum 72-hour IC_{50}	0.10–79.7	19.5	28.3	26	14	Rutherford *et al*., 1992, 1998; CREA Lab, 1995; Rutherford, 1999

[1] All tests were conducted in conformance with Environment Canada Biological Test Methods (Environment Canada, 1990a,b, 1992a,b,c).

APPENDIX D AQUATIC TOXICITY DATA FOR TREATED TMEs[1]

Test	Sample type[2]	Toxicity (% v/v)			n	No. of sites	References
		Range	Median	Mean			
Oncorhynchus mykiss 96-hour LC_{50}	P	18.0–>100	75.0	65.9	8	2	Environment Canada, 1988, 1989, 1991a,b,c,d,e, 1992d, 1994, 1995; Chen, 1989; Harris Industrial Testing Service, 1992, 1997, 1998, 1999; Rutherford *et al*., 1992; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995
	S	80.0–>100	>100	97.5	8	6	
	T	ND[3]	ND	ND	ND	ND	
Daphnia magna 48-hour LC_{50}	P	40.0–70.7	55.4	55.4	2	1	Environment Canada, 1991a,b,c,d,e; Rutherford *et al*., 1992; CREA Lab, 1995; Les Laboratoires Shermont Inc., 1995
	S	>100	>100	>100	3	3	
	T	ND	ND	ND	ND	ND	
Vibrio fischeri 15-minute EC_{50}	P	1.31–>99.0	15.9	36.1	8	3	Environment Canada, 1991a,b,c,d,e; Rutherford *et al*., 1992, 1998; Rutherford, 1999
	S	34.3–>99.0	>99.0	86.1	11	6	
	T	>99.0	>99.0	>99.0	6	3	
Vibrio fischeri LOEC	P	ND	ND	ND	ND	ND	Rutherford *et al*., 1998
	S	25.0–>100	50.0	65.0	5	3	
	T	>100	>100	>100	2	1	
Ceriodaphnia dubia 7-day LC_{50}	P	6.53–17.7	6.59	10.3	4	3	Rutherford *et al*., 1992, 1998; Rutherford, 1999
	S	61.1–>100	100	90.9	7	4	
	T	>100	>100	>100	4	4	
Ceriodaphnia dubia 7-day IC_{25}	P	2.24–12.9	5.00	4.69	4	3	Rutherford *et al*., 1992, 1998; Rutherford, 1999
	S	56.0–>100	91.2	81.3	7	4	
	T	>100	>100	>100	4	4	
Selenastrum capricornutum 72-hour IC_{50}	P	35.2– 57.7	46.5	46.0	2	2	Rutherford *et al*., 1992, 1998; CREA Lab, 1995; Rutherford, 1999
	S	30.4–>100	100	91.3	8	4	
	T	>100	>100	>100	4	4	

[1] All tests were conducted in conformance with Environment Canada Biological Test Methods (Environment Canada, 1990a,b, 1992a,b,c).

[2] Sample type: P = primary-treated TME; S = secondary-treated TME; T = tertiary-treated TME.

[3] ND = No data available.

Appendix E NP and NPE Concentrations[1] and Calculated EEV_{TEQ} Values for Untreated TMEs and On-site Primary- and Secondary-treated TMEs

