Review of the State of Knowledge of Municipal Effluent Science and Research

Review of Effluent Substances

Report Prepared for:

Development Committee for the MWWE Canada-Wide Strategy
Canadian Council of Ministers of the Environment

Report Prepared by:

Hydromantis Inc.
Minnow Environmental Inc.
University of Waterloo, Dept. of Civil Engineering

June 2005

PN 1356

TABLE OF CONTENTS

LIST OF TABLES

After Page …

LIST OF APPENDIX TABLES

GLOSSARY OF TERMS

Anthropogenic	Related to human activity
Biological nutrient removal	A wastewater treatment process that relies on microorganisms for removal of nitrogen and phosphorus
Carcinogenity	The ability of a substance to cause cancer
Congener	A substance which by structure, function or origin is similar to another
Cyanobacteria,	A class of algae, also referred to as blue-green algae
EC_{50}	The concentration of a substance which exerts an effect (typically some form of toxicity) to 50 % of the test population
Emerging Substance	A substance that is ay have been in existence for some time, but only recently has attracted interest because of potential environmental concerns
Halogenated	Containing a member of the halogen chemical group, which include, fluorine, chlorine, bromine and iodine
Heterocyclic	A substance which contain a chemical cyclic ring structure in which other atoms than carbon, such as sulfur, oxygen or nitrogen are found as part of the ring.
Hydrophilic	The tendency of a substance to have an affinity for the water phase
Hydrophobic	The tendency of a substance to have an affinity for the non-aqueous phase
Lentic	of or relating to or living in still waters (as lakes or ponds)
Lotic	of or relating to or living in actively moving water
Lipophilic	The tendency of a substance to have an affinity for lipids (fatty material)
Metabolite	A substance that is the result of biological transformation (metabolism) of another substance (referred to as the “parent” substance

Metalloid	A substance that can behave as either a metallic or non-metallic substance
Methemoglobinemia	A medical condition also called infantile cyanosis, or blue baby syndrome
Nephelometric	Causing the scattering of light
Nutraceuticals	biologically active food supplements, typically botanical-based substances
Nitrification	A wastewater treatment process in which microorganisms convert ammonium-nitrogen to nitrate- and nitrite-nitrogen
Polybrominated diphenyl ethers	A class of brominated organic compounds that are used as flame retardants
Priority Pollutant	A name applied to substances in wastewater that were designated by the U.S. EPA to be of environmental significance in the late 1970s
Plaque-forming units	A measurement of the concentration of viruses in a water sample
Reverse Osmosis	A wastewater treatment process in which water is purified by driving the water through a membrane at high pressure, leaving behind the impurities in a concentrated waste stream
Soil Aquifer Treatment	Treatment of wastewater by infiltration through soil
Smoltification	The physiological change that salmon and similar fish undergo in freshwater while migrating toward saltwater that allow them to live in the ocean
Terpenes	a class of hydrocarbons, produced by many plants, particularly evergreens
Total organic carbon	A measure of wastewater strength based on the presence of all organic chemical compounds
Turbidity	A measure of the light-scattering potential of a water sample

ACRONYMS

APEO	Alkylphenol ethoxylate
BNR	Biological nutrient removal
BOD	Biochemical Oxygen Demand
CAS	Chemical Abstract Service
CCME	Canadian Council of Ministers of the Environment
CEPA	Canadian Environmental Protection Act
COA	Canada-Ontario Agreement
CSO	Combined sewer overflow
CWWA	Canadian Water and Wastewater Association
DC	Development committee (of CCME)
DWSPL	Drinking Water Substances Priority List
E1	Estrone, a hormone metabolite
E2	17β-Estradiol, a natural hormone
EE2	17α-Ethinylestradiol, a synthetic contraceptive compound
E3	Estriol, a hormone metabolite
EDC	Endocrine disrupting compound
EPA	Environmental Protection Agency
FOG	Fats, oil and grease
MWWE	Municipal Wastewater Effluent
NOEC	No observable effect concentration
NPEO	Nonylphenol ethoxylate (a type of APEO)
NTU	Nephelometric turbidity unit
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated diphenyl ether

PCBs	Polychlorinated biphenyls
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulphonate
(PFU)	Plaque-forming units
POP	Persistent organic pollutant
PPCP	Pharmaceutical and personal care products
RO	Reverse osmosis
SAT	Soil aquifer treatment
SSO	Sanitary sewer overflow
STWs	Sewage treatment works
TOC	Total organic carbon
TSS	Total suspended solids
WHO	World Health Organization

EXECUTIVE SUMMARY

Background

In November 2003, the Canadian Council of Ministers of the Environment (CCME) agreed to develop a Canada-wide strategy for municipal wastewater effluent (MWWE). The Strategy involves three principal tenets, including:

- Harmonizing the regulatory framework among the federal, provincial and territorial jurisdictions;
- Coordination of science and research activities; and
- Use of an environmental risk management model to guide decision making.

For the Strategy to be effective, the Development Committee (DC) must understand the current state of knowledge on MWWE; i.e., the science and research, evolving treatment technologies and best management practices. Consequently, the DC has commissioned this study to provide a comprehensive review of the current state of knowledge of MWWE science and technology respecting the treatment of conventional pollutants as well as emerging substances of concern.

The objectives of the entire study were to:

1. Prepare a comprehensive consolidated inventory of harmful substances and emerging problematic substances found or likely to be found in Canadian MWWE. Identify substance sources, typical effluent concentrations, and an annotated assessment of effects on the natural aquatic environment and on human health associated with the various substances or groups of substances.
2. Prepare an annotated summary of existing and emerging treatment technologies for treatment of conventional pollutants, harmful substances and emerging pollutants from objective 1. The technologies will be assessed for their applicability to variations in Canadian climates, environments, regions and receiving waters.
3. Provide a review of best management practices for specific issues related to municipal wastewater treatment, including but not limited to:
    - Infiltration and inflow to municipal sewer systems
    - Reduction and treatment of sanitary and combined sewer overflows (SSOs and CSOs)

- Management of hauled wastes such as septage, landfill leachate or industrial/commercial wastewaters
- Small or remote community wastewater issues, including treatment cost and pollutant management
- Discharges of treated effluents to marine environments
- Lagoon issues, including ice cover and ammonia removal in winter, and algae removal in summer
- Flow reductions to wastewater treatment plants using alternative technologies and source control plans, including water reuse and reclamation technologies
- Aging collection system needs and upgrading practices
- Wastewater treatment facility performance monitoring and quality control practices.

This report addresses the first study objective and constitutes the deliverable for Task 1.

Methodology

Compilation of Substance Master List

The initial task involved the development of a list of wastewater substances for investigation and categorization. Many agencies or organizations, including a number to which Canada has been a collaborator, have established lists of substances of concern in the water environment as part of their agreement principles. The master list for this project was compiled from a number of environmentally significant lists, including the Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes with 25 priority toxics; the Canada-Ontario Agreement (COA) Respecting the Great Lakes Basin Ecosystem with 41 substances, and the European Union list of 33 priority substances in “Annex X” of the Water Framework Directive (2000/60/EC). The master list also included substances for which water quality guidelines have been developed by either Canadian (CCME) or U.S. (EPA) jurisdictions. A number of mostly non-specific substances that have often been monitored in MWWE (sometimes referred to as “conventional” parameters) were added to the Master List, including biochemical oxygen demand, colour, hardness, oil and grease, dissolved oxygen, pH, phosphorus, temperature, total dissolved solids, totals suspended solids, total organic carbon, total residual chlorine and turbidity.

Substances from two drinking water lists were included in the master list: Health Canada's Guidelines for Canadian Drinking Water Quality, and Health Canada's Drinking Water Substance Priority List. The drinking water substances were included in the municipal effluent substance list on the basis that data regarding human health effects of waterborne substances would be applicable to treated effluents as well, although drinking water guidelines *per se* would be applicable only to surface and groundwaters used as drinking water sources and not directly applicable to effluent.

Finally, the list was filtered to eliminate entries that were not applicable to an evaluation of municipal wastewater effluents, such as listings for taste, gasoline or other fuels, asbestos, sulphur and nitric oxides, and many of the chlorofluorocarbons or bromofluorocarbons that are of concern to air pollution. The compiled master list was comprised of a total of 242 substances.

Substance Categorization

From the Master list, the substances were categorized in three ways.

Method 1. Grouping by Chemical Class and Chemical Abstract Service (CAS) Number. This procedure recognizes that lists of substances are often organized according to the type of chemical and chemical structure and that users may seek information based on certain traditional groupings by chemical class.

Method 2. Grouping by Environmental Effects. Most substances on the Master List are there because of documented environmental and/or human health effects. Substances were sorted in terms of their environmental properties, such as whether they are persistent, bioaccumulative, and toxic or exhibit other important attributes.

Method 3. Grouping by Wastewater Process Treatability. Different levels of wastewater treatment will remove substances to different extents. Although there are many processes in use across Canada, the recommended classifications are: lagoon, primary, secondary, tertiary biological nutrient removal (BNR), tertiary filtration and several advanced processes (such as membranes) that are capable of additional reductions of the substances.

Sources of the wastewater substances were identified as either domestic, industrial/commercial or diffuse in nature, but the categories are not mutually exclusive. For example, some pesticides may enter wastewater treatment systems either from domestic use (insecticides for pets, wash-up of herbicide applicators) or from industrial manufacture or use. Substances from domestic sources include a variety of non-specific (conventional) pollutants, metals, organics, pharmaceuticals and personal care products. Substances from industrial or commercial

sources are those that are manufactured, used or generated as by-products in processing. The industrial sources of substances in municipal wastewater were categorized by the 5-digit North American Industry Classification System. Substances from diffuse sources are those that enter the wastewater system from surface runoff or combined sewer systems, such as metals, oil and grease, pesticides and polycyclic aromatic hydrocarbons, PCBs, dioxins and furans, and pathogenic organisms.

Substance Assessment

Environmental benchmarking concentration guidelines, above which effects on aquatic biota, human health or human uses of water would result, were tabulated to identify those substances of greatest potential concern in municipal wastewater effluents. National guidelines developed by CCME or the U.S. EPA, established by rigorous technical review, were adopted for this purpose. CCME guidelines were preferentially selected and U.S. EPA guidelines were used in cases where a CCME guideline has not been developed for a given substance. In the absence of Canadian or U.S. national guidelines, provincial guidelines were selected to allow for a broader range of substances to be considered in the evaluation. Because the protocols for provincial guidelines development may not have been consistently subjected to the same rigorous protocols and level of scientific scrutiny, Substances that exceeded provincial water quality guidelines in MWWE have been recommended for further investigation of the basis for the guideline

Concentrations of substances in municipal effluents were compiled from a number of sources, including a government reports, from municipalities in Western and Central Canada, and from the technical literature. The literature reviewed included in-house sources, published literature reviews and conference proceedings, and from internet searches. The effluent concentration data were entered into a spreadsheet containing the Master List of substances to allow comparison to benchmark concentrations. Data were also sought for representative concentrations of “emerging” substances of concern. Because these substances are in the emerging state of knowledge, there are few water quality guidelines available for use as benchmarks in comparisons. Because of the interest in effluent irrigation in Central and Western Canada, concentrations of emerging substances in groundwater or in soil aquifer treatment were reviewed.

Any substance that exceeded its respective CCME (or EPA) benchmark concentration for human or ecological protection was identified as a substance of potential concern for aquatic environments receiving MWWE. If a substance exceeded a provincial guideline, the substance was identified as of potential concern, but greater cautionary doubt as a potential substance of concern was attached to it than those flagged on the basis of exceeding a national guideline.

Three other groups of substances emerged as a result of the evaluation described above:

Substances for which effluent data were found, but for which no national or provincial water quality guidelines exist for use as a benchmark. The environmental or human health implications of the effluent concentrations could not be evaluated;

Substances for which water quality guidelines have been developed, but no information was found regarding MWWE concentrations or analytical method detection limits were not reported such that a comparison could be made to the applicable benchmark(s); and

Substances lacking both water quality guidelines and effluent data.

All the substances on the Master List were grouped into one of the four applicable categories.

Results

Classifications

The first classifying procedure made use of the chemical nature of the substances by organizing all the chemicals on the Master List according to the general class and sub-class of chemical to which the substance belongs.

The vast majority of substances on the Master List produce some type of toxic effect among humans or aquatic biota if present at high enough concentrations. Toxic concentrations of all chemicals are specific to each exposed species and each substance; therefore, no attempt was made to rank all the substances in terms of relative toxicity. However, some substances exhibit additional characteristics that make them particularly problematic in the environment, such as persistence or the tendency to bioaccumulate, or to cause cancer (carcinogens). Other substances tend to be a problem from the standpoint of promoting eutrophication (nutrients), imparting objectionable taste or odour to water (undesirable aesthetic properties). Therefore, the Master List was also sorted according to this type of organization. Many of the substances in this table exhibit more than one of the aforementioned characteristics, and therefore the categories are not mutually exclusive. More than half the substances included in the Master List did not exhibit, or were not identified with, any of the environmental problems.

Potential Substances of Concern

Sixty-nine substances were identified as being of potential concern in MWWE because effluent concentrations were sometimes greater than benchmark concentrations for protection of human water uses or ecological health (Table ES.1). They included organic (priority pollutants and chemicals of emerging concern), inorganic and non-specific substances. Of the 69 substances identified as being of potential concern, 42 were flagged on the basis of a provincial water

quality guideline, a limited number of studies (e.g., less than five studies), and/or the lowest benchmark was exceeded in only a small percentage of studies (<25). The evidence for these 42 substances is weaker than for the others. Judgment on application of provincial guidelines should be evaluated before a decision is made to include or exclude these substances from further consideration with respect to MWWE management. Judgment will also be required to determine whether substances for which only a small proportion of studies reported effluent concentrations greater than the benchmark are truly a concern in MWWE. Additional effluent data may be required for some substances, as well as rigorous environmental substance assessments, when adequate concentration data have been compiled.

Other uncertainties associated with the assessment are:

1. Many of the studies from which the data were taken were not from Canada, and thus may not be representative of the full range of treatment types, treatment performance, industrial versus domestic contributions, nor geographic locations in Canada;

2. Both effluent data and water quality guidelines were available for only some of all those included in the Master List, so many substances could not be evaluated with respect to potential risk to human health or aquatic environments. There are also limited substances for which guidelines exist for all possible water uses (e.g., for both marine and freshwater environments as well as for protection of human uses of water). Lack of guidelines may exist because there are inadequate data available in the literature to satisfy the protocols for guidelines development, rather than a lack of potential adverse effects; and

3. A substance may not pose a risk to human health or the environment even in cases where effluent concentrations exceed an identified benchmark, because a) there may be safety factor incorporated into the derivation of the benchmark (i.e., the lowest effect concentrations reported in the literature may have occurred at levels that are higher than the benchmark by some factor), and/or b) the benchmark pertains to concentrations in receiving water, not effluent, and thus the assessment does not account for site-specific effluent mixing and dilution.

Substances Found but Lacking a Benchmark Guideline

A total of 26 substances were included in the Master List and found at quantifiable levels in MWWE, but currently lack a benchmark that could be used to evaluate the significance of the effluent data with respect to protection of human water uses or aquatic biota. Effluent data were also found for another 101 substances that were not included in the original Master List. Those

ultimately identified as being prevalent in MWWE and posing risks to human health or the environment should be considered for environmental guidelines development.

Substances with a Benchmark Guideline but no MWWE Concentration Data

Many substances on the Master List (68 in total) have one or more water quality benchmarking guidelines, but either have no matching concentration data, or were reported as being less than an unspecified analytical method detection limit. Many of the substances in this grouping are more likely to be from diffuse sources, including pesticides, PCBs, PCDDs, and PCDFs, and are unlikely to be present in MWWE unless entering through inflow to sewers from surface runoff, or from combined sewers.

Substances with Neither Benchmarks nor MWWE Concentration Data

In this grouping of 34 substances are biological pathogens (viruses and protozoa such as *Giardia* sp.), chlorinated municipal effluents, and chlorinated disinfection by-products. The environmental significance of this group of substances is uncertain. There are also many industrial chemicals and pesticides in this class, which are likely to be of concern if discharged to the environment in sufficient quantities.

Substances with MWWE Concentration Data below Benchmark Guideline

Forty-four substances were found at concentrations below the most sensitive benchmark value used. Many of these substances are representative of the historical “priority pollutants” established by the U.S. EPA in the late 1970s. A substantial number of the substances appear in this list based on a limited number of studies (two or fewer), and so attempts should be madde to validate their inclusion in this category

Effluent Irrigation

Besides direct discharge to surface waters, MWWE may be returned to the environment by application to land, either by irrigation, soil in filtration basins or by direct injection. European and American treatment facilities have decades of experience in some cases. Studies suggest that metals will bind fairly tightly to soils with little mobility in groundwater, even under conditions representative of acid rain. Some organic compounds may undergo sorption and/or biodegradation in the soil and in groundwater, while others, such as the antiepileptic drug carbamazepine are refractory and found in many groundwaters under the influence of infiltrated effluent. The more water-soluble and neutrally charged the organic substance is, the more likely it is to remain mobile and be transported with groundwater. When sorption is important to removal in the soil, factors such as organic matter content, pH and pore size are important. In other cases, bacteria may exist in almost all soils to biodegrade substances, as appears to be

the case with the 4-nonylphenol, a metabolite of alkylphenol ethoxylate surfactants in wastewater treatment. Evidence suggests that in soil aquifer treatment, substance removal from effluent of secondary treatment quality is at least as good and possibly better than removal form an reverse osmosis permeate.

Key Information Gaps

Benchmarks

Many substances included in the Master List, and others identified as present in some MWWE based on review of the literature, do not have water quality guidelines. Without such guidelines, or a suitable alternative benchmark, it is impossible to judge whether substances identified in wastewater may impair receiving water uses. The list of substances should be reviewed in a systematic manner to identify those of greatest potential for adverse effects with a view to developing appropriate guidelines or alternative benchmarks.

MWWE Data

There is a lack of effluent concentration data for most of the substances on the project Master List. There are reasons for this paucity of data, including little or no regulatory pressure to monitor them, the cost of analyses, and the absence of commercially available capability to quantify some of the substances at low levels in complex wastewater. As a result of the paucity of concentration data, it is not possible to assess regional or other differences in substance concentrations within Canada. There is need for a comprehensive survey of the substances in MWWEs, but only after a review of the availability and adequacy of analytical methodologies.

Substance Treatability

Municipal treatment plants are designed to treat human waste and their ability to reduce effluent concentrations of industrial chemicals, pesticides, PPCPs and other substances is only partly understood. A compendium of treatability data, highlighting specific substance removal efficiencies by municipal wastewater treatment processes, including soil aquifer treatment, generated by many researchers in Canada (e.g., Environment Canada in Burlington and Ontario Region, Trent University, University of Guelph, Ryerson University) as well as internationally, would be very useful to environmental and health practitioners. Gathering of this information into a focused, yet comprehensive report would assist in filling gaps in substance treatability data.

Recommendations

Based on this assessment, it is recommended that:

- Substances identified as being of potential concern on the basis of applicable provincial water quality or drinking water guidelines should be evaluated to confirm or refute the suitability of such guidelines for use as benchmarks.
- Additional effluent data should be collected for substances that have water quality guidelines but have been rarely or never been measured in MWWE. For substances with neither concentration data nor benchmarking guidelines, if such substances are found to be prevalent in MWWE based on effluent monitoring surveys, such substances should be considered for potential water quality guidelines development. Effluent data could be collected by selecting facilities to represent a range of sizes, treatment type, industrial loadings, and geographic locations so as to represent a reasonable cross-section of Canadian facilities. Substances shown to be consistently below analytical detection limits could be eliminated from further consideration.
- Prior to any field survey of trace substances in MWWEs, a significant effort should be made to collect data from municipalities and other jurisdictions. If after this information collecting effort there are still missing data, the most significant potential substances of concern identified by this study should be compared to existing commercial analytical capabilities to determine if in fact the substances can be routinely measured at a useful level. The comparison of analytical protocols with the substances of potential concern should be completed by qualified laboratory personnel.

Substances identified by one of the above approaches as being present in MWWE, but for which no water quality guidelines exist, should be recommended to the CCME or to Environment Canada for potential development of water quality guidelines. In the meantime, it may be appropriate to consider the use/development of alternative, interim benchmarks to complete a preliminary screen of potential substances of concern. For example, benchmarks published by Suter and Tsao (1996) have been routinely used in environmental risk assessments and may be adequate to ascertain whether MWWE concentrations of a given substance are typically well above or well below the benchmark concentration and thus should remain on, or could be eliminated from, the Master List.

1.0 INTRODUCTION

1.1 Background

In November 2003, the Canadian Council of Ministers of the Environment (CCME) agreed to develop a Canada-wide strategy for municipal wastewater effluent (MWWE). The Strategy involves three principal tenets, including:

- Harmonizing the regulatory framework among the federal, provincial and territorial jurisdictions;
- Coordination of science and research activities; and
- Use of an environmental risk management model to guide decision making.

For the Strategy to be effective the Development Committee (DC) must understand the current state of knowledge on MWWE; i.e., the science and research, evolving treatment technologies and best management practices. Consequently, the DC has commissioned this study to provide a comprehensive review of the current state of knowledge of MWWE science and technology respecting the treatment of conventional pollutants as well as emerging substances of concern.

1.2 Objectives

As expressed in CCME's Request for Proposal (RFP) for this study, the objectives of the entire study are to:

1. Prepare a comprehensive consolidated inventory of harmful substances and emerging problematic substances found or likely to be found in Canadian MWWE. Identify substance sources, typical effluent concentrations, and an annotated assessment of effects on the natural aquatic environment and on human health associated with the various substances or groups of substances.
2. Prepare an annotated summary of existing and emerging treatment technologies for treatment of conventional pollutants, harmful substances and emerging pollutants from objective 1. The technologies will be assessed for their applicability to variations in Canadian climates, environments, regions and receiving waters.
3. Provide a review of best management practices for specific issues related to municipal wastewater treatment, including but not limited to:
    - Infiltration and inflow to municipal sewer systems

- Reduction and treatment of sanitary and combined sewer overflows (SSOs and CSOs)
- Management of hauled wastes such as septage, landfill leachate or industrial/commercial wastewaters
- Small or remote community wastewater issues, including treatment cost and pollutant management
- Discharges of treated effluents to marine environments
- Lagoon issues, including ice cover and ammonia removal in winter, and algae removal in summer
- Flow reductions to wastewater treatment plants using alternative technologies and source control plans, including water reuse and reclamation technologies
- Aging collection system needs and upgrading practices
- Wastewater treatment facility performance monitoring and quality control practices.

This report addresses the first study objective and constitutes the deliverable for Task 1.

2.0 METHODS

2.1 Development of the Master List of Substances

Many substances in the aquatic environment are identified as of being of potential concern because they are either toxic, or may become toxic if they are persistent, and/or have a tendency to bioaccumulate, bioconcentrate or biomagnify. Substances or organisms may also be of concern if they cause illness or disease, or contribute to eutrophication, anoxic or low oxygen concentrations in receiving aquatic environments. Toxic substances were defined In the 1978 Great Lakes Water Quality Agreement between Canada and the United States, as substances "which can cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances." The International Joint Commission has adopted the definition of a persistent compound as any toxic chemical that has a half-life greater than eight weeks in any medium (water, air, sediment, soil, or living things). Bioaccumulation is a general term describing the net accumulation of a substance in the tissues of an organism, whether taken up directly from water or through consumption of food. Bioconcentration is the term used to describe the net accumulation that results specifically from direct uptake from water. Biomagnification is the process by which tissue concentrations increase as substance passes up through two or more steps in the food chain.

Many agencies or organizations, including a number to which Canada has been a collaborator, have established lists of substances of concern in the water environment as part of their agreement principles. Such commitments include the Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes, and the Canada-Ontario Agreement (COA) Respecting the Great Lakes Basin Ecosystem. The Canada-U.S. Agreement lists 25 substances as "toxic" in their list of Level I and Level II compounds (IJC 2005). The COA list includes 41 substances (GreenOntario 2005). Similarly, the European Union has published a list of 33 priority substances in "Annex X" of the Water Framework Directive (2000/60/EC). These lists were compiled to create a master list of substances (the "Master List"; Appendix Table A.1). The Master List was filtered as it was being compiled to eliminate entries that were not applicable to an evaluation of municipal wastewater effluents, such as listings for taste, gasoline or other fuels, asbestos, sulphur and nitric oxides, and many of the chlorofluorocarbons or bromofluorocarbons that are of concern to air pollution.

Two other lists were used to compile the Master List. These were the Guidelines for Canadian Drinking Water Quality (Health Canada 2004) and Health Canada's Drinking Water Substances

Priority List (DWSPL) (Health Canada 2005d). The reason for including substances from these drinking water lists in the municipal effluent substance list was that data regarding human health effects of waterborne substances would be applicable to treated effluents as well, although drinking water guidelines *per se* would be applicable only to surface and groundwaters used as drinking water sources and not directly applicable to effluent. Although some progress was made on incorporating substances from Environment Canada's National Pollutant Release Inventory (Environment Canada 2005a), and from the U.S. EPA Toxics Release Inventory (EPA 2005a), it became clear that the number of substances were unwieldy because these lists because these lists include substances of concern in air, solid and hazardous waste, as well as in aqueous media, only the latter of which was of direct interest to this project. Consequently, use of these two large substance lists in compiling the master substance list was not pursued further.

Also, substances for which water quality guidelines have been developed by either Canadian (CCME 2003) or U.S. (U.S. EPA 2002) jurisdictions were added to the Master List. These are substances for which there was previously sufficient evidence of risk to aquatic biota or to human users of water, as well as adequate data available in the literature, to support the derivation of water quality guidelines.

Lastly, a number of mostly non-specific substances that have often been monitored in MWWE (sometimes referred to as "conventional" parameters) were added to the Master List, including biochemical oxygen demand, colour, hardness, oil and grease, dissolved oxygen, pH, phosphorus, temperature, total dissolved solids, totals suspended solids, total organic carbon, total residual chlorine and turbidity.

The Master List was constructed in a spreadsheet so it would ultimately provide the greatest utility to the CCME Development Committee. Recommendations for three types of categorization procedures were requested in the project RFP. The adoption of a spreadsheet format allows future users to sort, add and delete information as more data become available.

2.2 Classification of Substances

The Development Committee requested that three procedures be developed for categorizing the substances. The rationale for the three categories selected follows.

Method 1. Grouping by Chemical Class and Chemical Abstract Service (CAS) Number. This procedure recognizes that lists of substances are often organized according to the type of chemical and chemical structure and that users may seek information based on certain traditional groupings by chemical class. CAS numbers were also included because they are

unique identifiers accompanying the substance name and help to avoid ambiguity because of different naming conventions.

Method 2. Grouping by Environmental Effects. Most substances on the Master List are there because of documented environmental and/or human health effects. Substances can be sorted in terms of their environmental properties, such as whether they are persistent, bioaccumulative, and toxic or exhibit other important attributes.

Method 3. Grouping by Wastewater Process Treatability. Different levels of wastewater treatment will remove substances to different extents. Although there are many processes in use across Canada, the recommended classifications are: lagoon, primary, secondary, tertiary biological nutrient removal (BNR), tertiary filtration and several advanced processes (which might include activated carbon, membranes, resin adsorbers, oxidation processes) that are capable of additional reductions of the substances. With this categorization procedure, it is possible to review the level of treatment at different municipalities within the various Provinces and Territories to determine for each what the likelihood of removal is for the different substances. Note that in this assessment, the removal efficiency is based only on reduction through the liquid treatment processes, and does not consider any accumulation within the residual solids, or in any wastewater process air emissions.

2.3 Identify Major Sources of Substances

Sources of substances presented in the Master List were identified using either CCME (CCREM 1987) or EPA (2005) reference documents, or websites (e.g. Spectrum Laboratories 2005). The sources were generally identified as either domestic, industrial/commercial or diffuse in nature, but the categories are not mutually exclusive. For example, some pesticides may enter wastewater treatment systems from both domestic use (insecticides for pets, wash-up of herbicide applicators) or from industrial manufacture or use. Substances from domestic sources include a variety of conventional, metal, organics, pharmaceuticals and personal care products. Substances from industrial or commercial sources are those that are manufactured, used or generated as by-products in processing. The industrial sources of substances in municipal wastewater were determined from a publication by the Canadian Water and Wastewater Association (CWWA, 2000). Only those industrial sources, listed by the North American Industry Classification System, for which the potential contribution was ranked high, were included in the categorization. Substances from diffuse sources are those that enter the wastewater system from surface runoff or combined sewer systems, such as metals, oil and grease, pesticides and polycyclic aromatic hydrocarbons, PCBs, dioxins and furans, and pathogenic organisms. Based on the subsequent evaluation of substance concentrations in effluent, a sub-set of chemicals

was reviewed in more detail including more specific chemical source information, taken from the same literature sources described above.

2.4 Selection of Benchmarks for Human Health and Ecological Protection

To identify substances of potential concern in municipal wastewater effluents (MWWE), it was necessary to have a reliable, conservative estimate of the concentration(s) of any given substance above which effects on aquatic biota, human health or human uses of water may result. In consultation with the project committee, it was agreed that Canadian (CCME 2003) national guidelines or American (U.S. EPA 2002) guidelines would be appropriate benchmarks for this purpose. Such national benchmark values are developed according to defined protocols regarding data type, quantity, and quality, and each technical rationale undergoes rigorous technical review. While there may be additional information in the literature regarding the ecological or human health effects of other substances on the Master List of substances, a full literature review for each substance was considered beyond the scope of this project.

CCME guidelines were preferentially selected and U.S. EPA guidelines were used in cases where a CCME guideline has not been developed for a given substance (Appendix Table A.2). In the absence of national guidelines, provincial water guidelines or objectives were selected to allow for a broader range of substances to be considered in the evaluation. However, the protocols for provincial objective development may not have been consistently subjected to the same rigorous protocols and level of scientific scrutiny. Therefore, substances that exceeded provincial water quality benchmarks in MWWE have been recommended for further investigation of the basis for the objective.

It is evident from Appendix Table A.2 that no guidelines have been developed for many substances. In particular, there is a need to establish more guidelines for protection of marine aquatic life. Also, in many cases, the CCME and/or EPA environmental effects concentrations are lower than the human drinking water guidelines values.

2.5 Identification of Municipal Wastewater Effluent Concentrations

Concentrations of substances in municipal effluents were compiled from a number of sources, including a review of municipal effluents for Canadian Environmental Protection Act (CEPA) Toxics, completed by Environment Canada's Ontario Region, from municipalities in Western and Central Canada, and from the technical literature. The literature reviewed included in-house sources, published literature reviews and conference proceedings (e.g., Water Environment Annual Conference Proceedings, American Water Works Association Annual Water Quality Technical Conference), and from internet searches.

Effluent concentration data collected for these substances, included a variety of "conventional" pollutants (such as biochemical oxygen demand (BOD), suspended solids and nutrients such as ammonia and phosphorus), as well as historical "priority" pollutants identified in surveys dating back to the late 1970s and early 1980s. The compiled substances were entered into a spreadsheet containing the Master List of substances to allow comparison to benchmark concentrations (water quality guidelines) as described in Section 2.6.

Data were also sought from literature reviews to identify representative concentrations of emerging substances of concern. Because these substances are in the "emerging" state of knowledge, there were few water quality guidelines available for use as benchmarks in comparisons.

2.6 Identify and Characterize Substances of Potential Concern

Any substance that exceeded its respective CCME (or EPA) benchmark concentration for human or ecological protection was identified as a substance of potential concern for aquatic environments receiving MWWE. As described in Section 2.4, some substances lacked a national water quality guideline, but one or more guidelines existed from provincial jurisdictions. In such cases, the most stringent available provincial guideline was selected as the benchmark for comparison to effluent levels, so as to include more rather than fewer substances in the assessment. However, such substances should be considered with greater caution than those flagged on the basis of exceeding a national guideline.

2.7 Substances Categorized for Additional Investigation

Four other groups of substances emerged as a result of the evaluation described above:

Substances for which effluent data were found, but for which no national or provincial water quality guidelines exist for use as a benchmark. Although there may be information in the literature regarding the environmental and/or human health effects associated with some such substances, the compilation of such diffuse information was considered beyond the scope of this project. Therefore, the environmental or human health implications of the effluent concentrations could not be evaluated;

Substances for which water quality guidelines have been developed, but no information was found regarding MWWE concentrations or analytical method detection limits were not reported such that a comparison could be made to the applicable benchmark(s); and

Substances lacking both water quality guidelines and effluent data. Many of the so-called "emerging" substances are found in this category

Substances for which the concentration data collected were lower than the benchmarking guideline values.

All the substances on the Master List were grouped into one of the four applicable categories (the three categories above plus those discussed in Section 2.6) and recommendations have been made with respect to the type of follow up action, if any, that may be appropriate for each group.

2.8 Characteristics of Substances found in MWWE

Each of the substances or groups of substances identified in MWWE was reviewed in more detail and summaries of their sources and properties have been prepared (Section 4.0). Where possible, the environmental condition(s) affecting the expression of toxicity of a given substance in different receiving environments has been discussed. This includes factors such as pH, hardness, and salinity, which are known to increase or lessen the toxicity of some substances. Other key chemical attributes have also been noted, where relevant, such as carcinogenicity, persistence or tendency to bioaccumulate or biomagnify.

3.0 RESULTS

3.1 Categorization of Substances

At the request of the CCME Science and Research Subcommittee, the substances in the Master List were categorized by three methods, chemical class, environmental effects, and treatment removal, as described below.

3.1.1 Categorization by Chemical Compound Class

The substance Master List for this study was compiled in alphabetical order, with accompanying Chemical Abstracts Service number, as shown in Appendix Table A.1. The Master list consists of 242 substances, congener groups (polychlorinated dioxins, PCBs for example), pathogenic organisms, and non-specific substances such a biochemical oxygen demand (BOD) and total suspended solids (TSS), often referred to as “conventional” pollutants.

A number of substance mixtures are included in the master list, including the congener groups noted above, as well as more general terms such as chlorinated wastewater effluents, polycyclic hydrocarbons, total phenols, and C_{10} – C_{13} chloroalkanes. In fact, municipal effluents are complex mixtures of many different types of substances. Application of whole effluent toxicity testing is one method to try to account for the potential toxicity of all the substances in an effluent. The focus of this study, however, is on specific substances or mixtures of substances.

The first classifying procedure makes use of the chemical nature of the substances. Appendix Table A.3 shows all the chemicals on the Master List organized according to the general class and sub-class of chemical to which the substance belongs. Note that the list also includes 12, mostly non-specific parameters that are often considered to be “conventional” pollutant measurements in MWWEs.

3.1.2 Categorization by Environmental Effects

Substances may also be categorized by their environmental effect. The vast majority of substances on the Master List produce some type of toxic effect among humans or aquatic biota if present at high enough concentrations. Exceptions include the non-specific parameters, such as biochemical oxygen demand and total organic carbon, which do not have specific toxic properties in themselves, but rather indicate the aggregate quantities of various biodegradable, oxygen consuming substances, or substances with organic carbon. Any specific substance measured as part of the BOD or TOC parameter will exhibit its own level of toxicity. Toxic concentrations of all substances are specific to each exposed species and each substance; therefore, no attempt has been made to rank all the substances in terms of relative toxicity.

However, some substances exhibit additional characteristics that make them particularly problematic in the environment, such as persistence or the tendency to bioaccumulate. Other substances tend to be a problem from the standpoint of promoting eutrophication (nutrients), imparting objectionable taste or odour to water (undesirable aesthetic properties), or causing cancer (carcinogens).

Appendix Table A.4 shows the Master List, sorted according to this type of organization. It is evident from Table A.4 that many of the substances exhibit more than one of the aforementioned characteristics and therefore the categories are not mutually exclusive. Also, more than half the substances included in the Master List do not exhibit any of the characteristics shown in the columns (e.g., non-specific substances and those that are merely potentially toxic). Therefore, this type of organization is not likely the most useful for categorizing substances, but the information may useful for any future evaluations of such substances. A separate table shows the same information presented in Table A.4, but is organized by chemical class to facilitate searches for the properties of specific substances (Appendix Table A.5).

An assessment of the relative toxicities of the substances identified in MWWE to arrive at a potential toxic factor for each substance is a complex task beyond the scope of this study. A non-rigorous procedure to assess which of the substances may present the most significant toxic potential may be to rank the magnitude of the most sensitive benchmarking guideline, from lowest to highest, for each substance as provided in Table A.8. [Note the most sensitive guideline may be other than a CCME or EPA guidelines for freshwater and marine environments.] The types of substances with the lowest benchmark values and also that cross over several health and environmental effects in Table A.4 are likely to have the highest “toxic potential”, and tend to be representatives of polycyclic aromatic hydrocarbons, pesticides, halogenated hydrocarbons and organometallic compounds.

3.1.3 Categorization by Treatment Removal

Treatment facilities may remove substances to a greater or lesser extent based on the process configurations. The categories of treatment applied in this assessment are lagoons (waste stabilization ponds), primary treatment, non-nitrifying activated sludge, nitrifying activated sludge, nitrifying activated sludge with effluent filtration, biological nutrient removal (nitrogen and phosphorus), and nitrifying activated sludge with a membrane process capable of 95% rejection of substances,. For classification purposes, an arbitrary rating was applied based on estimated removal efficiencies. Process removal efficiencies were estimated using Hydromantis’ TOXCHEM+ fate modelling software (Appendix Table A.6). The categorization used was that an estimated removal efficiency of less than 50% was rated as poor; an estimated removal

efficiency of between 50 and 74% was rated as moderate, and a removal efficiency of between 75% and 94% was rated as good, while an estimated removal efficiency of 95% or higher was rated as excellent. The categorization was limited to the 64 substances deemed of potential concern (as identified in Section 3.4) due to the lack of physical-chemical data needed for modeling the substances.

The classification is complicated by the fact that wastewater treatment itself may result in formation of certain substances (called breakdown products or metabolites), which may pose more of an environmental concern than the parent compound.

Primary treatment generally resulted in poor removal of the substances of potential concern. Only 4 substances were listed as achieving excellent removal. These 4 substances are industrial solvents, whose removal was accomplished by stripping and volatilization to the atmosphere. The conventional non-nitrifying activated sludge system removed 18 substances at the excellent category and a further 15 substances at good efficiency. Conversion of these plants to nitrification was predicted to increase the number of substances with excellent removal to 26, with 12 rated at good removal efficiency. Many of the substances with improved removal efficiencies were PAHs; both improved biodegradation and sorption to waste solids were deemed responsible for the enhanced removals. Filtration of a nitrified effluent was predicted to result in minor improvement in treatment efficiencies, with the number of substances with excellent removal rising to 29, while the number with good removal efficiencies remained steady at 12. Implementation of biological nutrient removal provided improved removal efficiencies of the substances, with the number of substances in the excellent removal class rising to 34, and the number with good removal declining to 8. The BNR process was predicted to be more effective in removing phthalate esters, nonylphenol and nonylphenol ethoxylates, and nitrate and nitrite. The lagoon process, though lower in technology, achieved high removal efficiencies because of the long retention times characteristic of the process. Lagoon performance was similar to the BNR process, with 34 substances rated as excellent removal, and 4 rated as good removal. The best overall removal efficiencies were the nitrified treatment plant with a reverse osmosis unit operating at 95 % rejection efficiency. Of the total, 51 were rated as having excellent removal, while 12 more received good removal. Only the pesticide 2,4,5-T was predicted to have poor removal in this process train; it was the only substance that registered poor removal in all the processes investigated here.

3.2 Sources of Substances in MWWEs

Substances can enter wastewater treatment systems from a number of sources, and so be discharged in MWWEs. Moreover, wastewater treatment itself may result in formation of certain

substances, which may pose more of an environmental concern than the parent compound. Formation of nonylphenol (NP) or nonylphenol diethoxylate (NP_2EO), and carboxlylic acid derivatives from biodegradation of higher ethoxylated nonylphenol (i.e. NP_nEO (n>4)) is a case in point (Bennie et al. 1998; Ball and Reinhard, 1985; Ahel et al. 1986). When chlorine is used as a disinfectant, inorganic chloramines, trihalomethanes, haloacetic acids, haloacetonitriles and other disinfection by-products may be formed (Krasner 1999).

For the substances included in the Master List, general sources include domestic wastewater treatment, industrial and/or commercial sources, and/or diffusive or non-point sources (Appendix Table A.7). The latter class includes surface runoff that becomes inflow to collection systems, substances that may enter in infiltrating groundwater (e.g. the gasoline additive MTBE), or substances that are discharged as a result of treating flow from combined sewer systems, in which collected storm water may be combined with sanitary wastewater for treatment.

A publication by the Canadian Water and Wastewater Association (CWWA 2000) on sources of substances in municipal sewers, was used to identify the most probable industries as sources of specific substances. In the CWWA document, the probability of the industrial sector as a source for each substance is rated as high, medium or low. Based on the narrative for each probability rating in the publication, only those industrial categories listed as being of high probability were included in this report.

From an evaluation described below in Section 3.4, a sub-set of chemicals was reviewed in more detail including more specific chemical source information (see Section 4.0).

3.3 Substance Concentrations in MWWEs

Effluent concentrations reported from Canadian municipalities and through the literature review for this study are provided in Appendix Table A.8. It is evident that the substances examined in each individual study represented only a fraction of all the substances included in this project's Master List. Effluent data were found for a total of 136 of the 242 substances included in the Master List. As discussed in Section 3.4.2, the literature review identified another 101 substances that have been measured in MWWE, but were not included in the original Master List.

3.4 Comparison of Effluent Concentrations to Benchmarks

3.4.1 Substances Exceeding Benchmarks

Sixty-nine substances were identified as being of potential concern in MWWE because effluent concentrations were sometimes greater than benchmark concentrations for protection of human

water uses or ecological health (Table 3.1). They included organic (priority pollutants and chemicals of emerging concern), inorganic and non-specific substances. Of the 69 substances identified as being of potential concern, 42 were flagged on the basis of a provincial water quality guideline, a limited number of studies (e.g., less than five studies), and/or the lowest benchmark was exceeded in only a small percentage of studies (<25%; Table 3.2). The basis of applicable provincial guidelines should be evaluated before a decision is made to include or exclude these substances from further consideration with respect to MWWE management. A judgment will also be required in future to determine whether substances for which only a small proportion of studies reported effluent concentrations greater than the benchmark are truly a concern in MWWE. Additional effluent data may be required for some substances.

In addition, there are other uncertainties associated with the assessment:

1. Many of the studies from which the effluent concentration data were taken were not from Canada, and thus may not be representative of the full range of treatment types, treatment performance, industrial versus domestic contributions, nor geographic locations in Canada;

2. Both effluent data and water quality guidelines were available for only some of all those included in the Master List, so many substances could not be evaluated with respect to potential risk to human health or aquatic environments. There are also limited substances for which guidelines exist for all possible water uses (e.g., for both marine and freshwater environments as well as for protection of human uses of water). Lack of guidelines may be because there are inadequate data available in the literature to satisfy the protocols for guidelines development, rather than a lack of potential adverse effects; and

3. A substance may not pose a risk to human health or the environment even in cases where effluent concentrations exceed an identified benchmark, because a) there may be safety factor incorporated into the derivation of the benchmark (i.e., the lowest effect concentrations reported in the literature may have occurred at levels that are higher than the benchmark by some factor), and/or b) the benchmark pertains to concentrations in receiving water not effluent and thus the assessment does not account for site-specific effluent mixing and dilution, nor site-specific expression of toxicity as potentially influenced by physical-chemical properties of the receiving environment.

Further to 3 (b), above, even substances that are found in MWWE at concentrations well over the benchmark in the majority of effluents may not be universally of concern from a human health or environmental perspective. For example, substances that are not persistent and

Table 3.1. Screening Summary of Substances found in Effluent at Concentrations Exceeding One or More Benchmarks

Main Class	Sub-class	Chemical Name	Benchmark Concentrations (ug/L)[a]					Number of Studies Reporting Results	Concentration Range Reported	% of Studies With At Least One Sample Above Benchmark				
			Environmental Freshwater	Environmental Marine	Drinking Water	Recreational	Agricultural			Environmental Freshwater	Environmental Marine Water	Drinking Water	Recreational Use	Agricultural
Biological	Pathogen - Bacteria	Fecal coliforms	-	-	0/100ml	-	-	1	20 - 4000	-	-	100	-	-
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	1	0.7	-	-	-	14	0.1 - 350	50	50	-	-	-
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	-	-	0.009	-	-	3	0.043 - 790	-	-	100	-	-
Inorganic	Anion	Cyanide	5	1	200	-	-	4	0.5 - 43	25	50	0	-	-
Inorganic	Anion	Fluoride	120	-	1,500	-	1,000	3	1 - 150	33	-	0	-	0
Inorganic	Metal/Metalloid	Aluminum	5-100	-	100	-	5,000	13	<20 - 5800	100	-	62	-	8
Inorganic	Metal/Metalloid	Antimony	20	-	6	-	-	3	0.43 - 9	0	-	33	-	-
Inorganic	Metal/Metalloid	Arsenic	5	12.5	25	-	100	5	0.7 - 23	20	20	0	-	0
Inorganic	Metal/Metalloid	Barium	1,000	-	1,000	-	-	5	38.23 - 9040	20	-	20	-	-
Inorganic	Metal/Metalloid	Boron	200	-	5,000	-	500-6,000	4	110 - 1300	50	-	0	-	50
Inorganic	Metal/Metalloid	Cadmium	0.0025-0.097	0.12	5	-	5.1	14	0.014 - 14	93	57	14	-	14
Inorganic	Metal/Metalloid	Chromium (hexavalent)	1	1.5	50 (total)	-	8	9	0.64 - 140	89	89	22	-	56
Inorganic	Metal/Metalloid	Chromium (trivalent)	8.9	56		-	4.9	15	<0.2 - 140	33	13	-	-	33
Inorganic	Metal/Metalloid	Cobalt	0.9	-		-	50	6	0.58 - 15	83	-	-	-	0
Inorganic	Metal/Metalloid	Copper	2-4	3.1	1,000	-	200-1,000	16	3.3 - 190	100	100	0	-	0
Inorganic	Metal/Metalloid	Iron	300	-	300	-	5,000	11	39 - 5230	45	-	45	-	9
Inorganic	Metal/Metalloid	Lead	1-7	8.1	10	-	200	16	0.2 - 91	56	44	38	-	0
Inorganic	Metal/Metalloid	Magnesium	-	-	200	-	-	4	3540 - 25380	-	-	100	-	-
Inorganic	Metal/Metalloid	Manganese	700-1,900	-	50	-	200	11	7 - 753	9	-	27	-	9
Inorganic	Metal/Metalloid	Mercury	0.026	0.016	1	-	3	9	0.0065 - 0.36	100	89	0	-	0
Inorganic	Metal/Metalloid	Molybdenum	73	-	-	-	10-50	6	2.57 - 47	0	-	-	-	33
Inorganic	Metal/Metalloid	Nickel	25-150	8.2	-	-	200	15	2.1 - 900	27	67	-	-	13
Inorganic	Metal/Metalloid	Selenium	1	71	10	-	20-50	4	0.3 - 30.6	50	0	25	-	25
Inorganic	Metal/Metalloid	Silver	0.1	1.9	-	-	-	8	0.12 - 1250	88	75	-	-	-
Inorganic	Metal/Metalloid	Vanadium	6	-	-	-	100	2	<20 - 10.8	50	-	-	-	0
Inorganic	Metal/Metalloid	Zinc	30	81	5,000	-	1,000-5,000	16	<10 - 1400	75	38	0	-	6
Inorganic	Miscellaneous	Sulphide (as H_2S)	2	2	50	-	-	3	<0.05 - 131	100	100	67	-	-
Inorganic	Nutrient	Ammonia	19	-	-	-	-	5	50 - 31000	100	-	-	-	-
Inorganic	Nutrient	Nitrate	13,000	16,000	45,000	-	-	2	<60 - 28400	100	100	0	-	-
Inorganic	Nutrient	Nitrite	60	-	3,200	-	10,000	2	5 - 4800	100	-	100	-	0
Inorganic	Nutrient	Phosphorus (total)	5-15	0.1	-	-	-	4	190 - 6900	100	100	-	-	-
Non-specific	Physical/Chemical	pH	6.5-9.0	7.0-8.7	6.5-8.5	5.0-9.0	-	4	6.38 - 8.18	25	25	25	0	-
Non-specific	Physical/Chemical	Total residual chlorine	2	-	-	-	-	1	<10 - 950	100	-	-	-	-
Non-specific	Physical/Chemical	Turbidity	increase 2-8 NTU or 10%	-	1 NTU	-	-	1	0.46 - 200	0	-	100	-	-
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	1.8	-	-	-	100	7	<0.5 - 4	71	-	-	-	0
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	100	-	5	-	5	11	<1 - 10	0	-	9	-	9
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	111	-	30	-	-	17	0.42 - 120	6	-	12	-	-
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	10	-	-	-	-	12	<0.5 - 27	8	-	-	-	-
Organic	Alkyl benzene	Ethylbenzene	90	25	2.4	-	2.4	14	<0.5 - 4.91	0	0	7	-	7
Organic	Alkyl benzene	Toluene	2	215	24	-	24	14	<0.25 - 15	21	0	0	-	0
Organic	Alkylphenol & Ethoxylates	Nonylphenol	1	0.7	-	-	-	15	<0.020 - 16	60	67	-	-	-
Organic	Aromatic Hydrocarbon	Phenols, Total	4	-	-	-	2	10	0.067 - 40	50	-	-	-	50
Organic	Aromatic Hydrocarbon	Xylene	2-40	-	300	-	-	16	<0.2 - 27	25	-	0	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	0.012	-	-	-	-	6	0.05 - 0.43	67	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	0.018	-	-	-	-	6	0.04 - 0.65	67	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	0.015	-	0.01	-	-	8	0.006 - 0.77	50	-	63	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	0.00002	-	-	-	-	4	0.23 - 0.33	50	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	0.0002	-	-	-	-	7	0.008 - 0.56	71	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene	0.1 (marine)	-	-	-	-	7	0.012 - 0.72	29	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	0.002	-	-	-	-	3	ND - 0.22	33	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	0.02	-	-	-	-	3	ND - 0.2	33	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	0.04	-	-	-	-	4	<0.05 - 0.97	25	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	3	-	-	-	-	5	<0.05 - 15	20	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	0.00007	-	-	-	-	3	ND - 0.69	33	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	0.4	-	-	-	-	7	<0.05 - 1.1	43	-	-	-	-
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	0.025	-	-	-	-	7	0.01 - 0.65	57	-	-	-	-
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	0.7	42	200	-	-	9	<0.5 - 4.61	11	0	0	-	-
Organic	Chlorophenol	Chlorophenol	7	-	-	-	-	1	20	100	-	-	-	-
Organic	Chlorophenol	Dichlorophenol (2,4-)	0.2	-	900	-	-	6	0.08 - 16	17	-	0	-	-
Organic	Hydrocarbons with N,P,S substitution	Quinoline	3.4	-	-	-	-	1	18	100	-	-	-	-
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	16	-	50,000	-	-	7	1.2 - 54	43	-	0	-	-
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	19	-	-	-	-	6	0.3 - 1620	17	-	-	-	-
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	0.0043	0.004	7	-	-	3	0.01 - 0.08	100	100	0	-	-
Organic	Pesticide - Chlorinated hydrocarbon	DDT	0.001	0.001	30	-	-	4	ND - 0.02	50	50	0	-	-
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	0.02	0.0087	-	-	-	3	ND - 0.13	33	33	-	-	-
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	0.01	0.16	4	-	4	7	0.01 - 0.79	57	14	0	-	0
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	4	-	100	-	100	5	0.02 - 34	20	-	0	-	0
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	2.6	4.2	-	-	0.025	3	20 - 400	33	33	-	-	33
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	4	-	280	-	100	4	0.03 - 92	25	-	0	-	0
Organic	Pesticide - Organophosphorus	Diazinon	0.08	-	20	-	-	2	ND - 1	100	-	0	-	-

Note: Table is 11x17 inch format.

[a] Refer to Table A.5 for details on benchmark values.

Table 3.2. Substances of Potential Concern that Need Further Investigation

Main Class	Sub-class	Substance Name	Basis for Further Investigation
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	Provincial drinking water criterion. Only measured in 3 studies
Inorganic	Anion	Cyanide	Only measured in 4 studies
Inorganic	Anion	Fluoride	Only measured in 2 studies
Inorganic	Metal/Metalloid	Antimony	Provincial criterion for protection of aquatic life. Only measured in 2 studies
Inorganic	Metal/Metalloid	Arsenic	Small percentage of samples had concentrations greater than lowest benchmark[a].
Inorganic	Metal/Metalloid	Barium	Provincial criterion for protection of aquatic life. Small percentage of samples had concentrations greater than lowest benchmark[a].
Inorganic	Metal/Metalloid	Boron	Provincial criterion for protection of aquatic life.
Inorganic	Metal/Metalloid	Cobalt	Provincial criterion for protection of aquatic life.
Inorganic	Metal/Metalloid	Magnesium	Provincial criteria for protection of aquatic life and drinking water. Only measured in 4 studies
Inorganic	Metal/Metalloid	Molybdenum	Agricultural irrigation water criterion.
Inorganic	Metal/Metalloid	Vanadium	Provincial criterion for protection of aquatic life. Only measured in 2 studies
Inorganic	Miscellaneous	Sulphide (as H_2S)	Only measured in 3 studies
Inorganic	Nutrient	Nitrate	Only measured in 2 studies
Inorganic	Nutrient	Nitrite	Only measured in 2 studies
Inorganic	Nutrient	Phosphorus (total)	Provincial criterion for protection of aquatic life. Only measured in 4 studies
Non-specific	Physical/Chemical	pH	Only measured in 4 studies
Non-specific	Physical/Chemical	Turbidity	Only measured in 1 study
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	Provincial criterion for protection of aquatic life. Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Alkyl benzene	Ethylbenzene	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Alkyl benzene	Toluene	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	Provincial criterion for protection of aquatic life. Only measured in 4 studies
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	Provincial criterion for protection of aquatic life.

Table 3.2. Substances of Potential Concern that Need Further Investigation

Main Class	Sub-class	Substance Name	Basis for Further Investigation
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	Provincial criterion for protection of aquatic life. Only measured in 3 studies
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	Provincial criterion for protection of aquatic life. Only measured in 4 studies
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	Only measured in 4 studies
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	Provincial criterion for protection of aquatic life. Only measured in 3 studies
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Chlorophenol	Chlorophenol	Only measured in 1 study
Organic	Chlorophenol	Dichlorophenol (2,4-)	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Hydrocarbons with N,P,S substitution	Quinoline	Only measured in 1 study
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	Only measured in 3 studies
Organic	Pesticide - Chlorinated hydrocarbon	DDT	Only measured in 4 studies
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	Only measured in 3 studies
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	Only measured in 3 studies. Small percentage of samples had concentrations greater than lowest benchmark[a].
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	Only measured in 3 studies
Organic	Pesticide - Organophosphorus	Diazinon	Provincial criterion for protection of aquatic life. Only measured in 2 studies

[a] Substances that were found at concentrations greater than the lowest benchmark in less than 25% of studies.

bioaccumulative may have no measurable effects in effluent receiving environments with a large assimilative (dilution) capacity (e.g., subsurface, open ocean discharges). In such locations, a decision to limit the concentrations in an effluent discharge (and thus possibly trigger requirements for additional treatment technology) would reflect precautionary or societal values, and may not necessarily produce measurable environmental benefits using current scientific tools and approaches. Such circumstances may arise when the most sensitive benchmark value is a drinking water guideline (iron for example), and iron salts may be used for phosphorus removal in wastewater treatment.

Therefore, the 69 substances shown in Tables 3.1 and 3.2 should be considered only a preliminary list of potential substances of concern.

3.4.2 Substances Found In MWWE But Lacking a Benchmark

A total of 26 substances were included in the Master List and found at quantifiable levels in MWWE, but currently lack a benchmark that could be used to evaluate the significance of the effluent data with respect to protection of human water uses or aquatic biota (Appendix Table A.9). Of these, five were non-specific parameters which are typically used as general indicators of treatment system performance, including biochemical oxygen demand (BOD), total suspended solids (TSS), oil and grease, total organic carbon (TOC) and total residual chlorine. Their non-specific nature precludes development of a meaningful benchmark. The remaining substances included pathogens (*Cryptosporidium* sp., *Giardia* sp.), polyaromatic hydrocarbons (benzo(b)fluoranthene, indeno(1,2,3-c,d)pyrene, total polycyclic aromatic hydrocarbons (non-specified)), industrial chemicals (bromochloromethane, chloromethyl methyl ether, bis(chloromethyl)ether, octachlorostyrene, acrylonitrile octylphenol and 4,4'-biphenyldiamine), pesticide residues (2,4,5-TP, DDD and DDE), polyhalogenated congener mixtures (polybrominated biphenyls, polychlorinated dibenzodioxins and polychlorinated dibenzofurans), and pharmaceutical and personal care products (PPCPs), which have emerged as substances of potential concern (clofibric acid/clofibrate, caffeine and estradiol).

Effluent data were also found for another 101 substances that were not originally included in the Master List (Appendix Table A.10). Other than the non-specific substances for which it is not possible to assess potential effects, many substances on this list have the potential to be of concern because they either known to be biologically active (e.g. pharmaceuticals), or they have chemical properties that are similar to substances with identified environmental concerns or human health effects such persistence, bioaccumulation or toxicity. For some substances, more data are needed to verify their prevalence in MWWE. If so identified, and if risks to human health and/or the environment are indicated by the available literature, they should be considered for environmental guidelines development (Figure 3.1).

3.4.3 Substances with Benchmarks but Lacking MWWE Data

Many of the substances on the project's Master List (68) have one or more water quality guidelines that could be used as a benchmark, but either have no matching concentration data (Table 3.3), or were reported as being less than an unspecified analytical method detection limit (e.g., chloromethyl methyl ether in Appendix Table A.8). Although a number of these substances may enter a municipal treatment plant in industrial wastewaters, many substances in this grouping can be contributed either in part by or entirely by diffuse sources (e.g. *E. coli*, PAHs). Others, such as pesticides and polychlorinated biphenyls (PCBs) and are unlikely to be present in MWWE unless entering through inflow to sewers from surface runoff, or from combined sewers. Still others, such as methyl tert-butyl ether (MTBE), a gasoline additive, are likely to be present only from infiltration of groundwater contaminated with gasoline and the additive. The algal toxin Microcystin-LR is not properly an effluent substance, but can develop under appropriate conditions in water bodies influenced by nutrients in MWWE.

It is recommended that analytical methods be reviewed to identify the capability to analyze for these substances in MWWE. If methods are available, a comprehensive sampling survey of MWWE could be completed to identify the potential adverse effects associated with these substances. If no methods are currently available in Canada for these substances, it may be appropriate to develop analytical procedures so that the potential hazard of the substances in the effluents can be assessed.

3.4.4 Substances with Neither Benchmarks nor MWWE Concentration Data

Another 34 substances from the Master List have neither environmental benchmarking guidelines nor effluent concentration data for comparison with the benchmarks (Table 3.4). Biological agents such as viruses and protozoa (general) would be costly to monitor on a regular basis. Others are disinfection by-products that have been flagged as of concern in potable water treatment, including chlorate and chlorite (by-products of disinfection with chlorine dioxide), and haloacetic acids, chloral hydrate and cyanogens chloride (from chlorine disinfection) (Singer 1999). Chlorinated municipal effluents themselves are listed as a substance. The environmental significance of this group of substances is uncertain, although many of the substances are industrial chemicals and pesticides, and likely to be of concern if discharged to the environment in sufficient quantities. If such substances are found to be prevalent in MWWE based on effluent monitoring surveys, such substances should be considered for potential water quality guidelines development.

Table 3.3. Substances with Benchmark but Lacking Effluent Concentration Data

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)	1.5
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)	0/100mL
Inorganic	Anion	Bromate	10
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)	0.5
Inorganic	Metal/Metalloid	Thallium	0.8
Non-specific	Physical/Chemical	Colour	15 TCU
Non-specific	Physical/Chemical	Total dissolved solids	500000
Non-specific	Physical/Chemical	Temperature	15°C
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	0.9
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene	2
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	20
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)	100
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	0.6
Organic	Chlorobenzene	Chlorobenzene	1.3
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	8
Organic	Dioxins and Furans	Dibenzofuran	0.3
Organic	Hydrocarbons with N,P,S substitution	Acridine	4.4
Organic	Hydrocarbons with N,P,S substitution	Aniline	2.2
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid	400
Organic	Oxygenate - Acetaldehyde	Formaldehyde	0.8
Organic	Oxygenate - Alcohol	Ethylene glycol	192000
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	500000
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	500000
Organic	Oxygenate - Ether	Methyl t-butyl ether	20
Organic	Oxygenated Compounds	Acrolein	0.03
Organic	Pesticide - Bipyridylium	Diquat	0.5
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)	10
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	0.0019
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	0.03
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	0.0002
Organic	Pesticide - Chloroacetanilide	Metolachlor	7.8
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	6.1
Organic	Pesticide - Dinitroaniline-based	Trifluralin	0.2
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	5
Organic	Pesticide - N-methyl carbamate	Aldicarb	0.15
Organic	Pesticide - N-methyl carbamate	Bendiocarb	40
Organic	Pesticide - N-methyl carbamate	Carbaryl	0.2
Organic	Pesticide - N-methyl carbamate	Carbofuran	1.8
Organic	Pesticide - Organophosphorus	Azinphos-methyl	20
Organic	Pesticide - Organophosphorus	Chlorpyrifos	0.002
Organic	Pesticide - Organophosphorus	Dimethoate	6.2
Organic	Pesticide - Organophosphorus	Malathion	0.1
Organic	Pesticide - Organophosphorus	Parathion	0.013
Organic	Pesticide - Organophosphorus	Phorate	2
Organic	Pesticide - Organophosphorus	Terbufos	1
Organic	Pesticide - Phosphoroglycine	Glyphosate	65
Organic	Pesticide - Pyrethroid	Deltamethrin	0.0004
Organic	Pesticide - Pyridine carboxylic acid	Picloram	29
Organic	Pesticide - Quaternary Ammonium	Dodecyl dimethyl ammonium chloride	1.5
Organic	Pesticide - Substituted benzene	Chlorothalonil	0.18
Organic	Pesticide - Thiocarbamate	Triallate	0.24
Organic	Pesticide - Thiophthalinide	Captan	1.3
Organic	Pesticide - Triazine	Atrazine	1.8
Organic	Pesticide - Triazine	Cyanazine	2
Organic	Pesticide - Triazine	Simazine	10
Organic	Pesticide - Triazinone	Metribuzin	1
Organic	Pesticide - Uracil	Bromacil	5
Organic	Pesticide - Urea-based	Diuron	1.6
Organic	Pesticide - Urea-based	Linuron	7
Organic	Pesticide - Urea-based	Tebuthiuron	0.27
Organic	Polyhalogenated Polyphenyl	PCBs	0.014

Table 3.3. Substances with Benchmark but Lacking Effluent Concentration Data

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]
Organometals	Alkyl lead	Tetraethyl lead	0.0007
Organometals	Alkyl lead	Tetramethyl lead	0.006
Organometals	Alkyl lead	Triethyl lead	0.4
Organometals	Alkyl mercury	Methyl mercury	0.004
Organometals	Alkyl Tin	Tributyltin	0.001
Organometals	Alkyl Tin	Tricyclohexyltin	250
Organometals	Aromatic Tin	Triphenyltin	0.022

Table 3.4. Substances Lacking both Benchmark and Effluent Concentration Data

Main Class	Sub-class	Chemical Name
Biological	Pathogen - Protozoan	Protozoa (general)
Biological	Pathogen - Virus	Viruses
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride
Inorganic	Anion	Chlorate
Inorganic	Anion	Chlorite
Inorganic	Disinfectant	Chlorine dioxide
Inorganic	Miscellaneous	Cyanogen Chloride
Non-specific	Miscellaneous	Chlorinated wastewater effluents
Non-specific	Physical/Chemical	Hardness
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride
Organic	Dioxins and Furans	Dibenzo-p-dioxin
Organic	Haloacetonitrile	Haloacetonitriles
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)
Organic	Halocarboxylic acids	Haloacetic acids
Organic	Hydrocarbons with N,P,S substitution	Acrylamide
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)
Organic	Oxygenate - Acetaldehyde	Acetaldehyde
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters
Organic	Oxygenate- Carboxylic Acid	Resin Acids
Organic	Oxygenated - Epoxide	Ethylene oxide
Organic	Pesticide - Bipyridylium	Methyl-parathion
Organic	Pesticide - Chloroacetanilide	Alalchlor
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop
Organic	Pesticide - Organophosphorus	Chlorfenvinphos
Organic	Pesticide - Organophosphorus	Temephos
Organic	Pesticide - Urea-based	Isoproturon
Organic	Polyhalogenated Polyphenyl	Aroclor 1254
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls
Organometals	Alkyl lead	Alkyl lead

3.4.5 Substances with Concentrations lower than Benchmark Values

After sorting the substances into the previously noted categories, a number of substances still remain. These are the substances which were identified as having identified concentration data that did not exceed a benchmark guideline value. The 44 substances are listed in Table 3.5 with the observed concentration range, most sensitive benchmark guideline value, and number of studies used to make the determination. Many of the substances included in this list are from historical lists of "priority pollutants" typical of the list developed by the U.S. EPA in the late 1970s. There are also a number of relatively common cations and anions, such as sodium, calcium, chloride and sulphate. Note that many of the substances are relegated to the category on the basis of only one or two studies. For such substances, it is recommended that additional concentration data be acquired and compiled to see if the substances truly belong in this category, or whether based on additional data, the categorization needs to be reviewed. If the data cannot be acquired from other studies, then a sampling survey should be considered to supplement the existing data.

3.5 Substance Fate in Municipal Effluent Irrigation and Soil Filtration

Europeans have some of the longest experience with using treated MWWE for irrigation. In Germany, Ternes et al. (2003) reported on a field that has been irrigated for over 40 years with treated effluent. The effluent is from the Braunschweig facility which employs nitrification and denitrification. The soil is a fine sand overlying a medium sand, with a pH of 5.8 in the surface layer, and organic matter, reported as humic substances, of just under 1%. Many classes of pharmaceuticals were removed in the soil aquifer treatment (SAT), including the estrogenic hormones, synthetic musks, beta-blockers, macrolide antibiotics, antiphlogistics, sympathomimetics and lipid regulators. The phase contrast media iopromide was partially removed in wastewater treatment, and was not detected in downstream wells. Some compounds showed little or no reduction through soil aquifer treatment, including the antiepileptic carbamazepine, the antibiotic sulfamethoxasole and several phase contrast media compounds, including diatrizoate, iohexol, iopamidol and iothalamic acid. In general, the removal or non-removal of pharmaceuticals through SAT reflects the situation in the wastewater treatment facility. If the compound is refractory in wastewater treatment, it is not likely to be removed in SAT.

An effluent irrigation site in eastern Austria receives effluent from a small treatment facility employing nitrification/denitrification and chemical phosphorus removal (Kreuzinger et al. 2004). Effluent from the facility passes through a polishing lagoon, a gravel filter prior to arrival at the infiltration basins. Using boron in the wastewater as a conservative tracer, the authors were

Table 3.5. Substances with Concentration Data that do not Exceed Benchmarks

Chemical Name	Concentration Range Reported	Number of Studies Reporting Results	Lowest Benchmark (ug/L)[a]
Acenaphthene	0.1 - 0.93	5	5.8
Aldrin	0.005 - 0.01	4	0.7
Benzene	<0.25 - 0.92	10	5
Beryllium	<10	1	11
Bromoform	ND	2	60
Calcium	2540 - 369000	4	1,000,000
Chloride	38000 - 55000	2	230,000
Dibromochloromethane	0.43 - <1	9	40
Dicamba	ND	2	10
Dichlorobenzene (1,3-)	ND - <1	8	150
Dichlorobenzene (1,4-)	0.06 - 5.0	17	5
Dichlorobromomethane	0.43 - <1	7	100
Dichloroethane (1,1-)	ND - 2.3	4	200
Dichloroethene (1,1-)	ND - <1	8	14
Dichloroethene (1,2-)	0.52 - <1	9	200
Dichloromethane	0.5 - 2.69	10	50
Dichloropropane (1,2-)	ND	2	0.7
Dichloropropene (1,2-) (cis and trans)	ND - 1.81	9	7
Dinoseb	ND	2	0.05
Endrin	ND	2	0.0023
Heptachlor + Heptachlor epoxide	ND	2	0.0036
Hexachloro-1,3-butadiene	ND	2	1.3
Hexachlorobenzene	ND - 0.002	4	0.0065
Iodo-2-propynyl butyl carbamate (3-)	ND	2	1.9
Lithium	1.9 - 2.0	2	2500
Mirex	ND	2	0.001
Naphthalene	0.05 - 0.38	6	1.1
Pentachlorobenzene	ND	2	6
Pentachlorophenol	0.2 - 0.3	6	0.5
Sodium	33600 - 48400	2	200,000
Styrene	ND - <1	8	72
Sulphate	11000 - 13000	2	500,000
Tetrachlorobenzene (1,2,3,4-)	ND	2	1.8
Tetrachlorobenzene (1,2,3,5-)	ND	2	0.1
Tetrachlorobenzene (1,2,4,5-)	ND	2	0.1
Tetrachloroethane (1,1,2,2-)	<1 - 6.23	9	70
Tetrachloromethane	ND	2	5
Tetrachlorophenol (2,3,4,6-)	ND	2	1
Trichlorobenzene (1,2,4-)	0.01 - 0.36	4	24
Trichlorobenzene (1,3,5-)	ND	2	0.65
Trichloroethane (1,1,2-)	0.38 - <1	9	800
Trichloroethylene	<0.5 - 14	11	21
Trichlorophenol (2,4,6-)	0.1 - 0.42	5	5
Uranium	0.05 - 0.11	2	5

[a] See Table A.5 for details.

able to distinguish the augmentation of the infiltrating effluent plume with other groundwater. Removal efficiencies of pharmaceuticals and personal care products (PPCPs) through the treatment facility, polishing pond and by soil infiltration are provided in Table 3.6.

Mechanisms in wastewater treatment proposed by Kreuzinger et al. (2004) included sorption and biodegradation, with photosynthesis occurring for some compounds in the polishing pond such as diclofenac and roxithromycin. Acidic compounds such as ibuprofen and bezafibrate were readily removed by biodegradation in the treatment plant, with additional removal in the polishing steps. Neutral compounds such as diazepam and carbamazepine showed little removal in wastewater treatment, polishing steps or in groundwater. The polycyclic musks tonalide and galaxolide were deemed to undergo some removal, primarily by sorption to solids, in both treatment and polishing steps; because there was little organic matter in the soil, there was little removal of these compounds. A final observation was that compounds present in the groundwater 75 days after infiltration were still likely to be detected after 140 days in the subsurface (Kreuzinger et al. 2004)

The fate of pharmaceuticals in American wastewaters has been investigated by Sedlak and Pinkston, (2004). Both treatment facilities alone and with membranes or soil aquifer treatment (SAT) were reviewed. The SAT site investigated near Tuscon, AZ demonstrated that almost all of the removal of the pharmaceuticals tested (diclofenac, gemfibrozil, ibuprofen, naproxen and metaprolol) were removed between a shallow well at 5 m soil depth and 40 m depth. Little or no removal was observed between the infiltration pond and the 5 m shallow well. Three of the pharmaceuticals were present in concentrations between 1,000 and 4,000 ng/L in the shallow well, but were non-detected at the deeper 40 m well Sedlak and Pinkston (2004).

A parallel study of an engineered constructed wetland found that there was virtually no removal of the pharmaceuticals through the wetland, even with a 7 day retention period (Sedlak and Pinkston 2004). The hormone 17α-estradiol was reduced from 2 ng/L in the wetland influent to less than 0.5 ng/L in the final pond outlet; the removal was attributed to a mechanism such as photo-oxidation because the hormone is resistant to biodegradation in activated sludge (Sedlak and Pinkston 2004). The authors assert that most pharmaceuticals are not likely to be sorbed in activated sludge treatment because they have octanol-water partition coefficients less than a log value of 2, with the exception of hormones, which typically have log K_{ow} values of 4 or higher. It therefore seems reasonable that some sorption of the hormones would take place in the constructed wetlands.

Removal of steroidal hormones by SAT for water reclamation was investigated by Mansell et al. (2004). Studies were conducted at bench-scale using soil columns of silica sand. An initial hypothesis that sorption in the soil columns would follow the octanol-water partition coefficients

Table 3.6. Removal of PPCPs by Wastewater Treatment and Soil Infiltration (Kreuzinger et al., 2004).

Agent	Approximate Removal (%) by		
	Treatment Plant	**Polishing Pond**	**Soil Aquifer Treatment**
Diclofenac	14 (sorption)	67 (photo-oxidation)	No additional removal in first 25 d; but below LOD after 50 d.
Bezafibrate	99	Additional	No additional removal in groundwater til after 140 d
Ibuprofen	99	Additional	No additional removal in groundwater til after 140 d
Diazepam	No removal	No removal	No removal in first 25 d, below LOD after 75 d
Carbamazepine	10	5	30 % after 100 d
Synthetic musks (tonalide, galaxolide)	80 (sorption)	10	No removal after 140 d
Iopromide	Nearly complete		Very little
Roxithromycin	40	45-86	Completely removed after 25 d

LOD = level of detection

of the steroids examined did not follow. Given that the log K_{ow} values for estriol, testosterone, and 17β-estradiol were 2.45, 3.32, and 4.01 respectively, the estradiol was expected to be the most strongly bound in the soil column tests. In the results, 17β-estradiol was the most mobile of the three steroids and testosterone was the most strongly bound. Overall removal efficiencies of the soil columns for the 3 steroids were 79 % for 17β-estradiol, 84 % for estriol and 97 % for testosterone (Mansell et al. 2004). Important factor related to the steroids behaviour in the soil columns were that removals were better in soils that had a higher clay, silt or organic matter content, that the removal was independent of redox condition (oxic or anoxic) and that the organic substrate composition was not a factor (Mansell et al. 2004). The issue of silt and clay content may be related either to the pore size in the soils, or to the greater specific surface area of smaller particles relative to their size, or to sites for electronic interactions between the substances and silt/clay particles, relative to silica.

Bench-scale column and batch studies were used to assess factor influencing the fate of PPCPs in SAT (Rauch et al. 2004). Both a secondary effluent and a reverse osmosis-treated secondary effluent spiked with the substances of interest were examined. They note that hydrophilic substances such as NDMA and the solvent 1,4-dioxane are not well sorbed by soil organic carbon and are therefore quite mobile. In the soil column studies under anoxic conditions, the secondary effluent resulted in development of higher levels of biomass activity than did the RO permeate. Carbamazepine showed no removal in any column compared to controls, confirming observations of other studies. Ibuprofen was removed to below detection limits after 20 hours in the RO permeate column, and 58 hours for the secondary effluent column. These results were opposite to expectations because of the higher biomass activity in the secondary effluent-treated column. The effect of pH on sorption of ibuprofen, with later biodegradation in the soil columns, was found to be significant effect up to a pH value of 7 (Rauch et al., 2004).

The 23rd Avenue Rapid infiltration Project is located outside of Phoenix, AZ. Secondary effluent from the 23rd Avenue treatment facility is infiltrated through a soil composed primarily of loamy sand with underlying sand gravel layers. Prior to chlorination of the secondary effluent sent to infiltration bacterial reduction was 99 %, leaving about 10^4counts/10 mL of fecal coliforms in the infiltrated water. After implementing chlorination of the effluent destined for infiltration, fecal coliform levels in the effluent were on the order of 3500 counts/100 mL, and the infiltrated water had fecal coliform levels of 0.27/100 mL (Bouwer and Rice 1984). Similarly virus levels declined form 0.1 – 2 plaque-forming units (PFU) per 100 L to 0 following secondary effluent chlorination of the water to be infiltrated.

Non-halogenated organics were removed by infiltration by generally greater than 90 %, including both aliphatic and aromatic organics such as m,p-xylene, styrene, naphthalene, phenanthrene and diethyl phthalate. Removal efficiencies of chlorinated organics were much poorer, ranging from 0 for trichlorophenol and pentachlorophenol to 88 % for chloroform (Bouwer and Rice 1984).

Bouwer and Rice (1984) and Rice and Bouwer (1984) make the case for using primary effluent instead of the more highly treated secondary effluent for soil aquifer treatment in areas where the soil is carbon-depleted. Testing by Rice and Bouwer (1984) demonstrated that removal efficiencies of conventional pollutants such as ammonia-N, organic-N, phosphate and organic were higher with primary effluent than secondary effluent. Ultimately, the infiltration capacity of the soil site depends on the hydraulic conductivity of the soil and the composition of the suspended solids. Optimal treatment is achieved when the suspended solids are large and organic rather than small and inorganic (by Rice and Bouwer, 1984).

The wastewater of Mexico City also undergoes overland treatment and soil aquifer treatment. Untreated wastewater is transported to the Tula Valley for aquifer recharge. The quality of the reclaimed water is considered to be the equivalent or better to secondary treatment (Jimenez and Chavez 2004). Although a few organics such as alkylbenzenes and chlorobenzenes were identified in the reclaimed water, most common volatile organics (e.g., o,m-xylenes, p-cresol, ethylbenzene, chloroform and tetrachloroethylene) were completely removed to non-detectable levels. Metal removal was variable with some being reduced in concentration by over 90 % (aluminum, chromium, iron and manganese), some in the range of 50 – 90 % (arsenic copper and lead), while mercury and cyanides were reduced by less than 50 % (Jimenez and Chavez 2004). Nitrate levels increased significantly in the reclaimed water compared to the wastewater. Because of the aridity of the area, and with the consideration of using the reclaimed water as a potential source of potable, water, the authors recommended membrane filtration.

Lee et al. (2004a) investigated metal removal in soil aquifer treatment at pilot scale using riverbank soil. They found in tests with cadmium, chromium and lead that soil aquifer treatment resulted in removal of the metals, without desorption, even under conditions simulating acid rain (water pH = 4.3), when the metals should become more mobile. Based on more extensive testing with lead, the metal concentration in the wastewater to be treated was the most significant factor (including TOC concentration in the wastewater) in sorption to the soil. Lee et al. (2004) suggested that soil column tests could be used to predict metal breakthrough to the reclaimed water.

The degradation of the surfactant metabolite 4-nonylphenol (4-NP) in soils from Ontario and the Canadian High Arctic was investigated by Topp and Starratt (2000). The soils ranged in pH from

5.8 to 7.4, and typically had organic matter content in the range of 0.8 to 4.6 %, although one soil from the Arctic was an organic soil with 26.2 % organic matter. Tests of degradation of radio-labelled 4-NP with the soils were conducted both with and without an amendment of sewage sludge solids. Results reported here will focus on results without sewage sludge, as they are more pertinent to effluent irrigation factors. In all soils, the 4-NP was rapidly mineralized at 30 ^{o}C to CO_2, with an initial rapid phase lasting for about 10 d, in which about 30 % of the compound was mineralized, followed by a slower second phase, raising the total quantity of parent compound mineralized to about 40 % (Topp and Starratt 2000). The remaining radioactivity was not readily extractable, suggesting it may have been incorporated into biomass, remained bound as parent compound or as metabolites. Mineralization was inhibited by either a lack of soil moisture, or an overabundance of it (flooded condition). Studies of temperature effects revealed that as the temperature declined over a range of 30 to 4 ^{o}C, the lag period prior to initial mineralization increased, the maximum mineralization rate decreased, and the quantity of recovered CO_2 decreased (Topp and Starratt 2000). The authors concluded the ability of soil microorganisms to degrade 4-NP is widespread, and that biodegradation in the soil is possible under conditions of the Canadian growing season (Topp and Starratt 2000).

From the above discussion, the following observations can be summarized. Soil characteristics (including soil silt clay, sand and organic matter content and pH) can affect the mobility and fate of substance. The redox condition in the soil (i.e. aerobic or anoxic environment) was not an issue for removal of hormones, but the effect of redox environment on fate of other substances was mostly not identified. Groundwater monitoring studies showed that if substances are not well removed in wastewater treatment, they will not likely be well removed in soil aquifer treatment. Substances with higher log K_{ow} (i.e. more hydrophobic) values are more likely to sorb to soils than hydrophilic, water soluble substances. The level of effluent treatment prior to soil filtration does not appear to be an issue, as substances were removed at least as effectively, and perhaps more so, than with higher quality treated effluents. Other studies have been identified subsequent to the preparation of this report that may add to the discussion of solids aquifer treatment. A paper by Amy et al. (1994) was discovered in the late stages of this review and was not included.

3.6 Effect of Regional Differences on MWWE Quality

As part of this task, a comparison was to be made between concentrations of substances in effluents from different regions of Canada, to assess factors contributing to possible differences. Such an assessment would require data from many treatment facilities from different regions of Canada, to develop means and standard deviations for a statistical comparison. In fact, there are insufficient substance data to permit this type of assessment. Instead, this discussion is a

more general review of the types of differences in effluent quality or treatment that might be expected.

A major difference in municipal WW effluent from the south of Canada to the north is the effect of temperature, particularly when biological treatment process are involved. The microorganisms involved in wastewater treatment are directly affected by temperature: as the temperature drops, microbial activity in degrading the organic substances in wastewater treatment also declines. This effect has long been understood in the biological conversion of ammonia-N to nitrate-N in wastewater treatment, a process called nitrification. The rate of nitrification declines significantly with temperature. For each 10 ^{o}C decline in temperature the rate of ammonia conversion is cut in half (U.S. EPA, 1993). Although nitrification may occur at temperatures as low as 4 ^{o}C, it is slow compared to the removal rate at 20 ^{o}C, and so treatment plants in Canada's North would experience more difficulty in producing a nitrified effluent. Thus, the ammonia-N level in plants in more northern climates would be expected to be higher for a greater part of the year than equivalent facilities in southern Canada.

Similarly, the biodegradation of specific organic substances can be affected by temperature. The industrial surfactant ethoxylated nonylphenol (NPEO) has been shown to exhibit more resistance to biodegradation in wastewater treatment at colder temperatures. Several studies have shown that when the temperature of treatment declines from the range of 20 ^{o}C or higher to 16 ^{o}C or lower, the removal efficiency of NPEO becomes increasingly erratic, and is more likely to produce foam (Mann and Reid 1971; Stiff et al. 1973; Kravetz et al. 1983; Tanghe et al. 1998).

If biodegradation of the organic substances is reduced at lower temperatures, then it may be reasonably assumed that more of the substance might be sorbed to solids and discharged in the effluent. The ultimate fate of each substance, however, is dependent on its chemical properties and the operation of the facility.

Freezing temperatures for an extended period in the North presents its own set of problems. Because all receiving streams are likely to be frozen solid, the method of effluent disposal is likely to be of concern to a number of municipalities. Lagoon storage may well be required in such circumstances, until break-up of ice in the spring, allowing for discharge of the stored effluent. Hydrogen sulphide formation may be an issue in this situation.

Another principal difference between treatment in the Canadian North and South is in the population density and degree of industrialization. Southern Canada has a higher level of industrialization than northern Canada, and so the concentrations and loadings of industrial

substances such as chlorinated solvents petroleum-based products, plasticizers and metals are anticipated to be higher in southern Canada.

Source water characteristics also have an effect on wastewater composition. Wastewater from geographic areas with a sedimentary bedrock basis, such as limestone or dolomite, will have higher levels of dissolved substances and hardness than facilities located on an igneous bedrock granitic or basaltic). At the concentrations of most substances in this study, the influence of dissolved solids and hardness levels would not be expected to influence treatment efficiency to a large degree. The greatest concern might be in salt accumulation in soils in which effluent irrigation was practiced. The accumulated salts could affect the growth of both bacteria degrading substances in the sub-soil, as well as any crops grown on the surface.

Geographic differences between eastern Canada and Central/Western Canada can result in some of the same issues discussed above. Related to population and industrial differences, and differences in source water characteristics. Lagoon treatment is a popular method of treatment for smaller communities throughout Canada. Lagoons can be very effective in reducing substance levels because of long retention times and through photo-oxidation of organic substances, a removal mechanism that is of slight importance in larger mechanical treatment facilities. For example, Kreuzinger et al. (2004) attributed removal of the pharmaceutical diclofenac in a polishing pond to photo-oxidation. In the same study, concentrations of a number of other pharmaceuticals and PCPs such as the antibiotic roxithromycin and the musk fragrance tonalide and galaxolide, were reduced by more than 50 % from the polishing pond influent to outlet.

Quantity of precipitation may affect the wastewater quality and type of treatment in Central/Western Canada, compared to Eastern Canada. With higher precipitation levels, Eastern Canada may have more dilute wastewater due to infiltration and inflow, and perhaps because of higher water utilization rates. It is not clear from this review, however, whether this factor truly affects treatment efficiency between the different areas. As a result of dryer conditions, use of effluent irrigation for water reclamation is likely to be more widespread in Central/Western Canada than in Eastern Canada. Issues of effluent irrigation and soil aquifer treatment were discussed separately.

Another consideration is that effluent receiving environments differ in size and physical-chemical properties. These factors can affect whether effects will be expressed in receiving environments, as well as the magnitude of effects. For example, separate guidelines have been developed by CCME and the U.S. EPA for protection of marine versus freshwater environments, confirming that there are likely to be differences in environmental effects for at least some substances between these two types of environment. Site-specific

dilution/assimilative capacity will likely be the largest single factor determining whether effluent substances will impact receiving environments and some regulatory jurisdictions have taken this into account in methods for setting site-specific effluent limits (Minnow 2005). Receiving environment differences were also briefly addressed in the comparison of effluent concentrations to benchmarks (Section 3.4.1), and more detailed assessment herein is beyond the scope of this study.

4.0 SUBSTANCE DESCRIPTIONS

In this chapter, descriptions are provided for selected substances including the non-specific (conventional) substances, those of potential concern as defined in Table 3.1, and those that are considered “emerging” substances, which may not be familiar to many readers of this report. The chapter is intended to provide context as to why substances appear in Table 3.1, the list of substances of potential concern resulting from this study, and to provide an annotation of the emerging pollutants.

Note: The study makes use of on-line references, some of which can be edited on-line, and thus should be considered as non-scientific sources. This report attempted to use the most reliable of the available on-line sources.

4.1 Non-Specific (Conventional) Substances

Most effluent concentration limits for the non-specific substances are determined by the Provinces and Territories. There are no CCME or EPA guideline values for protection of aquatic life. Some substances have Canadian Drinking Water Guideline values (e.g. total dissolved solids, colour, turbidity) which were either not exceeded by studies reviewed in this projector there were no data available.

4.1.1 Biochemical Oxygen Demand (BOD_5)

The measurement BOD_5 is an indicator measurement of substances that can be degraded biologically, consuming dissolved oxygen in the process, over a test period of 5 days. Discharges of BOD in receiving environments with limited assimilative capacity sometimes impact in receiving environments by reducing dissolved oxygen concentrations to levels below those required for aquatic biota and it is in this context that BOD is considered a pollutant. A five-day test is used for convenience, and typically represents 60 to 70 % of the ultimate BOD (Metcalf and Eddy 1991). The BOD test can provide variable results depending on whether oxidizable nitrogen compounds are present in the wastewater. For this reason, measurements are variously reported as carbonaceous (with out nitrogen effect) or total BOD (including nitrogen effect).

BOD_5 concentrations can range from approximately 100 mg/L in weak wastewaters to over 400 mg/L in strong wastewaters (Metcalf and Eddy 1991). Strong wastewaters may have a high industrial contribution from sectors such as food and beverage processing. Weak wastewaters may be of primarily domestic content with substantial quantities of infiltration and inflow. In some communities in northern Canada, the wastewater may be weak also because houses leave a trickle of water running continuously to prevent pipes from freezing.

Primary treatment may result in removal of 25 to 40 % of BOD_5 in the raw wastewater, while secondary treatment may achieve reductions of 80 to 90 %, or higher, depending on the influent concentration. Concentrations of BOD_5 in secondary effluents in the range of 5-10 mg/L may now be routinely achieved.

4.1.2 Total Suspended Solids

The total suspended solids measurement is a gravimetric measurement of the quantity of a mixture of organic particles, silt, and clay remaining in suspension in wastewater after settling. Concentrations of total suspended solids range from 100 mg/L for weak sewage to 350 mg/L for strong sewage (Metcalf and Eddy 1991). Suspended solids can be contributed by a wide variety of industries (see Table A.11), as well as domestic and stormwater inputs. Suspended solids discharged in MWWEs effluent to receiving environments can accumulate in deposits that are unsightly and impact aquatic biota resident in sediments, and contribute organic loading (measured as BOD) to receiving waters, resulting in a decline in dissolved oxygen (D.O.) concentrations. Toxic substances, such as metals, pesticides, polyaromatic hydrocarbons and endocrine disrupting compounds like nonylphenol, may also be adsorbed onto the surfaces of suspended solids, which can be released once in the aquatic environment.

Primary treatment can remove 50 to 65 % of total suspended solids in wastewater, while in secondary treatment (activated sludge can remove 80 to 90 % of TSS; trickling filters are less effective at 65 to 85 % removal efficiency) (Metcalf and Eddy, 1991). Secondary effluent concentrations in the 5 to 20 mg/L range are routinely achievable. Tertiary filtration can reduce TSS concentrations to 1-5 mg/L.

4.1.3 Total Dissolved Solids

Most Sensitive Guideline Value: 500,000 ug/L (Canadian Drinking Water Guidelines)

The concentration of total dissolved solids in municipal wastewaters may range from 250 to 850 mg/L for weak and strong wastewaters, respectively (Metcalf and Eddy 1991). A wide variety of industries may contribute dissolved solids to municipal wastewaters. The concentrations are also reflective of municipal potable water source. Domestic use of potable water increases the mineral content in wastewater by 150 to 380 mg/L, primarily from sodium, bicarbonate, chloride and nitrate (Metcalf and Eddy 1991). If the dissolved solids are inorganic salts, conventional secondary and tertiary wastewater treatment processes will generally exert little removal.

4.1.4 Colour

Most Sensitive Guideline Value: 15 true colour units (Canadian Drinking Water Guidelines)

Colour in municipal effluents is an aesthetic consideration rather than an actual pollutant, as any dyes that pass through secondary treatment tend to be stable and do not consume additional oxygen in the aquatic environment. Most secondary treated municipal effluents do not exhibit much colour, but are clear and colourless. Primary treated effluent may exhibit a brownish-grey tinge. Certain industries, such as textile dyeing and manufacturing, or paperboard and boxboard manufacturers, may contribute dyes to their sewered wastewaters.

4.1.5 Hardness

Hardness is in indication of the quantity of calcium and magnesium content of the water, and in municipal effluents is a reflection of the potable water source. Wastewater treatment processes generally have little effect on the hardness of wastewater.

4.1.6 Fats, Oil and Grease

Fats, oil and grease, (FOG) if discharged in treated effluents, can create unsightly floating matter and films or sheens on water surfaces. It may also interfere with biological life forms in the surface waters (Metcalf and Eddy 1991). The source of fats and oils in municipal wastewater is from food preparation and dish cleaning in homes and restaurants, while mineral oils and greases arise from auto shops, garages and streets. A wide variety of industries are capable of discharging oils and grease to municipal sewers (Table A.11). Typical concentrations in wastewater range from 50 mg/L for weak wastewater to 150 mg/L for strong wastewater (Metcalf and Eddy 1991).

In wastewater treatment much of the FOG floats and is removed by mechanical skimming. When oil coats suspended particles, it becomes more difficult to treat. Fats are not easily biodegraded by bacteria.

4.1.7 Total Organic Carbon (TOC)

This measurement is similar in application to the BOD_5 test, in that it is a measure of the organic carbon that can be oxidized (i.e. consume dissolved oxygen). It can include non-biodegradable organic carbon, however, which by definition the BOD_5 test does not include non-biodegradable carbon. Inorganic carbon, such as CO_2 or carbonates, is removed by pretreatment prior to analysis. In some laboratories, the test performed is actually a filterable organic carbon analysis, in which organic solids are digested with acid to make them soluble prior to analysis. Because the terms may be used interchangeably by some, care should be taken to differentiate between the two analyses.

The concentration of TOC in raw wastewater may range from 80 mg/L for a weak wastewater to 290 mg/L for a strong wastewater (Metcalf and Eddy 1991). Removal efficiencies for different levels of treatment described above for BOD, are applicable to TOC.

4.1.8 Turbidity

Most Sensitive Guideline Value: 1 Nephelometric Turbidity Unit (Canadian Drinking Water Guidelines)

Turbidity is a measure of the light-scattering potential of wastewater, caused by the presence of colloidal and suspended material. Units of measurement are typically NTU, or nephelometric turbidity units. While primary treatment results in only a minor reduction in turbidity at best, secondary treatment in most cases can result in a large reduction in turbidity. In treated secondary effluent, turbidity has been related to the total suspended solids concentration according to the following (Metcalf and Eddy 1991):

Turbidity (NTU) = TSS (mg/L)/(2.3 to 2.4)

Turbidity is associated with the presence of very fine particles, which may include viruses, and so it is of concern in water disinfection, especially with ultraviolet light disinfection. Viruses may be shielded from the UV light, and so pass through the disinfection treatment without inactivation. Chemical coagulation and effluent filtration can decrease turbidity levels.

4.1.9 pH

Most Sensitive Guideline Value: 6.5 – 9.0 (CCME Freshwater)

Most Sensitive Guideline Value: 7.0 – 8.7 (CCME Marine)

The pH parameter is not technically a non-specific substance, because it is a measurement of the hydrogen ion concentration. It has been grouped in this annotation with other non-specific substances because it is a commonly measured “conventional” parameter, as the other substances are. Because many treatment plants use biological systems for wastewater treatment, pH must be maintained within a range tolerated by the biomass involved in waste reduction. Many municipalities specify in sewer use bylaws that industrial wastewaters discharged to municipal sewers must be within a certain range specified in standard pH units (e.g., 6.5 and 8.5 (OMOE 1998); 5.5 – 9.5 (Nova Scotia, 2005a); 5.5 - 12.0 (GVRD, 2001)).

The operating pH range for secondary treatment of municipal wastewater is 6.0 to 9.0 standard pH units, with an optimum range of 7.0-7.5 (Eckenfelder and O’Connor, 1961). However, the mode of operations can significantly affect the working pH. For example, nitrification is a process that consumes alkalinity, dropping the operating pH. Because the alkalinity present in

wastewater is to a large degree governed by the potable water source, facilities with very soft water, such as in the Canadian Shield or in the Rocky Mountains, may find the nitrification can significantly drop the pH to a level of 6.0 or lower, and thus alkalinity may need to be added for the process to continue. Fluctuations in pH may occur on a daily basis in wastewater lagoons due to photosynthesis. As algae consume carbon dioxide during photosynthesis, the pH can rise, while at night when respiration occurs, carbon dioxide re-enters the water system and the pH declines (Metcalf and Eddy 1991).

Disinfection with gaseous chlorine or hypochlorite solution becomes more effective at lower pH values. Hence with chlorination, a pH value of 6.5 results in more effective disinfection than at a pH of 7.5.