Textile mill	Date	Sample type[2]	4-NP (µg/L)	NP1EO (µg/L)	NP2EO (µg/L)	NP3–17EO (µg/L)	Total EEV_{TEQ}[3] (µg/L)
Britex, Bridgetown,	9-Jul-96	U	904.6	101.4	140.5	8167	1066
Nova Scotia	10-Jul-96	U	799.3	254.4	583.4	96.42	1219
	11-Jul-96	U	185.4	213.4	479.0	189.0	532.5
C.S. Brooks, Magog,	17-Mar-98	U	0.68	0.23	0.21	7.77	0.94
Quebec	8-May-98	U	0.26	1241	0.000[4]	853.0	624.8
Cambridge Towel,	13-Mar-98	U	0.23	5.43	11.80	210.4	9.89
Cambridge, Ontario	13-May-98	U	0.95	17.70	39.33	189.1	30.41
Coats Bell, Arthur, Ontario	22-Apr-99	U	0.38[5]	36.40	36.60	2040	47.08
CookshireTex,	18-Mar-98	U	7.41	14.13	128.3	1409	85.69
Cookshire, Quebec	6-May-98	U	3.47	34.99	241.1	3271	157.9
Lainages Victor,	20-Mar-98	U	3.35	92.77	488.6	7905	333.5
St-Victor, Quebec	5-May-98	U	2.68	57.90	506.4	8811	328.9
	15-Jul-99	U	0.38[5]	114	1090	29600	750.4
Les Industries Troie, St-Pamphile, Quebec	14-Jul-99	U	1.95	4.37	43.80	7090	61.49
Montreal Woolens,	13-Mar-98	U	25.62	65.10	218.7	4162	188.3
Cambridge, Ontario	12-May-98	U	15.48	51.53	233.6	4834	182.2
Penman's, Cambridge,	13-Mar-98	U	0.58	69.15	252.3	4567	184.2
Ontario	13-May-98	U	2.84	25.57	171.3	3436	118.5
Spinrite, Listowel, Ontario	21-Apr-99	U	21.3	9.04	7.30	271	30.83
Stanfield's, Truro,	3-Jul-96	U	5.84	14.7	31.55	1828	38.10
Nova Scotia	4-Jul-96	U	4.90	8.67	27.76	1459	30.41
	5-Jul-96	U	3.05	8.80	27.03	2559	33.76
Tandem Fabrics,	16-Jul-96	U	211	1.54	0.97	319.9	4.96
Moncton, New Brunswick	17-Jul-96	U	106	2.32	2.32	50.18	3.63
	18-Jul-96	U	153	0.74	0.64	147.9	2.95
Tiger Brand, Cambridge,	13-Mar-98	U	0.58	18.10	204.5	6846	146.1
Ontario	13-May-98	U	2.89	39.70	276.4	5768	189.8
Wink Industries,	19-Feb-98	U	1.05	21.19	54.58	3987	58.87
Caraquet, New Brunswick	4-Jun-98	U	5.75	13.60	70.19	1286	54.08
Britex, Bridgetown,	9-Jul-96	P	11.32	257.1	592.0	798.4	439.8
Nova Scotia	10-Jul-96	P	13.33	37.17	115.0	4065	109.8
	11-Jul-96	P	10.39	48.63	106.3	8636	131.1
	3-Nov-99	P	1930	498	149.0	987	2258
Coats Bell, Magog, Quebec	21-Apr-99	P	0.38[5]	25.70	63.40	613	48.00

(continued)

Textile mill	**Date**	**Sample type** [2]	**4-NP (µg/L)**	**NP1EO (µg/L)**	**NP2EO (µg/L)**	**NP3–17EO (µg/L)**	**Total EEV_{TEQ}** [3] **(µg/L)**
C.S. Brooks, Magog,	17-Mar-98	S	0.68	1870	0.000 [4]	315.45	937.2
Quebec	8-May-98	S	0.05 [5]	0.52	0.25	2.59	0.44
Wink Industries, Caraquet,	19-Feb-98	S	0.60	4.10	3.92	208.09	5.65
New Brunswick	4-Jun-98	S	3.56	1.12	0.93	2.07	4.59

1 Bennie (1998); Rutherford (1999).

2 Sample type: U = untreated, P = on-site primary treatment, S = on-site secondary treatment.

3 Total $EEV_{TEQ} = \sum$ (4-NP µg/L) (1) + (NP1EO µg/L) (0.5) + (NP2EO µg/L) (0.5) + (NP3–17EO µg/L) (0.005).

4 NP1EO and NP2EO were not resolvable due to high concentrations; number listed under NP1EO is the sum of both parameters.

5 Where NP and NPEs were not detected in samples, those values were presented as the method detection limit (MDL)/2 in order to calculate EEV_{TEQ}s.