The toxic potency of weak acids and bases in wastewater vary based on pH because pH alters the proportion of chemical present in un-ionized versus ionized form. Generally, the un-ionized form is more toxic than the ionized form. For example, the weak base ammonia becomes more toxic as pH increases because more ammonia converts to the un-ionized form. Conversely, sulphide, a weak acid, is more toxic at lower pH values, which favour formation of the un-ionized form.

4.1.10 Temperature

Most Sensitive Guideline Value: 15 ^{o}C (Canadian Drinking Water Guideline)

Temperature is not a measurement of a non-specific wastewater substance. It has been grouped in this annotation with other non-specific substances because it is a commonly measured “conventional” parameter, as the other non-specific substances are. In wastewater treatment, the rate of bacterial use of soluble organic substrate (measured as BOD_5, TOC or other parameter) is temperature dependent. Biodegradation kinetics significantly slow down in winter operation. Nitrification stops when the temperature falls to about 5 ^{o}C, while the carbon-consuming heterotrophic bacteria become dormant at about 2 ^{o}C (Metcalf and Eddy 1991). This sensitivity clearly makes biological treatment in winter a challenge in the Canadian North. At the other extreme, nitrification and aerobic digestion of solids ceases if the wastewater temperature rises above 50 ^{o}C. As a general rule of thumb, biokinetic rates double for each increase of 10 Celsius degrees.

Wastewater effluent temperature can become a problem in aquatic receiving environments when it lowers the solubility, and hence the concentration of dissolved oxygen (Clark et al. 1971). Because the microbial biomass in secondary treatment requires a temperature range for operation, effluents are not generally in the range that adversely affects organisms in receiving waters. In fact, warm temperatures may attract organisms and promote greater biological

activity/productivity because of the warmth and nutrient content relative to the ambient receiving water. This can cause shifts in the composition of biological communities which may be perceived as either beneficial or detrimental.

4.2 Inorganic Substances

4.2.1 Metals and Metalloids

Aluminum

Most Sensitive Guideline Value : 5 - 100 ug/L CCME Freshwater

Effluent Range: 40 - 5800 ug/L

MWWE concentrations of aluminum may sometimes be well above the CCME guidelines for both protection of freshwater aquatic life (no marine value available) and drinking water (Table 3.1). Aluminum is the third most abundant element in the environment and has many domestic and industrial uses, including water treatment, abrasives, furnace linings, food additives, pharmaceuticals and alloy production (ATSDR 2004). Aluminum enters aquatic environments by natural weathering of rocks and in wastewaters from mines or industries using aluminum in processing, or as a flocculant (alum) in municipal wastewater. In aquatic environments, aluminum is most toxic at pH of approximately 5.0 and at pH greater than 6.5 (Schofield and Trojnar, 1980; CCREM 1987). Aluminum is not known to produce any carcinogenic, bioaccumulative or persistent effects; however some studies have linked high concentrations of this metal to Alzheimer's Disease (ATSDR 2004).

Antimony

Most Sensitive Guideline Value : 6 ug/L Canadian Drinking Water Guideline

Effluent Range: 0.54 - 9 ug/L

Antimony enters the aquatic environment via natural weathering of rocks and soil runoff, as well as from anthropogenic sources such as effluents from mining and manufacturing operations and municipal sewage treatment facilities (CCREM 1987). Information about its aquatic chemistry and toxicity is limited. Ontario has developed an interim water quality objective (Appendix Table A.2) but other major jurisdictions such as the CCME and U.S. EPA have concluded the data are too limited for development of a guideline. Therefore, further information is required before a conclusive determination can be made regarding the risks to the environment or human health water uses associated with MWWE discharges of antimony.

Arsenic

Most Sensitive Guideline Value : 5 ug/L CCME Freshwater

Effluent Range: 0.7 - 23 ug/L

Arsenic is released into the environment by weathering of arsenic-containing rocks and volcanic activity, but human activities account for more of the global releases (CCREM 1987). Arsenic enters aquatic environments via municipal and industrial effluents, as well as atmospheric deposition (Demayo et al. 1979). Arsenic can exist in any of four oxidation states (-3, 0, +3, +5) and can form a wide range of compounds with organic matter, other metals, and other inorganic substances (e.g., sulphur) (CCREM 1987). Arsenate (AsO_4^{3-}) is the stable form in aerobic waters. It can bioaccumulate in some aquatic species, but does not seem to biomagnify.

Boron

Most Sensitive Guideline Value : 200 ug/L Ontario PWQO

Effluent Range: 110 - 1300 ug/L

Boron is a naturally occurring element that is found in the form of borates in the oceans, sedimentary rocks, coal, shale, and some soils. (WHO 1998). The primary sources of boron in MWWEs are laundry detergents, while industrial sources include agricultural chemicals and fertilizers, glass and ceramics manufacturing, and coal combustion and mining (Nicholson 2005). In wastewater, boron is present as the borate ion (Nicholson 2005). Kreuzinger et al. (2004) reported effluent concentrations of boron at 1.3 mg/L in an Austrian municipal effluent, while in Switzerland, Giger et al. (1987) observed levels of 0.8 – 1.2 mg/L. In Israel, where effluent irrigation has been practiced for decades, legislation has been implemented banning of boron in detergents to battle increasingly saline soils. As a result, effluent levels have dropped from 0.6 mg/L pre-ban to 0.3 mg/L post-ban (Weber and Juanico 2004). Boron accumulates in aquatic and terrestrial plants but does not magnify through the food-chain (WHO 1998). Bacteria are relatively tolerant towards boron, and based on acute toxicity values, invertebrates are less sensitive to boron than microorganisms. Acute tests with several fish species yielded toxicity values ranging from about 10 to nearly 300 mg/L, with rainbow trout *(Oncorhynchus mykiss)* and zebra fish *(Brachydanio rerio)* the most sensitive at around 10 mg/L (WHO 1998).

Barium

Most Sensitive Guideline Value: 1000 ug/L Canadian Drinking Water Guideline

Effluent Range: 40 - 5800 ug/L

Although barium is a common element in the earth's crust, only trace levels are normally found in aquatic systems (CCREM 1987). Barium is used in the manufacture of metal alloys, paints, pigments, paper, soap, rubber, cement and various other products and thus can be found in the effluents various manufacturing operations. It is also found in the effluent from mining and smelting operations and in drilling wastewaters. It readily associates with other substances in water such as carbonate ions and sulphate, causing it to precipitate. Barium can accumulate in some marine biota, but information about its biological effects is scarce. Saskatchewan has developed an interim water quality objective (Appendix Table A.2) but other major jurisdictions such as the CCME and U.S. EPA have concluded the data are too few for development of a guideline. Therefore, further information is required before a conclusive determination can be made regarding the risks to the environment or human health water uses associated with MWWE discharges of barium.

Cadmium

Most Sensitive Guideline Value : 0.017 ug/L CCME Freshwater

Effluent Range: 0.014 - 14 ug/L

Cadmium is highly toxic to some aquatic biota, and guidelines for protection of freshwater aquatic life are typically in the parts per trillion range (Appendix Table A.2). Effluent concentrations are often greater than such values (Table 3.1). The CCME limit for cadmium is based on water hardness; as hardness increases, toxicity decreases. Cadmium is only moderately removed from wastewater treatment systems. As a result, cadmium is often a target substance in source control programs. Cadmium is extracted as a by-product during the production of other metals such as zinc, lead, or copper. It can be used in batteries, electronic equipment, photography supplies, lubricants, glass, ceramics, pigments, metal coatings, plastics, and some metal alloys (ATSDR 2004). This metal can enter the environment from metal smelters, mining, manufacturing industries, agricultural runoff and the burning of fossil fuels (Friberg et al. 1974). The toxicity of cadmium in aquatic environments also depends on other factors such as the presence of organic compounds and other metals, which tend to lessen cadmium toxicity; pH and temperature also affect the toxicity level of cadmium. In aquatic environments cadmium may exist as a free ion or combined with a salt. Cadmium can come out of solution by exchanging with calcium ions in carbonate lattice structures or through adsorption to humic substances (U.S. EPA 1979). If cadmium is readily available, organisms ranging from macrophytes to fish may accumulate it (Florence 1982), however tissue concentrations will decrease with increasing water hardness (Kinkade and Erdman 1975).

Chromium (hexavalent)

Most Sensitive Guideline Value : 1 ug/L CCME Freshwater

Effluent Range: 0.64 - 140 ug/L

Total chromium levels in treated effluent may exceed water quality guidelines for protection of aquatic life, but this could not be conclusively determined because effluent values are typically measured as total chromium, while environmental guidelines are expressed as either the tri- or hexavalent form (Table 3.1). Chromium is a naturally occurring element in the environment; however, the hexavalent form is only produced by industries. Hexavalent chromium is highly soluble and mobile in water and it does not readily adsorb to settling particles (Cheremisinoff and Habib 1972). The toxicity of chromium increases as water hardness decreases. It can enter the environment from companies involved in chrome plating, dyes and pigments, leather tanning, wood preserving, drilling muds, rust and corrosion inhibitors, textiles, and toner for copying machines (ATSDR 2004). Hexavalent chromium can easily penetrate cell membranes and accumulate in the tissues of organisms and it is also believed to be carcinogenic. Removal of chromium in wastewater treatment is quite variable, (e.g. 30 to 80 %), in part because it exists as both the trivalent and hexavalent states.

Cobalt

Most Sensitive Guideline Value : 0.9 ug/L Ontario PWQO

Effluent Range: 0.58 - 15 ug/L

Cobalt is used in alloys, coating tools, production of magnets, tires, appliances and petroleum products (Telewiak 1985). Cobalt may enter the aquatic environment through runoff from areas rich in cobalt-containing ores, coal mine drainage, emissions from coal burning industries, agricultural runoff and road and airport traffic (Smith and Carson 1981). Cobalt is an essential trace metal in humans (ATSDR 2004) and is not known to accumulate or be carcinogenic. The behaviour of cobalt in wastewater treatment is not well known. It was not one of the U.S. EPA Priority Pollutants from the 1970s and 1980s, and so has received little study in wastewater treatment.

Although a CCME guideline exists for cobalt for protection of agricultural water uses, there are no CCME or EPA guidelines for protection of aquatic life and an Ontario guideline for protection of aquatic life is orders of magnitude lower (Appendix Table A.2). Ontario has developed an interim water quality objective (Appendix Table A.2) but other major jurisdictions such as the CCME and U.S. EPA have concluded the data are too limited for development of a guideline.

MWWE levels cobalt may exceed the Ontario benchmark (Table 3.1). Therefore, further information is required before a conclusive determination can be made regarding the risks to the environment or human health water uses associated with MWWE discharges of cobalt.

Copper

Most Sensitive Guideline Value : 2-4 ug/L CCME Freshwater

Effluent Range: 3.3 - 190 ug/L

Copper concentrations in MWWE may well exceed levels considered protective of freshwater aquatic biota, but they may not pose a risk to humans, based on measured effluent levels (Table 3.1) and relative benchmark concentrations (Appendix Table A.2). Copper removal efficiency may be variable in wastewater treatment systems, (e.g. as low as 30%), but is often in the range of 60 to 80%. There is no water quality guideline specifically for protection of marine environments in Canada, although the U.S. EPA has adopted a value (3.1 ug/L) similar to the freshwater values used in Canada (2-4 ug/L). Natural sources of copper in aquatic environments include weathering or solution of copper mineral, but anthropogenic sources may contribute 33-60% of the total annual global input to aquatic environments (Demayo and Taylor 1981). Anthropogenic sources include mining, smelting and refining industries and other industries, corrosion of copper pipes and use of copper compounds as algicides, fungicides and pesticides (CCREM 1987). Copper exhibits complex behaviour in the aquatic environment, being found in forms ranging from dissolved ions to inorganic or organic ligand complexes. Sorption and precipitation play major roles in determining the abiotic fate of copper in aquatic environments. The ionic forms tend to be more soluble and toxic in acidic than basic waters and it is not biomagnified to any significant extent (CCREM 1987).

Iron

Most Sensitive Guideline Value : 300 ug/L CCME Freshwater

Effluent Range: 39 - 5230 ug/L

Iron is the fourth most abundant element in the earth's crust and is naturally released to the environment by the weathering of sulphide ores and igneous, sedimentary, and metamorphic rocks. It is also released from mines, mineral processing, and iron- and steel-related industries. The chemical behaviour of iron in water is determined by oxidation-reduction reactions, pH and the presence of coexisting inorganic and organic chemical complexing agents (CCREM 1987). Iron concentrations in MWWE may exceed the benchmarks for drinking water and protection of

freshwater biota (both 300 ug/L), but no guideline has been established in Canada or the U.S. for marine environments (Table 3.1 and Appendix Table A.2).

Lead

Most Sensitive Guideline Value : 1-7 ug/L CCME Freshwater

Effluent Range: 0.2 - 91 ug/L

The CCME guidelines for protection of freshwater biota range from 1 to 7 ug/L, based on increasing water hardness. Although CCME has not published a value for protection of marine biota, the U.S. EPA has adopted a value of 8.1 ug/L (Appendix Table A.2). Lead may be released into the environment through the weathering of sulphide ores, but anthropogenic inputs predominate, though activities such as mining, milling and smelting of lead-containing ores, and combustion of fossil fuels (CCREM 1987). Chemical speciation of lead compounds in water is complex and depends on several modifying factors such as pH, dissolved oxygen and the presence of coexisting inorganic and organic chemical complexing agents. Older water pipes and solders may contribute to drinking and domestic wastewater today, although lead is no longer used in modern plumbing. Old paint containing lead on walls and trim can be a source of potential lead contamination in small children (CCME 2005). Many former sources of potential lead contamination have been phased out, including use as a gasoline additive and in lead-based solders in canned foods. Lead is a potent neurotoxin, particularly among small children, and can cause impairment of cognitive skills and contribute to learning disorders (ATSDR, 2000).

Magnesium

Most Sensitive Guideline Value : 200 ug/L Alberta Drinking Water Guideline

Effluent Range: 3540 - 25380 ug/L

Magnesium is a common constituent in the earth's crust and in natural water. Along with calcium, it is one of the main contributors to water hardness. The only available water quality guideline in Canada or the U.S. is a value adopted by Alberta (for drinking water) and their rationales have not been evaluated in the context of this project (Appendix Table A.2). If there is not adequate scientific basis for this value, magnesium should be removed from the list of substances of potential concern.

Manganese

Most Sensitive Guideline Value : 50 ug/L Canadian Drinking Water Guideline

Effluent Range: 7 - 753 ug/L

Aquatic life and drinking water guidelines for manganese have been established in Canada; however, no marine guidelines exist (Appendix Table A.2). Manganese concentrations in MWWE may exceed the benchmark for drinking water (Table 3.1), which was generally established to prevent staining of laundry and encrustation of plumbing (CCREM 1987). This concentration is believed to be more than adequate to protect human health (ATSDR 2004). Manganese and manganese compounds are common, natural constituents of soils and sedimentary and metamorphic rocks. The weathering of surficial manganese deposits generally contributes only a small amount of manganese to natural waters (CCREM 1987). Anthropogenic sources of manganese to the surface waters originate mainly through atmospheric industrial emissions and through the burning of fossil fuels. The most significant point sources of airborne manganese include iron- and steel-producing plants, power plants, coke ovens, and dust from uncontrolled mining operations (ATSDR 2004). The chemical behaviour of manganese in surface waters is similar to iron, with which it is commonly associated. Manganese compounds in aquatic environments are typically present in oxide-bound suspended forms that are moderately stable. However, pronounced changes in aqueous manganese concentrations may result from changes in redox potential, dissolved oxygen, pH and organic matter levels.

Mercury

Most Sensitive Guideline Value : 0.016 ug/L CCME Marine water

Effluent Range: 0.0065 – 0.36 ug/L

In Canada, mercury concentrations in MWWE may exceed levels considered protective of both marine and freshwater aquatic biota, but they generally do not pose a risk to humans based on measured effluent levels (Table 3.1) and relative benchmark concentrations (Appendix Table A.2). The CCME freshwater guideline value, at 0.026 ug/L is only slightly higher than the marine value.

Natural sources of mercury to aquatic environments originate through weathering of all types of rock and decay of organic materials. Much of the global input of mercury to the environment occurs through natural processes, but anthropogenic sources such as gold recovery, fossil fuel combustion, paint application and the chlor-alkali industry may account for substantial input (CCREM 1987). Dental offices may be a source of mercury in municipal wastewaters. In the aquatic environment, mercury typically exists as inorganic or organic forms, the speciation of which depends on oxidation-reduction potential, pH and the type of ligands present, in addition

to bacterial action, which can convert inorganic mercury to organic (methylmercury) forms. Mercury readily sorbs to particulate matter and sediment and as a result, is typically found in low concentrations in surface water. However, methylmercury has a high affinity for biotic tissues and may be accumulated in organisms either directly from the water or through the food web. Increased water temperature and low pH conditions may accelerate this process. Bioconcentration factors for aquatic organisms are usually high because of rapid uptake and slow depuration. In general, bottom feeding organisms (including fish) and top predators in the food chain accumulate the greatest concentrations of mercury. Human health-related effects due to mercury exposure are related to nervous system or kidney damage.

Molybdenum

Most Sensitive Guideline Value : 10 - 50 ug/L CCME Agriculture Irrigation

Effluent Range: 2.6 – 47 ug/L

The CCME guideline value for molybdenum in freshwater is 73 ug/L; there is no corresponding marine criteria. The maximum recommended concentration for molybdenum in irrigation water is 10-50 ug/L (CCME1987), which is the most sensitive guideline value. Molybdenum is an essential trace element in plant nutrition. The greatest concern with respect to molybdenum in MWWES would appear to be when soil irrigation is practiced. While it is not toxic to plants at normal concentrations in soil and water, it can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum. (Agriculture Canada, 2005a). Molybdenum is used as an alloying agent in steel, improving the strength of steel at high temperatures, and in some nickel-based alloys, (e.g. "Hastelloys (R)") which are heat-resistant and corrosion-resistant to chemical solutions. It is used in electrodes for electrically heated glass furnaces, in nuclear energy applications and for missile and aircraft parts, as a catalyst in the refining of petroleum, and as a filament material in electronic and electrical applications. Molybdenum sulfide is useful as a lubricant, especially at high temperatures (Spectrum Laboratories, 2005).

Nickel

Most Sensitive Guideline Value : 25 - 150 ug/L CCME Freshwater

Effluent Range: 2.9 - 900 ug/L

The CCME nickel guidelines for the protection of freshwater biota ranges from 25 to 150 μg/L, depending on water hardness (Appendix Table A.2). Although the CCME has not published a value for protection of marine biota, the U.S. EPA has adopted a value of 8.2 μg/L, which is well below the EPA freshwater value of 52 ug/L (Appendix Table A.2). No drinking water guidelines

for nickel have been developed in Canada (Appendix Table A.2). In most instances, MWWE concentrations were less than the water quality guideline (Table 3.1). Nickel enters the environment primarily through the natural weathering of minerals and rocks, and as a result of anthropogenic activities, such as the burning of fossil fuels (CCREM 1987). Aqueous nickel concentrations are generally very low under neutral to alkaline pH conditions when nickel often co-precipitates with iron and manganese oxides and/or sorbs to organic matter (ATSDR 2004). However, nickel may become increasingly mobile at pH levels below 6.0 and/or in waters with low hardness (CCREM 1987).

Selenium

Most Sensitive Guideline Value : 1 ug/L CCME Freshwater

Effluent Range: 0.3 – 30.6 ug/L

While CCME has not developed a marine guideline value for selenium, the EPA value for protection of marine aquatic species is 71 ug/L. Selenium (Se) is a metalloid, meaning that it adopts chemical behaviours of both metallic and non-metallic substances depending on circumstances. It occurs naturally as a result of weathering of rocks and soils as well as volcanic activity. Anthropogenic sources include atmospheric or wastewater releases from coal or metal mining, smelting, and/or refining operations (CCREM 1987). Selenium is an essential element required for the health of humans, animals and plants, but becomes a toxicant at elevated concentrations. Inorganic selenium, found in water or in sediments is converted to organic selenium at the base of aquatic food chains (e.g., bacteria and algae) and then transferred through dietary pathways to other aquatic organisms (invertebrates, fish, amphibians) and aquatic-feeding birds. This is more apt to occur in areas with slow-moving water and high hydraulic retention times (lentic habitats), than in fast-flowing systems (lotic habitats). Selenium tends to biomagnify up the food chain, meaning that it accumulates to higher concentrations among organisms higher in the food web (Minnow 2004).

Silver

Most Sensitive Guideline Value : 0.11 ug/L CCME Freshwater

Effluent Range: 0.12 - 1250 ug/L

An interim freshwater quality guideline for silver of 0.1 μg/L has been adopted by CCME, but no guidelines for the protection of marine environments or drinking water have been developed in Canada (Appendix Table A.2). The U.S. EPA has adopted a marine guideline of 1.9 μg/L (Appendix Table A.2). MWWE concentrations can exceed these values (Table 3.1). Natural

weathering of silver bearing rock is the primary process by which silver enters the environment (ATSDR 2004). Anthropogenic sources of silver are relatively minor, the most significant of which include mining, photography and electronic industry sources as well as landfills (CCREM 1987). Silver is generally stable over the pH and redox range found in natural waters and has a very low solubility. Silver may become increasingly toxic with decreasing water hardness.

Vanadium

Most Sensitive Guideline Value : 6 ug/L Ontario PWQO

Effluent Range: 10.8 - <20 ug/L

Vanadium is a ubiquitous element in the earth's crust and is largely released to the environment by surface erosion, although it may also enter aquatic environments by atmospheric deposition, in effluents from ore mining and processing and steel manufacturing, and from leaching of waste rock piles and coal ash (CCREM 1987). It may bind to naturally occurring organic complexing agents, adsorb on clay particles or adsorb on and co-precipitate with ferric oxides. Ontario has developed an interim water quality objective (Appendix Table A.2) but other major jurisdictions such as the CCME and U.S. EPA have concluded the data are too limited for development of a guideline. Therefore, further information is required before a conclusive determination can be made regarding the risks to the environment or human health water uses associated with MWWE discharges of vanadium.

Zinc

Most Sensitive Guideline Value : 30 ug/L CCME Freshwater

Effluent Range: <10 - 1400 ug/L

Zinc guidelines for the protection of aquatic life and drinking water have been established by CCME; however, no marine guideline exists (Appendix Table A.2). The U.S. EPA has adopted a value of 81 ug/L for marine organisms, which is slightly lower than the EPA freshwater value of 120 ug/L (Appendix Table A.2). Zinc concentrations in MWWE may exceed levels considered protective of freshwater aquatic biota, but generally do not pose a risk to humans based on measured effluent levels (Table 3.1) relative to benchmark concentrations (Appendix Table A.2). The CCME drinking water guideline for zinc of 5,000 ug/L is based on aesthetic (taste and appearance) considerations and is well protective of any human health-related effects (CCREM 1987). Zinc accumulation in aquatic systems commonly occurs through both natural and anthropogenic sources. Geochemical weathering represents the largest natural source of zinc whereas municipal wastewater, mining and related industry, combustion of wood,

waste incineration and atmospheric emissions constitute the primary anthropogenic sources (CCREM 1987). In freshwater, chemical speciation of zinc is influenced by pH and water hardness, with toxicity generally increasing with decreasing levels of each respective parameter (ATSDR 2004). Sorption to organic substances and precipitation are also important processes determining the fate and toxicity of zinc in aquatic environments (CCREM 1987). Zinc is readily bioaccumulated in freshwater organisms, but it does not tend to biomagnify.

4.2.2 Nutrients

Ammonia (unionized)

Most Sensitive Guideline Value : 19 ug/L CCME Freshwater

Effluent Range: 50 – 27,700 ug/L

Natural sources of ammonia include chemical and biochemical transformations of nitrogenous matter, excretion of ammonia by biota and nitrogen fixation processes of dissolved nitrogen gas in water (Brezonik 1972). Ammonia is also discharged in a wide variety of industrial and sewage effluents. Concentrations of ammonia (as nitrogen) can vary from less than 1 mg/L in a well-run nitrifying secondary and tertiary treatment plants, to levels of 25-30 mg/L, typical of raw sewage levels in primary treatment or non-nitrifying secondary treatment plants. The aquatic toxicity of ammonia increases dramatically with increased pH, promoting the formation of un-ionized ammonia, which is more toxic than the ionic form (CCREM 1987). Ammonia toxicity also increases as temperature decreases. The CCME has established a guideline for protection of aquatic life of 19 ug/L based on unionized ammonia, but has no guideline for marine waters (Appendix Table A.2). In the U.S., equations are used to establish site-specific water quality guidelines for both marine and freshwater environments based on ambient conditions of pH and temperature. While the equations differ for marine and freshwater habitats, the range of sensitivity of marine and freshwater aquatic biota to ammonia is not dramatically different (U.S. EPA 1989). Nitrogen is typically the nutrient limiting algal growth in marine and estuarine environments, although there can be site-specific exceptions. MWWE often contain ammonia concentrations that may be toxic to aquatic biota. Ammonia does not bioaccumulate or persist in aquatic environments and is only known to have negative effects on humans in highly concentrated forms through direct contact (ATSDR 2004).

Nitrate/Nitrite,

Most Sensitive Nitrate Guideline Value : 13,000 ug/L CCME Freshwater

Effluent Range: <60 – 28,400 ug/L

Most Sensitive Nitrite Guideline Value : 60 ug/L CCME Freshwater

Effluent Range: 5 – 4,800 ug/L

Nitrate and nitrite may be produced during secondary wastewater treatment, when ammonia-N is biologically converted to the oxidized forms by nitrifying bacteria. When effluent is discharged to sensitive receiving water with low dilution, the nitrification process in wastewater treatment is encouraged to reduce effluent toxicity resulting from ammonia-N. In the aqueous environment, the effects of nitrate and nitrite are largely associated with increased algal and plant growth where nitrogen is the limiting nutrient. Excess nitrate and nitrite is therefore more problematic from a nuisance standpoint. Excess concentrations may also result in changes to aquatic community structure and may result in reduced oxygen when plant material dies and decomposes. The CCME guideline values for nitrate in freshwater and marine environments are similar in magnitude, with the freshwater value being slightly lower at 13,000 ug/L, compared to the marine value of 16,000. CCME has not established a marine value for nitrite, have a freshwater guideline value of 60 ug/L. Nitrite levels in MWWES may exceed the 60 ug/L guideline during partial nitrification.

The main health concern related to nitrate and nitrite is methemoglobinemia (infantile cyanosis, or blue baby syndrome). Small infants (less than six months are at risk because of reduced levels of gastric acid allow nitrate to be converted to nitrite in the stomach. In the bloodstream, nitrite oxidized the iron in hemoglobin to methemoglobin, which cannot transport oxygen in the blood, leading to the bluish tinge to skin, a symptom of asphyxiation (University of Nebraska, 2005). Although nitrate and nitrite levels in wastewater discharged to surface waters are not likely to be of concern, groundwater impacted by effluent irrigation, by septic tank leachate or when effluent is used for potable water recharge are potential sources contributing to elevated concentrations in drinking water (U.S. EPA, 1993).

Phosphorus

Most Sensitive Guideline Value : 0.1 ug/L elemental phosphorus, EPA Marine

Effluent Range: 190 – 6,900 ug/L

Phosphorus is the nutrient in wastewater that was identified as a key factoring over-fertilization of the Great Lakes through the period 1950 to 1970. A ban on phosphorus in detergents and chemical control of phosphorus in MWWEs led to a recovery of Great Lakes quality, especially in shallow Lake Erie. Although a typical effluent limitation for total phosphorus in MWWEs is 1 mg/L when imposed, lower concentrations may be specified (for example down to 0.1 mg/L (100 ug/L)) in site-specific locations. Phosphorus is typically the nutrient limiting algal growth in

freshwater environments, although there can be site-specific exceptions. Excess concentrations of phosphorus in MWWEs can result in algal blooms(e.g., cyanobacteria), decreased water transparency, foul odours from decaying algal mass and depletion of dissolved oxygen (Wisconsin DNR, 2003). In combination, these factors can lead to a shift in the biological populations in the water column and the lake or river bottom. Phosphorus is bound tightly by soil by adsorption and precipitation with iron, aluminum and calcium in the soil (Environment Canada, 1984). There is little concern over phosphorus levels when effluent irrigation is practiced; rather, nitrogen is the nutrient of concern in effluent irrigation. CCME has nor developed guideline values for total phosphorus in either freshwater or marine environments. The U.S. EPA has adopted a value of 0.1 ug/L for protection of marine waters, but has no corresponding value for freshwaters.

4.2.3 Other Inorganic Substances

Cyanide

Most Sensitive Guideline Value : 5 ug/L CCME Freshwater

Effluent Range: 1.3 - 420 ug/L

The benchmark guideline for protection of freshwater aquatic life is based on free, rather than total, cyanide. There is no guideline for marine environments in Canada, but the U.S. EPA has adopted a value (1 ug/L) that is lower than the guidelines for protection of freshwater aquatic life used in both Canada (5 ug/L) and the U.S. (5.2 ug/L). Cyanide removal in wastewater treatment is highly variable due to the different free or complexed forms that may be present (e.g. from as high as 80% to negative removal resulting from increases during treatment). Since the available effluent data are based on total cyanide, it is not possible to definitively determine whether such concentrations pose a risk to aquatic biota. Cyanides are chiefly released into aquatic environments as a result of gold milling, but may also occur in effluents from steel mills, oil refineries, electroplating industries and even through some natural environmental processes (CCREM 1987). Cyanide occurs in free, simple, complex, and organic forms in surface waters, but little information is present on predominant forms in Canadian aquatic environments (CCREM 1987). With respect to free cyanide, the molecular form (HCN) is expected to predominate over the ionic form in most surface waters. The HCN form is volatile (CCREM 1987) and is not expected to be persistent under most environmental conditions and biomagnification has not been demonstrated.

Fluoride

Most Sensitive Guideline Value : 120 ug/L CCME Freshwater

Effluent Range: 90 - 150 ug/L

Fluoride concentrations in MWWE slightly exceeded the freshwater environmental benchmark in one of two samples for which data were available (Table 3.1). No guideline has been developed for protection of marine biota in Canada or the U.S., and drinking water guidelines tend to be much less stringent (Appendix Table A.2). Some municipalities fluoridate their waters at low concentrations to help prevent dental caries. Fluorides are used in a variety of industrial processes, including metal plating, metal casting, welding, and the manufacture of aluminum, steel, bricks, tiles, glass and ceramics, adhesives and metallurgical fluxes (CCREM 1987). Fluoride also enters aquatic systems as a result of its addition to domestic water supplies and resulting sewage discharge. The presence of calcium and chloride reduce the toxicity of fluoride to fish (CCREM 1987). Because of the limited effluent concentration data available for fluoride, it is recommended that it be included in effluent surveys to expand the database, hence allowing for assessment of how significant a potential substance it may be,

Sulphide

Most Sensitive Guideline Value : 2 ug/L as hydrogen sulphide EPA Freshwater and Marine

Effluent Range: <0.05 - 131 ug/L

Although no guidelines for the protection of aquatic life have been established by CCME, the Ontario and the U.S. EPA have adopted a value of 2 μg/L (Appendix Table A.2) for freshwater. The U.S. EPA also applies this value for the protection of marine life (Appendix Table A.2). A drinking water guideline for sulphide of 50 μg/L exists in Canada (Appendix Table A.2), which stems from disagreeable taste and odour. Such guidelines can be exceeded in MWWE (Table 3.1). Sulphide is commonly found in aquatic systems where anaerobic conditions predominate as the result of bacterial reduction of sulphate and organic sulphur compounds (CCREM 1987). Due to the same process, domestic and industrial wastewaters are often significant sources of sulphide. Sources of sulphur compounds to natural waters include geochemical weathering and atmospheric deposition. The dominant anthropogenic source of sulphur is fossil fuel combustion (CCREM 1987).

4.3 Organic Substances (Priority Pollutants)

4.3.1 Aromatic Compounds

Chlorophenols

Most Sensitive Monochlorophenol Guideline Value : 7 ug/L CCME Freshwater

Effluent Range: 20 ug/L

Most Sensitive 2,4-Dichlorophenol Guideline Value : 0.2 ug/L CCME Freshwater

Effluent Range: 0.08 - 16 ug/L

Chlorinated phenols are used as disinfectants, biocides, preservatives, dyes, pesticides and industrial and medical organic chemicals (CCREM 1987). There are many different types of chlorophenols, depending on the vels of chlorination, and included monochlorophenols, dichlorophenols, trichlorophenols, tetrachlorophenols and pentachlorophenol Aquatic life guidelines published by the B.C. Ministry of Water, Land and Air Protection are pH-dependent. Two sets of guidelines are published for 2,3,4,6-tetrachlorophenol. One set ranges from 1.1 – 36 ug/L, while the other ranges from 0.5 – 17 ug/L. Note that the second range is slightly more sensitive than the CCME freshwater guideline value. Because of the apparent inconsistency, the CCME freshwater guideline has been used as the most sensitive for this substance. Of the 10 dichlorophenol isomers, only 2,4-dichlorophenol is in use as a primary chemical in Canada, serving as an intermediate in the manufacture of some chlorophenoxy herbicides and in the production of other pesticides, germicides and disinfectants (CCREM 1987). Pentachlorophenol is the most widely used chlorophenol in industry. Chlorophenols are released to aquatic environments in industrial effluents and as a result of the chlorination of MWWE. Pentachlorophenol can be persistent and bioaccumulative and tends to be more so than the phenols with less chlorine substitution.

Dichlorobenzenes

Most Sensitive 1,2-Dichlorbenzene Guideline Value: 0.7 ug/L CCME Freshwater

Effluent Range: <0.5 – 4.6 ug/L

This group of similar substances includes three isomers, namely the 1,2-dichlorobenzene, 1,3-dichlorobenzene and 1,4-dichlorobenzene. Dichlorobenzene (DCB) in MWWE may sometimes exceed accepted drinking water guidelines, but may be less of a concern with respect to protection of aquatic life (Table 3.1). In wastewater treatment, DCB removal efficiency may be in the range of 40 to 70 %. Chlorinated benzenes are used as industrial solvents, dielectric

fluids, pesticides, chemical intermediates, medicines, dyes and deodorants (OMOE 1984). Dichlorobenzene may enter the environment through sublimation of mothballs and toilet deodorizers, seepage from waste sites or agricultural runoff (ATSDR 2004). The major ways in which dichlorobenzene can be removed from the environment include volatilization, adsorption and bioaccumulation (U.S. EPA 1979). Chronic exposure can lead to toxic effects in humans, but it is not considered to be carcinogenic.

Ethylbenzene

Most Sensitive Ethylbenzene Guideline Value: 2.4 ug/L Canadian Drinking Water Guideline

Effluent Range: <0.5 – 4.9 ug/L

The primary sources of ethylbenzene in the environment, along with related compounds, benzene, toluene and the 3 xylene isomers, are the petroleum and coke (metallurgical) industries. The main uses of ethylbenzene include as a feedstock for chemical synthesis (mostly styrene), in the rubber and plastic industries, and as gasoline additives (Health Canada 1986). Ethylbenzene is an industrial chemical, and as a result its appearance in municipal wastewater would be attributed to industrial wastewaters discharged to municipal sewers. The compound may also be found in consumer products such as paint, ink, pesticides and gasoline (BCWLAP, 1999). Because it can be released into the air from burning oil, gas and coal (BCWLAP, 1999), as a result of atmospheric deposition it may enter treatment plants in stormwater. Overall removal of ethylbenzene in wastewater treatment is expected to be on the order of 90 % plus, because it is readily biodegradable and strippable to the air. In a survey of Ontario treatment facilities, ethylbenzene was only detected in 2 of 28 secondary plant effluents, and in most facilities was below the detection limit of 2.0 ug/L (OMOE 1988). The aquatic toxicity of ethylbenzene appears to be similar in fresh and marine environments, in the range of 1-5 mg/L for EC_{50} and NOEC endpoints (BCWLAP, 1999). The toxicity in freshwater is approximately the same in soft and hard waters (BCWLAP, 1999).

Nonylphenol and Its Ethoxylates

Most Sensitive Nonylphenol and its Ethoxylates Guideline Value: 0.7 ug/L CCME Marine

Effluent Range Nonylphenol: 0.2 – 16 ug/L

MWWE concentrations of nonlyphenol may exceed water quality guidelines for protection of both marine and freshwater aquatic life (Table 3.1). No drinking water guidelines have been established (Appendix Table A.2). Nonylphenols are not naturally occurring and are only present in the environment due to anthropogenic inputs. In MWWEs, nonylphenol is typically

seen as a metabolite resulting from microbial degradation of nonylphenol polyethoxylate under anaerobic conditions (Ahel et al., 1994)) Nonylphenol monoethoxylate and nonylphenol diethoxylate are the most common ethoxylates in MMWES, and are themselves metabolites of the parent polyethoxylated compound, which may have up to 20 ethylene oxide units in its structure (Ahel et al., 1994). Nonylphenols have many uses including: detergents, emulsifiers, wetting agents, dispersing agents, textile processing, pulp and paper processing, paints, resins and protective coatings, oil and gas recovery, steel manufacturing, pest control products and power generation. Domestically, nonylphenol can be found in cosmetics, cleaners and paints (Environment Canada 2005e). This chemical enters aquatic environments primarily through industrial or municipal wastewater discharges and can bioaccumulate in aquatic organisms in low to moderate levels. The primary negative affect of this chemical is its estrogenic property, which may cause the expression of female traits in some fish. Humans may also experience estrogenic effects at high, chronic doses and nonylphenol is not known to be carcinogenic (Environment Canada 2005e).

Phenols (Total)

Most Sensitive Guideline Value: 4 ug/L CCME Freshwater

Effluent Range: 0.067 – 40 ug/L

Concentrations of phenols in MWWE sometimes exceed the CCME guideline for protection of freshwater aquatic life (Table 3.1). There are no guidelines for protection of marine environments or drinking water (Appendix Table A.2). Phenols are a broad group of aromatic hydrocarbons, having a hydroxyl group bound to a benzene ring. Phenol occurs naturally, but is primarily used for the manufacturing of phenolic resins (ATSDR 2004). Chlorinated phenols are used as disinfectants, preservatives, pesticides, dyes and industrial and medical organic chemicals (see previous discussion of chlorophenols). Nitrophenols are used in pigments, dyes, pharmaceuticals, lumber preservatives, rubber chemicals, photography and pesticides (CCREM 1987). Phenols can enter the aquatic environment mainly through industrial, municipal or agricultural runoff. The environmental behaviour of each compound is dependent on its physical and chemical properties. Some chlorinated phenols may bioaccumulate or be carcinogenic.

Polycyclic Aromatic Hydrocarbons (PAHs)

Most Sensitive Anthracene Guideline Value: 0.012 ug/L CCME Freshwater

Effluent Range Anthracene: 0.05 – 0.43 ug/L

Most Sensitive Benzo(a)anthracene Guideline Value: 0.018 ug/L CCME Freshwater

Effluent Range Benzo(a)anthracene: 0.04 – 0.65 ug/L

Most Sensitive Benzo(a)pyrene Guideline Value: 0.01 ug/L CCME Freshwater

Effluent Range Benzo(a)pyrene: 0.006 – 0.77 ug/L

Most Sensitive Benzo(g,h,i)perylene Guideline Value: 0.00002 ug/L Ontario PWQO

Effluent Range Benzo(g,h,i)perylene: 0.23 – 0.33 ug/L

Most Sensitive Benzo(k)fluoranthene Guideline Value: 0.0002 ug/L Ontario PWQO

Effluent Range Benzo(k)fluoranthene: 0.008 – 0.56 ug/L

Most Sensitive Chrysene Guideline Value: 0.1 ug/L BC Aquatic Protection (Marine)

Effluent Range Chrysene: 0.012 – 0.21 ug/L

Most Sensitive Dibenzo(a,h)anthracene Guideline Value: 0.002 ug/L Ontario PWQO

Effluent Range Dibenzo(a,h)anthracene: 0.22 ug/L

Most Sensitive Dimethylnaphthalene Guideline Value: 0.02 ug/L Ontario PWQO

Effluent Range Dimethylnaphthalene: 0.03 – 0.2 ug/L

Most Sensitive Fluoranthene Guideline Value: 0.04 ug/L CCME Freshwater

Effluent Range Fluoranthene: 0.97 ug/L

Most Sensitive Phenanthrene Guideline Value: 0.4 ug/L CCME Freshwater

Effluent Range Phenanthrene: <0.05 – 1.1 ug/L

Most Sensitive Pyrene Guideline Value: 0.025 ug/L CCME Freshwater

Effluent Range Pyrene: <0.05 – 0.65 ug/L

MWWE concentrations of numerous PAHs exceeded the respective guidelines for protection of aquatic life and/or drinking water guidelines, including anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, dimethylnaphthalene, fluoranthene, phenanthrene, and pyrene (Table 3.1). All of these chemicals are high molecular weight and poorly soluble in water, and thus tend to be found primarily associated with organic and inorganic material in suspended or bed sediments (Herbes 1977). PAHs enter the environment from volcanoes, forest fires, residential

wood burning, and exhaust from automobiles and trucks. They can enter surface water through atmospheric deposition, discharges from industrial plants and wastewater treatment plants, or be released to soils at hazardous waste sites or storage containers (NRCC, 1983). Some PAHs are used in research, medicines and the manufacturing of dyes, plastics, and pesticides. Others are contained in asphalt used in road construction or in crude oil, coal, coal tar pitch, creosote, and roofing tar (ASTDR 2004). These PAHs are bioaccumulative or persistent given their affinity for sediments and other particles and benzo(a)pyrene, dibenzo(a,h)anthracene and benzo(k)fluoranthene are believed to be carcinogenic.

Toluene

Most Sensitive Guideline Value: 2 ug/L CCME Freshwater

Effluent Range: <0.25 – 15 ug/L

Toluene is a monoaromatic hydrocarbon. MWWE concentrations of toluene can exceed the CCME guideline for protection of aquatic life (2 ug/L), but the guideline for marine life is much higher 215 ug/L, and is less apt to be exceeded in MWWE (Table 3.1 and Appendix Table A.2). Toluene occurs naturally in crude oil and is produced anthropogenically in the process of making gasoline and other fuels from crude oil, in making coke from coal, and as a by-product in the manufacture of styrene. Domestic products containing toluene include paints, paint thinners, fingernail polish, lacquers, adhesives, rubber and in some printing and leather tanning processes (ATSDR 2004). Toluene can enter the aquatic environment from spills of solvents and petroleum products, leaking underground storage tanks at gasoline stations and other facilities or seepage from landfill/disposal sites (ATSDR 2004). Toluene is removed from the environment by breakdown into other chemicals, volatilization or by microorganisms in soil and it also evaporates from surface water and surface soils (U.S. EPA 1979). Toluene can be taken up into fish and shellfish, plants, and animals, but it does not concentrate or build up to high levels because most animal species can convert toluene into other compounds that are excreted. Toluene will cause nervous system dysfunction upon repeated exposure and possible brain damage, however symptoms can return to normal when exposure has ceased (ATSDR 2004).

Xylene

Most Sensitive Ortho-xylene Guideline Value: 40 ug/L Ontario Interim PWQO

Most Sensitive Meta-xylene Guideline Value: 2 ug/L Ontario Interim PWQO

Most Sensitive Para-xylene Guideline Value: 30 ug/L Ontario Interim PWQO

Effluent Range: <0.2 – 27 ug/L

Xylene is the name of three isomeric monoaromatic compounds having similar structure and identical molecular weight. Depending on the orientation of the two methyl groups on the benzene ring, the isomers are designated as ortho-, meta- and para-xylene. Chemical industries produce xylene from petroleum. Xylene also occurs naturally in petroleum and coal tar and may be formed during forest fires (ATSDR, 2005c). It is used as a solvent in the printing, rubber, and leather industries, and with other solvents, as a cleaning agent, a thinner for paint, and in varnishes. Xylene is used as a chemical intermediate in the chemical, plastics, and synthetic fiber industries and as an ingredient in the coating of fabrics and papers. Isomers of xylene are used in the manufacture of certain polymers (chemical compounds), such as plastics (ATSDR, 2005c) Xylene can enter soils and waterways as a result of spills or leaking stoarage tanks. (Health Canada, 1986). Most xylene in surface water evaporates into the air in less than a day. The rest of it is slowly broken down into other chemicals by small aquatic organisms. Only very small amounts are taken up by plants, fish, and birds. Both short- and long-term exposure to high concentrations of xylene can also cause a number of effects on the nervous system, such as headaches, lack of muscle coordination, dizziness, confusion, and changes in one's sense of balance. (ATSDR, 2005c). Xylene consumed orally is likely to be metabolized quickly to water soluble acids or related compounds, and excreted by the kidneys (Health Canada, 1986). Concentrations of xylene in wastewater range from non-detectable to 27 ug/L. While there are no CCME or EPA aquatic guidelines for xylene, observed concentrations might exceed provincial water quality objectives of 2 – 30 ug/L depending on the isomer. Because of their similar chemical structures, the meta- and para-isomers are combined in one analytical measurement.

4.3.2 Pesticides

2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT) and Metabolites

Most Sensitive DDT Guideline Value: 0.001 ug/L EPA Freshwater and Marine

Effluent Range: 0.02 ug/L

Limited data indicate DDT concentrations in MWWE may exceed guidelines for protection of aquatic life (Table 3.1). Chlorinated hydrocarbon pesticides are not readily removed in wastewater treatment. DDT was formerly used to control insects on agricultural crops and insects that carry diseases, but it was banned in the early 1970s and today is only used in a few countries to control malaria (ATSDR 2004). DDT breaks down very slowly in soils and in water will stick to particles settling into the sediment. Due to its hydrophobic and lipophilic nature,

DDT may still bioaccumulate to high levels in the food chain (U.S. EPA 1980). It is also subject to long-range atmospheric and oceanic transport (IPCS, 1989), as Arctic mammals such as polar bears exhibit the pesticide residues in their tissues. (Derocher et al., 2003). DDT is acutely toxic to aquatic invertebrates at concentrations as low as 0.3 – 0.5 ug/L (IPCS, 1989). The metabolites of DDT include dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE). Of the two DDE has attracted more attention. Based on their chemical structures, both metabolites behave in the environment similarly to the parent DDT. DDE is reported to cause a wide variety of health problems in humans and wildlife. In humans it may cause cancer and damages to the liver and to the nervous and reproductive systems. In birds it can also result in eggshell thinning (Environment Canada, 2005f). The metabolite DDE is more likely to be found in the fatty tissues of animals than the parent DDT. (IPCS, 1989)

Chlordane

Most Sensitive Guideline Value: 0.004 ug/L EPA Marine

Effluent Range: 0.01 – 0.08 ug/L

Limited effluent data indicate that effluent chlordane concentrations may exceed water quality guidelines for protection of freshwater and marine biota (Table 3.1). In general, chlorinated hydrocarbon pesticides are not readily removed in wastewater treatment. Chlordane is a man-made chemical that was formerly used as an insecticide in agriculture, fumigation or for domestic lawns and gardens. Although it has not been in use since the early 1980s, it persists strongly in soils and adheres readily to sediment particles in aquatic environments (ATSDR 2004). Chlordane is known to bioaccumulate in aquatic food chains (U.S. EPA 1979) and is also believed to be a human carcinogen.

Diazinon

Most Sensitive Guideline Value: 0.08 ug/L Ontario PWQO

Effluent Range: not detected – 1 ug/L

Diazinon is an organophosphorus pesticide used for soil and household insect pests and on a variety of crops (Health Canada 1986). There are no CCME guideline values for protection of aquatic life in either freshwater or marine environments. The most sensitive guideline value is a Provincial Water Quality Objective from the Province of Ontario. As of December 31, 2004, the U.S. EPA banned the use of diazinon in household applications. Diazinon is very toxic to birds, non-target insects such as honeybees, fish and invertebrates (EPA, 2000). Although at one

time diazinon was determined to be a contributor to whole effluent toxicity, principally in the southern U.S., due to its restricted use, it is rarely detected in the literature review for this study.

Endosulfan

Most Sensitive Guideline Value: 0.02 ug/L CCME Freshwater

Effluent Range: not detected - 0.13 ug/L

Endosulfan is a chlorinated hydrocarbon pesticide used to control insects on food and non-food crops and also as a wood preservative (ASTDR, 2004). It is hydrophobic, and so will tend to sorb to solids in water. Drift from crop spraying can move long distances (ATSDR, 2004). Endosulfan degrades more quickly than other hydrocarbon pesticides, but the degradation product endosulfan sulphate is more persistent than the parent (Pesticide News, 2005). Alkaline soil conditions favour the degradation if the parent compound (Pesticide News, 2005). The pesticide is highly toxic to fish and other wildlife. As an acute toxicant, endosulfan affects the activity of the central nervous system; as a chronic toxicant, it may effect the kidneys, liver and developing fetuses, and may be a mutagen (Pesticide News, 2005).

Hexachlorocyclohexane (Lindane)

Most Sensitive Guideline Value: 0.01 ug/L CCME Freshwater

Effluent Range: 0.01 – 0.79 ug/L

Lindane concentrations in MWWE may exceed guidelines established to protect aquatic life (Table 3.1). Lindane is no longer used as an insecticide for canola seed in Canada, but may still be used as an insecticide on some cereal and vegetable crops (Environment Canada 2005g). It is also used in shampoos and lotions to treat lice and scabies (ATSDR 2004) which may be the major source in domestic wastewater. It may enter aquatic environments through agricultural runoff, industrial discharges or direct/indirect application (Edwards 1973). Lindane is fairly stable in aquatic environments and sorption to suspended particles or organisms and volatilization is limited. When sedimentation does occur, anaerobic processes in sediments are efficient at biodegrading lindane into other chemicals (CCREM 1987). Depuration rates in organisms appear to be rapid and lindane is not a known carcinogen.

Chlorophenoxy Herbicides (2,4-D, 2,4,5-T, MCPA)

Most Sensitive 2,4-D Guideline Value: 4 ug/L CCME Freshwater

Effluent 2,4-D Range: 0.02 – 34 ug/L

Most Sensitive 2,4,5-T Guideline Value: 4 ug/L CCME Freshwater

Effluent 2,4-D Range: 0.03 – 92 ug/L

Most Sensitive MCPA Guideline Value: 2.6 ug/L CCME Freshwater

Effluent 2,4-D Range: 20 – 400 ug/L

Chlorophenoxy herbicides are a group of pesticides widely used of broadleaf weed control in agriculture and domestic use, and as defoliants (IARC, 1986). Included in this group are 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and monochlorophenoxyacetic acid (MCPA), dichlorprop and mecoprop. Chlorophenoxy herbicides have been detected in numerous groundwater samples across Canada (Agriculture Canada, 2005). Potential entry of 2,4-D to the environment is from direct application for weed control (surface runoff and drift from lawn and turf applications in sewered areas) and from manufacture and transport (Health Canada, 1991) It biodegrades rapidly in water and non-acidic aerated soils, leaving 2,4-dichlorophenol as the principal degradation product (Health Canada, 1991). Mobility in soil to groundwater is retarded by the organic content and alkalinity of the soil (Health, Canada, 1991). MCPA is mobile in soil, and has the potential to contaminate groundwater (CCCF (2005). Health Canada (1991) concludes the evidence of carcinogenicity of 2,4-D is inconclusive, and it is non-genotoxic. Environmental effect on other herbicides on this category is scarce.

4.3.3 Other Organic Chemicals

Phthalates

Most Sensitive Bis(2-ethylhexyl) phthalate Guideline Value: 16 ug/L CCME Freshwater

Effluent Bis(2-ethylhexyl) phthalate Range: 1.2 – 540 ug/L

Most Sensitive Di-n-butyl phthalate Guideline Value: 19 ug/L CCME Freshwater

Effluent Di-n-butyl phthalate Range: 0.3 – 1,620 ug/L

Phthalate esters represent a large group of chemicals widely used as plasticizers in polyvinyl chloride (PVC) resins, adhesives and cellulose film coating, as well as in cosmetics, rubbing alcohol, insecticides and repellent, tablet coating and solid rocket propellants (CCREM 1987). Consequently, they can be released to the environment from a wide variety of sources, including the effluents of chemical and petrochemical manufacturing plants and other industrial and municipal effluents (CCREM 1987). They are insoluble in pure water, but can be sorbed and transported in water in association with humic acids, particles and biota. Depending on the

specific phthalate and environmental conditions, bioaccumulation can occur but depuration is also typically rapid once exposure ceases.

MWWE concentrations of bis(2-ethylhexyl)phthalate may well exceed the level considered protective of freshwater biota (Table 3.1). There were no water quality guidelines established for marine environments by Canada or the U.S., and a drinking water guideline has been established only by Ontario (Appendix Table A.2). Bis(2-ethylhexyl)phthalate (DEHP) is a phthalate ester, a group of compounds used in making plasticizers in polyvinyl chloride (PVC) adhesives, resins and cellulose film coating. It is also used in rubbing alcohol, cosmetics, insect repellents and insecticides, tablet coating and solid rocket propellants (Pierce et al. 1980). It is also present in many domestic plastic products such as wall coverings, tablecloths, floor tiles, various types of upholstery, shower curtains, garden hoses, swimming pool liners, clothing, some toys, packaging film and sheets and sheathing for wire and cable (ATSDR 2004). DEHP may enter the aquatic environment from industrial settings, landfills, and waste disposal sites. Phthalate esters are not soluble in water but may be transported/solubilized by fulvic or humic acids, which is a pH dependent process (as pH decreases, solubilization increases). DEHP may also adsorb to aquatic organisms and particulate matter and in some cases, bioaccumulation can be high (U.S. EPA 1979). In terms of human health, larger doses or chronic exposure are required to elicit significant negative effects (ATSDR 2004); however this chemical is considered to be carcinogenic.

Di-*n*-butyl phthalate is used as a plasticizer (Softening agent) polyvinyl chloride plastics and nitrocellulose lacquers, which are commonly used to make many products such as carpets, paints, glue, insect repellents, hair spray, nail polish, and rocket fuel (ATSDR, 2004). Because many plastic components and lacquers in everyday use contain di-n-butyl phthalate, water that contacts these items may end up with residues of the substance. Industrial sources include plastics and resin manufacturers and others that use these products in their manufacturing processes. It may occur in stormwater due to breakdown of plastic litter and from dry deposition of dust particles (ATSDR, 2004). It may also be contained in municipal landfill leachates directed to wastewater treatment facilities. Di-*n*-butyl phthalate appears to have relatively low toxicity, and adverse effects on humans from exposure to di-*n*-butyl phthalate have not been reported (ATSDR, 2004).

Halogenated Aliphatic Chemicals

Most Sensitive Chloroform Guideline Value: 1.8 ug/L CCME Freshwater

Effluent Chloroform Range: <0.5 – 4.0 ug/L

Most Sensitive 1,2-Dichloroethane Guideline Value: 5 ug/L Canadian Drinking Water Guidelines

Effluent Chloroform Range: 0.33 – 10 ug/L

Most Sensitive 1,1,1-Trichloroethane Guideline Value: 10 ug/L Ontario PWQO

Effluent Chloroform Range: <0.5 – 27 ug/L

Most Sensitive Tetrachloroethylene Guideline Value: 30 ug/L Canadian Drinking Water Guidelines

Effluent Tetrachloroethylene Range: 0.42 – 120 ug/L

MWWE concentrations of trichloromethane (chloroform) can exceed the CCME guideline for protection of freshwater aquatic life, but no guideline is available for marine environments (Table 3.1 and Appendix Table A.2). Chloroform was formerly used for anesthetic purposes, but today it is primarily used in the manufacturing of other chemicals. Chloroform enters the environment from chemical companies, paper mills, wastewater from sewage treatment plants and drinking water to which chlorine has been added. It may also enter water and soil from spills or leaks from storage and waste sites (ATSDR 2004). Chloroform dissolves easily in water, but does not adhere to soil very well. This enables it to travel down through soil to groundwater where it can enter a water supply (ATSDR 2004). Chloroform has a low affinity for organic carbon and lipids, therefore it does not appear to bioaccumulate, but it may persist in groundwater. In large doses, chloroform can have nervous system effects in humans, while long-term exposure may cause liver or kidney damage (ATSDR 2004). There is also sufficient evidence to link chloroform to cancer.

The CCME freshwater guideline for 1,2-dichloroethane is 100 ug/L, however the Canadian Drinking Water Guideline value of 5 ug/L is more stringent. The main use of 1,2-dichloroethane in Canada is as a vinyl chloride intermediate (Health Canada 2005a). Entry to municipal wastewater includes the discharge of effluents from industries that use or produce 1,2-dichloroethane, effluents from the treatment of contaminated groundwater, and leachates from waste disposal sites (Environment Canada 2005b). 1,2-dichloroethane is classified as "probably carcinogenic to humans".

The CCME has not developed any guideline values for 1,1,1-trichloroethane. The substance is mostly an industrial chemical used as a solvent and degreasing agent. Although it has some use in paper correction fluids, and in consumer products such as household cleaners, glues, and aerosol sprays. The main concern about 1,1,1-trichlorooethane appears to be the hazard it poses as an upper-atmosphere ozone-depleting substance Environment Canada 2005c).

The CCME freshwater guideline for tetrachloroethylene is 100 ug/L, however the Canadian Drinking Water Guideline value of 30 ug/L is more stringent. Tetrachloroethylene (also referred to as perchloroethylene or PERC) is mainly used as a drycleaning agent and an industrial degreasing solvent. Entry to municipal wastewater is therefore most probable from those industrial sectors. Contamination of groundwater by improper disposal of drycleaning solvents has been reported (Health Canada, 2005b). Health Canada has classified tetrachloroethylene as a possible human carcinogen. (Health Canada 2005b).

As a group the halogenated aliphatic chemical in this category are similar in physical and chemical properties. They are relatively low molecular weight compounds that are relatively soluble in water, and exhibit sufficient vapour pressure that a substantial fraction of the incoming mass will volatilize during wastewater treatment. Accumulation in sludge would not be expected. In the subsoil and groundwater, these would be expected to behave similar to chloroform, i.e. have substantial mobility.

Quinoline

Most Sensitive Guideline Value: 3.4 ug/L CCME Freshwater

Effluent Range: 18 ug/L

Effluent concentration data for quinoline are very limited. Quinoline is a heterocyclic compound that incorporates nitrogen in the ring structure. Although used mainly as an intermediate in the manufacture of other products, It is also used as a catalyst, a corrosion inhibitor, in metallurgical processes, in the manufacture of dyes, as a preservative for anatomical specimens, in polymers and agricultural chemicals, as a solvent for resins and terpenes, and as an antimalarial medicine (EPA 2005b). Quinoline may be found in wastewaters from petroleum refining, coal mining, quenching and coking, wood preservation, and release in shale oil and synthetic coal conversion wastewaters. Underground coal gasification has been a source of quinoline contamination of groundwater (EPA 2005b). The U.S. EPA has classified quinoline as a probable human carcinogen (EPA 2005b).

4.4 Biological Agents

Note: With the exception of fecal coliform bacteria, the biological agents are not included in Table 3.1, which summarizes the substances of potential concern based on concentrations exceeding the most sensitive guideline values. Annotations have been provided for the other biological agents. Concentration data are limited for these biological agents.

4.4.1 Bacteria

Fecal coliform and *E. coli*

Most sensitive Fecal Coliform guideline Value: 0 CFU/100 mL (BC Drinking Water)

Observed range: 20-4000 CFU/100 mL

Neither the CCME nor EPA have developed aquatic guidelines for fecal coliforms or for *E.coli.* the Province of Bristish Columbia has developed a drinking water guideline for fully treated drinking water of 0 colony forming units/100 mL. Provinces have also developed water quality objectives based on recreational contact and shellfish harvesting. For example, for shellfish harvesting, British Columbia has published median *E. coli* and fecal coliform concentrations of 14/100 mL as a median and 43/100 mL as the 90th percentile value. As examples of guideline values for recreational contact, Ontario and B.C. have *E. coli* guideline values of 100 and 77 per 100 mL, respectively, expressed as geometric means, while B.C. also has a guideline value of 200/100 mL for fecal coliforms.

Fecal coliform are rod-shaped bacteria (called bacilli) that are used as indicators of recent contamination by fecal matter. *Escherichia coli* (*E. coli*) is a major subset of fecal coliform bacteria. It is possible to distinguish between humans or other animals as sources of fecal coliforms and *E. coli* only with highly sophisticated procedures (AWWA 1999). One person may release 100 to 400 billion coliform organisms each day (Metcalf and Eddy 1991). Thus, the presence of these bacteria in municipal effluents may result from either human (domestic) wastewater, or animals such as feces of dogs and cats that are an inflow component of wastewater, or from birds (e.g. gulls that float and scavenge in clarifiers). *E. coli* is approximately 0.5 um in width, and 2 um in length (Metcalf and Eddy 1991). Untreated stormwater or wastewater bypasses may result in elevated concentrations of fecal coliform bacteria being discharged to receiving waters, and fecal coliform levels in nearshore waters may be related to storm events.

Pathogenic fecal coliform can be responsible for the development of gastroenteritis in humans, leading to diarrhea. A particularly virulent strain of E. coli, [0157:H7] traced to cattle was responsible for the Walkerton, ON, water tragedy of 2000. The bacteria are relatively non-resistant to disinfection by either chemical means (chlorine, or ozone) or UV light disinfection.

Enterococci

British Columbia has established guideline values for enterococci of 20/100 mL as a geometric mean for recreational contact, and for shellfish harvesting 4/100 mL as a median value of samples, and 11/100 mL as the 90th percentile value.

Enterococci are spherical in shape, typically ranging in size from 1 to 3 um in diameter. They are found in fewer numbers than fecal coliforms, but exhibit better survival properties in seawater than other bacteria (Metcalf and Eddy 1991), and so may be better indicators of contamination in marine environments than fecal coliforms. Enterococci are not pathogenic, but are used as indicators of fecal contamination, which can lead to gastroenteritis and respiratory illness (New Zealand 2005). Disinfection is used to control the number of organisms discharged in MWWEs. Untreated stormwater or wastewater bypasses may result in elevated concentrations of enterococci being discharged to receiving waters. Enterococci levels in nearshore waters may be closely related to rainfall (New Zealand 2005).

4.4.2 Algal Toxins (typified by Microcystin L-R)

These toxins are not actually discharged in MWWEs, but may result from excessive growth of cyanobacteria, also referred to as blue-green algae, attributed to the presence of treated effluents, such as in sewage stabilization ponds. Blue green algae most responsible for toxic effects are likely to be Anabaena flos-aquae, Microcystis aeruginosa and Aphanizomenon flos-aquae (AWWA 1999). A combination of environmental conditions (such as warm temperatures, nutrients, water levels and quiescent or slow-moving water bodies), can contribute to excessive growth of cyanobacteria. The Canadian Drinking Water Guideline for Microcystin L-R is 1.5 ug/L. There are no CCME or EPA aquatic guidelines for algal toxins.

Cyanotoxins are produced in the algal cells and are released to the water column when the cells rupture or die. Sixty-five microcystin toxins have been identified, but the specific toxin Microcystin-LR is used as a surrogate indicator for the presence of other toxins. There are three known modes of toxic action, including attack on the liver, attack on the nervous system, or skin irritation; there is also the suggestion that microcystin toxins are likely to be tumour promoters (Charlton et al. 2001). The algal toxins may also contribute to avian botulism (AWWA 1999).

Standard wastewater treatment processes are not designed to remove algal toxins, and the effluent may in fact contribute to their production. Health Canada recommends removal of the algal cells followed by chemical oxidation by ozone, permanganate, or chlorine (Health Canada 2005c). Nutrient control in wastewater treatment would appear to be the most appropriate treatment action.

4.4.3 Protozoa

There are neither CCME nor EPA aquatic guidelines for *Giardia* and *Cryptosporidium* levels in aquatic environments. The two protozoa of greatest interest in Canadian wastewater are *Giardia* species and *Cryptosporidium* species. Giardiasis symptoms include diarrhea, fatigue and cramps; cryptosporidiosis is similar but with more severe and longer-lasting symptoms. Sources of the two protozoa in MWWEs are likely to be the feces of infected persons, as well as infiltration of contaminated surface runoff. The protozoa occur as cysts or oocysts in water until they reach the digestive tract of the host, where they ex-cyst and multiply.

Giardia lamblia is the species of principal concern in wastewater effluents. *Cryptosporidium parvum* is the species that is infective to humans (AWWA 1999). *Giardia* cysts are larger (11-14 um in length) than *Cryptosporidium* cysts (5-8 um) (AWWA 1999). As a result, *Giardia* cysts may be more readily removed by gravitational settling and filtration processes than *Cryptosporidium*. Both cysts are resistant to chlorine disinfection compared to bacteria and viruses, however ozone is an effective disinfectant, as is chlorine dioxide in most cases. UV disinfection has been shown effective in inactivating *Cryptosporidium* cysts. Drinking water from surface water supplies is filtered and disinfected to remove and inactivate these pathogenic organisms.

4.4.4 Viruses

Viruses are extremely small particles (e.g., 15 to 80 nm). Municipal wastewater may contain a number of different viral types, including enteroviruses (polio, ECHO, Coxsackie viruses which cause gastroenteritis), rotavirus, Norwalk virus and reovirus (all of which also cause gastroenteritis), adenovirus (respiratory illness), parvovirus (typically an enteric virus of dogs and cats), and calicivirus (typically an enteric virus of rabbits and cats) (AWWA 1999). Other potential viruses of concern in wastewater include Hepatitis A (Metcalf and Eddy 1991) which may be shed in human feces, but not HIV, for which wastewater is a hostile environment, meaning that the conditions for virus survival are not in wastewater are not favourable. (Rescuenet.com 2005).

Viruses require a live host in which to multiply so their numbers do not increase in wastewater, as bacteria can. Different levels of treatment can result in different removal efficiencies of viruses. For example, primary treatment my result in no effective removal of viral densities; and primary effluents may actually have higher numbers of viruses than raw wastewater due to break-up of fecal matter in primary treatment. (WPCF 1986). Activated sludge and trickling filter treatment may resulting 50% and 90% reductions, respectively, in non-disinfected effluents, and chemically assisted primary treatment for phosphorus may also remove 90% of

viruses in wastewater (WPCF 1986). Chemical disinfection is believed to result from inactivating the virus, by reacting with the proteinacious material of the viral capsule, thereby altering the chemical structure of the viral attachment site, making it impossible to attach to a host cell (WPCF 1986). In water representative of a high quality secondary effluent, reductions of 4 logs (99.99%) of most viruses were observed by 30 minutes at low temperature (2 ^{o}C), low free chlorine residual (0.5 mg/L) and elevated pH of 7.8; although a few virus types required a longer contact time under the test conditions (WPCF 1986).

4.5 Emerging Substances

Annotations are provided for these so-called “emerging” substances which may prove to be of potential concern. Because they are emerging, there are few guidelines developed to address their presence in MWWEs.

Of the substances included in the Master List that were not specifically identified as substances of concern, a number will undoubtedly emerge as being so, once more research is conducted into their occurrence in MWWE and aquatic environments, as well as their effects. Among the substances recently receiving attention are pharmaceuticals and personal care products (PPCPs). These include a broad spectrum of substances ranging from prescription drugs to diagnostic agents, fragrances, sunscreen agents, surfactants, insect repellents and numerous others, some of which are listed in Appendix Table A.10. These compounds and their biologically active metabolites can be introduced to aquatic environments via a number of routes, but primarily by both untreated and treated sewage (Daughton and Ternes 1999, Kolpin et al. 2001). Some PPCPs are extremely persistent in that they are resistant to degradation and others may be similarly problematic simply by virtue of their continual infusion into the aquatic environment (i.e., persistent/perpetual exposure).

Another category of chemicals receiving much attention are endocrine disrupting substances. This too is a broad group of chemicals, some of which originate as PPCPs and others, which originate in, or from breakdown products of, industrial effluents. Although there is mounting evidence that at least some of the PPCPs and endocrine disrupting substances may be causing environmental effects (Daughton and Ternes 1999, Daughton 2001a, McBride and Wyckoff 2002, WHO 2002), water quality guidelines have not yet been developed. This is likely an indication that either the risks of specific chemicals within these categories have not yet been confirmed and/or there are too few data available to satisfy the minimum requirements for water quality guidelines development (Figure 3.1).

4.5.1 Hormones and Pharmaceuticals

Hormones

Human hormones discharged in municipal effluents may be potent contributors to estrogenic activity to aquatic species receiving waters (Suidan et al., 2005; Drewes et al., 2005). Because therapeutic hormonal doses prescribed are very low, their presence in municipal wastewater are also at the very low concentration range, often at the ng/L level. Both male and female hormones may be found in wastewater. While steroid estrogen hormones enter wastewater as a conjugated metabolite, wastewater treatment effectively converts the conjugates to their parent form (Birkett and Lester, 2003). Lee et al. (2004) reported levels of the natural hormone 17β-estradiol (given the abbreviation E2) and its metabolites estrone (E1), estriol (E3) and 16α-hydroxyestrone (16α-OH-E1) as well as the synthetic contraceptive compound 17α-ethinylestradiol (EE2) and testosterone in Toronto wastewaters. Many of the hormones in the incoming sewage, at individual concentrations up to 180 ng/L, were reduced by biodegradation below the detection limit of 1 ng/L (Lee et al. 2004b). Estrogen concentrations in municipal effluents in Germany, Brazil and Canada were reported by Ternes et al. (1999). Effluent concentration of estrone (E1) ranged up to 70 ng/L, 5 ngL for 16α-OH-E1, 64 ng/L E2, and 42 ng/L for EE2 (Ternes et al. 1999). A study by Conor Pacific environmental technologies (2000) for Environment Canada reported detectable concentrations of hormones in Canadian secondary treatment and lagoon effluents as Estrone: 0.6 – 141 ng/L, E2 as 0.16 – 22 ng/L and EE2 as 0.15 – 28 ng/L. Data related to this Environment Canada were published more recently by Servos et al. (2005) with EE2 ranging from 0.2 – 78 ng/L, with a mean value of 1.8 ng/L, and estrone ranging from 1 –96 ng/L with a mean value of 17 ng/L. A study in Japan found very high removals of the hormones E2, E1 and EE2, however, the metabolite estrone was associated with as much as one-quarter of the estrogenicity of treated municipal effluents in Japan (Tanaka et al., 2003). Both the hydraulic and solids retention time positively influence the removal of hormones such as E1 and E2 (Birkett and Lester 2003).

Pharmaceuticals

Pharmaceuticals and personal care products together combine a vast array of chemical compounds that may end up in treated sewage. As with hormones detected in municipal wastewater, the pharmaceutical compounds, whether present as parent compounds or metabolites, are typically found in the ng/L range when detected. Pharmaceutical found in MWWEs are used to treat a highly diverse range of human and small animal applications. The following section provides an overview of some the principal classes of pharmaceutical found in wastewater. A major review of these compounds as substances can be found in Daughton and

Ternes (1999). Several observations by Daughton and Ternes are highly relevant to this discussion:

"Only a very small percentage of commercially used PPCPs have been investigated for their occurrence in the environment. Drug classes that will experience huge usage rates (e.g. impotence drugs such as sildenafil citrate) have no associated environmental occurrence or exposure data."

"The low volatility of PPCPs means their distribution through the environment will primarily occur through aqueous transport and food-chain dispersal. The polar, nonvolatile nature of most drugs prevents their escape from the aquatic realm".

"Compared with POPs [persistent organic pollutants], there is a paucity of information on the fate, especially, biotransformation and phototransformation, of PPCPs".

"The removal efficiencies of most PPCPs from STWs [sewage treatment works] is poorly understood. And then, in those instances where efficiencies have been determined, only the disappearance of the parent compound has been tracked – this approach ignores the issue of fate (e.g. bioreactive metabolites, and conjugates of the parent PPCP)."

The classes of drugs and pharmaceuticals reviewed by Daughton and Ternes (1999) include: antibiotics, antidepressants/obsessive-compulsive regulators, antieplileptics, antineoplastics, beta-blockers-sympathomimetics, blood lipid regulators, diagnostic contract media, hormones/mimics, nonopioid analgesics/non-steroidal anti-inflammatories, impotence drugs, retinoids, tranquilizers, antipsychotics.

Antibiotics include a number of sub-groups including macrolides, sulphonamides fluoroquinolines, quinoxaline-dioxides, peniciilins and tetracyclines (Daughton and Ternes 1999; Miao et al. 2004).

Macrolides are a group of antibiotics produced by various strains of Streptomyces that have a complex macrocyclic structure (Biology Online 2005). The antibiotic activity stems from the presence of a macrolide ring, a large lactone ring to which one or more deoxy sugars, usually cladinose and desosamine, are attached (Wikipedia 2005). Examples of macrolides found in wastewater include erythromycin, clarithromycin and roxithromycin (Miao et al. 2004). Macrolides are used clinically as broad-spectrum antibiotics, particularly against gram-positive bacteria (Biology Online, 2005). Other classes of antibiotics found in Canadian wastewater at concentrations in the 8-360 ng/L median concentration range include sulfonamides, (e.g., sulfamethoxasole), fluoroquinolones (e.g ciprofloxacin and ofloxacin) and tetracycline (Miao et al., 2004).

Beta-Blockers are drugs that oppose the excitatory effects of norepinephrine released from sympathetic nerve endings at beta-receptors and are used for the treatment of angina, hypertension, arrhythmia, and migraine. They are also called beta-adrenergic blocking agent. (American Heritage 2005). Examples of this class of drug found in European MWWEs 100-2500 ng/L range include propanolol, atenolol, sotalol and metropolol (Ternes et al. 2004; Paxeus 2004). Bronchodilators (β2-Sympathomimetics) are a type of medication that relaxes the muscles surrounding the airways. It helps breathing and relieves asthma symptoms (LSU, 2005). Albuterol was found in low ng/L in a U.S. wastewater treatment facility (Braghetta et al., 2002). Vasodilators are substances that cause blood vessels in the body to become wider by relaxing the smooth muscle in the vessel wall, reducing blood pressure (since there is more room for the blood) and potentially allowing blood to flow around a clot (Wikipedia 2005). The vasodilators pentoxifylline at 500 ng/L (Metcalfe et al. 2003) and diltiazem (15-35 ng/L) (Braghetta et al.2002) were identified in wastewater effluent surveys.

The term **antipsychotic** is applied to a group of drugs used to treat psychosis, such as the phenothiazines or butyrophenones. Common conditions with which antipsychotics might be used include schizophrenia, mania and delusional disorder. Antipsychotics also have some effects as mood stabilizers, leading to their occasional use in treating mood disorder (particularly bipolar disorder) even when no signs of psychosis are present, They are sometimes referred to, incorrectly, as major tranquilizers (American Heritage 2005; Wikipedia 2005). No effluent data for these pharmaceuticals were noted.

Blood lipid regulators reduce serum triglyceride levels, and increases cholesterol carried in high density lipoprotein (HDL) in the blood (MedicineNet.com 2005). Examples of this class of drug found in municipal wastewaters in North America and Europe include Gemfibrozil, Clofibrate (and its metabolite clofibric acid), bezafibrate, and fenofibrate (Braghetta et al. 2002; Metcalfe et al., 2003; Paxeus and Schroder (2004). Clofibric acid in particular is widespread in the aquatic environment. Metcalfe et al. (2003) found a median concentration of Gemfibrozil in Canadian MWWEs of 1300 ng/L, while Lee et al. (2003a) reported Gemfibrozil concentrations in secondary effluents in the Toronto/Hamilton, Ontario area ranging from 20 to 540 ng/L, with a mean removal efficiency of only 5 %. The review by Daughton and Ternes concludes that this class of pharmaceutical is poorly removed by wastewater treatment processes.

Anticonvulsants are drugs used to treat or prevent convulsions (for example, epilepsy). In MWWEs, carbamazepine is a frequently occurring anti-epileptic drug (Braghetta et al., 2002; Metcalfe et al., 2003; Paxeus and Schroder (2004). Ternes et al. (2003) found carpamazepine at concentrations on the order of 2000-3000 ng/L in wastewater treatment plant effluents, and determined that it was poorly removed by wastewater treatment processes.

Little is known about the fate of **tranquilizers** such as diazepam in wastewater treatment or the aquatic environment. In German effluents, concentrations in treated effluents up to 40 ng/L were noted in the review by Daughton and Ternes (1999). Because of their widespread use, however, it is probable that the compounds are either metabolized by humans prior to discharge to wastewater treatment plants, or are degraded during transit in sewers, or undergo at least primary biodegradation in the wastewater treatment

Nonsteroidal anti-inflammatory drugs are medicines that relieve pain, swelling, stiffness, and inflammation. Analgesics are those medications that reduce or eliminate pain (answers.com 2005) Analgesics and nonsteroidal anti-inflammatory drugs (NSAIDs) are prescribed for a variety of painful conditions, including arthritis, bursitis, tendinitis, gout, menstrual cramps, sprains, strains, and other injuries. They do not cure the diseases or injuries responsible for these problems (CHClibrary.org, 2005). Analgesics and NSAIDs found in wastewater include ibuprofen, ketoprofen, fenoprofen, diclofenac, acetaminophen, naproxen, and antipyrine at concentrations up to 12500 ng/L (Braghetta et al. 2002; Metcalfe et al. 2003; Paxeus and Schroder 2004). In a survey of secondary treatment facilities in the Toronto/Hamilton, ON area, Lee et al. (2003a) reported the following secondary effluent concentrations and removal efficiencies for NSAIDs:

Salicylic Acid: 0.02 – 1.03 ug/L; mean removal efficiency 98 %

Ibuprofen: 0.04 – 0.97 ug/L; mean removal efficiency 87 %

Naproxen: 0.21 – 1.11 ug/L; mean removal efficiency 70 %

Ketoprofen: 0.03 – 0.15 ug/L; mean removal efficiency 18 %

Diclofenac – sodium: 0.02 – 0.21 ug/L; mean removal efficiency 0 %

Indomethacin: 0.03 – 0.24 ug/L; mean removal efficiency 40 %

Histamine (H-2) blockers are used for control of peptic ulcers, an eroded area in the stomach lining or in the first part of the duodenum (beginning of the small intestine) due to overproduction of gastric acid (Oregon State 2005). Anti-ulcer medications found in wastewater include cimetidine (nd-312 ng/L) and ranitidine (nd-28 ng/L) (Braghetta et al. 2002).

Antineoplastic medications block the formation of neoplasms (cells or growths that may become cancerous). (Cancer Hub 2005). The review by indicates that these compounds, if discharged by hospitals to municipal sewers, are not likely to be removed by municipal wastewater treatment. The substances are of major concern because they appear to be highly genotoxic to exposed aquatic organisms (Daughton and Ternes 1999). Metcalfe et al. (2003) did not detect the antineoplastics cyclophosphamide and ifosfamide in a survey of 18 Canadian wastewater effluents.

The blood glucose regulator metformin, used in control of diabetes, has been detected in U.S. (Braghetta et al. 2002) and Australian (Khan and Ongerth 2002) wastewater treatment facilities.

Phase contrast media are used to enhance X-raying of soft tissues. Many of the compounds are highly branched compounds which incorporate iodine, and so are difficult to degrade in wastewater treatment (Daughton and Ternes 1999). Phase contrast media compounds found in European wastewater include iopromide, diatrizoate, iothalamic acid, iohexol and iopamidol; the initial two compounds listed were found in German effluents in the 3,000-4,000 ng/L range (Ternes et al. 2003). Phase contract media are discharged by hospitals to municipal wastewater systems, and so are unlikely to appear in wastewaters of municipalities without hospitals (Kreuzinger et al. 2004).

Retinoids are pharmaceutical derivatives of Vitamin A used for treatment of skin disorders such as acne, for anti-aging treatment and for treatment of leukemia (Daughton and Ternes 1999). The concern with respect to these compounds in the environment is the potential to cause embryonic deformities, especially in frogs and other amphibians (Daughton and Ternes 1999). No effluent concentration data for this class of pharmaceutical was noted.

Impotence drugs such as sildenafil citrate (Viagra) have become one of the most widely prescribed in the last decade. According to Daughton and Ternes (1999), there is a virtual absence of data on effluent concentrations and environmental effects studies. They caution that the intended therapeutic effect of the drug could be a problem for non-target organisms in the wider environment.

Stimulants including caffeine, paranthine and cotinine have been detected in wastewater effluents at concentrations up to 1800 ng/L (Braghetta et al. 2002; Skadsen 2004). Approximately 90 % of caffeine was removed by a large activated sludge treatment facility in Sweden, with an effluent concentration of 4,000 ng/L reported (Paxeus and Schroder 1996).

Other types of pharmaceuticals of which there is virtually no concentration or fate data include so-called **nutraceuticals** (biologically active food supplements, typically botanicals) (Daughton and Ternes 1999) and **illicit drugs**, such as anabolic steroids (Daughton 2001b).

4.5.2 PBDE Flame Retardants

Also among the substances of emerging concern is a class of flame retardants known as polybrominated diphenyl ethers. These compounds have been found accumulating in waterfowl around the Great Lakes and other areas. Entry through municipal wastewater effluents may result from the washing of clothing or other textiles.

PBDEs are one of the fastest accumulating substances now being examined, with exponential increases in human breast milk, marine animal tissues and bird eggs Environment Canada, 2005d; Hemminger, 2005.) Potential health concerns arising from PBDE exposure include disruption of thyroid hormone function, neurodevelopmental effects, and animal carcinogenicity. (Washington State University, 2005).

The compounds are widely used as flame retardants, i.e. agents that slow the spread of fire, in the textiles, furniture, electronic component and building insulation sectors (Washington State University, 2005). Their chemical structure is similar to that of polychlorinated biphenyls (PCBs) (Hemminger, 2005), and thus have many of the same environmental concerns as PCBs. Their retardant action can be accomplished either through incorporation into a polymeric material (reactive treatment), or as an additive. Emissions are much more likely when used as an additive. PBDEs are not used commercially as single isomeric compounds (congeners), of which there are potentially 209 (Washington State University, 2005), but rather are mixtures of congeners (similar to the commercial Arochlor PCB mixtures). Three mixtures are used commercially, namely the PentaBDE, OctaBDE and DecaBDE. Use of a fourth mixture, TetraBDE, has been discontinued (Washington State University, 2005).

The PBDEs as a group have very high octanol-water partition coefficients (Environment Canada, 2005d), which indicate that they will tend to preferentially sorb to wastewater solids, and thus be removed to the residual solids (sludge) fraction. Due to the high degree of bromination they would not be expected to biodegrade readily in secondary treatment. The high affinity for PBDEs to solids is likely the reason they are detected in sludge samples (Environment Canada 2005d; Hale et al. 2001) but not in effluents. Concentrations in different sludges from various U.S. locations and Toronto range from 7,300 to 24,900 ug/kg (Environment Canada 2005d). Their presence in Arctic seal blubber is indicative of long-range air transport from industrial areas of North America (Environment Canada 2005d).

The main potential exposure is identified as oral, through food ingestion. Foods with high levels of fats (fish, processed meats, cheese) had the highest levels (up to 3078 ng/kg wet weight in salmon fillets) (Washington State University 2005). Most is excreted with feces to end up in wastewater. Foods grown with biosolids having PBDEs are a potential exposure route. Banning of some PBDE applications in Sweden has resulted in significantly lower concentrations in human samples than in North America (Washington State University 2005).

4.5.3 Personal Care Products

A wide variety of personal care products in municipal wastewaters have been identified in the last decade (see e.g., Daughton and Ternes, 1999). Among the many substances identified are

components personal grooming products, household cleaning and laundry products (fragrances and whitening agents), outdoor products (sunscreens and insect repellents and the like. This section attempts to summarize this large and growing body of wastewater substances.

Synthetic musks are used to enhance the smell of detergents, soaps, shampoos, air fresheners, deodorants, cosmetics and other personal care products (USInfo 2005). Classes of musks include nitro musks, mainly musk xylene and musk ketone, as well as polycyclic musks, primarily HHCB (galaxolide) and AHTN (tonalide). Others of interest include ADBI (celestolide), AHMI (phantolide) and AITI (traseolide) (OSPAR Commission, 2004). These substances have come under scrutiny because the nitro musk have demonstrated estrogenic activity in laboratory tests, and may exert endocrine disrupting properties, potentially including miscarriages; moreover, most of the synthetic musks have been observed in human adipose tissue and breast milk (Peck and Hornbuckle, 2004). Recent research has suggested that two of the most widely used aromatic musks, AHTN and HHCB, can exert anti-estrogenic activity (Scheurs et al. 2005), the opposite of many of the endocrine disrupting chemicals discussed in this section.

Concentrations of synthetic musks in municipal wastewaters are likely to be in the ng/L range e.g., 40 ng/L for musks xylene and ketone to 1,640 ng/L for HHCB (Peck and Hornbuckle 2004). Lee et al. (2003b) measured for polycyclic and nitro musks in secondary effluents in the Toronto/Hamilton, Ontario region with the following results: ADBI (celestolide) range 14 – 25 ng/L with a median of 16 ng/L; AHMI (phantolide) range 5 – 7 ng/L with a median of 5 ng/L; ATH range of 39 – 92 ng/L with a median of 54 ng/L; HHCB (galaxolide) range of 825 – 1570 ng/L with a median of 915 ng/L; AHTN (tonalide) range of 337 – 661 ng/L with a median of 422 ng/L; musk xylene range of 1.4 – 16.1 ng/L with a median of 6.2 ng/L; and musk ketone range of 22.2 – 62.8 ng/L with a median of 44.0 ng/L. In wastewater treatment, the musk fragrances are expected to sorb strongly to activated sludge, with some limited biodegradation (OSPAR 2004); volatilization is not anticipated to be an important removal mechanism. Although data are limited, because of the hydrophobicity of the compounds, their presence in residual wastewater solids is expected.

Parabens (alkyl-p-hydroxybenzoates) are a widely used suite of antimicrobial preservatives in foods, cosmetics (skin creams, tanning lotions, etc.), toiletries, and pharmaceuticals (Danish EPA 2001). The alkyl group may consist of methyl, ethyl propyl or butyl chains. As the carbon number of the alkyl chain increases, anti-microbial activity increases but water solubility decreases. The toxicity of these compounds (acute and chronic) is low, but there is some weak estrogenic activity associated with the compounds (Danish EPA 2001). A recent study has found parabens associated with breast tumours, but the cause-and-effect association has not been shown (Health Report Company 2005). Environmental test chamber results have shown

that the compounds can mineralize to a large extent, in both aerobic and anaerobic conditions (Danish EPA 2001), but their fate in wastewater treatment plants has not been well documented.

Antiseptics such as Triclosan are used in a wide variety of products including toothpaste, footwear products, hand soaps, acne creams and in plastic toys and kitchen products, while disinfectant products are used in hospitals, in households and by animal breeders (Daughton and Ternes 1999). Disinfectants are mostly halogenated phenolic compounds such as biphenylol, chlorophene, and 4-chlorocresol. In secondary effluents in the Toronto/Hamilton, Ontario region, triclosan concentrations ranged from 30 to 740 ng/L, with a mean removal effieincy in treatment of 81 % (Lee et al., 2003a). Paxeus (2004) reported effluent triclosan concentrations for European treatment facilities in the range of 90 to 700 ng/L. In a review of triclosan removal through various wastewater treatment studies, Thompson et al. (2005) reported removal efficiencies of triclosan in activated sludge to range from 95.0 to 97.5 %, with effluent concentrations ranging from 27 to 1,100 ng/L. For trickling filters, removal was not as complete, ranging from 58.0 to 96.5 % with effluent concentrations form 130 to 2,700 ng/L. Removal efficiencies in European facilities ranged from 55 to 91 % (Paxeus, 2004), suggesting good if incomplete removal. Thompson et al. (2005) suggest that in a highly aerobic wastewater treatment environment, removal of triclosan will be by biodegradation, but in oxygen-limited systems, such as may occur in some fixed film operations, sorption may be the most important removal mechanism.

Sunscreen agents are used to prevent the skin from burning from exposure to harmful ultraviolet light from the sun. Para-amino benzoic acid (PABA), once widely used a few years ago is scarcely now used because of the high incidence of allergies to the compound (LEAS 2005). Agents used in the formulation include methylbenzylidene camphor, 2-hydroxy-4-methoxybenzophenone (oxybenzone) and 2-ethylhexyl-4-methoxycinnamate, as well as the newer compound avobenzene (1-[4-(1,1-dimethylethyl)phenyl]-3(4-methoxyphenyl)-1,3-propanedione) (Daughton and Ternes 1999). Eriksson et al. (2003) identified the sunscreen agent parasol MCX (3-(4-methoxyphenol)-2-propenoic acid, 2-ethylhexyl ester) in grey wastewater from a Danish apartment complex at a concentration of 0.5 ug/L. Sunscreens enter the wastewater treatment system from personal hygiene (washing, bathing, showering) following applications, as well as from laundering of clothes, which transfers the sunscreen from garments to the laundry wash water, which is then sewered. Due to the high lipophilicity of the compounds, and the fact that the compound applied dermally has been found in human breast milk, there is concern over the exposure of these compounds to aquatic organisms that can

biomagnify them by several orders of magnitude (Daughton and Ternes 1999). Effluent concentration data for this class of substance is mostly lacking.

The most commonly used **insect repellent** is N,N-diethyl-m-toluamide, also known as DEET. DEET enters the wastewater treatment system from personal hygiene (washing, bathing, showering) following applications, as well as from laundering of clothes, which transfers the insect repellent from garments to the laundry wash water, which is then sewered. Removal efficiencies for DEET in a German study (Knepper 2004a) varied from 0% in winter to 90 % in late summer, indicating there may be some acclimation period. In non-peak mosquito season, influent concentrations were 260 to 490 ng/L, rising to almost 3000 ng/L in peak season. Another identified repellent with reported use in Germany is called Bayrepel (1-piperidinecarboxylic acid, 2-(2-hydroxyethyl), 1-methylpropyl ester) (Knepper 2004a). Bayrepel influent levels in 2000 were 0.6 to 1.4 ug/L, with n.d. effluent levels. An initial report by Knepper (2004a) suggests that Bayrepel may degrade more readily than DEET based on comparison of influent and effluent wastewater samples collected in the summer months. Subsequently, Knepper (2004b) indicated that Bayrepel undergoes rapid primary biodegradation in aerobic treatment to the metabolite Bayrepel-acid (1-piperidinecarboxylic acid, 1-methylpropyl ester, 2-acetic acid). The fate of this metabolite in the aquatic environment is unknown at this time. Recently, the U.S. Centers for Disease Control approved the use of repellents containing the chemical picaridin or the oil of lemon eucalyptus as DEET alternatives (CBS News 2005). These alternate repellents have been in use in Europe and Australia since the 1980s. No wastewater effluent data associated with these substances were found.

4.5.4 Organic Siloxanes

Polyorganosiloxanes have a broad variety of uses in both industrial and domestic applications. Domestic applications are the chief sources in wastewater. The organosiloxanes are used as foam-control agents in laundry detergents, in shampoos, hair conditioners, creams, gels, textiles and water repellents (Lukasiak et al. 1997). In industry, they are used in adverse environments involving corrosive chemicals, high humidity, high heat and electric fields (Lukasiak et al. 1997). Such applications include encapsulating materials for computer semiconductors, transformer coolants, bearing lubricants, and gaskets in engine parts. The industrial uses are not expected to contribute to their appearance in municipal wastewaters, however.

There are three broad classes of organosiloxanes, including, volatile methylsiloxanes (VMS), polydimethylsioxanes (PDMS), and polyethermethylsiloxanes (PEMS) (Lukasiak et al.1997). Some volatile methylsilicones, and a prominent volatile degradation product of PDMS, dimethylsilane diol (DMSD), may be subject to atmospheric long-range transport (Maguire 2001). Specific compounds of interest include octamethylcyclotetrasiloxane (referred to as D4),

and decamethylcyclopentasiloxane (D5). The organosiloxanes are found in municipal wastewater influents and effluents at up to 710 µg/L and 13 µg/L, respectively. (Maguire, 2001). Studies by Parker et al (1999) suggest that close to 90 % of the compounds D4 and D5 are removed during wastewater treatment by both sorption to sludge solids and by stripping and volatilization to the atmosphere. The compounds are considered to be essentially non-biodegradable (Parker et al 1999, Lukasiak et al. 1997).

The aquatic toxicities of PDMS and PEMS, and the degradation product dimethylsilane diol (DMSD) are low, e.g. (chronic NOEL to Daphnia magna of > 10 mg/L), while the low molecular weight VMS compounds are much more toxic to aquatic organisms, with NOECs in the µg/L range (Maguire, 2001). The VMSs can also bioaccumulate significantly. Maguire (2001) recommended the organosiloxanes be included in environmental fate research studies, including wastewater influents effluents and sludges, as well as other media, in both northern and southern Canada, because so little environmental fate data are available.

4.5.5 Polyfluorinated Surfactant Compounds

This group of substances principally involves the perfluorooctane sulphonate (PFOS) anion, usually found as either the acid or a metal salt, and perfluorooctanoic acid (PFOA). Organic compounds designated as perfluorinated means that fluorine atoms have replaced hydrogen atoms in all C-H bonds (Swackhammer et al. 2004). These fluorinated surfactants had a variety of uses including fire-fighting foams, as a stain repellent for clothing, in cosmetics, in paper and paper packaging and as a non-stick coating on cooking utensils. Industries that use products with PFOS include metal plating, semi-conductor mfg, photography, and in aviation hydraulic fluids (UK Environmental Agency, 2004). The major supplier of these compounds, 3M, discontinued manufacturing of these compounds due to potential adverse health effects and concerns of environmental persistence (Reicher, 2005).

In domestic wastewater, washing of clothing and the cooking utensils would appear to be the most probable source of these substances in MWWEs. Although the chemical properties of the PFOS would indicate they should not undergo long-range transport in air, their detection in remote Arctic areas indicates they do travel. The probable mechanism is as a neutral derivative that reverts to the free acid form when it degrades (Swackhammer et al., 2004). Because they are airborne substances, however, the route of entry to wastewater treatment could include airborne deposition, leading to collection in stormwater and infiltration in groundwater. Areas beneath fire-fighting schools or military bases are prone to groundwater contamination of these compounds (Moody and Field, 1999).

The substances are of environmental concern because of their ability to persist and biomagnify. The substances have been found globally in birds, fish and both marine and land mammals (Swackhammer et al. 2004). A summary of biodegradation studies performed with biomass from wastewater treatment plants suggests that PFOS are non-biodegradable at exposure ties of up to 35 days. Concentrations used were in the 2-21 mg/L range. Recoveries were considered good. Most of the PFOS was associated with the biomass rather than in sludge (UK Environment Agency, 2004). Consequently these compounds, if detected in municipal wastewater, would most likely be associated with residual solids, and thus could be a problem in agricultural land application.

4.5.6 Alkylphenol Surfactants

Alkylphenols (APs) and their ethoxylates (APEOs) are surface active-agents (surfactants). These agents have a hydrophobic component (the alkyl moiety of the compound) and a hydrophilic component (the ethoxylate portion), that allow the surfactants to mix substances into water that otherwise would tend not to. The number of ethylene oxide units in the hydrophilic chain can vary from 3 to >20 (Bennie et al., 1998). The species of greatest environmental concern are the ethoxylated nonylphenols and ethoxylated octylphenols, and their parent alkylphenols.

These surfactants are used industrially in a wide array of products and applications, including detergents, emulsifiers, dispersants, antifoamers, dyeing assists, stabilizers, lubricants, spermicides and pesticide adjuvants (Bennie et al., 1998).