APPENDIX F MILL DISCHARGE SITES

City	Textile mill company name	MWWTP name [1]	Receiving water body	Treatment	TME flow [2] (m^3/day)	MWWTP flow (1000 m^3/day)
Windsor	Nova Scotia Textiles	None	St. Croix River	None	121	N/A
Ste-Anne-de-la-Pérade	Les Tricots Godin	None	Ste. Anne River	None	16	N/A
Bridgetown	Britex	Britex	Annapolis River	Primary	1130	1.1
Moncton	Tandem Fabrics	City of Moncton	Peticodiac River	Primary	400	86.4
Cornwall	Richelieu Hosiery International	Cornwall WPCP	St. Lawrence River	Primary	73	43.2
Vancouver	E.F.A. Hosiery Manufacturing	GVRD	Strait of Georgia	Primary	176	346
Vancouver	West Coast Woolen Mills 1986	GVRD	Strait of Georgia	Primary		
St-Jean-sur-Richelieu	J.B. Martin	Haut-Richelieu	Richelieu River	Primary	765	69.1
St-Jean-sur-Richelieu	Textiles Novacolor	Haut-Richelieu	Richelieu River	Primary		
Montréal	Wertex Hosiery	MUC	St. Lawrence River	Primary	28 753	2765
Montréal	Gordon Yarns Dyers	MUC	St. Lawrence River	Primary		
Montréal	Domino (1986)	MUC	St. Lawrence River	Primary		
Saint-Laurent	Blanchissage Royal	MUC	St. Lawrence River	Primary		
Montréal	Bonneterie Avalon 1992	MUC	St. Lawrence River	Primary		
Montréal	Bonneterie Paris Star	MUC	St. Lawrence River	Primary		
Dorval	2998530 Canada	MUC	St. Lawrence River	Primary		
Ville St-Michel	Cansew	MUC	St. Lawrence River	Primary		
Montréal	Colorfast	MUC	St. Lawrence River	Primary		
Montréal	Doubletex	MUC	St. Lawrence River	Primary		
Verdun	Supreme Dyeing	MUC	St. Lawrence River	Primary		
Montréal	American & Efird Canada	MUC	St. Lawrence River	Primary		
Montréal	Finition & Teinture Drouin	MUC	St. Lawrence River	Primary		
Montréal	Giltex, Division of Canadelle	MUC	St. Lawrence River	Primary		
Montréal-Est	Les Teinturiers Hubbard (1991)	MUC	St. Lawrence River	Primary		
Montréal	Impression Permanentes	MUC	St. Lawrence River	Primary		
Lachine	Lagran Canada (Division of Leedye)	MUC	St. Lawrence River	Primary		
Montréal	Industries de Lavage Dentex	MUC	St. Lawrence River	Primary		
Saint-Laurent	Manufacture de Bas Gina	MUC	St. Lawrence River	Primary		
Montréal	Manufacturier de Bas Culotte L'Amour	MUC	St. Lawrence River	Primary		
Montréal	Michel Exclusif	MUC	St. Lawrence River	Primary		

(continued)

City	Textile mill company name	MWWTP name[1]	Receiving water body	Treatment	TME flow[2] (m^3/day)	MWWTP flow (1000 m^3/day)
Montréal	Nalpac	MUC	St. Lawrence River	Primary		
Montréal	Siebruck Hosiery	MUC	St. Lawrence River	Primary		
Montréal	Teinture et Finition Prestige	MUC	St. Lawrence River	Primary		
Montréal	Perfect Dyeing Canada	MUC	St. Lawrence River	Primary		
Montréal	Teinturerie Performance	MUC	St. Lawrence River	Primary		
Montréal	Agmont America	MUC	St. Lawrence River	Primary		
Ville D'Anjou	Les Teinturiers Concordes Dyers	MUC	St. Lawrence River	Primary		
Montréal	Tex-Dye	MUC	St. Lawrence River	Primary		
Saint-Laurent	Manoir Knitting	MUC	St. Lawrence River	Primary		
Lasalle	Pacalis Dyeing & Finishing	MUC	St. Lawrence River	Primary		
Montréal-Nord	Manufacturier de Bas Iris	MUC	St. Lawrence River	Primary		
Anjou	Vinatexco	MUC	St. Lawrence River	Primary		
Prescott	Prescott Finishing	Prescott WPCP	St. Lawrence River	Primary	287	3.4

[1] WPCP = Water Pollution Control Plant; GVRD = Greater Vancouver Regional District; MUC = Montreal Urban Community.

[2] The TME flow presented is the total volume of TMEs for all mills discharging to an MWWTP.