In secondary treatment, the APEOs undergo degradation by sequential removal of the ethylene oxide units until the compounds are left with only one or two ethylene oxide units i.e., $APnEO_{n=1,2}$. Primary degradation of the original APEO compounds is very high (Ahel et al. 1986), but metabolites remain that are less easily degraded and represent more of an environmental concern. As the EO chain length is shortened through aerobic biodegradation, the compounds become more hydrophobic and tend to sorb onto the solids, which is then a major loss mechanism for the compounds from wastewater treatment. The APnEOn=1,2s metabolites are stable, and only a small part of these compounds, are further degraded to the parent alkylphenol compound in aerobic secondary treatment (Giger et al. 1987). These refractory $APnEO_{n=1,2}$s may be converted to carboxylic acids (APECs) in secondary treatment (Giger et al. 1987), and end up discharged to receiving waters. An additional concern is that in the disinfection process with chlorine, the $APnEO_{n=1,2}$s and APECs may become chlorinated, becoming more refractory in the process (Ball et al. 1989). Of particular interest to wastewater treatment of these compounds in Canada is the apparently strong dependence on the temperature of treatment for successful removal. Several studies have shown that when the

temperature of treatment declines from the range of 20ºC or higher to 16ºC or lower, the removal efficiency becomes increasingly erratic (Mann and Reid 1971; Stiff et al. 1973; Kravetz et al. 1983; Tanghe et al. 1998).

A survey of Canadian wastewaters by Bennie et al. (1998) found 4-nonylphenol concentrations in effluents to range from < 0.020 – 13 μg/L, NP1EO in the range of 0.072 to 26 μg/L, and NP2EO from 0.099 – 26 μg /L. A second survey by Conor Pacific (2000) for Environment Canada provided the following ranges of alkylphenols, their ethoxylates and metabolites in the effluents of secondary treat plants and lagoons:

4-nonylphenol: 0.005 – 6.2 ug/L 4-t-octylphenol: - 0.30 ug/L

octylphenol carboxylate: 0.037 – 3.0 ug/L octylphenol ethoxycarboxylate: 0.06 – 1.3 ug/L

nonylphenol carboxylate: 0.29 – 54 ug/L nonylphenol ethoxycarboxylate: 0.77 – 114 ug/L

nonylphenol monoethoxylate: 0.07 – 91 ug/L nonylphenol diethoxylate: 0.04 – 83 ug/L

nonylphenol polyethoxylate (3-17): 0.29 – 38 ug/L

In 3 wastewater treatment facilities in Kansas, NP1EO was not detected in 2 of the 3 plants, concentrations of NP2EO ranged from 0.4 – 16 μg /L, and NP 0.5 – 23 μg /L (Keller et al. 2003).

The ethoxylated compounds appear to be of lesser environmental concern that the parent alkylphenol compounds, which exert greater toxic effects than their ethoxylated counterparts (Servos 1999). Alkylphenols and their ethoxylates are estrogenic compounds, with reported adverse effects in fish including induction of vitellogenin, growth of tests, altered steroid metabolism disruption of smoltification, and intersex characteristics (Servos 1999).

4.5.7 N-Nitrosodimethylamine

Domestic wastewater may contribute a significant fraction of N-nitrosodimethylamine (NDMA) to the raw wastewater content from household sources that have not been identified at this time; however, other sources in municipal wastewater include sewer root treatment and circuit board plating operations (dimethyldithiocarbamate, DTC) (Sedlak et al. 2004). Within a wastewater treatment facility, NDMA may be contributed by cationic polymers and by chloramination for disinfection (i.e. when chlorine is combined with ammonia) (Sedlak et al. 2004). In a survey of California treatment facilities, concentrations in raw wastewater were very low at 17 to 170 ng/L, while the median effluent concentration was 46 ng/L with a maximum of 360 ng/L (Sedlak et al. 2004). Removal of NDMA appears to be highly variable, ranging from almost no removal to 93 %. The type of disinfection used (chlorine or UV light, for example), and the level of biological treatment (nitrification or not) may cause the great variability in removal. NDMA is identified as

an animal carcinogen and a probable human carcinogen by the U.S. EPA. (California DHS 2005).

4.5.8 RV Fragrances

Recreational vehicles (RVs) with on-board wastewater holding tanks often apply, chemical, bacteriological or enzymatic treatments to both treat the waste, stabilize it and/or keep it from becoming malodorous before it is discharged at a waste transfer station or treatment facility. Chemical formulations typically contain strong oxidants or antimicrobials that prevent the breakdown of the waste. Such substances include formaldehyde, glutaraldehyde, paraformaldehyde, quaternary based compounds, phenol based compounds, or alcohols (Trisyn 2005), as well as chlorine and chlorine dioxide (Billydump 2005). Many formulations contain a fragrance or perfume to assist in masking malodours from the holding tanks; however, information on the specific compounds is difficult to obtain. Fragrances mentioned in promotional materials on internet websites include evergreen (pine and cedar); citrus and fruit (lemon, orange, apple, berry, winterberry), herb and spice (cinnamon, mint, vanilla), and floral (lavender, wild hyacinth, rose) and other (ocean) (Alken-Murray 2005; DWDavies 2005; NaturalMagic 2005; UBLCorp. 2005). The fragrances may be natural oils or extracts, such as the citrus oils and evergreen resins), or they may be synthetic fragrances, but the specific compounds are not clear from the available public documentation.

There are few (if any) aquatic environmental fate data available for these compounds. Paxeus and Schroder (1996) reported concentrations of a number of fragrances or “odorants” in the Goteborg Sweden activated sludge treatment facility. While influent sewage concentrations were typically in the 1 – 5 ug/L range, effluent concentration were less than the 0.5 ug/L detection limit. Erikkson et al. (2003) reported in a survey of domestic “grey” wastewater in Denmark that over 40 fragrances and flavours were identified, mostly in the 1-10 ug/L range. Menthol was the highest at 32 ug/L. Of particular note, Erikkson et al. (2003) suggested that some of the compounds within the list of fragrances and flavours may cause allergies, cancer and have a teratogenic effect.

5.0 IDENTIFICATION OF KEY INFORMATION GAPS

5.1 Benchmarks

It is evident that many substances included in the Master List, and others identified as present in some MWWE based on review of the literature, do not have water quality guidelines. Without such guidelines, or a suitable alternative benchmark, it is difficult to judge whether substances identified in wastewater may impair receiving water uses. The list of substances should be reviewed in a systematic manner to identify those of greatest potential for adverse effects with a view to developing appropriate guidelines or alternative benchmarks.

5.2 MWWE Data

There are two issues related to the municipal wastewater effluent data reviewed for this study. The first is the lack of effluent concentration data for many of the substances on the project Master List. There are reasons for this paucity of data, including little or no regulatory pressure to monitor them, the cost of analyses, and the absence of commercially available capability to quantify some of the substances at low levels in complex wastewater.

A second issue stemming from the paucity of data was the inability to assess regional or other differences in substance concentrations within Canada. As a result, there is need first to make a concerted effort to collect and summarize data currently residing with municipalities and other jurisdictions. Such efforts are time-consuming and were beyond the scope of this project, but are none-the-less very worthwhile. If data are not forthcoming from this exercise, there is a need for a comprehensive sampling survey of the substances in MWWEs, but only after a review of the availability and adequacy of analytical methodologies. Such a survey should be designed to capture the effects of regional differences and seasonal variations that need to be identified.

5.3 Treatability of Substances

Municipal treatment plants are designed to treat human waste and their ability to reduce effluent concentrations of industrial chemicals, pesticides, PPCPs and other substances is only partly understood. Use of soil aquifer treatment in Canada, either resulting unintentionally from effluent irrigation, or deliberately as a polishing step, has not been reported in the technical literature. As arid areas of Canada may need to apply this land-based treatment in the near future for aquifer recharge, a better understanding of substance fate in the non-saturated and groundwater zones is needed. A compendium of treatability data highlighting specific substance removal efficiencies by municipal wastewater treatment processes, including soil aquifer

treatment, similar to the U.S. EPA Treatability Database (U.S. EPA, 1994) from the 1980-90s would be very useful. Through this study it has become apparent that many researchers in Canada are investigating substances in MWWE either from a treatability or effects perspective (e.g., Environment Canada in Ontario, Trent University, University of Guelph, Ryerson University). Gathering of this information into a focused, yet comprehensive report would assist in filling gaps in substance treatability data.

6.0 SUMMARY AND RECOMMENDATIONS

A total of 65 substances were identified as being of potential concern, because they may be contained in MWWE at concentrations greater than guidelines that were established to protect the health of aquatic biota or human uses of water. It is recognized that such guidelines are not typically applied directly to effluent, but they served as benchmarks to complete a preliminary screen of effluent data. This assessment should be considered preliminary based on limited available effluent data and water quality guidelines for many substances. Moreover, some prioritization may be appropriate, as substances such as iron and manganese may be less of an environmental or health hazard than some other metals and organics (e.g., mercury, cadmium, PAHs, pesticides). Lastly, evidence of effluent concentrations greater than applicable benchmarks does not in itself indicate such substances are necessarily a concern from a human or environmental health perspective. Some such substances that are also not persistent or bioaccumulative can be assimilated in environments having adequate dilution capacity, resulting in environmental concentrations that have no measurable impact.

Based on the assessment to date, it is recommended that:

- Substances identified as being of potential concern on the basis of applicable provincial water quality guidelines should be evaluated to confirm or refute the suitability of such guidelines for use as benchmarks.
- Additional effluent data should be collected for substances that have water quality guidelines but have been rarely or never been measured in MWWE. Effluent data could be collected by selecting facilities to represent a range of sizes, treatment type, industrial loadings, and geographic locations so as to represent a reasonable cross-section of Canadian facilities. Substances shown to be consistently below analytical detection limits could be eliminated from further consideration.
- Prior to any field survey of trace substances in MWWEs, the most significant potential substances of concern identified by this study should be compared to existing commercial analytical capabilities to determine if in fact the substances can be routinely measured at a useful level. The comparison of analytical protocols with the substances of potential concern should be completed by qualified laboratory personnel.
- Substances identified by one of the above approaches as being present in MWWE, but for which no water quality guidelines exist, should be recommended to the CCME or to Environment Canada for investigation and potential development of water quality guidelines. In the meantime, it may be appropriate to consider the use/development of

alternative, interim benchmarks to complete a preliminary screen of potential substances of concern. For example, benchmarks published by Suter and Tsao (1996) have been routinely used in environmental risk assessments and may be adequate to ascertain whether MWWE concentrations of a given substance are typically well above or well below the benchmark concentration and thus should remain on, or could be eliminated from, the Master List.

7.0 REFERENCES

Note: The study makes use of on-line references, some of which can be edited on-line, and thus should be considered as non-scientific sources. This report attempted to use the most reliable of the on-line sources possible.

A1B2C3. 2005. http://www.a1b2c3.com/drugs/. Accessed April 2005.

Agriculture Canada. 2005. Pesticides. http://res2.agr.gc.ca/publications/hw/06c_e.htm. Accessed May 2005.

Agriculture Canada. 2005a. Field Iirriigation and Water Quality. http://www.agr.gc.ca/pfra/water/fieldirr_e.htm. Accessed June 2005.

Ahel, M., Giger, W. and Koch, M. 1986. Behaviour of Non-ionic Surfactants in Biological Wastewater Treatment. in Organic Micropollutants in the Aquatic Environment (ed. by A. Bjørseth and G. Angeletti). Proc. 4th European Symposium, Vienna, Austria, Oct. 22-24, 1985. D. Reidel Publishing Company, Boston.

Ahel, M., Giger, W. and Koch, M. 1994. Behaviour of Alkylphenol Polyethoxylate Surfactants in the Aquatic Environment – I. Occurrence and Transformation in Sewage. Water Research. 28(5): 1131-1142.

Air Resources Board California. 2005. www.arb.ca.gov/toxics/. Accessed April 2005.

Alcide. 2005. http://www.alcide.com/. Accessed April 2005.

Alken-Murray. 2005. http://www.alken-murray.com/trtlu2msd.htm. Accessed May 2005.

American Heritage. 2005. The American Heritage Dictionary of the English Language, Fourth Edition .Published by Houghton Mifflin Company.

Amy, G.L., Debroux, J., Arnold, R. and Wilson, L.G. 1994. Role of Ozone Pretreatment in Enhancingthe Biodegradability of Wastewater Effluent in a Soil Aquifer Treatment System Intended for Potable Recovery. Paper presented at Biodegradable Organic Matter Conference, Montreal Quebec, Canada.

Answers.com 2005. www.answers.com. Accessed April, 2005.

ATSDR (Agency for Toxic Substances and Disease Registry). 2004. www.atsdr.cdc.gov/toxpro2.html

ATSDR. 2005a. http://www.atsdr.cdc.gov/. Accessed April 2005.

ATSDR. 2005b. Lead Toxicity. http://www.atsdr.cdc.gov/HEC/CSEM/lead/lead.pdf. Accessed June 2005.

ATSDR. 2005c. Public Health Statement for Xylene. http://www.atsdr.cdc.gov/toxprofiles/phs71.html. Accessed June 2005.

AWWA. 1999. Water Quality and Treatment (5th ed.). Prepared by American Water Works Association. McGraw-Hill, Toronto.

Ball, H.A., Reinhard, M. and McCarty, P.L. 1989. Biotransformation of halogenated and non-halogenated octylphenol polyethoxylate residues under aerobic and anaerobic conditions. Environmetnal Science & Technology, 23: 951-961.

BCWLAP. 1999. British Columbia Ministry of Water, Land and Air Protection. Ambient Water Quality Guidelines for Ethylbenzene.

http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/ethylbenzene.html. Accessed May 2005.

Bennie, D.T., Sullivan, C.A., Lee, H.-B. and Maguire, R.J. 1998. Alkylphenol Polyethoxylate Metabolites in Canadian Sewage Treatment Plant Streams. Water Quality Research Journal of Canada, 33(2): 231-252.

Beyond Pesticides. 2005. http://www.beyondpesticides.org/infoservices/pesticidefactsheets. Accessed April 2005.

Billydump. 2005. http://www.billydump.com/3r/3rhome.htm. Accessed May 2005.

Biology Online. 2005. http://www.biology-online.org/dictionary/macrolide. Accessed May 2005.

Birkett, J.W. and Lester, J.N. 2003. Endocrine Disrupters in Wastewater and Sludge Treatment Processes. Lewis Publishers, Boca Raton, FL.

Bouwer, H. and Rice, R.C. 1984. Renovation of Wastewater at the 23rd Avenue Rapid Infiltration Project. Journal Water Pollution Control Federation, 56(1): 76-83.

Braghetta, A.H., Gillogly, T., Brownawell, B. and Benotti, M. 2002. Removal of Pharmaceuticals and Endocrine Disrupting Compounds through Advanced Wastewater Treatment Trechnologies. Proc. Water Quality Technology Conference, American Water Works Association (CD-ROM). Denver CO.

Brezonik, P.L. 1972. Nitrogen: Sources and Transformations in Natural Waters. Pp. 1-50. In: H.E. Allen and J.R. Kramer (Eds.), Nutrients in Natural Waters. John Wiley and Sons, Toronto, Ontario.

Brown, K.D. 2004. Pharmaceutically Active Compounds in Residential and Hospital Effluent, Municipal Wastewater and the Rio Grande in Albuquerque, New Mexico. Publication WRP-9, Water Resources Program, The University of New Mexico.

Cain, T.G., Kolpin, D.W., Vargo, J.D. and Wichman, M.D. 2003. Occurrence of Antibiotics and Sterols at Select Surface and Wastewater Sites in Iowa. Retrieved from U.S. Geological Service web site, April 2005.

California DHS 2005. California Drinking Water: NDMA-Related Activities. California Department of Health Services.

http://www.dhs.ca.gov/ddwem/chemicals/NDMA/NDMA.htm. Accessed April, 2005

Cancer Hub. 2005. www.cancerhub.info/reference/glossary.aspx. Accessed May, 2005.

Canviro Consultants. 1991. Fluctuation of Trace Substances in Municipal Sewage Treatment Plants. Phase II Field Studies. Ontario Ministry of the Environment, Toronto, ON

Carballa, M., Omil, F., Lema, J.M., Llompart, M., Garcia-Jares, C., Rodriguez, I., Gomez, M. and Ternes, T. 2004. Behavior of Pharmaceuticals, Cosmetics and Hormones in a Sewage Treatment Plant. Water Research. 38: 2918-2926.

CBS News. 2005. More Options to Fight West Nile. http://www.cbsnews.com/stories/2005/04/28/health/main691587.shtml. Accessed May 2005.

CHClibrary.org. 2005. http://www.chclibrary.org/micromed/00058510.html Accessed April, 2005.

CCCF (Canadian Child Care Federation) 2005. MCPA. http://www.cfc-efc.ca/healthy-spaces/glossary_en.php?GID=79. Accessed May 2005.

CCME (Canadian Council for Ministers of the Environment). 2003. Canadian Environmental Quality Guidelines. Summary Table.

CCME. 2005. Lead. http://www.ccme.ca/sourcetotap/lead.html. Accessed June 2005.

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian Water Quality Guidelines.

Charlton, M., Giddings, M., Holmes, C, Carmichael, W. and Ridal, J. 2001. 2. Algal Toxins and Taste and Odour. in Threats to Sources of Drinking Water and Aquatic Ecosystem

Health in Canada. NWRI Report Series No. 1. National Water Research Institute, Environment Canada, Burlington, ON.

Chlorine Dioxide Council. 2005. http://www.clo2.com/reading/. Accessed April 2005.

Cicek, N., Londry, K., Oleszkiewicz, J.A. and Lee, Y. (2004). Evaluation of the Fate of Synthetic and Natural Hormones in a Full Scale Treatment Plant. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA

Clark, J.W., Viessman, W., Jr., and Hammer, M.J. 1971. Water Supply and Pollution Control. 2nd Ed. International Textbook Company, Toronto.

Conor Pacific Environmental Technologies Inc. 2000. Characterization of Selected Canadian Municipal Wastewater Treatment Plants for the Occurrence, Fate and Release of Endocrine Disrupting Compounds. Report Prepared for Environment Canada. March.

Cornell University. 2005. http://pmep.cce.cornell.edu/profiles/extoxnet. Accessed April 2005.

CWWA (2000). Directory of Sources of Substances Entering Municipal Sewer Systems, 1st edition. Canadian Water and Wastewater Association, Ottawa, ON.

Cheremisinoff, P.N. and Habib, Y.H. 1972. Cadmium, Chromium, Lead, Mercury: a Plenary Account for Water Pollution. Water Sewage Works, 119: 73-86.

Danish EPA (2005). http://www.mst.dk/udgiv/publications/2001/87-7944-596-9/html/kap08_eng.htm. Accessed May 2005.

Daughton, C.G., and Ternes, T.A. 1999. Pharmaceuticals and Personal Care Products in the Environment: Agents of Subtle Change? Environmental Health Perspectives 107(suppl. 6): 907-938.

Daughton, C.G. 2001a. Pharmaceuticals in the Environment: Overarching Issues and Overview," in Pharmaceuticals and Personal Care Products in the Environment: Scientific and Regulatory Issues. Daughton, C.G. and Jones-Lepp, T. (eds.), Symposium Series 791; American Chemical Society: Washington, D.C. pp. 2-38.

Daughton, C.G. 2001b. Illicit Drugs in Municipal Sewage: [also note: Post Publication Commentary. **http://www.epa.gov/nerlesd1/chemistry/pharma/book-post.htm**] Proposed New Non-Intrusive Tool to Heighten Public Awareness of Societal Use of Illicit/Abused Drugs and Their Potential for Ecological Consequences. in Pharmaceuticals and Personal Care Products in the Environment: Scientific and

Regulatory Issues, Daughton, C.G. and Jones-Lepp, T. (eds.), Symposium Series 791; American Chemical Society: Washington, D.C. pp. 348-364.

Demayo, A., M.C. Taylor, and S.W. Reeder. 1979. Guidelines for Surface Water Quality. Volume 1: Inorganic Chemical Substances, Arsenic. Inland Waters Directorate, Water Quality Branch, Environment Canada. Ottawa, Ontario.

Demayo, A. and Taylor, M.C. 1981. Copper. *In* Guidelines for Surface Water Quality. Vol. 1. Inorganic Chemical Substances. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Derocher, A.E., Wolkers, H., Colborn, T., Schlabach, M., Larsen, TS. And Wiig, O. 2003. Substances in Svalbard Polar Bear Samples Archived since 1967 abd Possible Population Level Effects. The Science of the Total Environment, 301: 163-174.

Drewes, J. E., Hemming, J., S.J., Schauer, J. and Sonzogni, W. 2004. An Assessment of Endocrine Disrupting Activity during Wastewater Treatment through the Use of Bioassays and Chemical Measurements. Proceedings WEFTEC 2004 on CD-ROM. Water Environment federation, Alexandria, VA

Drewes, J.E., Hemming, J., Ladenburger, S.J., Schauer, J. and Sonzogni, W. 2005. An Assessment of Endocrine Disrupting Activity during Wastewater Treatment through the Use of Bioassays and Chemical Measurements. Water Environ. Research, 77(1):12.

DWDavies., 2005. http://dwdavies.com/housekeeping/sanitizers.htm. Accessed May 2005.

Eckenfelder, Jr., W.W. and O'Connor, D.J. 1961. Biological Waste Treatment. Pergamon Press, New York,

EcoInfo 2005. http://www.ecoinfo.ec.gc.ca/env_ind/. Accessed April 2005.

Edwards, C.A. 1973. Persistent Pesticides in the Environment. CRC Press, Cleveland, Ohio.

Emerick, R.W and Pedri, J.E. 2004. Impact of Pond-Type treatment Processes in Reducing Both Average and Peak Concentrations of dissolve and Total Recoverable Metals. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Environment Canada. 1984. Manual for Land Application of Treated Municipal Wastewater and Sludge. Environmental Protection Service, Report No. EPS 6-EP-84-1. March.

Environment Canada. 2005. http://www.ec.gc.ca/ceparegistry/regulations. Accessed April 2005.

Environment Canada 2005a. National Pollutant Release Inventory. http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm. Accessed March 2005.

Environment Canada 2005b. CEPA Toxics Priority List Risk Management and Risk Assessment Document for 1,2-Dichloroethane. http://www.ec.gc.ca/substances/ese/eng/psap/PSL1_1_2_dichloroethane.cfm. Accessed May 2005.

Environment Canada 2005c. CEPA Toxics Priority List Risk Management and Risk Assessment Document for 1,1,1-Trichloroethane.

http://www.ec.gc.ca/substances/ese/eng/psap/PSL1_1_1_1_trichloroethane.cfm. Accessed May 2005.

Environment Canada 2005d. Environmental Screening Assessment Report on Polybrominated Diphenyl Ethers. http://www.ec.gc.ca/CEPARegistry/documents/subs_list/PBDE_draft/PBDE_P1.cfm. Accessed January 2005.

Environment Canada. 2005e. http://www.ec.gc.ca/substances/ese/eng/psap/final/npe.cfm

Environment Canada. 2005f. Descriptions of Some Toxic Substances Found in the Pacific and Yukon Region. http://www.ecoinfo.ec.gc.ca/env_ind/region/toxin_descript/toxin_description_e.cfm. Accessed May 2005.

Environment Canada. 2005g. Agricultural Pesticides and the Environment. http://www.ec.gc.ca/science/sandeoct01/article3_e.html. Accessed June 2005.

EPA. 2000. Overview of Diazinon Revised Risk Assessment. http://www.epa.gov/pesticides/op/diazinon/overview.pdf. Accessed June 2005.

EPA. 2005. http://www.epa.gov/safewater/. Accessed April 2005.

EPA 2005a. U.S. Environmental Protection Agency (EPA) Toxics Release Inventory. http://www.epa.gov/tri/chemical/index.htm. Accessed March, 2005.

EPA 2005b. U.S. Environmental Protection Agency (EPA) Technology Transfer Website, Air Toxics Network. Hazard Summary for Quinoline. http://www.epa.gov/ttn/atw/hlthef/quinolin.html

Erikkson, E., Auffarth, K., Eilersen, A-M., Henze, M. and Ledin, A. 2003. Household Chemicals and Personal Care Products as Sources of Xenobiotic Organic Compounds in Grey Wastewater. Water SA, 29(2): 135-146.

European Parliament 2005. http://www.europarl.org.uk/. Accessed April 2005.

EWG. 2005. http://www.ewg.org/reports/. Accessed April 2005

Fact Monster. 2005. http://www.factmonster.com/. Accessed April 2005.

Farre, M., Kloter, G., Petrovic, M., Alonso, M.C., Lopez de Alda, M.J. and Barcelo, D. 2002. Identification of Toxic Compounds in Wastewater Treatment Plants during a Field Experiment. Analytica Chemical Acta, 456: 19-30.

FindArticles. 2005. http://www.findarticles.com/p/articles/. Accessed April 2005.

Florence, T.M. 1982. The Speciation of Trace Elements in Water. Talanta, 29: 345-364.

Francis-Floyd, R. and C. Watson. 2005. University of Florida. www.edis.ifas.ufl.edu/FA031. Accessed April 2005.

Friberg, L., M. Piscator, G.F. Nordberg and T. Kjellstrom. 1974. Cadmium in the Environment. Chemical Rubber Co. Press Inc., Cleveland, Ohio.

Giger, W., Ahel, M., Koch., M., Laubscher, H.U., Schaffner, C., Schneider, J. 1987. Behaviour of Alkylphenol Polyethoxylate Surfactants and of Nitrilotriacetate in Sewage Treatment. Water Science and Technology, 19: 449-460.

GreenOntario. 2005. Toxic and Hazardous Substances Overview. http://www.greenontario.org/strategy/toxics.html#offenders. Accessed March, 2005.

GVC. 2005. http://www.greatvistachemicals.com/. Accessed April 2005.

GVRD 2001. GVRD Sewer Use Bylaw Review. Background Paper and Recommendations – Discharge Limit Evaluation. Draft. Greater Vancouver Regional District. http://www.gvrd.bc.ca/sewerage/bylaw/workshop_rec_limitsSep01.pdf. Accessed May 2005.

Hale, R.C., La Guardia, M.J., Harvey, E.P., Gaylor, M.O., Mainor, T.M. and Duff, W.H. (2001). Flame Retardants: Persistent Pollutants in Land-applied Sludges. Nature, 412, July 12. http://www.mindfully.org/Pesticide/Sludge-PBDE-Hale.htm Accessed April, 2005.

Health Canada (1986). In Guidelines for Canadian Drinking Water – Supporting Documents. Diazinon. http://www.hc-sc.gc.ca/hecs-sesc/water/pdf/dwg/diazin.pdf. Accessed June 2005.

Health Canada 2004. Guidelines for Canadian Drinking Water. Ottawa.

Health Canada 2005. http://www.hc-sc.gc.ca/hecs-sesc/ Accessed April 2005.

Health Canada 2005a. Guidelines for Canadian Drinking Water - Supporting Document for 1,2-Dichloroethane. http://www.hc-sc.gc.ca/hecs-sesc/water/pdf/dwg/dich-1-2.pdf. Accessed May 2005.

Health Canada, 2005b. Guidelines for Canadian Drinking Water - Supporting Document for Tetrachloroethylene. http://www.hc-sc.gc.ca/hecs-sesc/water/pdf/dwg/tetra.pdf. Accessed May 2005.

Health Canada, 2005c. Guidelines for Canadian Drinking Water - Supporting Document for Cyanobacterial Toxins. http://www.hc-sc.gc.ca/hecs-sesc/water/pdf/microcys.pdf. Accessed May 2005.

Health Canada 2005d. http://www.hc-sc.gc.ca/hecs-sesc/water/priority_lst.htm. Accessed March, 2005.

Health Report Company 2005. http://www.health-report.co.uk/parabens.htm. Accessed May 2005

Hemminger, P. 2005. Flame Retardant Chemical Found in Fish and Humans. http://www.rense.com/general19/fih.htm. Accessed April, 2005

Herbes, S.E. 1977. Partitioning of Polycyclic Aromatic Hydrocarbons between Dissolved and Particulate Phase in Natural Waters. Water Research, 11: 493-496.

Huffman, D.E. Widmer, G., Berg, T.L. and Gennacarro, A. 2004. Finding Infectious Protozoan Parasites in Reclaimed Water. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Inchem 2005. http://www.inchem.org/documents/. Accessed April 2005.

International Joint Commission. 2005. 1995-97 Priorities and Progress Under the Great Lakes Water Quality Agreement. http://www.ijc.org/rel/boards/iaqab/priorities/pr9597.html. Accessed May 2005.

IPCS (International Program on Chemical Safety) 1989. Environmental Health Criteria 83. DDT and its Derivatives – Environmental Aspects. World Health Organization. Geneva. http://www.inchem.org/documents/ehc/ehc/ehc83.htm. Accessed May 2005.

ITASS (Denmark). 2005. http://www.itass.dk/. Accessed April 2005.

ITK 2005. http://www.itk.ca/environment/. Accessed April 2005.

Jacobsen, B.N., Kjersgaard, D., Winther-Nielsen, M. and Gustavson, K. 2004. Combined Chemical analyses and Biomonitoring at Avedore Wastewater Treatment Plant in 2002. Water Science and Technology, 50(5): 37-43.

Jimenez, B. and Chavez, A. 2004. Quality Assessment of an Aquifer Recharged with Wastewater for its Potential Use as Drinking source: "El Mezquital Valley" Case. Water Science and Technology, 50(2): 269-276.

Keller, H., Xia, K., and Bhandari, A. 2003. Occurrence and Degradation of Estrogenic Nonylphenol and Its Precursors in Northeast Kansas Wastewater Treatment Plants. ASCE Practice Periodical of Hazardous, Toxic and Radioactive Waste Management. October, 203-213.

Khan, S. and Ongerth, J.E. 2002. Pharmaceutical Residuals in Water – Compounds, Sources and Controlling Characteristics. Proc. Water Quality Technology Conference, American Water Works Association (CD-ROM). Denver, CO.

Kinkade, M.L. and Erdmand, H.E.. 1975. The Influence of Hardness Components (Ca^{2+} and Mg^{2+}) in Water on the Uptake and Concentration of Cadmium in a Simulated Freshwater Ecosystem. Environmental Research, 10: 308-317.

Knepper, T.P. 2004a. Analysis of Insect Repellents. Water Science & Technology, 50(5): 301-308.

Knepper, T.P. 2004b. Analysis and Mass Spectrometric Characterization of the Insect Repellent Bayrepel and its Main Metabolite Bayrepel-acid. Journal of Chromatography A, 1046:159-166.

Kolpin, D.W., Furlong E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B. and Buxton, H.B. 2001. Pharmaceuticals, Hormones, and Other Organic Wastewater Substances in U.S. Streams, 1999-2000: A National Reconnaissance. Environmental Science and Technology, 36(6): 1202-1211.

Krasner, S. 1999. Chemistry of Disinfection By-Product Formation. in Formation and Control of Disinfection By-Products in Drinking Water, ed. By P.C. Singer. American Water Works Association, Denver, CO.

Kravetz, L., Chung, H., Guin, K.F., Shebs, W.T. and Smith, L.S. 1983. Primary and Ultimate Biodegradation of an Alcohol Ethoxylate and a Nonylphenol Ethoxylate under Average Winter Conditions in the U.S. Tech. Bull # SC:779-83, Shell Chemical Company, Houston, TX.

Kreuziner, N., Clara, M., Strenn, B. and Vogel, B. 2004. Investigation on the Behavior of Selected Pharmaceuticals in the Groundwater after Infiltration of Treated Wastewater. Water Science and Technology, 50(2): 221-228.

LEAS (Labor Environmental Alliance Society). 2005. http://www.leas.ca/faq.htm#q3. Accessed May 2005.

Lee, H.-B., Sarafin, K., Peart, T.E. and Swoboda, M.L. 2003a. Acidic Pharmaceuticals in Sewage – Methodology, Stability Test, Occurrence, and Removal from Ontario Samples. Water Quality Research Journal of Canada, 38(4): 667-682.

Lee, H.-B., Peart, T.E and Sarafin, K. 2003b. Occurrence of Polycyclic and Nitro Musk Compounds in Canadian Sludge and Wastewater Samples. Water Quality Research Journal of Canada, 38(4): 683-702.

Lee, S.Y., Lee, J-U., Choi, H. and Kim, K-W. 2004a. Sorption Behaviors of Heavy metals in SAT (Soil Aquifer Treatment) System. Water Science and Technology, 50(2): 263-268.

Lee, H.-B., Peart, T.E., Chan, J. and Gris, G. 2004b. Occurrence of Endocrine-disrupting chemicals in Sewage and Sludge Samples in Toronto, Canada. Water Quality Research Journal of Canada, 39(1): 57-63.

Levine, A.D., Harwood, V.J., Scott, T.M, and Rose, J.B. 2004. Effectiveness of Secondary Effluent Filtration for Removal of Bacteria, Enteroviruses, and Protozoan Pathogens in Wastewater Reclamation Facilities. Proceedings WEFTEC 2004 on CD-ROM. Water Environment federation, Alexandria, VA

LSU. 2005. Louisiana State University. .www.medschool.lsuhsc.edu/asthma_center/glossary.asp. Accessed May, 2005.

Lukasiak, J., Dorosz, A., Prokopowicz, M., Rosciszewski, P. and Falkiewicz, B. 1997. Biodegradation of Siloxanes. http://www.wiley-vch.de/books/biopoly/pdf_v09/vol09_15.pdf. Accessed April, 2005.

Maguire, R.J. 2001. Preliminary Environmental Assessment of Organosilicon Substances. Environment Canada, National Water Research Institute, Burlington/Saskatoon, NWRI Contribution No. 01-037.

Makepeace, D.K., Smith, D.W. and Stanley, S.J. 1995. Urban Stormwater Quality. Summary of Contaminant Data. Critical Reviews in Environmental Science and Technology, 25(2): 93-139.

Mann, A.H. and Reid, V.W. 1971. Biodegradation of Synthetic Detergents Evaluation by Community Trials Part 2: Alcohol and Alkylphenol Ethoxylates. Journal of American Oil Chemists' Society, 48: 794-797.

Mansell, J., Drewes, J.E., and Rauch, T. 2004. Removal Mechanisms of Endocrine Disrupting Compounds (Steroids) during Soil Aquifer Treatment. Water Science and Technology, 50(2): 229-237.

McBride, M. and J. Wyckoff. 2002. Emerging Liabilities from Pharmaceuticals and Personal Care Products. Environmental Claims Journal, 14: 175-189.

MedicineNet.com. 2005. Accessed April, 2005

Metcalf and Eddy. 1991. Wastewater Engineering: Treatment, Disposal, Reuse 3rd edition. McGraw-Hill, Toronto.

Metcalfe C.D., Koenig, B.G., Bennie, D.T., Servos, M., Ternes, T.A. and Hirsch, R. 2003. Occurrence of Neutral and Acidic Drugs in the Effluents of Canadian Sewage Treatment Plants. Environmental Toxicology and Chemistry, 22(12): 2872-2880.

Miao, X-S., Bishay, F., Chen, M. and Metcalfe, C.D. 2004. Occurrence of Antimicrobials in the Final Effluents of Wastewater Treatment Plants in Canada. Environmental Science and Technology, 38(13): 3533-3541.

Minnow Environmental Inc. 2004. Selenium Uptake in Biota Inhabiting Lentic and Lotic Areas of the Elk River Watershed. Prepared for Elk Valley Selenium Task Force. November 2004.

Minnow Environmental Inc. 2005. Environmental Risk-Based Approaches for Managing Municipal Wastewater Effluents (MWWE). Prepared for Canadian Council for Ministers of the Environment. April 2005.

Mitjans, D. and Ventura, F. 2004. Determination of Musks and Other Fragrance Compounds at ng/L Levels Using CLSA (Closed Loop Stripping Analysis) and GC/MS Detection. Water Science and Technology, 50(5), 119-123.

Moody, C.A. and Field, J.A. 1999. Determination of Perfluorocarboxylates in Groundwater Impacted by Fire-Fighting Activity. Environmental Science and Technology. Accessed via http://pubs.acs.org/cgi-bin/jtextd?esthag/asap/html/es981355+.html. May 2005.

Nasu, M., Goto, M., Kato, H., Oshima, Y. and Tanaka, H. 1999. Study on Endocrine Disrupting Chemicals in Wastewater Treatment Plants. Water Science and Technology, 43(2): 101-108.

National Institutes of Health 2005. http://www.ncbi.nlm.nih.gov/. Accessed April 2005.

NaturalMagic 2005. http://www.naturalmagic.com/boat_deodorizers.htm. Accessed May 2005.

Natural Resources Canada. 2005. http://www.nrcan.gc.ca/. Accessed April 2005.

New Zealand. 2005. http://www.arc.govt.nz/library/r59820_2.pdf. Accessed May 2005.

Nicholson K. 2005. Boron Environmental Chemistry. http://knicholson.netfirms.com/boron.html. Accessed May, 2005.

NRCC (National Research Council of Canada). 1983. Polycyclic Aromatic Hydrocarbons in Aquatic Environment: Formation, Sources, Fate and Effects on Aquatic Biota. Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, Ottawa. NRCC No. 18981. 209 pp.

Nova Scotia.2005. http://www.gov.ns.ca/enla/water/. Accessed April 2005.

Nova Scotia. 2005a. Manuals – Sewer Use Model Bylaws. http://www.gov.ns.ca/snsmr/muns/infr/sew/discharg.asp. Accessed May 2005.

NWRI (National Water Research Institute). 2005. http://www.nwri.ca/sande. Accessed April 2005.

OMOE (Ontario Ministry of the Environment). 1984. Chlorinated Benzenes in the Aquatic Environment. Scientific Criteria Document for Standard Development. No. 3-84. Water Resources Branch, Toronto, Ontario.

OMOE. 1988. Thirty Seven Municipal Water Pollution Control Plants. Pilot Monitoring Study. Volume I. Interim Report. Water Resources Branch, Toronto.

OMOE. 1998. The Proposed 1998 Model Sewer Use By-law. http://www.ene.gov.on.ca/envision/env_reg/documents/a/pa8e0029.pdf. Accessed May, 2005.

Oregon State. 2005. http://pharmacy.oregonstate.edu/drug_policy/reviews-evaluations/antiulcer.html Accessed April, 2005.

ORTEPA 2005. http://www.ortepa.org/. Accessed April 2005.

OSHA. 2005. http://www.osha-slc.gov/. Accessed April 2005.

OSPAR Commissison (2004). Musk Xylene and Other Musks. http://www.ospar.org/documents/dbase/publications/p00200_BD%20on%20musk%20xylene.pdf. Accessed May 2005.

Parker, W.J., Shi, J., Fendinger, N.J., Monteith, H.D., and Chandra, G. 1999. Pilot Plant Study to Assess the Fate of Two Volatile Methyl Siloxane Compounds during Municipal Wastewater Treatment. Environmental Toxicology and Chemistry, 18(2): 172-181.

Patterson, D.B., Brumley, W.C., Kelliher, V. and Ferguson, P.L. (2000). Application of U.S. EPA Methods to the Determination of Pharmaceuticals and Personal Care Products in the Environment: Determination of Clofibric Acid in Sewage Effluent by GC/MS. Accessed March 2005 from www.epa.gov/nerlesd1/chemistr/org-anal/reports/clofibric/clofibric.htm.

Paxeus, N., Robinson, P. and Balmer, P. 1992. Study of Organic Pollutants in Municipal Wastewater in Sweden. Water Science and Technology, 25(11): 249-256.

Paxeus, N. 2004. Removal of Selected Non-steroidal Anti-inflammatory Drugs (NSAIDs), Gemfibrozil, Carbamazepine, β-blockers, Trimethoprim and Triclosan in Conventional Wastewater Treatment Plants in Five EU Countries and Their Discharge to the Aquatic Environment. Water Science and Technology, 50(5): 253-260.

Paxeus, N. and Schroder, H.F. 1996. Screening for Non-regulated Organic Compounds in Municipal Wastewater in Goteborg, Sweden. Water Science and Technology, 33(6): 9-15.

Peck AM, Hornbuckle KC. 2004. Synthetic Musk Fragrances in Lake Michigan. Environmental Science and Technology 38(2): 367-372.

PesticideInfo. 2005. http://www.pesticideinfo.org/. Accessed April 2005.

Pesticide News. 2005. Endosulfan. http://www.pan-uk.org/pestnews/actives/endosulf.htm. Accessed May 2005.

Petrovic, M., Gonzalez, S. and Barcelo, D. 2003. Analysis and Removal of Emerging Substances in Wastewater and Drinking Water. Trends in Analytical Chemistry. 22(10): 685-696.

PIC. 2005. http://www.pic.int/en/. Accessed April 2005.

Pierce, R.C., Mathur, S.P., Williams, D.T. and Boddington, M.J. 1980. Phthalate Esters in the Aquatic Environment. Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, Ottawa. NRCC No. 17583. 108 pp.

PMRA. 2005. http://www.pmra-arla.gc.ca/english. Accessed May 2005.

Qureshi, A.A. and Dutka, B.J. 1979. Microbiological Studies on the Quality of Urban Stormwater Runoff in Southern Ontario, Canada. Water Research, 13: 977-985.

Rauch, T., Munroz, J.G. and Drewes, J.E. 2004. Metabolic Removal of Organic Micropollutants in Artificial Groundwater Recharge Systems Using Water of Impaired Quality. Proceedings of WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Reicher, A. 2000. The Day the Bubble Burst. Industrial Fire World, May/June issue. Accessed via http://www.fireworld.com/magazine/afff_2.html. May 2005.

RescueNet. 2005. (http://www.rescuenet.com/rn/vault/wastewtr.html). Accessed April 14, 2005

Rice, R.G. and Bouwer, H. 1984. Soil-Aquifer treatment Using Primary Effluent. Journal Water Pollution Control Federation, 56(1): 84-88.

Schreurs, R.H.M.M., Sonneveld, E., Jansen, J.H.J., Seinen, W and van der Burg, B. 2005. Interaction of Polycyclic Musks and UV Filters with the Estrogen Receptor (ER), Androgen Receptor (AR), and Progesterone Receptor (PR) in Reporter Gene Bioassays. Toxicological Sciences, 83(2): 264-272. accessed May 2005 from http://www.ingentaconnect.com/content/oup/toxsci/2005/00000083/00000002/art00264.

Schofield, C.L. and Trojnar, J.R. 1980. Aluminum Toxicity to Brook Trout (Salvelinus fontinalis) in Acidified Waters. In: T.Y. Toribara, M.W. Miller and P.E. Morrow (Eds), p. 341-362, Int. Conference on Environmental Toxicity. May 21-23, 1979, Rochester, New York.

Scruggs, C., Hunter, G., Snyder, E., Long. B and Snyder, S. 2004. EDCs in Wastewater: What's the Next Step? Proceeding WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Scruggs, C., Hunter, G., Snyder, E., Long. B and Snyder, S. 2005. EDCs in Wastewater: What's the Next Step? Water Environment and Technology March issue, pp.24-31.

Sedlak, D.L., Deeb, R.A., Hawley, E.L., Mitch, W.A., Durbin, T.D., Mowbray, S. and Carr, S. 2004. Sources and Fate of Nitrosodimethylamine (NDMA) and NDMA Precursors in Municipal Wastewater Treatment Plants. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Sedlak, D.L. and Pinkston, K.E. 2004. Factors Affecting the Concentrations of Pharmaceuticals Released to the Aquatic Environment. Proceedings of WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA.

Servos, M. 1999. Review of the Aquatic Toxicity, Estrogenic responses and Bioaccumulation of Alkylphenols and Alkylphenol Polyethoxylates. Water Quality Research Journal of Canada, 34(1), 123-177.

Servos, M.R., Bennie, D.T., Burnison, B.K., Jurkovic, A., McInnis, R., Neheli, T., Schnell, A., Seto, P., Smyth, S.A. and Ternes, T. 2005. Distribution of Estrogens, 17β – Estradiol and Estrone, in Canadian Municipal Wastewater Treatment Plants. Science of the Total Environment, 336: 155 – 170.

Singer, P. 1999. Formation and Control of Disinfection By-Products in Drinking Water. American Water Works Association, Denver, CO.

Skadsen, J.M., Rice, B.L. and Meyering, D.J. 2004. The Occurrence and Fate of Pharmaceuticals, Personal Care Products and Endocrine Disrupting Compounds in a Municipal Water Use Cycle: A case Study in the City of Ann Arbor. Report from

http://www.ci.ann-arbor.mi.us/PublicServices/Water/WTP/EndocrineDisruptors.pdf. Accessed May 2005.

Smith, I.C. and Carson, B.L. (eds.). 1981. Trace Metals in the Environment. Vol. 6. Cobalt. Ann Arbor Science Publ. Inc., Ann Arbor, Michigan.

Soroushian, F., Patel, M., Fitzsimmons, S. and Wehner, M. 2004. NDMA Removal and Reformation Prevention. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation. Alexandria, VA.

Spectrum Laboratories. 2005. http://www.speclab.com/compound. Accessed April 2005.

Stiff, M.J., Rootham, R.C. and Culley, G.E. 1973. The Effect of Temperature on the Removal of Non-ionic Surfactants during Small-scale Activated-sludge Sewage Treatment – I. Comparison of Alcohol Ethoxylates with Branched-chain Alkyl Phenol Ethoxylates. Water Research, 7: 1003-1010.

Suidan, M.T., Esperanza, M., Zein, M., McCauley, P., Brenner, R.C. and Venosa, A.D. 2005. Challenges in Biodegradation of Trace Organic Substances – Gasoline Oxygenates and Sex Hormones. Water Environment Research, 77(1): 4.

Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Substances of Concern for Effects on Aquatic Biota: 1996 Revision. Prepared by Risk Assessment Program, Health Sciences Research Division, Oak Ridge, Tennessee, for the Department of Energy, Office of Environmental Management.

Swackhammer, D.L., Paerl, H.W., Eisenreich, S.J., Hurley, J., Hombuckle, K.C., McLachlan, M., Mount, D., Muir, D. and Schindler, D. 2004. Impact of Atmospheric Pollutants on Aquatic Ecosystems. The Ecological Society of America Science Office. Accessed May 2005 from http://www.esa.org/science/Issues/TextIssues/issue12.php.

Tanaka, H., Sato, C., Komori, K., Yakou, Y., Tamamoto, H., Miyamoto, N. and Higashitani, T. 2003. Occurrence of Endocrine Disruptors in Sewage and Their Behavior in Sewage Treatment Plants in Japan. Environmental Sciences, 10(1): 1-24.

Tanghe, T., Devriese, G. and Verstraete, W. 1998. Nonylphenol Degradation in Lab-Scale Activated Sludge Units is Temperature Dependent. Water Research, 32(10): 2889-2896.

Telewiak, R.G. 1985. Cobalt. In: Canadian Minerals Yearbook. 1983-1984. Review and Outlook. Mineral Resources Canada, Ottawa. P. 21.1-21.5.

Ternes, T.A., Stumpf, M., Mueller, J., Haberer, K., Wilken, R.-D. and Servos, M. 1999. Behavior and Occurrence of Estrogens in Municipal Sewage Treatment Plants – 1. Investigations in Germany, Brazil and Canada. The Science of the Total Environment, 225: 81-90.

Ternes, T., Bonerz, M., Herrmann, N., Ried, A. and Teiser, B. 2003. Fate and Removal of Pharmaceuticals and Endocrine Disrupters by Irrigation of Treated Wastewater on agricultural Fields . Presentation at Envipharma Lyon, 2003. Accessed from http://www.eu-poseidon.com. April 2005.

Ternes, T.A., Joss, A., Anderson, H., Siegrist, H., Huber, M. and von Gunten, U. 2004. Fate of Estrogens in a Municipal Sewage Treatment Plant. PowerPoint presentation accessed May 2005 from http://www.uwf.rwth-aachen.de/ageesa/wosh/23/ternes.pdf

Thompson, A., Griffin, P., Stuetz and Cartmell, E. 2005. The Fate and Removal of Triclosan during Wastewater Treatment. Water Environment Research, 77(1): 63.

Topp, E. and Starratt, A. 2000. Rapid Mineralization of the Endocrine-Disrupting Chemical 4-Nonylphenol in Soil. Environmental Toxicology and Chemistry, 19(2): 313-318.

Trisyn. 2005. http://www.trisyn.com/ret-cap/ret-rm-cap.htm. Accessed May 2005.

Tuscon. 2005. http://www.tucsonshowguide.com/stories/.

UBLCorp. 2005. http://www.ublcorp.com/rvtoilets.html. Accessed May 2005.

UK Environmental Agency 2004. Environmental Risk Evaluation Report: Perfluorooctanesulphonate (PFOS). http://www.environment-agency.gov.uk/commondata/105385/pfos_rer_sept04_864557.pdf. Accessed May, 2005 as html file.

United Nations ECE. 2005. http://www.unece.org/env/. Accessed April 2005.

University of British Columbia. 2005. http://www.cher.ubc.ca/UBCSawmillStudy/. Accessed April 2005.

University of Nebraska. 2005. http://ianrpubs.unl.edu/water/g1369.htm. Accessed April 3005.

University of Waterloo. 2005http://wvlc.uwaterloo.ca/biology447. Accessed April 2005

U.S. Census. 2005. http://www.census.gov/epcd. Accessed April 2005.

U.S. EPA (United States Environmental Protection Agency). 1979. Water-related Environmental Fate of 129 Priority Pollutants. Vol. I. Introduction, Technical Background, Metals and Inorganics, Pesticides, Polychlorinated Biphenyls. Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C. EPA-440/4-79-029a. pp. 9-1 to 9-20, 20-1 to 20-11, 22-1 to 22-13, 75-1 to 75-8, 80-1 to 80-7.

U.S. EPA. 1980. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards Criteria, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, D.C. EPA 440/5-80-038.

U.S. EPA. 1989. Ambient Water Quality Criteria for Ammonia (Saltwater) – 1989. Office of Water Regulations and Standards Criteria, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, D.C. EPA 440/5-88-004.

U.S. EPA. 1993. Manual on Nitrogen Control. Office of Water, U.S. EPA, Washington, D.C., EPA/625/R-93/010.

U.S. EPA. 1994.Treability Database (MS-DOS). Release 5.0. Risk Reduction Engineering Laboratory, Cincinnati, OH. April 19.

U.S. EPA. 2002. National Recommended Water Quality Criteria: 2002. Office of Water, U.S. EPA, Washington, DC. EPA 822-R-02-047.

U.S. EPA. 2005a. http://www.epa.gov/OGWDW/dwh/t-voc/toluene.html. Accessed May 2005.

USInfo. 2005. http://usinfo.state.gov/gi/Archive/2004/Nov/01-558287.html. Accessed May 2005.

Vaughn, S.D., Hurley, W., Madhanagopal, T., Kunihiro, K. and Slifko, T. 2004. Effect of Hydraulic Loading and Chemical Addition on Filter Performance and Protozoa Removal: A Side-by-Side Comparison. Proceedings WEFTEC 2004 on CD-ROM. Water Environment Federation, Alexandria, VA

Washington State University 2005. Food and Environmental Quality Lab. Lecture #4: Polybrominated Diphenyl Ethers. http://feql.wsu.edu/esrp532/ESRP532Lecture17110104.pdf. Accessed January, 2005.

Weber, B. and Juanico, M. 2004. Salt Reduction in Municipal Sewage Allocated for Reuse: The Outcome of a New Policy in Israel. Water Science and Technology. 50(2): 17-22.

WHO (World Health Organization). 1998. Environmental Health Guideline 204. Boron. http://www.inchem.org/documents/ehc/ehc/ehc204.htm#SubSectionNumber:1.1.1. Accessed May 2005.

WHO. 2002. Global Assessment of the State-of-the-Science of Endocrine Disruptors. T. Damstra, S. Barlow, A. Bergman, R. Kavlock, and G. Van der Kraak (Eds.).

Wikipedia. 2005. www.en.wikipedia.org/. Accessed May 2005.

Wisconsin DNR. 2003. Alum Treatment to Control Phosphorus in Lakes. Wisconsin Department of Natural Resources.

http://www.dnr.state.wi.us/org/water/fhp/papers/alum_brochure.pdf. Accessed May 2005.

WPCF 1986. Wastewater Disinfection. Water Pollution Control Federation Manual of Practice FD-10. Alexandria, VA.

APPENDIX A
SUPPORTING TABLES

Table A.1. Master List of Substances

Substance Name	Name as Idenified in Source	CAS Number	Other Names	Main Class	Sub-class	Source List							
						Canada-Ontario[1]	Canada-U.S.[2]	CEPA Toxics[3]	GCDWQ[4]	DWSPL[5]	EU Annex X[6]	Water Quality Criteria[7]	Conventional and Non-specific Pollutants in MWWE
(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime	(4-chlorophenyl)cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime	94097-88-8	NCC ether	Organic	Aromatic Hydrocarbon - Halogenated			✍					
2,4-D	Dichlorophenoxyacetic acid (2,4-D)	94-75-7		Organic	Pesticide - Chlorophenoxy herbicide				✍			✍	
Acenaphthene	Acenaphthene	83-32-9		Organic	Aromatic Hydrocarbon - Polycyclic							✍	
Acetaldehyde	Acetaldehyde	75-07-0		Organic	Oxygenate - Acetaldehyde			✍					
Acridine	Acridine	260-94-6		Organic	Hydrocarbons with N,P,S substitution							✍	
Acrolein	Acrolein	107-02-8		Organic	Oxygenated Compounds			✍				✍	
Acrylamide	Acrylamide	79-06-1		Organic	Hydrocarbons with N,P,S substitution					✍			
Acrylonitrile	Acrylonitrile	107-13-1		Organic	Hydrocarbons with N,P,S substitution			✍					
Alalchlor	Alalchlor	15972-60-8		Organic	Pesticide - Chloroacetanilide						✍		
Aldicarb	Aldicarb + metabolites	116-06-3		Organic	Pesticide - N-methyl carbamate				✍			✍	
Aldrin	Aldrin/dieldrin	309-00-2		Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I		✍			✍	
Alkyl lead	Alkyl lead	EDF-171		Organometals	Alkyl lead		Level II						
Aluminum	Aluminum	39148-24-8		Inorganic	Metal/Metalloid					✍		✍	
Ammonia	Ammonia dissolved in water & gaseous ammonia	7664-41-7		Inorganic	Nutrient			✍	✍			✍	
Aniline	Aniline	62-53-3		Organic	Hydrocarbons with N,P,S substitution							✍	
Anthracene	Anthracene	65996-97-0		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II	Level II				✍	✍	
Antimony	Antimony	7440-36-0		Inorganic	Metal/Metalloid							✍	
Aroclor 1254	Aroclor 1254	11097-69-1	PCB	Organic	Polyhalogenated Polyphenyl								
Arsenic	Inorganic Arsenic compounds	7440-38-2		Inorganic	Metal/Metalloid			✍	✍	✍		✍	
Atrazine	Atrazine + metabolites	1912-24-9		Organic	Pesticide - Triazine				✍		✍	✍	
Azinphos-methyl	Azinphos-methyl	86-500-0		Organic	Pesticide - Organophosphorus				✍			✍	
Barium	Barium	7440-39-3		Inorganic	Metal/Metalloid				✍			✍	
Bendiocarb	Bendiocarb	22781-23-3		Organic	Pesticide - N-methyl carbamate				✍			✍	
Benzene	Benzene	1076-43-3		Organic	Aromatic Hydrocarbon			✍	✍		✍	✍	
Benzidine dihydrochloride	Benzidene dihydrochloride	531-85-1		Organic	Aromatic Hydrocarbon - Halogenated			✍					
Benzo(a)anthracene	Benzo(a)anthracene	56-55-3		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II	Level II					✍	
Benzo(a)pyrene	Benzo(a)pyrene	50-32-8		Organic	Aromatic Hydrocarbon - Polycyclic	Tier I			✍		✍	✍	
Benzo(b)fluoranthene	Benzo(b)fluoranthene	205-99-2		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II					✍		
Benzo(g,h,i)perylene	Benzo(g,h,i)perylene	191-24-2		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II	Level II				✍	✍	
Benzo(k)fluoranthene	Benzo(k)fluoranthene	207-08-9		Organic	Aromatic Hydrocarbon - Polycyclic						✍	✍	
Beryllium	Beryllium	7440-41-7		Inorganic	Metal/Metalloid							✍	
Biochemical Oxygen Demand	Biochemical Oxygen Demand		BOD	Non-specific	Physical/Chemical								✍
Biphenyldiamine (4,4'-)	Biphenyldiamine (4,4'-)	92-87-5	Benzidine	Organic	Hydrocarbons with N,P,S substitution			✍					
Bis(2-ethylhexyl)phthalate	Bis(2-ethylhexyl)phthalate	117-81-7	Dioctyl phthalate, Di(2-ethylhexyl) phthalate, DEHP	Organic	Oxygenate - Phthalic Ester			✍			✍	✍	
Bis(chloromethyl)ether	Bis(chloromethyl) ether	542-88-1	BCEE	Organic	Haloether			✍					
Boron	Boron	7440-42-8		Inorganic	Metal/Metalloid				✍			✍	
Bromacil	Bromacil	314-40-9		Organic	Pesticide - Uracil								
Bromate	Bromate	1554-45-4		Inorganic	Anion							✍	
Bromochloromethane	Bromochloromethane	74-97-5		Organic	Aliphatic Hydrocarbon - Halogenated			✍					
Bromoform	Tribromomethane	75-25-2		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Bromoxynil	Bromoxynil	1689-84-5		Organic	Pesticide - Hydroxy benzonitrile				✍			✍	
Butadiene (1,3-)	1,3-butadiene	106-99-0		Organic	Aliphatic Hydrocarbon			✍					
C10-13 chloroalkanes	C10-13 chloroalkanes	85535-84-8		Organic	Aliphatic Hydrocarbon - Halogenated						✍		
Cadmium	Cadmium & compounds	7440-43-9		Inorganic	Metal/Metalloid	Tier II	Level II	✍	✍		✍	✍	
Caffeine	Caffeine	58-08-2		Emerging	Pharmaceutical - Stimulant								
Calcium	Calcium	7440-70-2		Inorganic	Metal/Metalloid				✍			✍	
Captan	Captan	133-06-2		Organic	Pesticide - Thiophthalinide							✍	
Carbaryl	Carbaryl	63-25-2		Organic	Pesticide - N-methyl carbamate				✍			✍	
Carbofuran	Carbofuran	1563-66-2		Organic	Pesticide - N-methyl carbamate				✍			✍	
Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)	302-17-0		Organic	Haloalcohol					✍			
Chloramines (mono-, di-, tri-; organic, inorganic)	Inorganic chloramines			Inorganic	Disinfectant			✍	✍			✍	
Chlorate	Chlorate	not for anion alone		Inorganic	Anion					✍			
Chlordane	Chlordane	57-74-9		Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I		✍			✍	
Chlorfenvinphos	Chlorfenvinphos	470-90-6		Organic	Pesticide - Organophosphorus						✍		
Chloride	Chloride	not for anion alone		Inorganic	Anion				✍			✍	
Chlorinated wastewater effluents	Chlorinated Wastewater effluents			Non-specific	Miscellaneous			✍					
Chlorine dioxide	Chlorine Dioxide	10049-04-4		Inorganic	Disinfectant					✍			
Chlorite	Chlorite	not for anion alone		Inorganic	Anion					✍			
Chlorobenzene	Chlorobenzene	108-90-7	Monochlorobenzene	Organic	Chlorobenzene				✍			✍	
Chloroform	Chloroform	67-66-3	Trichloromethane	Organic	Aliphatic Hydrocarbon - Halogenated						✍	✍	
Chloromethyl methyl ether	Chloromethyl methyl ether	107-30-2		Organic	Haloether			✍					
Chlorophenol	Monochlorophenol	many congeners each has CAS No.		Organic	Chlorophenol							✍	
Chlorothalonil	Chlorothalonil	1897-45-6		Organic	Pesticide - Substituted benzene							✍	
Chlorpyrifos	Chlorpyrifos	2921-88-2		Organic	Pesticide - Organophosphorus				✍		✍	✍	
Chromium (trivalent and hexavalent)	Chromium	7440-47-3		Inorganic	Metal/Metalloid				✍			✍	
Chromium (trivalent and hexavalent)	Hexavalent chromium compounds	7440-47-3		Inorganic	Metal/Metalloid			✍					
Chrysene	Chrysene	218-01-9		Organic	Aromatic Hydrocarbon - Polycyclic								
Clofibric acid/clofibrate	Clofibric acid/clofibrate	637-07-0		Emerging	Pharmaceutical - Lipid Regulator								

Table A.1. Master List of Substances

Substance Name	Name as Idenified in Source	CAS Number	Other Names	Main Class	Sub-class	Source List							
						Canada-Ontario[1]	Canada-U.S.[2]	CEPA Toxics[3]	GCDWQ[4]	DWSPL[5]	EU Annex X[6]	Water Quality Criteria[7]	Conventional and Non-specific Pollutants in MWWE
Cobalt	Cobalt	7440-48-4		Inorganic	Metal/Metalloid							✍	
Colour	Colour			Non-specific	Physical/Chemical				✍			✍	✍
Copper	Copper	7440-50-8		Inorganic	Metal/Metalloid				✍	✍		✍	
Cryptosporidium sp.	*Cryptosporidium* sp.			Biological	Pathogen - Protozoan								
Cyanazine	Cyanazine	21725-46-2		Organic	Pesticide - Triazine				✍			✍	
Cyanide	Cyanide	57-12-5		Inorganic	Anion				✍			✍	
Cyanobacterial toxins (as Microcystin - LR)	Cyanobacterial toxins			Biological	Algal Toxin					✍		✍	
Cyanogen Chloride	Cyanogen chloride	506-77-4		Inorganic	Miscellaneous					✍			
DDD	Bis(*p*-chlorophenyl)-1,1-dichloroethane (2,2-)	72-54-8	Dichloro diphenyl dichloroethane	Organic	Pesticide - Chlorinated hydrocarbon								
DDE	Dichloro-2,2-bis(*p*-chlorophenyl)-ethene (1,1-)	72-55-9		Organic	Pesticide - Chlorinated hydrocarbon								
DDT	DDT	50-29-3	Dichloro diphenyl trichloroethane, Bis(p-chlorophenyl)-1,1,1-trichloroethane (2,2-)	Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I		✍			✍	
Deltamethrin	Deltamethrin	52918-63-5		Organic	Pesticide - Pyrethroid							✍	
Diazinon	Diazinon	333-41-5		Organic	Pesticide - Organophosphorus				✍			✍	
Dibenzo(a,h)anthracene	Dibenzo(a,h)anthracene	53-70-3		Organic	Aromatic Hydrocarbon - Polycyclic							✍	
Dibenzofuran	Dibenzofuran	132-64-9		Organic	Dioxins and Furans			✍				✍	
Dibenzo-p-dioxin	Dibenzo-p-dioxin	262-12-4		Organic	Dioxins and Furans			✍					
Dibromochloromethane	Dibromochloromethane	124-48-1		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dicamba	Dicamba	1918-00-9		Organic	Pesticide - Benzoic acid				✍			✍	
Dichlorobenzene (1,2-)	1,2-dichlorobenzene (o-dichlorobenzene)	95-50-1		Organic	Chlorobenzene				✍			✍	
Dichlorobenzene (1,3-)	Dichlorobenzene (1,3-)	541-73-1		Organic	Chlorobenzene							✍	
Dichlorobenzene (1,4-)	1,4-dichlorobenzene (p-dichlorobenzene)	106-46-7		Organic	Chlorobenzene		Level II		✍			✍	
Dichlorobenzidene (3,3'-)	3,3'-dichlorobenzidene	91-94-1		Organic	Aromatic Hydrocarbon - Halogenated			✍				✍	
Dichlorobromomethane	Dichlorobromomethane	75-27-4		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dichloroethane (1,1-)	Dichloroethane (1,1-)	75-34-3		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dichloroethane (1,2-)	1,2-dichloroethane	107-06-2		Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍		✍		
Dichloroethene (1,1-)	Dichloroethylene, 1,1-	75-35-4	Dichloroethylene	Organic	Aliphatic Hydrocarbon - Halogenated				✍			✍	
Dichloroethene (1,2-)	Dichloroethene (1,2-)	540-59-0, 156-59-2, & 156-60-5		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dichloromethane	Dichloromethane	75-09-2	Methylene chloride	Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍		✍	✍	
Dichlorophenol (2,4-)	Dichlorophenol, 2,4-	3757-76-4		Organic	Chlorophenol				✍			✍	
Dichloropropane (1,2-)	Dichloropropane (1,2-)	78-87-5		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dichloropropene (1,2-) (cis and trans)	Dichloropropene (1,2-) (cis and trans)	10061-02-6/542-75-6		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Dichlorprop	Dichlorprop	120-36-5		Organic	Pesticide - Chlorophenoxy herbicide					✍			
Diclofop-methyl	Diclofop-methyl	51338-27-3		Organic	Pesticide - Chlorophenoxy herbicide				✍			✍	
Dieldrin	Aldrin/dieldrin	60-57-1		Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I		✍			✍	
Dimethoate	Dimethoate	60-51-5		Organic	Pesticide - Organophosphorus				✍			✍	
Dimethylnaphthalene	Dimethylnaphthalene	571-61-9		Organic	Aromatic Hydrocarbon - Polycyclic							✍	
Di-n-butyl phthalate	Di-n-butyl phthalate	84-74-2		Organic	Oxygenate - Phthalic Ester							✍	
Dinitropyrene	Dinitropyrene	many congeners each has CAS No.		Organic	Hydrocarbons with N,P,S substitution	Tier II	Level II						
Dinoseb	Dinoseb	88-85-7		Organic	Pesticide - Dintrophenol derivative				✍			✍	
Diquat	Diquat	85-00-7		Organic	Pesticide - Bipyridylium				✍			✍	
Diuron	Diuron	330-54-1		Organic	Pesticide - Urea-based				✍		✍	✍	
Dodecyl dimethyl ammonium chloride	Dodecyl dimethyl ammonium chloride	7173-51-5	DDAC	Organic	Pesticide - Quaternary Ammonium							✍	
Endosulfan	Endosulfan	115-29-7		Organic	Pesticide - Chlorinated hydrocarbon						✍	✍	
Endrin	Endrin	72-20-8		Organic	Pesticide - Chlorinated hydrocarbon		Level II		✍			✍	
Escherichia coli (*E. coli*)	*Escherichia coli* (*E. coli*)			Biological	Pathogen - Bacteria							✍	
Estradiol	Estradiol	50-28-2		Emerging	Pharmaceuticals - Hormone								
Ethylbenzene	Ethylbenzene	100-41-4		Organic	Alkyl benzene				✍			✍	
Ethylene glycol	Ethylene glycol	107-21-1		Organic	Oxygenate - Alcohol							✍	
Ethylene oxide	Ethylene oxide	75-21-8		Organic	Oxygenated - Epoxide			✍					
Fecal coliforms	Fecal coliforms			Biological	Pathogen - Bacteria								
Fluoranthene	Fluoranthene	206-44-0		Organic	Aromatic Hydrocarbon - Polycyclic						✍	✍	
Fluorene	Fluorene	86-73-7		Organic	Aromatic Hydrocarbon - Polycyclic							✍	
Fluoride	Fluoride	13709-49-4		Inorganic	Anion				✍			✍	
Formaldehyde	Formaldehyde	50-00-0		Organic	Oxygenate - Acetaldehyde			✍				✍	
Giardia sp.	*Giardia* sp.			Biological	Pathogen - Protozoan								
Glyphosate	Glyphosate	1071-83-6		Organic	Pesticide - Phosphoroglycine				✍			✍	
Haloacetic acids	Haloacetic acids	many congeners each has CAS No.		Organic	Halocarboxylic acids					✍			
Haloacetonitriles	Haloacetonitriles	many congeners each has CAS No.		Organic	Haloacetonitrile					✍			
Hardness	Hardness			Non-specific	Physical/Chemical				✍				✍
Heptachlor + Heptachlor epoxide	Heptachlor + Heptachlor epoxide	76-44-8		Organic	Pesticide - Chlorinated hydrocarbon		Level II		✍			✍	
Hexachloro-1,3-butadiene	Hexachlorobutadiene	87-68-3	HCBD	Organic	Aliphatic Hydrocarbon - Halogenated		Level II	✍			✍	✍	
Hexachlorobenzene	Hexachlorobenzene	118-74-1		Organic	Chlorobenzene	Tier I	Level I				✍	✍	
Indeno(1,2,3-c,d)pyrene	Indeno(1,2,3-c,d)pyrene	193-39-5		Organic	Aromatic Hydrocarbon - Polycyclic						✍		
Iodo-2-propynyl butyl carbamate (3-)	Iodo-2-propynyl butyl carbamate (3-)	55406-53-6	IPBC	Organic	Pesticide - Carbamate							✍	

Table A.1. Master List of Substances

Substance Name	Name as Idenified in Source	CAS Number	Other Names	Main Class	Sub-class	Source List							
						Canada-Ontario[1]	Canada-U.S.[2]	CEPA Toxics[3]	GCDWQ[4]	DWSPL[5]	EU Annex X[6]	Water Quality Criteria[7]	Conventional and Non-specific Pollutants in MWWE
Iron	Iron	39331-38-9		Inorganic	Metal/Metalloid				✍			✍	
Isoproturon	Isoproturon	34123-59-6		Organic	Pesticide - Urea-based						✍		
Lead	Lead and compounds	7439-92-1		Inorganic	Metal/Metalloid						✍	✍	
Lindane	Hexachlorocyclohexane	58-89-9		Organic	Pesticide - Chlorinated hydrocarbon	Tier II	Level II		✍		✍	✍	
Linuron	Linuron	330-55-2		Organic	Pesticide - Urea-based							✍	
Lithium	Lithium	7439-93-2		Inorganic	Metal/Metalloid							✍	
Magnesium	Magnesium	7439-95-4		Inorganic	Metal/Metalloid							✍	
Malathion	Malathion	121-75-5		Organic	Pesticide - Organophosphorus				✍			✍	
Manganese	Manganese	7439-96-5		Inorganic	Metal/Metalloid				✍			✍	
MCPA	MCPA	94-74-6	Chloro-2-methyl phenoxy acetic acid (4-)	Organic	Pesticide - Chlorophenoxy herbicide					✍		✍	
Mercury	Mercury & compounds	7439-97-6		Inorganic	Metal/Metalloid	Tier I	Level I	✍	✍		✍	✍	
Methoxychlor	Methoxychlor	72-43-5		Organic	Pesticide - Chlorinated hydrocarbon				✍			✍	
Methyl bromide	Methyl bromide (Bromomethane)	74-83-9	Bromomethane	Organic	Aliphatic Hydrocarbon - Halogenated			✍				✍	
Methyl mercury	Methyl mercury	22967-92-6		Organometals	Alkyl mercury							✍	
Methyl t-butyl ether	Methyl t-butyl ether	1634-04-4	MTBE, Methyl tertiary-butyl ether	Organic	Oxygenate - Ether					✍		✍	
Methylenebis(2-chloroaniline) (4,4'-)	4,4'-methylenebis(2-chloroaniline)	101-14-4		Organic	Hydrocarbons with N,P,S substitution		Level II						
Methyl-parathion	Methyl-parathion	298-00-0		Organic	Pesticide - Bipyridylium				✍				
Metolachlor	Metolachlor	51218-45-2		Organic	Pesticide - Chloroacetanilide				✍			✍	
Metribuzin	Metribuzin	21087-64-9		Organic	Pesticide - Triazinone				✍			✍	
Mirex	Mirex	2385-85-5	Dechlorane	Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I	✍	✍			✍	
Molybdenum	Molybdenum	7439-98-7		Inorganic	Metal/Metalloid							✍	
Monochloroethene	Vinyl chloride	75-01-4		Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍			✍	
Naphthalene	Naphthalene	91-20-3		Organic	Aromatic Hydrocarbon - Polycyclic						✍	✍	
Nickel	Nickel, oxidic, sulphidic and soluble compounds	7440-02-0		Inorganic	Metal/Metalloid			✍				✍	
Nitrate	Nitrate	14797-55-8		Inorganic	Nutrient				✍	✍		✍	
Nitrilotriacetic acid	Nitrilotriacetic acid	139-13-9	NTA	Organic	Hydrocarbons with N,P,S substitution				✍			✍	
Nitrite	Nitrite			Inorganic	Nutrient					✍		✍	
N-Nitrosodimethylamine	N-Nitrosodimethylamine	62-75-9	NDMA	Emerging	Hydrocarbons with N,P,S substitution			✍				✍	
Nonylphenol	Nonylphenol	84852-15-3		Organic	Alkylphenol & Ethoxylates					✍	✍	✍	
Nonylphenol ethoxylate	Nonylphenol ethoxylate	9016-45-9, 26027-38-3		Emerging	Alkylphenol & Ethoxylates			✍				✍	
Octachlorostyrene	Octachlorostyrene	EDF-151		Organic	Aromatic Hydrocarbon - Halogenated	Tier I	Level I	✍					
Octylphenol	Octylphenol	1806-26-4		Organic	Alkylphenol & Ethoxylates						✍		
Oil and grease	Oil and grease			Non-specific	Physical/Chemical								✍
Paraquat (as dichloride)	Paraquat (as dichloride)	1910-42-5		Organic	Pesticide - Bipyridylium				✍			✍	
Parathion	Parathion	56-38-2		Organic	Pesticide - Organophosphorus				✍			✍	
PCBs	PCBs	1336-36-3	Polychlorinated biphenyls	Organic	Polyhalogenated Polyphenyl	Tier I	Level I	✍				✍	
PCDD	PCDD	many congeners each has CAS No.	Polychlorinated dibenzo-p-dioxins	Organic	Dioxins and Furans - Polychlorinated	Tier I	Level I	✍					
PCDF	PCDF	39001-02-0	Polychlorinated dibenzo-furans	Organic	Dioxins and Furans - Polychlorinated	Tier I	Level I	✍					
Pentachlorobenzene	Pentachlorobenzene	608-93-5		Organic	Chlorobenzene		Level II				✍	✍	
Pentachlorophenol	Pentachlorophenol	87-86-5	PCP	Organic	Chlorophenol	Tier II	Level II		✍		✍	✍	
Perylene	Perylene	198-55-0		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II	Level II					✍	
pH	pH			Non-specific [a]	Physical/Chemical				✍			✍	✍
Phenanthrene	Phenanthrene	85-01-8		Organic	Aromatic Hydrocarbon - Polycyclic	Tier II	Level II					✍	
Phenols, Total	Phenols	108-95-2		Organic	Aromatic Hydrocarbon				✍			✍	
Phorate	Phorate	298-02-2		Organic	Pesticide - Organophosphorus				✍			✍	
Phosphorus (total)	Phosphorus (total)			Inorganic	Nutrient							✍	✍
Phthalic acid esters	Phthalic acid esters	many compounds each has CAS No.		Organic	Oxygenate - Phthalic Ester				✍				
Picloram	Pichloram	1918-02-1		Organic	Pesticide - Pyridine carboxylic acid				✍			✍	
Polybrominated biphenyls	Polybrominated biphenyls	PJL335	PBB	Organic	Polyhalogenated Polyphenyl			✍					
Polybrominated diphenylethers	Polybrominated diphenylethers	many congeners each has CAS No.	PBDE	Organic	Polyhalogenated Polyphenyl						✍		
Polychlorinated terphenyls	Polychlorinated terphenyls	61788-33-8		Organic	Polyhalogenated Polyphenyl			✍					
Polycyclic hydrocarbons	Polycyclic hydrocarbons	130498-29-2		Organic	Aromatic Hydrocarbon - Polycyclic			✍	✍				
Propylene glycol (1,2-)	Propylene glycol (1,2-)	57-55-6		Organic	Oxygenate - Alcohol							✍	
Propylene glycol (1,3-)	Propylene glycol (1,3-)	57-55-6		Organic	Oxygenate - Alcohol							✍	
Protozoa	Protozoa			Biological	Pathogen - Protozoan					✍			
Pyrene	Pyrene	129-00-0		Organic	Aromatic Hydrocarbon - Polycyclic							✍	
Quinoline	Quinoline	91-22-5		Organic	Hydrocarbons with N,P,S substitution							✍	
Resin Acids	Resin Acids	many compounds		Organic	Oxygenate- Carboxylic Acid				✍				
Selenium	Selenium	7782-49-2		Inorganic	Metal/Metalloid				✍			✍	
Silver	Silver	7440-22-4		Inorganic	Metal/Metalloid				✍			✍	
Simazine	Simazine	122-34-9		Organic	Pesticide - Triazine				✍		✍	✍	
Sodium	Sodium	7440-23-5		Inorganic	Metal/Metalloid				✍			✍	
Styrene	Styrene	100-42-5		Organic	Aromatic Hydrocarbon							✍	
Sulphate	Sulphate			Inorganic	Anion				✍			✍	
Sulphide (as H_2S)	Sulphide (as H2S)	18496-25-8		Inorganic	Miscellaneous				✍			✍	
Tebuthiuron	Tebuthiuron	34014-18-1		Organic	Pesticide - Urea-based							✍	

Table A.1. Master List of Substances

Substance Name	Name as Idenified in Source	CAS Number	Other Names	Main Class	Sub-class	Source List							
						Canada-Ontario[1]	Canada-U.S.[2]	CEPA Toxics[3]	GCDWQ[4]	DWSPL[5]	EU Annex X[6]	Water Quality Criteria[7]	Conventional and Non-specific Pollutants in MWWE
Temephos	Temephos	3383-96-8		Organic	Pesticide - Organophosphorus				✍				
Temperature	Temperature			Non-specific [a]	Physical/Chemical				✍			✍	✍
Terbufos	Terbufos	13071-79-9		Organic	Pesticide - Organophosphorus				✍			✍	
Tetrachlorobenzene (1,2,3,4-)	Tetrachlorobenzene (1,2,3,4-)	634-66-2		Organic	Chlorobenzene		Level II					✍	
Tetrachlorobenzene (1,2,3,5-)	Tetrachlorobenzene (1,2,3,5-)	634-90-2		Organic	Chlorobenzene							✍	
Tetrachlorobenzene (1,2,4,5-)	Tetrachlorobenzene (1,2,4,5-)	95-94-3		Organic	Chlorobenzene		Level II					✍	
Tetrachloroethane (1,1,1,2-)	Tetrachloroethane (1,1,1,2-)	630-20-6		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Tetrachloroethane (1,1,2,2-)	Tetrachloroethane (1,1,2,2-)	79-34-6		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Tetrachloroethylene	Tetrachloroethylene	127-18-4	PERC, Perchloroethylene, Tetrachloroethene (1,1,2,2-)	Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍			✍	
Tetrachloromethane	Tetrachloromethane (carbon tetrachloride)	56-23-5	Carbon Tetrachloride	Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍			✍	
Tetrachlorophenol (2,3,4,6-)	Tetrachlorophenol, 2,3,4,6-	935-95-5		Organic	Chlorophenol				✍			✍	
Tetraethyl lead	Tetraethyl lead	78-00-2		Organometals	Alkyl lead							✍	
Tetramethyl lead	Tetramethyl lead	75-74-1		Organometals	Alkyl lead							✍	
Thallium	Thallium	7440-28-0		Inorganic	Metal/Metalloid							✍	
Tin	Tin	7440-31-5		Inorganic	Metal/Metalloid							✍	
Toluene	Toluene	108-88-3		Organic	Alkyl benzene				✍			✍	
Total dissolved solids	Total dissolved solids		TDS	Non-specific	Physical/Chemical				✍			✍	✍
Total organic carbon	Total organic carbon		TOC	Non-specific	Physical/Chemical				✍				✍
Total residual chlorine	Chlorine	7782-50-5		Non-specific	Physical/Chemical					✍			
Total suspended solids	Total suspended solids		TSS	Non-specific	Physical/Chemical								✍
Toxaphene	Toxaphene	8001-35-2		Organic	Pesticide - Chlorinated hydrocarbon	Tier I	Level I		✍			✍	
Triallate	Triallate	2303-17-5		Organic	Pesticide - Thiocarbamate				✍			✍	
Tributyltetradecylphosphonium chloride	Tributyltetradecylphosphonium chloride	81741-28-8		Emerging	Hydrocarbons with N,P,S substitution			✍					
Tributyltin	Tributyltin	688-73-3	TBT	Organometals	Alkyl Tin	Tier II	Level II				✍	✍	
Trichlorobenzene (1,2,3-)	Trichlorobenzene (1,2,3-)	120-82-1		Organic	Chlorobenzene							✍	
Trichlorobenzene (1,2,4-)	Trichlorobenzene, 1,2,4-	87-61-6		Organic	Chlorobenzene						✍	✍	
Trichlorobenzene (1,3,5-)	Trichlorobenzene (1,3,5-)	108-70-3		Organic	Chlorobenzene							✍	
Trichloroethane (1,1,1-)	1,1,1-trichloroethane	71-55-6		Organic	Aliphatic Hydrocarbon - Halogenated			✍				✍	
Trichloroethane (1,1,2-)	Trichloroethane (1,1,2-)	79-00-5		Organic	Aliphatic Hydrocarbon - Halogenated							✍	
Trichloroethylene	Trichloroethylene	79-01-6	TCE, Trichloroethene (1,1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated			✍	✍	✍		✍	
Trichlorophenol (2,4,6-)	Trichlorophenol, 2,4,6-	88-06-2		Organic	Chlorophenol				✍			✍	
Trichlorophenoxyacetic acid (2,4,5-)	Trichlorophenoxyacetic acid, 2,4,5- (2,4,5-T)	55491-33-3	Phenoxy herbicide	Organic	Pesticide - Chlorophenoxy herbicide				✍			✍	
Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)	93-72-1	Silvex	Organic	Pesticide - Chlorophenoxy herbicide				✍				
Tricyclohexyltin	Tricyclohexyltin	13121-70-5		Organometals	Alkyl Tin							✍	
Triethyl lead	Triethyl lead	56267-87-9		Organometals	Alkyl lead							✍	
Trifluralin	Trifluralin	1582-09-8		Organic	Pesticide - Dinitroaniline-based				✍		✍	✍	
Trihalomethanes (total)	Trihalomethanes (total)	many compounds each has CAS No.		Organic	Aliphatic Hydrocarbon - Halogenated				✍	✍		✍	
Triphenyltin	Triphenyltin	668-34-8		Organometals	Aromatic Tin							✍	
Turbidity	Turbidity			Non-specific	Physical/Chemical				✍	✍		✍	✍
Uranium	Uranium	7440-61-1		Inorganic	Metal/Metalloid				✍			✍	
Vanadium	Vanadium			Inorganic	Metal/Metalloid							✍	
Viruses	Viruses			Biological	Pathogen - Virus					✍			
Xylene	Xylenes (total)	1330-20-7		Organic	Aromatic Hydrocarbon				✍			✍	
Zinc	Zinc	7440-66-6		Inorganic	Metal/Metalloid				✍			✍	

Note: Table is 11x17 inch format

[1]Canada-Ontario Agreement Respecting Great Lakes Basin Ecosystem

[2]Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes

[3]Canadian Environmental Protection Act (1999):Toxic Substances List – Updated Schedule 1 as of August 13, 2003

[4]Guidelines for Canadian Drinking Water Quality

[5]Drinking Water Source Protection List

[6] Annex X of European Union Water Framework Directive (2000/60/EC)

[7] See Table A.2

[a] Designated non-specific only because this measure seems to fit best with other substances in this category.

Table A.2. Water Quality Guidelines for Protection of Water Uses (shade denotes benchmarks used in the evaluation of effluent data)

Substance Name	Criteria for Protection of Aquatic Life (ug/L)									Drinking Water Criteria (ug/L)						Recreation Criteria (ug/L)	Agricultural Criteria (ug/L	
	CCME[a]	EPA[b]	CCME[a]	EPA[b]	Ontario[c]	Manitoba[d]	Saskatchewan[e]	Alberta[f]	British Columbia[g]	Canada[a]	Ontario[h]	Manitoba[d]	Saskatchewan[i]	Alberta[j]	British Columbia[g]	Canada[a]	Canada[a] Irrigation	Canada[a] Livestock
	Freshwater	Freshwater	Marine	Marine														
(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime																		
2,4-D	**4**				4	4	4				**100**	100	100	100	100			**100**
Acenaphthene	**5.8**					5.8			6									
Acetaldehyde																		
Acridine	**4.4**					4.4			3									
Acrolein					**0.03**													
Acrylamide																		
Acrylonitrile																		
Alalchlor																		
Aldicarb	**1**		**0.15**			1				**9**	9	9		9	9		**54.9**	11
Aldrin		**3**		**1.3**	0.001					**0.7**	0.7	0.7		0.7	0.7			
Alkyl lead																		
Aluminum	**5-100**	87			15-75	5-100			20-50	**100**	100			100	200		**5,000**	5,000
Ammonia	**19**[k]				20[k]				100-2,000									
Aniline	**2.2**				2	2.2					**100**							
Anthracene	**0.012**				0.0008	0.012			4									
Antimony					**20**					**6**		6		6	6			
Aroclor 1254																		
Arsenic	**5**	150	**12.5**	36	5	150	50			**25**	25	25	25	25	25		**100**	25
Atrazine	**1.8**					1.8				**5**	5	5	5	5	9		**10**	5
Azinphos-methyl										**20**	20	20		20	20			
Barium							**1,000**			**1,000**	1,000	1,000	1,000	1,000	1,000			
Bendiocarb										**40**	40	40		40	40			
Benzene	**370**		**110**		100	370				**5**	5	5	5	5	5			
Benzidine dihydrochloride																		
Benzo(a)anthracene	**0.018**				0.0004	0.018			0.1									
Benzo(a)pyrene	**0.015**					0.015			0.01	**0.01**	0.01		0.01	0.01	0.01			
Benzo(b)fluoranthene																		
Benzo(g,h,i)perylene					**0.00002**													
Benzo(k)fluoranthene					**0.0002**													
Beryllium					**11**												**100**	100
Biochemical Oxygen Demand																		
Biphenyldiamine (4,4'-)																		
Bis(2-ethylhexyl)phthalate	**16**				0.6	16					**50,000**							
Bis(chloromethyl)ether																		
Boron					**200**					**5,000**	5,000	5,000	5,000	5,000	5,000		**500-6,000**	5,000
Bromacil	**5**					5											**0.2**	1,100
Bromate										**10**		10						
Bromochloromethane																		
Bromoform					**60**													**100**
Bromoxynil	**5**					5				**5**	5	5	5	5	5		**0.33**	11
Butadiene (1,3-)																		
C10-13 chloroalkanes																		
Cadmium	**0.0025-0.097**[l]	0.25	**0.12**	8.8	0.1-0.5	0.65-5.64	1			**5**	5	5	5	5	5		**5.1**	80
Caffeine																		
Calcium																		**1,000,000**
Captan	**1.3**					1.3												**13**
Carbaryl	**0.2**		**0.32**		0.2	0.2				**90**	90	90		90	90			**1,100**
Carbofuran	**1.8**					1.8				**90**	90	90	90	90	90			**45**
Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)																		
Chloramines (mono-, di-, tri-; organic, inorganic)	**0.5**		**0.5**							**3,000**	3,000	3,000		3,000	3,000			
Chlorate																		
Chlordane		**0.0043**		**0.004**	0.06						**7**				7			
Chlorfenvinphos																		
Chloride		**230,000**								**250,000**	250,000	250,000	250,000	250,000	250,000		**100,000-700,000**	
Chlorinated Wastewater effluents																		
Chlorine Dioxide																		
Chlorite																		
Chlorobenzene	**1.3**		**25**		15	1.3				**80**	80	80	80	80	80			
Chloroform	**1.8**					1.8												**100**
Chloromethyl methyl ether																		
Chlorophenol	**7**				7	7			1.7-130									
Chlorothalonil	**0.18**		**0.36**			0.18					**2**						**5.8**	170
Chlorpyrifos	**0.0035**	0.041	**0.002**	0.0056	0.001	0.0035				**90**	90	90	90	90	90			**24**
Chromium (hexavalent)	**1**	11	**1.5**	50	1	11-16	20 (total)			**50 (total)**	50 (total)	50 (total)	50 (total)	50 (total)	50 (total)		**8**	50

Table A.2. Water Quality Guidelines for Protection of Water Uses (shade denotes benchmarks used in the evaluation of effluent data)

Substance Name	Criteria for Protection of Aquatic Life (ug/L)									Drinking Water Criteria (ug/L)						Recreation Criteria (ug/L)	Agricultural Criteria (ug/L	
	CCME[a]	EPA[b]	CCME[a]	EPA[b]	Ontario[c]	Manitoba[d]	Saskatchewan[e]	Alberta[f]	British Columbia[g]	Canada[a]	Ontario[h]	Manitoba[d]	Saskatchewan[i]	Alberta[j]	British Columbia[g]	Canada[a]	Canada[a] Irrigation	Canada[a] Livestock
	Freshwater	Freshwater	Marine	Marine														
Chromium (trivalent)	**8.9**	74	**56**		8.9	see guidelines[d]	20 (total)			**50 (total)**	50 (total)	50 (total)	50 (total)	50 (total)	50 (total)		**4.9**	50
Chrysene									**0.1**									
Clofibric acid/clofibrate																		
Cobalt					**0.9**												**50**	1,000
Colour										**15 TCU**	15 TCU	15 TCU	15 ACU[m]	15 TCU	15 TCU			
Copper	**2-4**	9		**3.1**	1-5	see guidelines[d]	10	1.7-55	2	**1,000**	1,000		1,000	1,000	1,000		**200-1,000**	500-5,000
Cryptosporidium sp.																		
Cyanazine	**2**					2				**10**	10	10		10	10		**0.5**	10
Cyanide, free	**5**	5.2		**1**	5	5.2-22	10		5 WAD	**200**	200	200	200	200	200			
Cyanobacterial toxins (as Microcystin - LR)										**1.5**								
Cyanogen Chloride																		
DDD																		
DDE																		
DDT		**0.001**		**0.001**	0.003										**30**			
Deltamethrin	**0.0004**					0.0004												**2.5**
Diazinon					**0.08**					**20**	20	20		20	20			
Dibenzo(a,h)anthracene					**0.002**													
Dibenzofuran					**0.3**													
Dibenzo-p-dioxin																		
Dibromochloromethane					**40**						**50**							**100**
Dicamba	**10**				200	10				**120**	120	120	120	120	120		**0.006**	122
Dichlorobenzene (1,2-)	**0.7**		**42**		2.5	0.7				**200**	200	200	200	200	200			
Dichlorobenzene (1,3-)	**150**				2.5	150												
Dichlorobenzene (1,4-)	**26**				4	26				**5**	5	5	5	5	5			
Dichlorobenzidene (3,3'-)					**0.6**													
Dichlorobromomethane					200													**100**
Dichloroethane (1,1-)					**200**													
Dichloroethane (1,2-)	**100**				100	100				**5**	5	5	5	5	5			**5**
Dichloroethene (1,1-)					**40**					**14**	14	14	14	14	14			
Dichloroethene (1,2-)					**200**													
Dichloromethane	**98.1**				100	98.1				**50**	50	50	50		50			**50**
Dichlorophenol (2,4-)	**0.2**				0.2	0.2			0.6-20	**900**	900	900	900	900	900			
Dichloropropane (1,2-)					**0.7**													
Dichloropropene (1,2-) (cis and trans)					**7**													
Dichlorprop																		
Diclofop-methyl	**6.1**					6.1				**9**	9	9	9	9	9		**0.18**	9
Dieldrin		**0.056**		**0.0019**	0.001					**0.7**	0.7	0.7		0.7	0.7			
Dimethoate	**6.2**					6.2				**20**	20	20	20	20	20			**3**
Dimethylnaphthalene					**0.02**													
Di-n-butyl phthalate	**19**				4	19												
Dinitropyrene																		
Dinoseb	**0.05**					0.05				**10**	10	10		10	10		**16**	150
Diquat					**0.5**					**70**	70	70		70	70			
Diuron					**1.6**					**150**	150	150		150	150			
Dodecyl dimethyl ammonium chloride	**1.5**					1.5												
Endosulfan	**0.02**	0.056		**0.0087**	0.003	0.02												
Endrin		**0.036**		**0.0023**	0.002													
Escherichia coli (*E. coli*)										**0/100ml**					0/100ml	2000/100ml	**100/100ml**	
Estradiol																		
Ethylbenzene	**90**		**25**		8	90			200	**2.4**	2.4	2.4	2.4	2.4	2.4			**2.4**
Ethylene glycol	**192,000**				2,000	192,000												
Ethylene oxide																		
Fecal coliforms										**0/100ml**					0/100ml			
Fluoranthene	**0.04**				0.0008	0.04			4									
Fluorene	**3**				0.2	3			12									
Fluoride	**120**								200-300	**1,500**	1,500	1,500	1,500	1,500	1,500		**1,000**	1,000-2,000
Formaldehyde					**0.8**													
Giardia sp.																		
Glyphosate	**65**					65				**280**	280	280		280	280			**280**
Haloacetic acids																		
Haloacetonitriles																		
Hardness																		
Heptachlor + Heptachlor epoxide		**0.0038**		**0.0036**	0.001						**3**				3			
Hexachloro-1,3-butadiene	**1.3**				0.009	1.3												

Table A.2. Water Quality Guidelines for Protection of Water Uses (shade denotes benchmarks used in the evaluation of effluent data)

Substance Name	Criteria for Protection of Aquatic Life (ug/L)									Drinking Water Criteria (ug/L)						Recreation Criteria (ug/L)	Agricultural Criteria (ug/L	
	CCME[a]	EPA[b]	CCME[a]	EPA[b]	Ontario[c]	Manitoba[d]	Saskatchewan[e]	Alberta[f]	British Columbia[g]	Canada[a]	Ontario[h]	Manitoba[d]	Saskatchewan[i]	Alberta[j]	British Columbia[g]	Canada[a]	Canada[a] Irrigation	Canada[a] Livestock
	Freshwater	Freshwater	Marine	Marine														
Hexachlorobenzene					**0.0065**													**0.52**
Indeno(1,2,3-c,d)pyrene																		
Iodo-2-propynyl butyl carbamate (3-)	**1.9**					1.9												
Iron	**300**	1,000			300	300	1,000			**300**	300	300	300	300	300		**5,000**	
Isoproturon																		
Lead	**1-7**	2.5		**8.1**	1-5	see guidelines[d]	20		3-330	**10**	10	10	10	10	10		**200**	100
Lindane	**0.01**	0.95		**0.16**	0.01	0.01	0.1				**4**				4			**4**
Linuron	**7**					7											**0.071**	
Lithium																	**2,500**	
Magnesium														**200**	100,000[o]			
Malathion		**0.1**		**0.1**	0.1					**190**	190	190	190	190	190			
Manganese									**700-1,900**	**50**	50	50	50	50	50		**200**	
MCPA	**2.6**		**4.2**			2.6											**0.025**	25
Mercury	**0.026**	0.77	**0.016**	0.94	0.2	0.1	0.1	0.005	0.02	**1**	1	1	1	1	1			**3**
Methoxychlor		**0.03**		**0.03**	0.04					**900**	900	900		900	900			
Methyl bromide					**0.9**													
Methyl mercury	**0.004**							0.001		**1**				1				
Methyl t-butyl ether	**10,000**		**5,000**		200				440						**20**			
Methylenebis(2-chloroaniline) (4,4'-)																		
Methyl-parathion																		
Metolachlor	**7.8**				3	7.8				**50**	50	50		50	50		**28**	50
Metribuzin	**1**					1				**80**	80	80		80	80		**0.5**	80
Mirex		**0.001**		**0.001**	0.001													
Molybdenum	**73**				40	73			1,000								**10-50**	500
Monochloroethene					**600**					**2**	2	2	2	2	2			
Naphthalene	**1.1**		**1.4**		7	1.1			1									
Nickel	**25-150**	52		**8.2**	25	see guidelines[d]	25-100										**200**	1,000
Nitrate	**13,000**		**16,000**						40,000	**45,000**	10,000	45,000	45,000	45,000	45,000			
Nitrilotriacetic acid										**400**	400	400		400	400			
Nitrite	**60**					60			20-200	**3,200**	1,000	3,200		3,200				**10,000**
N-Nitrosodimethylamine											**0.009**							
Nonylphenol	**1**		**0.7**			1												
Nonylphenol ethoxylate	**1**		**0.7**		0.04	1												
Octachlorostyrene																		
Octylphenol																		
Oil and grease																		
Paraquat (as dichloride)										**10**	10	10		10	10			
Parathion		**0.013**			0.008					**50**	50	50		50				
PCBs		**0.014**		**0.03**	0.001		0.001		0.25-100		**3**							
PCDD																		
PCDF																		
Pentachlorobenzene	**6**				0.03	6												
Pentachlorophenol	**0.5**	15		**7.9**	0.5	0.5	0.5		0.2-5.5	**60**	60	60	60	60				
Perylene					**0.00007**													
pH	**6.5-9.0**	6.5-9	**7.0-8.7**	6.5-8.5	6.5-8.5	6.5-9.0		6.5-8.5	6.5-9.0	**6.5-8.5**	6.5-8.5	6.5-8.5	6.5-9	6.5-8.5	6.5-8.5	**5.0-9.0**		
Phenanthrene	**0.4**				0.03	0.4			0.3									
Phenols, Total	**4**				1	4	1	5										**2**
Phorate										**2**	2	2		2	2			
Phosphorus (total)				**0.1**	10-30			50	**5-15**									
Phthalic acid esters																		
Picloram	**29**				190	29				**190**	190	190	190	190	190			**190**
Polybrominated biphenyls																		
Polybrominated diphenylethers																		
Polychlorinated terphenyls																		
Polycyclic hydrocarbons																		
Propylene glycol (1,2-)	**500,000**				44,000	500,000												
Propylene glycol (1,3-)	**500,000**				10,000	500,000												
Protozoa																		
Pyrene	**0.025**					0.025												
Quinoline	**3.4**				10	3.4												
Resin Acids																		
Selenium	**1**	5		**71**	100	1	10		2	**10**	10	10	10	10	10		**20-50**	50
Silver	**0.1**	3.2		**1.9**	0.1	0.1	10		0.05-3									
Simazine	**10**				10	10				**10**	10	10		10	10		**0.5**	10
Sodium										**200,000**	200,000	200,000	300,000	200,000	200,000			
Styrene	**72**				4	72												
Sulphate									**100,000**	**500,000**	500,000	500,000	500,000	500,000	500,000			**1,000,000**
Sulphide (as H_2S)		**2**		**2**	2					**50**	50	50	50	50	50			

Table A.2. Water Quality Guidelines for Protection of Water Uses (shade denotes benchmarks used in the evaluation of effluent data)

Substance Name	Criteria for Protection of Aquatic Life (ug/L)									Drinking Water Criteria (ug/L)						Recreation Criteria (ug/L)	Agricultural Criteria (ug/L	
	CCME[a]	EPA[b]	CCME[a]	EPA[b]	Ontario[c]	Manitoba[d]	Saskatchewan[e]	Alberta[f]	British Columbia[g]	Canada[a]	Ontario[h]	Manitoba[d]	Saskatchewan[i]	Alberta[j]	British Columbia[g]	Canada[a]	Canada[a] Irrigation	Canada[a] Livestock
	Freshwater	Freshwater	Marine	Marine														
Tebuthiuron	**1.6**					1.6											**0.27**	130
Temephos															**280**			
Temperature						see guidelines[d]				**15°C**	15°C	15°C	15°C	15°C	15°C			
Terbufos										**1**	1	1		1	1			
Tetrachlorobenzene (1,2,3,4-)	**1.8**				0.1	1.8												
Tetrachlorobenzene (1,2,3,5-)					**0.1**													
Tetrachlorobenzene (1,2,4,5-)					**0.1**													
Tetrachloroethane (1,1,1,2-)					**20**													
Tetrachloroethane (1,1,2,2-)					**70**													
Tetrachloroethylene	**111**				50	111				**30**	30	30		50	30			
Tetrachloromethane	**13.3**					13.3				**5**	5	5	5	5	5			**5**
Tetrachlorophenol (2,3,4,6-)	**1**				1	1			0.5-36	**100**	10	100	100	100	100			
Tetraethyl lead					**0.0007**													
Tetramethyl lead					**0.006**													
Thallium	**0.8**				0.3	0.8												
Tin																		
Toluene	**2**		**215**		0.8	2			39	**24**	24	24	24	24	24			**24**
Total dissolved solids						see guidelines[d]				**500,000**	500,000	500,000	500,000	500,000	500,000		**500,000-3,500,000**	3,000,000
Total organic carbon																		
Total residual chlorine									**2**									
Total suspended solids																		
Toxaphene		**0.0002**		**0.0002**	0.008													
Triallate	**0.24**					0.24					**230**				230			**230**
Tributyltetradecylphosphonium chloride																		
Tributyltin	**0.008**	0.063	**0.001**	0.01	0.000005	0.008												**250**
Trichlorobenzene (1,2,3-)	**8**				0.9	8												
Trichlorobenzene (1,2,4-)	**24**		**5.4**		0.5	24												
Trichlorobenzene (1,3,5-)					**0.65**													
Trichloroethane (1,1,1-)					**10**													
Trichloroethane (1,1,2-)					**800**													
Trichloroethylene	**21**				20	21				**50**	50	50	50	50	50			**50**
Trichlorophenol (2,4,6-)	**18**				18	18			1.2-40	**5**	5	5	5	5	5			
Trichlorophenoxyacetic acid (2,4,5-)	**4**										**280**				280			**100**
Trichlorophenoxypropionic acid, 2,4,5-(2,4,5-TP)																		
Tricyclohexyltin																		**250**
Triethyl lead					**0.4**													
Trifluralin	**0.2**					0.2				**45**	45	45	45	45	45			**45**
Trihalomethanes (total)										**100**	100	100	100	100	100			
Triphenyltin	**0.022**				0.002	0.022												**820**
Turbidity					changes in Secchi disk readings 10%	see guidelines[d]			**increase 2-8 NTU or 10%**	**1 NTU**	1 NTU	1 NTU		1 NTU	1 NTU			
Uranium					**5**					**20**	100	20	20	20	100		**10**	200
Vanadium					**6**												**100**	100
Viruses																		
Xylene					**2-40**					**300**	300	300	300	300	300			
Zinc	**30**	120		**81**	20	see guidelines[d]	50		33-265	**5,000**	5,000	5,000	5,000	5,000	5,000		**1,000-5,000**	50,000

Note: Table is 11x17 inch format.

[a] - Canadian Environmental Quality Guildelines 2003, http://www.ccme.ca/assets/pdf/update3.2_cover_e.pdf

[b] - USEPA National Recommended Water Quality Criteria, 2002, http://epa.gov/waterscience/standards/wqcriteria.html (chronic criteria given unless acute criteria only available). Values for metals are based on dissolved, not total, concentration.

[c] - Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy (Ontario), July 1994

[d] - Manitoba Water Quality Standards, Objectives, and Guidelines 2002, http://www.gov.mb.ca/conservation/watres/mwqsog_2002.pdf

[e] - Saskatchewan Surface Water Quality Objectives, 1997, http://www.se.gov.sk.ca/environment/protection/water/MB110_Surface_Water_Quality_Objectives_b.pdf; for substances not given water quality objectives, a general objective of 1/100 of the 96 hour LC50 of each substance should be applied

[f] - Alberta Water Quality Guidelines for the Protection of Freshwater Aquatic Life, 1999, www3.gov.ab.ca/env/protenf/publications/surfwtrQual-Nov99.pdf

[g] - British Columbia Approved Water Quality Guidelines (Criteria), 1998, http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/approved.html. Criteria for protection of aquatic life are marine or freshwater, whichever is more stringent.

[h] - Ontario Drinking Water Standards, August 2000

[i] - Saskatchewan's Drinking Water Quality Standards and Objectives (summarized), 2002, www.se.gov.sk.ca/environment/protection/water/Drinking_Water_Standards/post.pdf

[j] - Alberta does not have its own set of drinking water quality guidelines, the province uses the Canadian criteria, see a

[k] - Criterion pertains to un-ionized ammonia while effluent data are reported as total ammonia

[l] - range based on hardness following Cd limit = 10^(0.86(log(hardness))-3.2)

[m] - APU - Apparent Colour Unit

[n] - to protect recreational water use

[o] - taste threshold

Table A.3. Classification of Master List of Substances

Main Class	Sub-class	Substance Name	CAS Number	Other Names
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)		
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)		
Biological	Pathogen - Bacteria	Fecal coliforms		
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.		
Biological	Pathogen - Protozoan	*Giardia* sp.		
Biological	Pathogen - Protozoan	Protozoa		
Biological	Pathogen - Virus	Viruses		
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	9016-45-9, 26027-38-3	
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	62-75-9	NDMA
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride	81741-28-8	
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate	637-07-0	
Emerging	Pharmaceutical - Stimulant	Caffeine	58-08-2	
Emerging	Pharmaceuticals - Hormone	Estradiol	50-28-2	
Inorganic	Anion	Bromate	1554-45-4	
Inorganic	Anion	Chlorate	not for anion alone	
Inorganic	Anion	Chloride	not for anion alone	
Inorganic	Anion	Chlorite	not for anion alone	
Inorganic	Anion	Cyanide	57-12-5	
Inorganic	Anion	Fluoride	13709-49-4	
Inorganic	Anion	Sulphate		
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)		
Inorganic	Disinfectant	Chlorine dioxide	10049-04-4	
Inorganic	Metal/Metalloid	Aluminum	39148-24-8	
Inorganic	Metal/Metalloid	Antimony	7440-36-0	
Inorganic	Metal/Metalloid	Arsenic	7440-38-2	
Inorganic	Metal/Metalloid	Barium	7440-39-3	
Inorganic	Metal/Metalloid	Beryllium	7440-41-7	
Inorganic	Metal/Metalloid	Boron	7440-42-8	
Inorganic	Metal/Metalloid	Cadmium	7440-43-9	
Inorganic	Metal/Metalloid	Calcium	7440-70-2	
Inorganic	Metal/Metalloid	Chromium (trivalent and hexavalent)	7440-47-3	
Inorganic	Metal/Metalloid	Chromium (trivalent and hexavalent)	7440-47-3	
Inorganic	Metal/Metalloid	Cobalt	7440-48-4	
Inorganic	Metal/Metalloid	Copper	7440-50-8	
Inorganic	Metal/Metalloid	Iron	39331-38-9	
Inorganic	Metal/Metalloid	Lead	7439-92-1	
Inorganic	Metal/Metalloid	Lithium	7439-93-2	
Inorganic	Metal/Metalloid	Magnesium	7439-95-4	
Inorganic	Metal/Metalloid	Manganese	7439-96-5	
Inorganic	Metal/Metalloid	Mercury	7439-97-6	
Inorganic	Metal/Metalloid	Molybdenum	7439-98-7	
Inorganic	Metal/Metalloid	Nickel	7440-02-0	
Inorganic	Metal/Metalloid	Selenium	7782-49-2	
Inorganic	Metal/Metalloid	Silver	7440-22-4	
Inorganic	Metal/Metalloid	Sodium	7440-23-5	
Inorganic	Metal/Metalloid	Thallium	7440-28-0	
Inorganic	Metal/Metalloid	Tin	7440-31-5	
Inorganic	Metal/Metalloid	Uranium	7440-61-1	
Inorganic	Metal/Metalloid	Vanadium		
Inorganic	Metal/Metalloid	Zinc	7440-66-6	
Inorganic	Miscellaneous	Cyanogen Chloride	506-77-4	
Inorganic	Miscellaneous	Sulphide (as H_2S)	18496-25-8	
Inorganic	Nutrient	Ammonia	7664-41-7	
Inorganic	Nutrient	Nitrate	14797-55-8	
Inorganic	Nutrient	Nitrite		
Inorganic	Nutrient	Phosphorus (total)		
Non-specific	Miscellaneous	Chlorinated wastewater effluents		
Non-specific	Physical/Chemical	Biochemical Oxygen Demand		BOD

Table A.3. Classification of Master List of Substances

Main Class	Sub-class	Substance Name	CAS Number	Other Names
Non-specific	Physical/Chemical	Colour		
Non-specific	Physical/Chemical	Hardness		
Non-specific	Physical/Chemical	Oil and grease		
Non-specific	Physical/Chemical	Total dissolved solids		TDS
Non-specific	Physical/Chemical	Total organic carbon		TOC
Non-specific	Physical/Chemical	Total residual chlorine	7782-50-5	
Non-specific	Physical/Chemical	Total suspended solids		TSS
Non-specific	Physical/Chemical	Turbidity		
Non-specific [a]	Physical/Chemical	pH		
Non-specific [a]	Physical/Chemical	Temperature		
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)	106-99-0	
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane	74-97-5	
Organic	Aliphatic Hydrocarbon - Halogenated	Bromoform	75-25-2	
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes	85535-84-8	
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	67-66-3	Trichloromethane
Organic	Aliphatic Hydrocarbon - Halogenated	Dibromochloromethane	124-48-1	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichlorobromomethane	75-27-4	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,1-)	75-34-3	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	107-06-2	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,1-)	75-35-4	Dichloroethylene
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,2-)	540-59-0, 156-59-2, & 156-60-5	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloromethane	75-09-2	Methylene chloride
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropane (1,2-)	78-87-5	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropene (1,2-) (cis and trans)	10061-02-6/542-75-6	
Organic	Aliphatic Hydrocarbon - Halogenated	Hexachloro-1,3-butadiene	87-68-3	HCBD
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	74-83-9	Bromomethane
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene	75-01-4	
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	630-20-6	
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,2,2-)	79-34-6	
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	127-18-4	PERC, Perchloroethylene, Tetrachloroethene (1,1,2,2-)
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloromethane	56-23-5	Carbon Tetrachloride
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	71-55-6	
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,2-)	79-00-5	
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethylene	79-01-6	TCE, Trichloroethene (1,1,2-)
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)	many compounds each has CAS No.	
Organic	Alkyl benzene	Ethylbenzene	100-41-4	
Organic	Alkyl benzene	Toluene	108-88-3	
Organic	Alkylphenol & Ethoxylates	Nonylphenol	84852-15-3	
Organic	Alkylphenol & Ethoxylates	Octylphenol	1806-26-4	
Organic	Aromatic Hydrocarbon	Benzene	1076-43-3	
Organic	Aromatic Hydrocarbon	Phenols, Total	108-95-2	
Organic	Aromatic Hydrocarbon	Styrene	100-42-5	
Organic	Aromatic Hydrocarbon	Xylene	1330-20-7	
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime	94097-88-8	NCC ether
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride	531-85-1	
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	91-94-1	
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene	EDF-151	
Organic	Aromatic Hydrocarbon - Polycyclic	Acenaphthene	83-32-9	
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	65996-97-0	
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	56-55-3	
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	50-32-8	
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene	205-99-2	
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	191-24-2	
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	207-08-9	

Table A.3. Classification of Master List of Substances

Main Class	Sub-class	Substance Name	CAS Number	Other Names
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene	218-01-9	
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	53-70-3	
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	571-61-9	
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	206-44-0	
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	86-73-7	
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene	193-39-5	
Organic	Aromatic Hydrocarbon - Polycyclic	Naphthalene	91-20-3	
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	198-55-0	
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	85-01-8	
Organic	Aromatic Hydrocarbon - Polycyclic	Polycyclic hydrocarbons	130498-29-2	
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	129-00-0	
Organic	Chlorobenzene	Chlorobenzene	108-90-7	Monochlorobenzene
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	95-50-1	
Organic	Chlorobenzene	Dichlorobenzene (1,3-)	541-73-1	
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	106-46-7	
Organic	Chlorobenzene	Hexachlorobenzene	118-74-1	
Organic	Chlorobenzene	Pentachlorobenzene	608-93-5	
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,4-)	634-66-2	
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,5-)	634-90-2	
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,4,5-)	95-94-3	
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	120-82-1	
Organic	Chlorobenzene	Trichlorobenzene (1,2,4-)	87-61-6	
Organic	Chlorobenzene	Trichlorobenzene (1,3,5-)	108-70-3	
Organic	Chlorophenol	Chlorophenol	many congeners each has CAS No.	
Organic	Chlorophenol	Dichlorophenol (2,4-)	3757-76-4	
Organic	Chlorophenol	Pentachlorophenol	87-86-5	PCP
Organic	Chlorophenol	Tetrachlorophenol (2,3,4,6-)	935-95-5	
Organic	Chlorophenol	Trichlorophenol (2,4,6-)	88-06-2	
Organic	Dioxins and Furans	Dibenzofuran	132-64-9	
Organic	Dioxins and Furans	Dibenzo-p-dioxin	262-12-4	
Organic	Dioxins and Furans - Polychlorinated	PCDD	many congeners each has CAS No.	Polychlorinated dibenzo-p-dioxins
Organic	Dioxins and Furans - Polychlorinated	PCDF	39001-02-0	Polychlorinated dibenzo-furans
Organic	Haloacetonitrile	Haloacetonitriles	many congeners each has CAS No.	
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)	302-17-0	
Organic	Halocarboxylic acids	Haloacetic acids	many congeners each has CAS No.	
Organic	Haloether	Bis(chloromethyl)ether	542-88-1	BCEE
Organic	Haloether	Chloromethyl methyl ether	107-30-2	
Organic	Hydrocarbons with N,P,S substitution	Acridine	260-94-6	
Organic	Hydrocarbons with N,P,S substitution	Acrylamide	79-06-1	
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile	107-13-1	
Organic	Hydrocarbons with N,P,S substitution	Aniline	62-53-3	
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)	92-87-5	Benzidine
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene	many congeners each has CAS No.	
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)	101-14-4	
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid	139-13-9	NTA
Organic	Hydrocarbons with N,P,S substitution	Quinoline	91-22-5	
Organic	Oxygenate - Acetaldehyde	Acetaldehyde	75-07-0	
Organic	Oxygenate - Acetaldehyde	Formaldehyde	50-00-0	
Organic	Oxygenate - Alcohol	Ethylene glycol	107-21-1	
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	57-55-6	
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	57-55-6	
Organic	Oxygenate - Ether	Methyl t-butyl ether	1634-04-4	MTBE, Methyl tertiary-butyl ether

Table A.3. Classification of Master List of Substances

Main Class	Sub-class	Substance Name	CAS Number	Other Names
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	117-81-7	Dioctyl phthalate, Di(2-ethylhexyl) phthalate, DEHP
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	84-74-2	
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters	many compounds each has CAS No.	
Organic	Oxygenate- Carboxylic Acid	Resin Acids	many compounds each has CAS No.	
Organic	Oxygenated - Epoxide	Ethylene oxide	75-21-8	
Organic	Oxygenated Compounds	Acrolein	107-02-8	
Organic	Pesticide - Benzoic acid	Dicamba	1918-00-9	
Organic	Pesticide - Bipyridylium	Diquat	85-00-7	
Organic	Pesticide - Bipyridylium	Methyl-parathion	298-00-0	
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)	1910-42-5	
Organic	Pesticide - Carbamate	Iodo-2-propynyl butyl carbamate (3-)	55406-53-6	IPBC
Organic	Pesticide - Chlorinated hydrocarbon	Aldrin	309-00-2	
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	57-74-9	
Organic	Pesticide - Chlorinated hydrocarbon	DDD	72-54-8	Dichloro diphenyl dichloroethane
Organic	Pesticide - Chlorinated hydrocarbon	DDE	72-55-9	
Organic	Pesticide - Chlorinated hydrocarbon	DDT	50-29-3	Dichloro diphenyl trichloroethane, Bis(p-chlorophenyl)-1,1,1-trichloroethane (2,2-)
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	60-57-1	
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	115-29-7	
Organic	Pesticide - Chlorinated hydrocarbon	Endrin	72-20-8	
Organic	Pesticide - Chlorinated hydrocarbon	Heptachlor + Heptachlor epoxide	76-44-8	
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	58-89-9	
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	72-43-5	
Organic	Pesticide - Chlorinated hydrocarbon	Mirex	2385-85-5	Dechlorane
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	8001-35-2	
Organic	Pesticide - Chloroacetanilide	Alalchlor	15972-60-8	
Organic	Pesticide - Chloroacetanilide	Metolachlor	51218-45-2	
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	94-75-7	
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop	120-36-5	
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	51338-27-3	
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	94-74-6	Chloro-2-methyl phenoxy acetic acid (4-)
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	55491-33-3	Phenoxy herbicide
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)	93-72-1	Silvex
Organic	Pesticide - Dinitroaniline-based	Trifluralin	1582-09-8	
Organic	Pesticide - Dintrophenol derivative	Dinoseb	88-85-7	
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	1689-84-5	
Organic	Pesticide - N-methyl carbamate	Aldicarb	116-06-3	
Organic	Pesticide - N-methyl carbamate	Bendiocarb	22781-23-3	
Organic	Pesticide - N-methyl carbamate	Carbaryl	63-25-2	
Organic	Pesticide - N-methyl carbamate	Carbofuran	1563-66-2	
Organic	Pesticide - Organophosphorus	Azinphos-methyl	86-500-0	
Organic	Pesticide - Organophosphorus	Chlorfenvinphos	470-90-6	
Organic	Pesticide - Organophosphorus	Chlorpyrifos	2921-88-2	
Organic	Pesticide - Organophosphorus	Diazinon	333-41-5	
Organic	Pesticide - Organophosphorus	Dimethoate	60-51-5	
Organic	Pesticide - Organophosphorus	Malathion	121-75-5	
Organic	Pesticide - Organophosphorus	Parathion	56-38-2	
Organic	Pesticide - Organophosphorus	Phorate	298-02-2	
Organic	Pesticide - Organophosphorus	Temephos	3383-96-8	
Organic	Pesticide - Organophosphorus	Terbufos	13071-79-9	
Organic	Pesticide - Phosphoroglycine	Glyphosate	1071-83-6	
Organic	Pesticide - Pyrethroid	Deltamethrin	52918-63-5	
Organic	Pesticide - Pyridine carboxylic acid	Picloram	1918-02-1	
Organic	Pesticide - Quaternary Ammonium	Dodecyl dimethyl ammonium chloride	7173-51-5	DDAC

Table A.3. Classification of Master List of Substances

Main Class	Sub-class	Substance Name	CAS Number	Other Names
Organic	Pesticide - Substituted benzene	Chlorothalonil	1897-45-6	
Organic	Pesticide - Thiocarbamate	Triallate	2303-17-5	
Organic	Pesticide - Thiophthalinide	Captan	133-06-2	
Organic	Pesticide - Triazine	Atrazine	1912-24-9	
Organic	Pesticide - Triazine	Cyanazine	21725-46-2	
Organic	Pesticide - Triazine	Simazine	122-34-9	
Organic	Pesticide - Triazinone	Metribuzin	21087-64-9	
Organic	Pesticide - Uracil	Bromacil	314-40-9	
Organic	Pesticide - Urea-based	Diuron	330-54-1	
Organic	Pesticide - Urea-based	Isoproturon	34123-59-6	
Organic	Pesticide - Urea-based	Linuron	330-55-2	
Organic	Pesticide - Urea-based	Tebuthiuron	34014-18-1	
Organic	Polyhalogenated Polyphenyl	Aroclor 1254	11097-69-1	PCB
Organic	Polyhalogenated Polyphenyl	PCBs	1336-36-3	Polychlorinated biphenyls
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls	PJL335	PBB
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers	many congeners each has CAS No.	PBDE
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls	61788-33-8	
Organometals	Alkyl lead	Alkyl lead	EDF-171	
Organometals	Alkyl lead	Tetraethyl lead	78-00-2	
Organometals	Alkyl lead	Tetramethyl lead	75-74-1	
Organometals	Alkyl lead	Triethyl lead	56267-87-9	
Organometals	Alkyl mercury	Methyl mercury	22967-92-6	
Organometals	Alkyl Tin	Tributyltin	688-73-3	TBT
Organometals	Alkyl Tin	Tricyclohexyltin	13121-70-5	
Organometals	Aromatic Tin	Triphenyltin	668-34-8	

[a] Designated non-specific only because this measure seems to fit best with other substances in this category.

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Aldrin	Organic	Pesticide - Chlorinated hydrocarbon	X	X	X			persistent, lipid soluble, biomagnifies
Bis(2-ethylhexyl)phthalate	Organic	Oxygenate - Phthalic Ester	X	X	X			persistent under anaerobic conditions
Chlordane	Organic	Pesticide - Chlorinated hydrocarbon	X	X	X			persistent, bioaccumulates
Dichlorobenzidene (3,3'-)	Organic	Aromatic Hydrocarbon - Halogenated	X	X	X			bioaccumulates in aquatic organisms
Dieldrin	Organic	Pesticide - Chlorinated hydrocarbon	X	X	X			persistent, lipid soluble, biomagnifies
Hexachlorobenzene	Organic	Chlorobenzene	X	X	X			readily bioaccumulates
PCBs	Organic	Polyhalogenated Polyphenyl	X	X	X			highly lipophilic, bioconcentrate to high concentrations in tissues
Toxaphene	Organic	Pesticide - Chlorinated hydrocarbon	X	X	X			persistent, extremely toxic to fish
Benzo(a)pyrene	Organic	Aromatic Hydrocarbon - Polycyclic	X	X				
Benzo(b)fluoranthene	Organic	Aromatic Hydrocarbon - Polycyclic	X	X				
Benzo(k)fluoranthene	Organic	Aromatic Hydrocarbon - Polycyclic	X	X				
Chloroform	Organic	Aliphatic Hydrocarbon - Halogenated	X	X				low affinity for organic carbon & lipids, may persist in groundwater, does not appear to bioconcentrate in animals
Heptachlor + Heptachlor epoxide	Organic	Pesticide - Chlorinated hydrocarbon	X	X				fish less sensitive than invertebrates, persistent in aquatic environments
Methoxychlor	Organic	Pesticide - Chlorinated hydrocarbon	X	X				
Paraquat (as dichloride)	Organic	Pesticide - Bipyridylium	X	X				
Parathion	Organic	Pesticide - Organophosphorus	X	X				
Arsenic	Inorganic	Metal/Metalloid	X		X			humans more sensitive than aquatic life, invertebrates more sensitive than fish, invertebrates may accumulate in tissues, not fish; high temperatures increase toxicity
Cadmium	Inorganic	Metal/Metalloid	X		X			little evidence for biomagnification, toxicity varies with water hardness, pH, temperature & presence of organic compounds, selenium and mixtures of metals
Chromium (trivalent and hexavalent)	Inorganic	Metal/Metalloid	X		X			phytoplankton more sensitive than fish; toxicity increases with decreasing water hardness
Dibenzo(a,h)anthracene	Organic	Aromatic Hydrocarbon - Polycyclic	X		X			
Hexachloro-1,3-butadiene	Organic	Aliphatic Hydrocarbon - Halogenated	X		X			depuration rate rapide, accumulates in aquatic organisms
Acrylonitrile	Organic	Hydrocarbons with N,P,S substitution	X					
Aniline	Organic	Hydrocarbons with N,P,S substitution	X					short half-life, no apparent bioaccumulation in aquatic life, invertebrates more sensitive than fish
Benzene	Organic	Aromatic Hydrocarbon	X					fish more sensitive than invertebrates, depuration in fish rapid
Beryllium	Inorganic	Metal/Metalloid	X					does not appear to biomagnify in fresh water; toxicity increases with decreasing water hardness
Bis(chloromethyl)ether	Organic	Haloether	X					
Bromate	Inorganic	Anion	X					
Bromoform	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Butadiene (1,3-)	Organic	Aliphatic Hydrocarbon	X					
Chloromethyl methyl ether	Organic	Haloether	X					
Chrysene	Organic	Aromatic Hydrocarbon - Polycyclic	X					
Dibromochloromethane	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Dichloroethane (1,1-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Dichloroethane (1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Dichloroethene (1,1-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Dichloromethane	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Formaldehyde	Organic	Oxygenate - Acetaldehyde	X					
Indeno(1,2,3-c,d)pyrene	Organic	Aromatic Hydrocarbon - Polycyclic	X					

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Lead	Inorganic	Metal/Metalloid	X					no apparent biomagnification; toxicity increases with decreasing water hardness
Linuron	Organic	Pesticide - Urea-based	X					
Monochloroethene	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Naphthalene	Organic	Aromatic Hydrocarbon - Polycyclic	X					
N-Nitrosodimethylamine	Emerging	Hydrocarbons with N,P,S substitution	X					
Pentachlorophenol	Organic	Chlorophenol	X				X	impairs flavour of edible portions of fish; toxicity increases with increasing chlorine substitution, chronic affect concentration for young rainbow trout increased with decreasing temperature
Quinoline	Organic	Hydrocarbons with N,P,S substitution	X					
Tetrachloroethane (1,1,1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Tetrachloroethane (1,1,2,2-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Trichloroethane (1,1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated	X					
Trichlorophenol (2,4,6-)	Organic	Chlorophenol	X				X	
Trifluralin	Organic	Pesticide - Dinitroaniline-based	X					
DDD	Organic	Pesticide - Chlorinated hydrocarbon		X	X			
DDE	Organic	Pesticide - Chlorinated hydrocarbon		X	X			
DDT	Organic	Pesticide - Chlorinated hydrocarbon		X	X			bioaccumulates, invertebrates most sensitive
Dichlorobenzene (1,2-)	Organic	Chlorobenzene		X	X			
Dichlorobenzene (1,3-)	Organic	Chlorobenzene		X	X			
Dichlorobenzene (1,4-)	Organic	Chlorobenzene		X	X			
Mercury	Inorganic	Metal/Metalloid		X	X			bottom feeders generally contain more mercury than do water column feeders; acute toxicity in fish increases with increasing temperature
Mirex	Organic	Pesticide - Chlorinated hydrocarbon		X	X			
Octachlorostyrene	Organic	Aromatic Hydrocarbon - Halogenated		X	X			
PCDD	Organic	Dioxins and Furans - Polychlorinated		X	X			bioaccumulates in tissues, persistent
PCDF	Organic	Dioxins and Furans - Polychlorinated		X	X			bioaccumulates in tissues, persistent
Polybrominated diphenylethers	Organic	Polyhalogenated Polyphenyl		X	X			
Anthracene	Organic	Aromatic Hydrocarbon - Polycyclic		X				
Benzo(g,h,i)perylene	Organic	Aromatic Hydrocarbon - Polycyclic		X				
Pentachlorobenzene	Organic	Chlorobenzene		X				can accumulate in sediment
Tetrachlorobenzene (1,2,3,4-)	Organic	Chlorobenzene		X				no food chain magnification reported; persistent and immobile, especially in sediment
Tetrachlorobenzene (1,2,3,5-)	Organic	Chlorobenzene		X				no food chain magnification reported; persistent and immobile, especially in sediment
Tetrachlorobenzene (1,2,4,5-)	Organic	Chlorobenzene		X				no food chain magnification reported; persistent and immobile, especially in sediment
Tetraethyl lead	Organometals	Alkyl lead		X				
Tetramethyl lead	Organometals	Alkyl lead		X				
Trihalomethanes (total)	Organic	Aliphatic Hydrocarbon - Halogenated		X				
Benzo(a)anthracene	Organic	Aromatic Hydrocarbon - Polycyclic			X			may bioaccumulate in invertebrates, but not in higher order aquatic organisms e.g. fish, vertebrates able to metabolize, depuration rapid
Biphenyldiamine (4,4'-)	Organic	Hydrocarbons with N,P,S substitution			X			accumulates moderately in aquatic organisms
Chromium (trivalent and hexavalent)	Inorganic	Metal/Metalloid			X			toxicity increases with decreasing water hardness
Fluoranthene	Organic	Aromatic Hydrocarbon - Polycyclic			X			

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Methyl mercury	Organometals	Alkyl mercury			X			
Nonylphenol	Organic	Alkylphenol & Ethoxylates			X			more toxic (and estrogenic) than nonylphenol ethoxylate; little bioconcentration
Nonylphenol ethoxylate	Emerging	Alkylphenol & Ethoxylates			X			Under aerobic and anaerobic treatment conditions will biodegrade to more toxic (and estrogenic) metabolites; little bioconcentration
Pyrene	Organic	Aromatic Hydrocarbon - Polycyclic			X			
Selenium	Inorganic	Metal/Metalloid			X			
Xylene	Organic	Aromatic Hydrocarbon			X		X	toxicity level of xylene is isomer dependent
Zinc	Inorganic	Metal/Metalloid			X		X	bioaccumulates, but no evidence of biomagnification; toxicity increases with decreasing water hardness
Total organic carbon	Non-specific	Physical/Chemical				X	X	
Ammonia	Inorganic	Nutrient				X		toxicity dependent on pH and temperature
Nitrate	Inorganic	Nutrient				X		
Nitrite	Inorganic	Nutrient				X		
Phosphorus (total)	Inorganic	Nutrient				X		
Chloride	Inorganic	Anion					X	
Colour	Non-specific	Physical/Chemical					X	
Copper	Inorganic	Metal/Metalloid					X	toxicity increases with decreasing: water hardness, alkalinity, dissolved oxygen, chelating agents, humic acids, amino acids and suspended solids
Dichlorophenol (2,4-)	Organic	Chlorophenol					X	toxicity decreases as pH increases
Ethylbenzene	Organic	Alkyl benzene					X	
Iron	Inorganic	Metal/Metalloid					X	toxicity to invertebrates is variable
Manganese	Inorganic	Metal/Metalloid					X	
Oil and grease	Non-specific	Physical/Chemical					X	
Sodium	Inorganic	Metal/Metalloid					X	
Sulphate	Inorganic	Anion					X	
Sulphide (as H_2S)	Inorganic	Miscellaneous					X	
Tetrachlorophenol (2,3,4,6-)	Organic	Chlorophenol					X	
Toluene	Organic	Alkyl benzene					X	
Total dissolved solids	Non-specific	Physical/Chemical					X	
Turbidity	Non-specific	Physical/Chemical					X	
(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime	Organic	Aromatic Hydrocarbon - Halogenated						
2,4-D	Organic	Pesticide - Chlorophenoxy herbicide						
Acenaphthene	Organic	Aromatic Hydrocarbon - Polycyclic						
Acetaldehyde	Organic	Oxygenate - Acetaldehyde						
Acridine	Organic	Hydrocarbons with N,P,S substitution						
Acrolein	Organic	Oxygenated Compounds						does not bioaccumulate
Acrylamide	Organic	Hydrocarbons with N,P,S substitution						
Alalchlor	Organic	Pesticide - Chloroacetanilide						
Aldicarb	Organic	Pesticide - N-methyl carbamate						does not appear to bioaccumulate, toxicity increases with decreasing water hardness
Alkyl lead	Organometals	Alkyl lead						
Aluminum	Inorganic	Metal/Metalloid						toxicity increases when pH < 6.5
Antimony	Inorganic	Metal/Metalloid						aquatic plants more sensitive than fish or invertebrates
Aroclor 1254	Organic	Polyhalogenated Polyphenyl						
Atrazine	Organic	Pesticide - Triazine						
Azinphos-methyl	Organic	Pesticide - Organophosphorus						
Barium	Inorganic	Metal/Metalloid						

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Bendiocarb	Organic	Pesticide - N-methyl carbamate						
Benzidine dihydrochloride	Organic	Aromatic Hydrocarbon - Halogenated						adverse affects on fish when surface water concentrations >100ug/L; does not accumulate
Biochemical Oxygen Demand	Non-specific	Physical/Chemical						
Boron	Inorganic	Metal/Metalloid						
Bromacil	Organic	Pesticide - Uracil						
Bromochloromethane	Organic	Aliphatic Hydrocarbon - Halogenated						
Bromoxynil	Organic	Pesticide - Hydroxy benzonitrile						toxicity increases with decreasing pH
C10-13 chloroalkanes	Organic	Aliphatic Hydrocarbon - Halogenated						
Caffeine	Emerging	Pharmaceutical - Stimulant						
Calcium	Inorganic	Metal/Metalloid						
Captan	Organic	Pesticide - Thiophthalinide						more toxic to fish than invertebrates
Carbaryl	Organic	Pesticide - N-methyl carbamate						
Carbofuran	Organic	Pesticide - N-methyl carbamate						
Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)	Organic	Haloalcohol						
Chloramines (mono-, di-, tri-; organic, inorganic)	Inorganic	Disinfectant						fish less sensitive than invertebrates
Chlorate	Inorganic	Anion						
Chlorfenvinphos	Organic	Pesticide - Organophosphorus						
Chlorinated wastewater effluents	Non-specific	Miscellaneous						
Chlorine dioxide	Inorganic	Disinfectant						
Chlorite	Inorganic	Anion						
Chlorobenzene	Organic	Chlorobenzene						
Chlorophenol	Organic	Chlorophenol						
Chlorothalonil	Organic	Pesticide - Substituted benzene						
Chlorpyrifos	Organic	Pesticide - Organophosphorus						
Clofibric acid/clofibrate	Emerging	Pharmaceutical - Lipid Regulator						
Cobalt	Inorganic	Metal/Metalloid						
Cryptosporidium sp.	Biological	Pathogen - Protozoan						
Cyanazine	Organic	Pesticide - Triazine						no bioaccumulation, depuration rapid, algae are sensitive
Cyanide	Inorganic	Anion						toxicity affected by light intensity, temperature, dissolved oxygen levels, presence/concentration of other contaminants and presence of free CN
Cyanobacterial toxins (as Microcystin - LR)	Biological	Algal Toxin						
Cyanogen Chloride	Inorganic	Miscellaneous						
Deltamethrin	Organic	Pesticide - Pyrethroid						
Diazinon	Organic	Pesticide - Organophosphorus						hydrolysed slowly in water
Dibenzofuran	Organic	Dioxins and Furans						
Dibenzo-p-dioxin	Organic	Dioxins and Furans						
Dicamba	Organic	Pesticide - Benzoic acid						
Dichlorobromomethane	Organic	Aliphatic Hydrocarbon - Halogenated						
Dichloroethene (1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated						
Dichloropropane (1,2-)	Organic	Aliphatic Hydrocarbon - Halogenated						
Dichloropropene (1,2-) (cis and trans)	Organic	Aliphatic Hydrocarbon - Halogenated						
Dichlorprop	Organic	Pesticide - Chlorophenoxy herbicide						
Diclofop-methyl	Organic	Pesticide - Chlorophenoxy herbicide						
Dimethoate	Organic	Pesticide - Organophosphorus						does not appear to bioaccumulate; toxicity increases with decreasing levels of water hardness, increasing temperature and pH
Dimethylnaphthalene	Organic	Aromatic Hydrocarbon - Polycyclic						
Di-n-butyl phthalate	Organic	Oxygenate - Phthalic Ester						bioaccumulation unlikely, depuration rapid
Dinitropyrene	Organic	Hydrocarbons with N,P,S substitution						
Dinoseb	Organic	Pesticide - Dintrophenol derivative						toxicity reduced at higher pH levels

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Diquat	Organic	Pesticide - Bipyridylium						
Diuron	Organic	Pesticide - Urea-based						
Dodecyl dimethyl ammonium chloride	Organic	Pesticide - Quaternary Ammonium						
Endosulfan	Organic	Pesticide - Chlorinated hydrocarbon						fish most sensitive
Endrin	Organic	Pesticide - Chlorinated hydrocarbon						short biological half-life
Escherichia coli (*E. coli*)	Biological	Pathogen - Bacteria						
Estradiol	Emerging	Pharmaceuticals - Hormone						
Ethylene glycol	Organic	Oxygenate - Alcohol						contributes to oxygen depletion in aquatic systems, fish less sensitive
Ethylene oxide	Organic	Oxygenated - Epoxide						
Fecal coliforms	Biological	Pathogen - Bacteria						
Fluorene	Organic	Aromatic Hydrocarbon - Polycyclic						
Fluoride	Inorganic	Anion						
Giardia sp.	Biological	Pathogen - Protozoan						
Glyphosate	Organic	Pesticide - Phosphoroglycine						
Haloacetic acids	Organic	Halocarboxylic acids						
Haloacetonitriles	Organic	Haloacetonitrile						
Hardness	Non-specific	Physical/Chemical						
Iodo-2-propynyl butyl carbamate (3-)	Organic	Pesticide - Carbamate						
Isoproturon	Organic	Pesticide - Urea-based						
Lindane	Organic	Pesticide - Chlorinated hydrocarbon						warm water fish more tolerant than cold water, depuration rates are rapid
Lithium	Inorganic	Metal/Metalloid						
Magnesium	Inorganic	Metal/Metalloid						
Malathion	Organic	Pesticide - Organophosphorus						
MCPA	Organic	Pesticide - Chlorophenoxy herbicide						
Methyl bromide	Organic	Aliphatic Hydrocarbon - Halogenated						
Methyl t-butyl ether	Organic	Oxygenate - Ether						
Methylenebis(2-chloroaniline) (4,4'-)	Organic	Hydrocarbons with N,P,S substitution						
Methyl-parathion	Organic	Pesticide - Bipyridylium						
Metolachlor	Organic	Pesticide - Chloroacetanilide						
Metribuzin	Organic	Pesticide - Triazinone						does not appear to bioaccumulate
Molybdenum	Inorganic	Metal/Metalloid						
Nickel	Inorganic	Metal/Metalloid						toxicity increases with decreasing water hardness
Nitrilotriacetic acid	Organic	Hydrocarbons with N,P,S substitution						
Octylphenol	Organic	Alkylphenol & Ethoxylates						
Perylene	Organic	Aromatic Hydrocarbon - Polycyclic						
pH	Non-specific [a]	Physical/Chemical						toxicity of several common pollutants may increase with increasing acidity or alkalinity
Phenanthrene	Organic	Aromatic Hydrocarbon - Polycyclic						
Phenols, Total	Organic	Aromatic Hydrocarbon						
Phorate	Organic	Pesticide - Organophosphorus						
Phthalic acid esters	Organic	Oxygenate - Phthalic Ester						
Picloram	Organic	Pesticide - Pyridine carboxylic acid						
Polybrominated biphenyls	Organic	Polyhalogenated Polyphenyl						
Polychlorinated terphenyls	Organic	Polyhalogenated Polyphenyl						
Polycyclic hydrocarbons	Organic	Aromatic Hydrocarbon - Polycyclic						
Propylene glycol (1,2-)	Organic	Oxygenate - Alcohol						
Propylene glycol (1,3-)	Organic	Oxygenate - Alcohol						1,3-PG isomer may be more toxic than 1,2-PG isomer
Protozoa	Biological	Pathogen - Protozoan						
Resin Acids	Organic	Oxygenate- Carboxylic Acid						
Silver	Inorganic	Metal/Metalloid						toxicity increases with decreasing water hardness

Table A.4. Categorization of Substances by Environmental Effects

Substance Name	Main Class	Sub-class	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
			Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Simazine	Organic	Pesticide - Triazine						does not appear to bioaccumulate or biomagnify, rapid depuration in fish
Styrene	Organic	Aromatic Hydrocarbon						high volatility
Tebuthiuron	Organic	Pesticide - Urea-based						
Temephos	Organic	Pesticide - Organophosphorus						
Temperature	Non-specific [a]	Physical/Chemical						
Terbufos	Organic	Pesticide - Organophosphorus						
Tetrachloroethylene	Organic	Aliphatic Hydrocarbon - Halogenated						more acutely toxic than di- or tri-
Tetrachloromethane	Organic	Aliphatic Hydrocarbon - Halogenated						
Thallium	Inorganic	Metal/Metalloid						
Tin	Inorganic	Metal/Metalloid						
Total residual chlorine	Non-specific	Physical/Chemical						
Total suspended solids	Non-specific	Physical/Chemical						
Triallate	Organic	Pesticide - Thiocarbamate						
Tributyltetradecylphosphonium chloride	Emerging	Hydrocarbons with N,P,S substitution						
Tributyltin	Organometals	Alkyl Tin						
Trichlorobenzene (1,2,3-)	Organic	Chlorobenzene						
Trichlorobenzene (1,2,4-)	Organic	Chlorobenzene						
Trichlorobenzene (1,3,5-)	Organic	Chlorobenzene						
Trichloroethane (1,1,1-)	Organic	Aliphatic Hydrocarbon - Halogenated						
Trichloroethylene	Organic	Aliphatic Hydrocarbon - Halogenated						
Trichlorophenoxyacetic acid (2,4,5-)	Organic	Pesticide - Chlorophenoxy herbicide						
Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)	Organic	Pesticide - Chlorophenoxy herbicide						
Tricyclohexyltin	Organometals	Alkyl Tin						
Triethyl lead	Organometals	Alkyl lead						
Triphenyltin	Organometals	Aromatic Tin						
Uranium	Inorganic	Metal/Metalloid						
Vanadium	Inorganic	Metal/Metalloid						
Viruses	Biological	Pathogen - Virus						

[a] - Canadian Water Quality Guidelines 1987

[b] - NPRI 2005, www.ec.gc.ca/pdb/npri/npri_si_e.cfm

[c] - Integrated Risk Information System (IRIS), www.epa.gov/iris/

[d] - Toxics Release Inventory (TRI) Public Data Release Report 2001, www.epa.gov/tri/chemical/oshacarc.htm

[e] - USEPA National Recommended Water Quality Criteria, 2002, www. epa.gov/waterscience/standards/wqcriteria.html (chronic criteria given unless acute criteria only available)

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)		1.5						
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)	100/100mL							
Biological	Pathogen - Bacteria	Fecal coliforms								
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.								
Biological	Pathogen - Protozoan	*Giardia* sp.								
Biological	Pathogen - Protozoan	Protozoa								
Biological	Pathogen - Virus	Viruses								
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	0.7				X			Under aerobic and anaerobic treatment conditions will biodegrade to more toxic (and estrogenic) metabolites; little bioconcentration
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine			X					
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride								
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate								
Emerging	Pharmaceutical - Stimulant	Caffeine								
Emerging	Pharmaceuticals - Hormone	Estradiol								
Inorganic	Anion	Bromate		10	X					
Inorganic	Anion	Chlorate								
Inorganic	Anion	Chloride	230000	= 250000					X	
Inorganic	Anion	Chlorite								
Inorganic	Anion	Cyanide	5	200						toxicity affected by light intensity, temperature, dissolved oxygen levels, presence/concentration of other contaminants and presence of free CN
Inorganic	Anion	Fluoride	120	1500						
Inorganic	Anion	Sulphate	= 1000000	= 500000					X	
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)	0.5	3000						fish less sensitive than invertebrates
Inorganic	Disinfectant	Chlorine dioxide								
Inorganic	Metal/Metalloid	Aluminum	5-100	100						toxicity increases when pH < 6.5
Inorganic	Metal/Metalloid	Antimony	20	6						aquatic plants more sensitive than fish or invertebrates
Inorganic	Metal/Metalloid	Arsenic	5	25	X		X			humans more sensitive than aquatic life, invertebrates more sensitive than fish, invertebrates may accumulate in tissues, not fish; high temperatures increase toxicity
Inorganic	Metal/Metalloid	Barium	1000	1000						
Inorganic	Metal/Metalloid	Beryllium	11		X					does not appear to biomagnify in fresh water; toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Boron	200	5000						
Inorganic	Metal/Metalloid	Cadmium	0.0025-0.097	5	X		X			little evidence for biomagnification, toxicity varies with water hardness, pH, temperature & presence of organic compounds, selenium and mixtures of metals
Inorganic	Metal/Metalloid	Calcium	1000000							
Inorganic	Metal/Metalloid	Chromium (hexavalent)	1	50 total	X		X			phytoplankton more sensitive than fish; toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Chromium (trivalent)	8.9				X			toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Cobalt	0.9							
Inorganic	Metal/Metalloid	Copper	2-4	= 1000					X	toxicity increases with decreasing: water hardness, alkalinity, dissolved oxygen, chelating agents, humic acids, amino acids and suspended solids
Inorganic	Metal/Metalloid	Iron	300	= 300					X	toxicity to invertebrates is variable

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Inorganic	Metal/Metalloid	Lead	1-7	10	X					no apparent biomagnification; toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Lithium	2500							
Inorganic	Metal/Metalloid	Magnesium	800-3800	200						
Inorganic	Metal/Metalloid	Manganese	200	= 50					X	
Inorganic	Metal/Metalloid	Mercury	0.016	1		X	X			bottom feeders generally contain more mercury than do water column feeders; acute toxicity in fish increases with increasing temperature
Inorganic	Metal/Metalloid	Molybdenum	73							
Inorganic	Metal/Metalloid	Nickel	25-150							toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Selenium	1	10			X			
Inorganic	Metal/Metalloid	Silver	0.1							toxicity increases with decreasing water hardness
Inorganic	Metal/Metalloid	Sodium		= 200000					X	
Inorganic	Metal/Metalloid	Thallium	0.8							
Inorganic	Metal/Metalloid	Tin	= 24							
Inorganic	Metal/Metalloid	Uranium	5	20						
Inorganic	Metal/Metalloid	Vanadium	6							
Inorganic	Metal/Metalloid	Zinc	30	= 5000			X		X	bioaccumulates, but no evidence of biomagnification; toxicity increases with decreasing water hardness
Inorganic	Miscellaneous	Cyanogen Chloride								
Inorganic	Miscellaneous	Sulphide (as H_2S)	2	50					X	
Inorganic	Nutrient	Ammonia	19					X		toxicity dependent on pH and temperature
Inorganic	Nutrient	Nitrate	13000	45000				X		
Inorganic	Nutrient	Nitrite	60	3200				X		
Inorganic	Nutrient	Phosphorus (total)	0.1					X		
Non-specific	Miscellaneous	Chlorinated wastewater effluents								
Non-specific	Physical/Chemical	Biochemical Oxygen Demand								
Non-specific	Physical/Chemical	Colour		= 15 TCU					X	
Non-specific	Physical/Chemical	Hardness								
Non-specific	Physical/Chemical	Oil and grease							X	
Non-specific	Physical/Chemical	Total dissolved solids		= 500000					X	
Non-specific	Physical/Chemical	Total organic carbon						X	X	
Non-specific	Physical/Chemical	Total residual chlorine								
Non-specific	Physical/Chemical	Total suspended solids								
Non-specific	Physical/Chemical	Turbidity	changes in Secchi disk readings < 10%	1 NTU					X	
Non-specific [a]	Physical/Chemical	pH	6.5-9.0	6.5-8.5						toxicity of several common pollutants may increase with increasing acidity or alkalinity
Non-specific [a]	Physical/Chemical	Temperature		= 15°C						
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)			X					
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane								
Organic	Aliphatic Hydrocarbon - Halogenated	Bromoform	60		X					
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes								
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	1.8		X	X				low affinity for organic carbon & lipids, may persist in groundwater, does not appear to bioconcentrate in animals
Organic	Aliphatic Hydrocarbon - Halogenated	Dibromochloromethane	40	50	X					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichlorobromomethane	100							
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,1-)	200		X					

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	100	5	X					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,1-)	40	14	X					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,2-)	200							
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloromethane	98.1	50	X					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropane (1,2-)	0.7							
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropene (1,2-) (cis and trans)	7							
Organic	Aliphatic Hydrocarbon - Halogenated	Hexachloro-1,3-butadiene	1.3		X		X			depuration rate rapide, accumulates in aquatic organisms
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	0.9							
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene	600	2	X					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	20		X					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,2,2-)	70		X					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	111	30						more acutely toxic than di- or tri-
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloromethane	13.3	5						
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	10							
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,2-)	800		X					
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethylene	21	50						
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)		100		X				
Organic	Alkyl benzene	Ethylbenzene	25	= 2.4					X	
Organic	Alkyl benzene	Toluene	2	= 24					X	
Organic	Alkylphenol & Ethoxylates	Nonylphenol	0.7				X			more toxic (and estrogenic) than nonylphenol ethoxylate; little bioconcentration
Organic	Alkylphenol & Ethoxylates	Octylphenol								
Organic	Aromatic Hydrocarbon	Benzene	110	5	X					fish more sensitive than invertebrates, depuration in fish rapid
Organic	Aromatic Hydrocarbon	Phenols, Total	4							
Organic	Aromatic Hydrocarbon	Styrene	72							high volatility
Organic	Aromatic Hydrocarbon	Xylene	2-30	= 300			X		X	toxicity level of xylene is isomer dependent
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime								
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride								adverse affects on fish when surface water concentrations >100ug/L; does not accumulate
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	0.6		X	X	X			bioaccumulates in aquatic organisms
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene				X	X			
Organic	Aromatic Hydrocarbon - Polycyclic	Acenaphthene	5.8							
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	0.012			X				
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	0.018				X			may bioaccumulate in invertebrates, but not in higher order aquatic organisms e.g. fish, vertebrates able to metabolize, depuration rapid
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	0.015	0.01	X	X				
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene			X	X				
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	0.00002			X				
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	0.0002		X	X				
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene			X					
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	0.002		X		X			
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	0.02							
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	0.04				X			
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	3							
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene			X					
Organic	Aromatic Hydrocarbon - Polycyclic	Naphthalene	1.1		X					
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	0.00007							
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	0.4							
Organic	Aromatic Hydrocarbon - Polycyclic	Polycyclic hydrocarbons								
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	0.025				X			

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Organic	Chlorobenzene	Chlorobenzene	1.3	80						
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	0.7	200		X	X			
Organic	Chlorobenzene	Dichlorobenzene (1,3-)	150			X	X			
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	26	5		X	X			
Organic	Chlorobenzene	Hexachlorobenzene	0.0065		X	X	X			readily bioaccumulates
Organic	Chlorobenzene	Pentachlorobenzene	6			X				can accumulate in sediment
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,4-)	1.8			X				no food chain magnification reported; persistent and immobile, especially in sediment
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,5-)	0.1			X				no food chain magnification reported; persistent and immobile, especially in sediment
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,4,5-)	0.1			X				no food chain magnification reported; persistent and immobile, especially in sediment
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	8							
Organic	Chlorobenzene	Trichlorobenzene (1,2,4-)	24							
Organic	Chlorobenzene	Trichlorobenzene (1,3,5-)	0.65							
Organic	Chlorophenol	Chlorophenol	7							
Organic	Chlorophenol	Dichlorophenol (2,4-)	0.2	900					X	toxicity decreases as pH increases
Organic	Chlorophenol	Pentachlorophenol	0.5	60	X				X	impairs flavour of edible portions of fish; toxicity increases with increasing chlorine substitution, chronic affect concentration for young rainbow trout increased with decreasing temperature
Organic	Chlorophenol	Tetrachlorophenol (2,3,4,6-)	1	100					X	
Organic	Chlorophenol	Trichlorophenol (2,4,6-)	18	5	X				X	
Organic	Dioxins and Furans	Dibenzofuran	0.3							
Organic	Dioxins and Furans	Dibenzo-p-dioxin								
Organic	Dioxins and Furans - Polychlorinated	PCDD				X	X			bioaccumulates in tissues, persistent
Organic	Dioxins and Furans - Polychlorinated	PCDF				X	X			bioaccumulates in tissues, persistent
Organic	Haloacetonitrile	Haloacetonitriles								
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)								
Organic	Halocarboxylic acids	Haloacetic acids								
Organic	Haloether	Bis(chloromethyl)ether			X					
Organic	Haloether	Chloromethyl methyl ether			X					
Organic	Hydrocarbons with N,P,S substitution	Acridine	4.4							
Organic	Hydrocarbons with N,P,S substitution	Acrylamide								
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile			X					
Organic	Hydrocarbons with N,P,S substitution	Aniline	2.2	100	X					short half-life, no apparent bioaccumulation in aquatic life, invertebrates more sensitive than fish
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)					X			accumulates moderately in aquatic organisms
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene								
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)								
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid		400						
Organic	Hydrocarbons with N,P,S substitution	Quinoline	3.4		X					
Organic	Oxygenate - Acetaldehyde	Acetaldehyde								
Organic	Oxygenate - Acetaldehyde	Formaldehyde	0.8		X					
Organic	Oxygenate - Alcohol	Ethylene glycol	192000							contributes to oxygen depletion in aquatic systems, fish less sensitive
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	500000							
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	500000							1,3-PG isomer may be more toxic than 1,2-PG isomer
Organic	Oxygenate - Ether	Methyl t-butyl ether	10000	20						
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	16	50000	X	X	X			persistent under anaerobic conditions

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	19							bioaccumulation unlikely, depuration rapid
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters								
Organic	Oxygenate- Carboxylic Acid	Resin Acids								
Organic	Oxygenated - Epoxide	Ethylene oxide								
Organic	Oxygenated Compounds	Acrolein								does not bioaccumulate
Organic	Pesticide - Benzoic acid	Dicamba	10	120						
Organic	Pesticide - Bipyridylium	Diquat	0.5	70						
Organic	Pesticide - Bipyridylium	Methyl-parathion								
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)		10	X	X				
Organic	Pesticide - Carbamate	Iodo-2-propynyl butyl carbamate (3-)	1.9							
Organic	Pesticide - Chlorinated hydrocarbon	Aldrin	1.3	0.7	X	X	X			persistent, lipid soluble, biomagnifies
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	0.004	7	X	X	X			persistent, bioaccumulates
Organic	Pesticide - Chlorinated hydrocarbon	DDD				X	X			
Organic	Pesticide - Chlorinated hydrocarbon	DDE				X	X			
Organic	Pesticide - Chlorinated hydrocarbon	DDT	0.001	30		X	X			bioaccumulates, invertebrates most sensitive
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	0.0019	0.7	X	X	X			persistent, lipid soluble, biomagnifies
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	0.02							fish most sensitive
Organic	Pesticide - Chlorinated hydrocarbon	Endrin	0.0023							short biological half-life
Organic	Pesticide - Chlorinated hydrocarbon	Heptachlor + Heptachlor epoxide	0.0036	3	X	X				fish less sensitive than invertebrates, persistent in aquatic environments
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	0.01	4						warm water fish more tolerant than cold water, depuration rates are rapid
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	0.03	900	X	X				
Organic	Pesticide - Chlorinated hydrocarbon	Mirex	0.001			X	X			
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	0.0002		X	X	X			persistent, extremely toxic to fish
Organic	Pesticide - Chloroacetanilide	Alalchlor								
Organic	Pesticide - Chloroacetanilide	Metolachlor	7.8	50						
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	4	100						
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop								
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	6.1	9						
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	2.6							
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	4	280						
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)								
Organic	Pesticide - Dinitroaniline-based	Trifluralin	0.2	45	X					
Organic	Pesticide - Dintrophenol derivative	Dinoseb	0.05	10						toxicity reduced at higher pH levels
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	5	5						toxicity increases with decreasing pH
Organic	Pesticide - N-methyl carbamate	Aldicarb	0.15	9						does not appear to bioaccumulate, toxicity increases with decreasing water hardness
Organic	Pesticide - N-methyl carbamate	Bendiocarb		40						
Organic	Pesticide - N-methyl carbamate	Carbaryl	0.2	90						
Organic	Pesticide - N-methyl carbamate	Carbofuran	1.8	90						
Organic	Pesticide - Organophosphorus	Azinphos-methyl		20						
Organic	Pesticide - Organophosphorus	Chlorfenvinphos								
Organic	Pesticide - Organophosphorus	Chlorpyrifos	0.002	90						
Organic	Pesticide - Organophosphorus	Diazinon	0.08	20						hydrolysed slowly in water
Organic	Pesticide - Organophosphorus	Dimethoate	6.2	20						does not appear to bioaccumulate; toxicity increases with decreasing levels of water hardness, increasing temperature and pH
Organic	Pesticide - Organophosphorus	Malathion	0.1	190						
Organic	Pesticide - Organophosphorus	Parathion	0.013	50	X	X				
Organic	Pesticide - Organophosphorus	Phorate		2						
Organic	Pesticide - Organophosphorus	Temephos								
Organic	Pesticide - Organophosphorus	Terbufos		1						
Organic	Pesticide - Phosphoroglycine	Glyphosate	65	280						

Table A.5. Toxicological Characteristics of Selected Parameters

Main Class	Sub-class	Substance Name	Environmental Effect Benchmark Concentration (ug/L)	Drinking Water Effect Benchmark Concentration (ug/L)	Human Health and Environmental Effects[a, b, c, d]					Other Key Properties[a, b, e]
					Known or Possible Carcinogen	Persistent	Bio-accumulates	Nutrient	Aesthetic	
Organic	Pesticide - Pyrethroid	Deltamethrin	0.0004							
Organic	Pesticide - Pyridine carboxylic acid	Picloram	29	190						
Organic	Pesticide - Quaternary Ammonium	Dodecyl dimethyl ammonium chloride	1.5							
Organic	Pesticide - Substituted benzene	Chlorothalonil	0.18	2						
Organic	Pesticide - Thiocarbamate	Triallate	0.24	230						
Organic	Pesticide - Thiophthalinide	Captan	1.3							more toxic to fish than invertebrates
Organic	Pesticide - Triazine	Atrazine	1.8	5						
Organic	Pesticide - Triazine	Cyanazine	2	10						no bioaccumulation, depuration rapid, algae are sensitive
Organic	Pesticide - Triazine	Simazine	10	10						does not appear to bioaccumulate or biomagnify, rapid depuration in fish
Organic	Pesticide - Triazinone	Metribuzin	1	80						does not appear to bioaccumulate
Organic	Pesticide - Uracil	Bromacil	5							
Organic	Pesticide - Urea-based	Diuron	1.6	150						
Organic	Pesticide - Urea-based	Isoproturon								
Organic	Pesticide - Urea-based	Linuron	7		X					
Organic	Pesticide - Urea-based	Tebuthiuron								
Organic	Polyhalogenated Polyphenyl	Aroclor 1254								
Organic	Polyhalogenated Polyphenyl	PCBs	0.014	3	X	X	X			highly lipophilic, bioconcentrate to high concentrations in tissues
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls								
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers				X	X			
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls								
Organometals	Alkyl lead	Alkyl lead								
Organometals	Alkyl lead	Tetraethyl lead	0.0007			X				
Organometals	Alkyl lead	Tetramethyl lead	0.006			X				
Organometals	Alkyl lead	Triethyl lead	0.4							
Organometals	Alkyl mercury	Methyl mercury	0.004				X			
Organometals	Alkyl Tin	Tributyltin	0.001							
Organometals	Alkyl Tin	Tricyclohexyltin	250							
Organometals	Aromatic Tin	Triphenyltin	0.022							

[a] - Canadian Water Quality Guidelines 1987

[b] - NPRI 2005, www.ec.gc.ca/pdb/npri/npri_si_e.cfm

[c] - Integrated Risk Information System (IRIS), www.epa.gov/iris/

[d] - Toxics Release Inventory (TRI) Public Data Release Report 2001, www.epa.gov/tri/chemical/oshacarc.htm

[e] - USEPA National Recommended Water Quality Criteria, 2002, www. epa.gov/waterscience/standards/wqcriteria.html (chronic criteria given unless acute criteria only available)

Table A.6. Categorization of Substances by Level of Process Treatment

	Treatment Technonlogy						
Substance of Concern	**Lagoon**	**Primary Treatment**	**Conventional CAS, non-nitrify**	**Nitrify CAS**	**Nitrify CAS + filter**	**BNR**	**Nitrify CAS + RO**
2,4-D	Moderate	Poor	Poor	Poor	Poor	Poor	Good
Aluminum	Poor	Moderate	Moderate	Moderate	Good	Good	Excellent
Ammonia	Excellent	Poor	Moderate	Excellent	Excellent	Excellent	Excellent
Anthracene	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Antimony[1]	Poor	Poor	Moderate	Moderate	Moderate	Moderate	Excellent
Arsenic[1]	Poor	Poor	Poor	Poor	Poor	Poor	Good
Barium[1]	Good	Poor	Moderate	Good	Good	Good	Excellent
Benzo(a)anthracene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
Benzo(a)pyrene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
Benzo(g,h,i)perylene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
Benzo(k)fluoranthene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
Bis(2-ethylhexyl)phthalate	Excellent	Poor	Good	Good	Good	Excellent	Excellent
Boron	Moderate	Poor	Moderate	Moderate	Moderate	Moderate	Excellent
Cadmium	Poor	Poor	Poor	Poor	Good	Moderate	Excellent
Chlordane	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Chloroform	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Chlorophenol	Excellent	Poor	Moderate	Moderate	Good	Good	Excellent
Chromium (hexavalent)	Moderate	Moderate	Moderate	Good			Excellent
Chromium (trivalent)					Excellent	Good	Excellent
Cobalt[1]	Moderate	Poor	Poor	Poor	Poor	Poor	Excellent
Copper	Poor	Poor	Moderate	Moderate	Moderate	Moderate	Excellent
Cyanide [1]	Moderate	Poor[2]	Moderate[2]	Moderate[2]	Moderate[1]	Moderate[1]	Excellent
DDT	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Dibenzo(a,h)anthracene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
Dichlorobenzene (1,2-)	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Dichlorobenzene (1,4-)	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Dichloroethane (1,2-)	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Dichlorophenol (2,4-)	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Dimethylnaphthalene	Excellent	Moderate	Good	Good	Good	Excellent	Excellent
Di-n-butyl phthalate	Excellent	Poor	Good	Good	Good	Excellent	Excellent
Endosulfan	Excellent	Poor	Poor	Poor	Poor	Poor	Good
Ethylbenzene	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Fluoranthene	Excellent	Poor	Good	Excellent	Excellent	Excellent	Excellent
Fluorene	Excellent	Moderate	Excellent	Excellent	Excellent	Excellent	Excellent
Fluoride [1]	Poor	Poor	Poor	Poor	Poor	Poor	Good
Iron [1]	Moderate	Moderate	Good	Good	Good	Good	Excellent
Lead	Poor	Poor	Poor	Poor	Poor	Poor	Excellent
Lindane	Excellent	Poor	Poor	Poor	Poor	Poor	Good
Magnesium [1]	Poor	Poor	Poor	Poor	Poor	Poor	Good
Manganese [1]	Moderate	Poor	Poor	Poor	Poor	Poor	Good
MCPA	Moderate	Poor	Poor	Poor	Poor	Poor	Good
Mercury	Poor	Moderate	Moderate	Moderate	Moderate	Good	Excellent
Nickel	Poor	Poor	Poor	Poor	Poor	Poor	Excellent
Nitrate[1]	Poor	Poor	Poor	Poor	Poor	Excellent	Good
Nitrite[1]	Poor	Poor	Poor	Poor	Poor	Excellent	Good
N-Nitrosodimethylamine	Excellent	Poor	Poor	Poor	Poor	Moderate	Good
Nonylphenol	Excellent	Poor	Good	Good	Good	Excellent	Excellent
Nonylphenol ethoxylate[1]	Excellent	Poor[4]	Excellent	Excellent[1]	Excellent	Excellent	Excellent
Perylene	Excellent	Moderate	Good	Excellent	Excellent	Excellent	Excellent
pH	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Phenols, Total	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Phosphorus (total)[1]	Good[3]	Poor	Good	Good	Excellent	Excellent	Excellent
Pyrene	Excellent	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Quinoline	Excellent	Poor	Moderate	Good	Good	Good	Excellent
Selenium	Poor	Poor	Poor	Poor	Poor	Poor	Good
Silver [1]	Good	Moderate	Good	Good	Good	Good	Excellent
Sulphide (as H_2S)	Excellent (Summer) Poor (Winter)	Poor	Excellent	Excellent	Excellent	Excellent	Excellent
Tetrachloroethylene	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Toluene	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Trichloroethane (1,1,1-)	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Trichlorophenoxyacetic acid (2,4,5-)	Moderate	Poor	Poor	Poor	Poor	Poor	Poor
Turbidity[1]	Good	Poor	Good	Good	Excellent	Excellent	Excellent
Vanadium	Moderate	Poor	Moderate	Moderate	Moderate	Moderate	Excellent
Zinc	Poor	Poor	Poor	Poor	Poor	Poor	Excellent

[1] based on professional judgement
[2] EPA (1982)
(3) assumes chemical phosphorus removal
[4] Giger et al, 1987

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime	94097-88-8	325320 - Pesticide and Other Agricultural Chemical Mfg		PIC 2005
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	94-75-7	325320 - Pesticide and Other Agricultural Chemical Mfg	diffusive, non-point source (parks, lawns)	per Makepeace et al. (1995)
Organic	Aromatic Hydrocarbon - Polycyclic	Acenaphthene	83-32-9	325190- Chemical mfg (other)	diffusive, non-point (auto tire particles, road oils, atmos. deposition	CWWA. 2000; per Makepeace et al. (1995)
Organic	Oxygenate - Acetaldehyde	Acetaldehyde	75-07-0	325199 - Acetaldehyde mfg; 311999 - nutritional yeast mfg		U.S. Census. 2005.
Organic	Hydrocarbons with N,P,S substitution	Acridine	260-94-6			
Organic	Oxygenated Compounds	Acrolein	107-02-8	325199 - acrolein mfg		U.S. Census. 2005.
Organic	Hydrocarbons with N,P,S substitution	Acrylamide	79-06-1	32519 Chemical mfrs and importers; 22132 - municipalities in sewer grouting; 23491 - grouting & sewer rehabilitating contractors		EPA 2005
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile	107-13-1	325190- Chemical mfg (other)		CWWA. 2000
Organic	Pesticide - Chloroacetanilide	Alalchlor	15972-60-8	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005
Organic	Pesticide - N-methyl carbamate	Aldicarb	116-06-3	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005
Organic	Pesticide - Chlorinated hydrocarbon	Aldrin	309-00-2	Banned in Canada since end of 1995; diffusive, non-point		ITK 2005; per Makepeace et al. (1995)
Organo-metals	Alkyl lead	Alkyl lead	EDF-171	325190- Chemical mfg (other)		CWWA. 2000
Inorganic	Metal/Metalloid	Aluminum	39148-24-8	333317- Aluminum rolling, drawing, extruding and alloying; 415110 - automobile and light duty truck wholesalers/distributors; automotive parts and accessories stores; automotive repair (general); 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325 - chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 331221 - cold-rolled steel shape mfg; 33422 - die-casting foundries (non-ferrous); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (Mainline); 4832112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - Hotels (except casino hotels) and motels; 33111 - iron and steel mills and ferro-alloy mfg; 541380 - Laboratories (testing); 812330 - linen & uniform supply; 488320 - marine cargo handling; 562920 - material recovery facilities; 331410 - metal smelting and refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge mfg; 332321metal window and door mfg; 332810 - metals-coating and allied activities; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg - other; 415290 - motor vehicle parts wholesaler/distributors (others-new); 51111 - newspaper publishers; 332329 - ornamental metal products mfrs (others); 322121 - paper (excepts newsprint) mills; 812930 - parking lots & garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition and locker mfg; 321112 - shingle and shake mills; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31331 - textile & fabric finishing; 485110 - urban transit systems; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other)	domestic wastewater (personal care products)	CWWA (2000)
Inorganic	Nutrient	Ammonia	7664-41-7	32552 - adhesive mfg; 324122 - asphalt shingle & coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 31212 - breweries; 56174 - carpet & upholstery cleaning services; 325313 - chemical fertilizer (except potash) mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 31132 - chocolate & confectionery mfg; 33410 - computer and peripheral mfg; 621210 - dental offices; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 325920 - explosives mfg; 722 - Food services and drinking places; 331529 - foundries (non-ferrous except die-casting); 311420 - Fruit & Vegetable Canning, pickling and drying; 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - Hotels (except casino hotels) and motels; 331511 - iron foundries; 541380 - Laboratories (testing); 31611 - Leather & hide tanning & finishing; 562920 - material recovery facilities; 332999 - metal product mfg (all other misc.); 327990 - mineral product mfg (all other non-metallic); 812930 - parking lots & garages; 325320 - pesticide & other agricultural chemical mfg; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				(Other); 32411 - petroleum refineries; 325410 - pharmaceutical and medicine mfg; 81292 - photo finishing services; 562910 - remediation services; 325210 - resin & synthetic rubber mfg; 311940 - seasoning & dressing mfg; 334410 - semiconductor mfg; 325610 - soap & cleaning compounds mfg; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 221310 - water supply & irrigation systems		
Organic	Hydrocarbons with N,P,S substitution	Aniline	62-53-3	polyurethane foam, agricultural chemicals, synthetic dyes, antioxidants, stabilizers for the rubber industry, herbicides, varnishes and explosives.		
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	65996-97-0	Source of dyestuffs (manufacture of alizarin dyes), chemical intermediate for dyes, raw material for anthraquinone; also in production of synthetic fibers, plastics and monocrystals, as a component of smoke screens, as scintillation counter crystals; in semiconductor research		Spectrum Laboratories 2005
Inorganic	Metal/Metalloid	Antimony	7440-36-0	325190 - chemical mfg (other basic organic); 327214 - glass mfg		CWWA (2000)
Organic	Polyhalogenated Polyphenyl	Aroclor 1254	11097-69-1	no longer used in North America; diffusive, non-point		per Makepeace et al. (1995)
Inorganic	Metal/Metalloid	Arsenic	7440-38-2	415110 - automobile and light duty truck wholesalers/distributors; automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 212233 - copper-zing ore mining; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 721111 - Hotels (except casino hotels) and motels; 21221 - iron ore mining; 541380 - Laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 212299 - metal ore mining (all other); 331410 - metal smelting & refining (non-ferrous except aluminum); 332810 - metals coating & allied products; 212232 - nickel-copper ore mining; 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 32411 - petroleum refineries; 325410 - pharmaceutical and medicine mfg; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 321112 - shingle & shake mills; 221330 - steam & air (conditioning and supply); 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation		CWWA. 2000
Organic	Pesticide - Triazine	Atrazine	1912-24-9	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005; per Makepeace et al. (1995)
Organic	Pesticide - Organophosphorus	Azinphos-methyl	86-500-0	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005; per Makepeace et al. (1995)
Inorganic	Metal/Metalloid	Barium	7440-39-3	Carrier for radium; alloys of barium with aluminum or magnesium are used as getters in electronic tubes; emissions from (140)ba contribute to fission products of uranium rods. emissions from (133)barium & (137m)ba are used as std in gamma-spectrometry. deoxidizer for copper; fray's metal; lubricant for anode rotors in x-ray tubes; spark-plug alloys. Used in paints, soap, paper and rubber, and in mfr ceramics and glass; used as a component in various proprietary nodularizing and deoxidizing alloys, Used extensively in manufacture of alloys for such products as nickel barium parts, used in ignition equipment for automobiles and in manufacture of lithopone, glass, ceramics and television picture tubes. used as a loader for paper, soap, rubber and linoleum; in radio industry for cleaning up last traces of gas in vacuum tubes. as heat stabilizer for plastics. The largest end use of barium is as a "getter" to remove the last traces of gases from vacuum and television picture tubes. It is also used to improve performance of lead alloy grids of acid batteries, as a component of grey and ductile irons, and in the manufacture of steel, copper and other metals.		Spectrum Laboratories 2005
Organic	Pesticide - N-methyl carbamate	Bendiocarb	22781-23-3	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, diffusive, non-point (crop and animal spraying)		Spectrum Laboratories 2005
Organic	Aromatic Hydrocarbon	Benzene	1076-43-3	811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 325190 - chemical mfg (other basic organic); 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 331511 - iron foundries; 541380 - Laboratories (testing); 812330 - linen & uniform supply; 482114 - passenger rail transportation; 32511 - petrochemical mfg; 32411 - petroleum refineries; 562910 - remediation services; 331514 - steel foundries; 485110 - urban transit systems; 562990 - waste management services (all other)		CWWA. 2000
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride	531-85-1	intermediate in production of dyes and pigments		
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	56-55-3	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	50-32-8	331511 - Iron foundries; 331514 - steel foundries	diffusive, non-point (auto tire particles, road oils, atmos. Deposition	CWWA. 2000; per Makepeace et al. (1995)
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene	205-99-2	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. Deposition	CWWA. 2000; per Makepeace et al. (1995)
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	191-24-2	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. Deposition	CWWA. 2000; per Makepeace et al. (1995)
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	207-08-9	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos.deposition	CWWA. 2000; per Makepeace et al. (1995)
Inorganic	Metal/Metalloid	Beryllium	7440-41-7	aerospace foundries, beryllium extraction nuclear reactors; fabrication & smelting; ceramics in nuclear weapons; dental alloys and prosthesis plating; electronics telecommunications tool and die mfg; heat-treating of gemstones		Tuscon 2005
Non-specific	Physical/Chemical	Biochemical Oxygen Demand		327910 abrasive product mfg; 32552 adhesive mfg; 488119 airport operations (other); 311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 324122 - asphalt shingle and coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; 811121 - Automotive body, paint and interior repair & maintenance; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 31212 - breweries; 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325 - chemical mfg; 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 31132 - chocolate & confectionery mfg; 31192 - coffee and tea mfg; 323113 - commercial screen printing; 31134 - confectionery mfg (non-chocolate); 311821 - cookie & cracker mfg; 325991 - custom compounding of purchased resins; 315210 - cut & sew clothing contracting; 332210 - cutlery & hand tool mfg; 331523 - die-casting foundries (non-ferrous); 312140 - distilleries; 81232 - dry cleaning & laundry services (except coin-operated); 611 - educational services; 325920 - explosives mfg; 311211 - flour milling; 311822 - flour mixes& dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 722 - food services & drinking places; 413110 - food wholesaler-distributors (general-line); 413190 - food wholesaler-distributors (specialty-line); 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (Mainline); 482112 - freight rail transportation (short-haul); 311420 - Fruit & Vegetable Canning, pickling & drying; 812210 - funeral homes; 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - Hotels (except casino hotels) and motels; 541380 - Laboratories (testing); 812310 - laundries (coin-operated) & drycleaning; 31611 - leather & hide tanning & finishing; 812330 - linen & uniform supply; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 332999 - metal product mfg (all other misc.); 311511 - milk mfg (fluid); 327990 - mineral product mfg (all other non-metallic); 51111 - newspaper publishers; 311224 - oilseed processing; 322121 - paper (excepts newsprint) mills; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 324190 - petroleum & coal products mfg; 32411 - petroleum refineries; 325410 - pharmaceutical & medicine mfg; 81292 - photo finishing services; 311615 - poultry processing; 32311 - printing; 323119 - printing (other); 413160 - red meat & meat product wholesaler-distributors; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 325210 - resin & synthetic rubber mfg; 311811 - retail bakeries; 322291 - sanitary paper product mfg; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 311919 - snack food mfg (other); 325640 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; ; 221330 - steam & air (conditioning and supply); 311310 - sugar mfg; 31193 - syrup & other flavouring concentrates mfg; 31331 - textile & fabric finishing; 312210 - tobacco stemming & redrying; 31183 - tortilla mfg; 485110 - urban transit systems; 321217 - waferboard mills; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 31213 - wineries; 321114 - wood preservation - milk mfg (fluid); 327990 - mineral product mfg (all other non-metallic); 51111 - newspaper publishers; 311224 - oilseed processing; 322121 - paper (excepts newsprint) mills; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 324190 - petroleum & coal products mfg; 32411 - petroleum refineries; 325410 - pharmaceutical & medicine mfg; 81292 - photo finishing services; 311615 - poultry processing; 32311 - printing; 323119 - printing (other); 413160 - red meat & meat product wholesaler-distributors; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 325210 - resin & synthetic rubber mfg; 311811 - retail bakeries; 322291 - sanitary paper product mfg; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 311919 - snack food mfg (other); 325640 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; ; 221330 - steam & air (conditioning and supply); 311310 - sugar mfg; 31193		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				- syrup & other flavouring concentrates mfg; 31331 - textile & fabric finishing; 312210 - tobacco stemming & redrying; 31183 - tortilla mfg; 485110 - urban transit systems; 321217 - waferboard mills; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 31213 - wineries; 321114 - wood preservation		
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)	92-87-5	used as a dye & as an intermed in the production of dyestuffs & pigments, and in the production of polyurethane-based high-strength elastomers, coatings, & rigid plastics; Very sensitive reagent for detection of gold and free chlorine ion water.		Spectrum Laboratories 2005
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	117-81-7	326220 - rubber &plastic hosing & belting mfg		CWWA. 2000
Organic	Haloether	Bis(chloromethyl)ether	542-88-1	used as intermediates in organic synthesis and in the production of anion exchange resins, membranes and other aromatic products.		OSHA 2005.
Inorganic	Metal/Metalloid	Boron	7440-42-8	331317 - aluminum rolling, drawing, extruding & alloying; 311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 31192 - coffee and tea mfg; 31134 - confectionery mfg (non-chocolate); 311821 - cookie & cracker mfg; 311515 - dairy products(dry & condensed mfg); 611 - educational services; 311211 - flour milling; 311822 - flour mixes& dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (Mainline); 482112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - hotels (except casino hotels) and motels; 31152 - ice cream & frozen dessert mfg; 541380 - Laboratories (testing); 812310 - laundries (coin-operated) & drycleaning; 812330 - linen & uniform supply; 562920 - material recovery facilities; 332810 - metals coating & allied activities); 311511 - milk mfg (fluid); 51111 - newspaper publishers; 311224 - oilseed processing; 322121 - paper (excepts newsprint) mills; 812930 - parking lots & garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 311615 - poultry processing; 32311 - printing; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 311811 - retail bakeries; 322291 - sanitary paper product mfg; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 321112 - shingle & shake mfg; 311919 - snack food mfg (other); 221330 - steam & air (conditioning and supply); 311310 - sugar mfg; 31193 - syrup & other flavouring concentrates mfg; 31331 - textile & fabric finishing; 485110 - urban transit systems; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation		CWWA. 2000
Organic	Pesticide - Uracil	Bromacil	314-40-9	325320 - Pesticide and Other Agricultural Chemical Mfg	diffusive, non-point crop and range spraying)	per Makepeace et al. (1995)
Inorganic	Anion	Bromate	1554-45-4	A strong oxidant, mainly used as a 31331 - printing and dyeing auxiliary, 3256 - hair permanent, 212220 - chemical agent or gold solvent in gold mines when used with sodium bromide	potential disinfection byproduct from ozone disinfection when bromide is present in source water	GVC 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane	74-97-5	As chemical Intermediate; as fire extinguishing agent.		Spectrum Laboratories 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Bromoform	75-25-2	325190- chemical mfg (other)	potential disinfection byproduct from water chlorination	CWWA. 2000
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	1689-84-5	325320 - Pesticide and Other Agricultural Chemical Mfg	diffusive, non-point crop and range spraying); A post-emergent pesticide controlling broad-leaf weeds in cereal crops and forage grasses	PMRA 2005
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)	106-99-0	32510 - resin & synthetic rubber mfg		ATSDR 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes	85535-84-8	Lubricating and cutting fluids in ferrous and non-ferrous applications; rubber, paints, sealants, leather, textiles, flame retardants for rubber and soft plastics		UN ECE 2005.
Inorganic	Metal/Metalloid	Cadmium	7440-43-9	488119 - airport operations (other); 441310 - automotive parts and accessories stores; 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 331490 - metal processing & alloying (except Fe, Cu and Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Emerging	Pharmaceutical - Stimulant	Caffeine	58-08-2	31132 - chocolate and confectionery manufacturing; 31192 - coffee & tea mfg; 325410 - pharmaceutical & medicine mfg; 312110 - soft drink & ice mfg	domestic wastewater via human urine	
Inorganic	Metal/Metalloid	Calcium	7440-70-2	622111 - hospitals general (except pediatric) (as chloride); 611 - educational services (as hydroxide)	diffusive, non-point	CWWA. 2000; per Makepeace et al. (1995)
Organic	Pesticide - Thiophthalinide	Captan	133-06-2	325320 - Pesticide and Other Agricultural Chemical Mfg	diffusive, non-point	per Makepeace et al. (1995)
Organic	Pesticide - N-methyl carbamate	Carbaryl	63-25-2	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005
Organic	Pesticide - N-methyl carbamate	Carbofuran	1563-66-2	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	EPA 2005
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)	302-17-0	325410 - pharmaceutical & medicine mfg	diffusive, non-point crop and animal spraying)	A1B2C3 2005
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)		water disinfection; wastewater disinfection		Hydromantis staff professional judgment
Inorganic	Anion	Chlorate	not for anion alone	32532 - Pesticide mfg, defoliant, herbicide, microbiocide	byproduct of water disinfection with chlorine dioxide	PesticideInfo 2005.
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	57-74-9	diffusive, non-point; Banned in Canada since end of 1995;		ITK 2005
Organic	Pesticide - Organophosphorus	Chlorfenvinphos	470-90-6	325320 - Pesticide and Other Agricultural Chemical Mfg, Nematocide, parasiticide	diffusive, non-point	Spectrum Laboratories 2005
Inorganic	Anion	Chloride	not for anion alone	325181 - Alkali & chlorine mfg; 325189 - chemical mfg (all other basic inorganic); 33111 - iron & steel mills & ferro-alloy mfg; 31611 - leather & hide tanning & finishing; 313 textile mills	diffusive, non-point, from winter road-salting	CWWA. 2000; per Makepeace et al. (1995)
Non-specific	Miscellaneous	Chlorinated wastewater effluents		domestic; chlorination of municipal wastewater effluents		
Inorganic	Disinfectant	Chlorine dioxide	10049-04-4	Chlorine dioxide is being used increasingly to control microbiological growth in a number of different industries, including the dairy industry,29-31 the beverage industry,32 the pulp and paper industries,33-37 the fruit and vegetable processing industries,38-41 various canning plants,42,43 the poultry industry,44-53 the beef processing industry,54 and miscellaneous food processing applications.55-59 It is seeing increased use in municipal potable water treatment facilities61-65 and in industrial waste treatment facilities,75-80 because of its selectivity towards specific environmentally-objectionable waste materials, including phenols, sulfides, cyanides, thiosulfates, and mercaptans.81 It is being used in the oil and gas industry for downhole applications as a well stimulation enhancement additive.		Chlorine Dioxide Council 2005.
Inorganic	Anion	Chlorite	not for anion alone	industrial; as acidified sodium chlorite, for sterilization and disinfection use in hospitals; dental operatories and pharmaceutical clean rooms; dairy industry antisepsis; antimicrobial food additive for poultry, red meat, seafood & fruits & vegetables; as pesticide for food contact surfaces	byproduct of water disinfection with chlorine dioxide	Alcide 2005
Organic	Chlorobenzene	Chlorobenzene	108-90-7	Solvent for pesticide formulation; manufacture of diisocyanate; degreaser of automobile parts, production of nitrochlorobenzene, silicone resin and other halogenated organic compounds, intermediate in phenol production		ATSDR 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	67-66-3	325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); hospitals general (except pediatric); 541380 laboratories (testing)		CWWA. 2000
Organic	Haloether	Chloromethyl methyl ether	107-30-2	used in the synthesis of chloromethylated compounds and as an alkylating agent and solvent used in the manufacture of water repellents, ion-exchange resins, and industrial polymers		EPA 2005
Organic	Chlorophenol	Chlorophenol	many congeners each has CAS No.	322191 - sanitary paper product mfg; 321114 - wood preservation		CWWA. 2000
Organic	Pesticide - Substituted benzene	Chlorothalonil	1897-45-6	32532 - Pesticide mfg, fungicide	diffuse, non-point	EPA 2005; per Makepeace et al. (1995)
Organic	Pesticide - Organophosphorus	Chlorpyrifos	2921-88-2	32532 - Pesticide mfg, insecticide	diffuse, non-point	ATSDR 2005; per Makepeace et al. (1995)
Inorganic	Metal/Metalloid	Chromium (hexavalent and trivalent)	7440-47-3	336410 - Aerospace product & parts mfg; 488119 - airport operations (other); 415110 - automobile & light duty truck wholesaler-distributors; 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 331221 - cold-rolled steel shape mfg; 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				bar mfg; 6212101 - dental offices; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 331511 - iron foundries; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 31611 - leather &hide tanning & finishing; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - Manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 331490 - metal processing & alloying (except Fe, Cu and Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal window & door mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 332329 - ornamental metal products mfg (other): 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 562910 - remediation services; 322291 - sanitary paper product mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation metal products mfg (other): 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 562910 - remediation services; 322291 - sanitary paper product mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene	218-01-9	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate	637-07-0	325410 – pharmaceutical & medicine mfg	domestic wastewater via human urine	
Inorganic	Metal/Metalloid	Cobalt	7440-48-4	811199- automotive repair & maintenance (all other); 325190 - chemical mfg (other basic organic); 33422 - communications broadcasting equipment mfg; 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 812330 - linen & uniform supply; 331410 - metal smelting & refining (non-ferrous except aluminum); 332810 - metals coating & allied activities; 336320 - motor vehicle electronic equipment mfg; 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 562910 - remediation services; 334410 - semiconductor mfg; 321112 - shingle & shake mills; 221330 - steam & air (conditioning and supply); 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation		CWWA. 2000
Non-specific	Physical/Chemical	Colour		dyes used in textiles and paperboard and boxboard manufacturers		
Inorganic	Metal/Metalloid	Copper	7440-50-8	488119 - airport operations (other); 336110 - automobile & light duty motor vehicle mfg; 415110 - automobile & light duty truck wholesaler-distributors; 811119 - automotive maintenance & mechanical & electrical (other); 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325 - chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 33422 - communications broadcasting equipment mfg; 334110 - computer & peripheral equipment mfg; 332314 - concrete reinforcing bar mfg; 331420 - copper rolling drawing, extruding and alloying; 212233 - copper-zinc ore mining; 6212101 - dental offices; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 21221 - iron ore	domestic wastewater from copper plumbing	CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - Manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 332999 - metal product mfg (all other misc.); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 51111 - newspaper publishers; 212232 - nickel-copper ore mfg; 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31331 - textile and fabric finishing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - Manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 332999 - metal product mfg (all other misc.); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 51111 - newspaper publishers; 212232 - nickel-copper ore mfg; 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31331 - textile and fabric finishing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 51111 - newspaper publishers; 212232 - nickel-copper ore mfg; 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31331 - textile and fabric finishing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.		domestic; diffusive, non-point		per Makepeace et al. (1995)
Organic	Pesticide - Triazine	Cyanazine	21725-46-2	325320 - Pesticide and Other Agricultural Chemical Mfg, herbicide	diffusive, non-point; herbicide used for controlling grasses & broadleaf weeds, mainly in cornfields	EWG 2005
Inorganic	Anion	Cyanide	57-12-5	415110 - automobile & light duty truck wholesaler-distributors; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh and frozen mfg; 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 212233 - copper-zinc ore mining; 331523 - die-casting foundries (nonn-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 311822 - flour mixes and dough mfg from purchased flour;331990 - food mfg (all other); 331529 - foundries (non-ferrous except die-casting); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 331511 - iron foundries; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 562920 - material		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				recovery facilities; 621510 - medical & diagnostic laboratories; 332439 - metal ore mining (other); 331490 - metal processing & alloying (except Fe, Cu & Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 332810 - metals coating & allied products; 51111 - newspaper publishers; 212232 - nickel-copper ore mfg; 812930 - parking lots and garages; 32411 - petroleum refineries; 81292 - photo finishing services; 32311 - printing; 562910 - remediation services; 337215 - shelving, showcase, partition & locker mfg; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 31331 - textile and fabric finishing; 31183 - tortilla mfg; 332720 - turned product & screw, nut & bolt mfg; 562990 - waste management services (all other); 562210 - waste treatment & disposal		
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)		diffusive, non-point		
Inorganic	Miscellaneous	Cyanogen Chloride	506-77-4	diffusive, non-point; no industrial use		
Organic	Pesticide - Chlorinated hydrocarbon	DDD	72-54-8	diffusive, non-point; Metabolite of DDT; DDT use banned in Canada in 1969		EcoInfo 2005; per Makepeace et al. (1995)
Organic	Pesticide - Chlorinated hydrocarbon	DDE	72-55-9	diffusive, non-point; Metabolite of DDT; DDT use banned in Canada in 1969		EcoInfo 2005; per Makepeace et al. (1995)
Organic	Pesticide - Chlorinated hydrocarbon	DDT	50-29-3	diffusive, non-point; DDT use banned in Canada in 1969		EcoInfo 2005; per Makepeace et al. (1995)
Organic	Pesticide - Pyrethroid	Deltamethrin	52918-63-5	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, insecticide	diffuse, non-point;	Beyond Pesticides. 2005. per Makepeace et al. (1995)
Organic	Pesticide - Organophosphorus	Diazinon	333-41-5	325320 – Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffuse, non-point;	EPA 2005
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	53-70-3	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Dioxins and Furans	Dibenzofuran	132-64-9	321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Dioxins and Furans	Dibenzo-p-dioxin	262-12-4	321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Aliphatic Hydrocarbon - Halogenated	Dibromochloromethane	124-48-1	domestic; no commercial use; is a chemical byproduct of water disinfection by chlorine		ATSDR 2005.
Organic	Pesticide - Benzoic acid	Dicamba	1918-00-9	32532 - Pesticide mfg, herbicide	diffuse, non-point;	Cornell University, 2005; per Makepeace et al. (1995)
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	95-50-1	323119 - printing (other)		CWWA. 2000
Organic	Chlorobenzene	Dichlorobenzene (1,3-)	541-73-1	323119 - printing (other); 541380 - laboratories (testing)		CWWA. 2000
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	106-46-7	323119 - printing (other)		CWWA. 2000
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	91-94-1	3,3'-Dichlorobenzidene is used as an intermediate in the manufacture of pigments or as a curing agent in polyurethane elastomers. In the United States, there are strict regulations requiring its use in closed systems (HSDB, 1991). The primary stationary sources that have reported emissions of 3,3'-dichlorobenzidene in California are commercial printing and publishing industries		Air Resources Board California 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	Dichlorobromomethane	75-27-4	domestic; no commercial use; is a chemical byproduct of water disinfection by chlorine		
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,1-)	75-34-3	used primarily to make other chemicals, to dissolve substances such as paint, varnish, and finish removers, and to remove grease		ATSDR 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	107-06-2	used in the production of vinyl chloride which is used to make a variety of plastic and vinyl products including polyvinyl chloride (PVC) pipes, furniture and automobile upholstery, wall coverings, housewares, and automobile parts. It is also used to as a solvent and is added to leaded gasoline to remove lead.		ATSDR 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,1-)	75-35-4	Virtually all of it is used in making adhesives, synthetic fibers, refrigerants, food packaging and coating resins such as the saran types		EPA 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,2-)	540-59-0, 156-59-2, & 156-60-5	Both the cis and trans forms - usually as a mixture - are used as a solvent for waxes, resins, and acetylcellulose; in the extraction of rubber; as a refrigerant; in the manufacture of pharmaceuticals and artificial pearls and in the extraction of oils and fats from fish and meat; as a chemical intermediate for making chlorinated compounds		EPA 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloromethane	75-09-2	Paint stripping in aircraft, consumer and commercial applications; flexible polyurethane foam blowing; pharmaceutical and chemical intermediates; adhesives; cleaning applications; and testing laboratories		Environment Canada. 2005
Organic	Chlorophenol	Dichlorophenol (2,4-)	3757-76-4	In synthesis of pesticide for helminthes and mites. As Intermediate for herbicides such as 2,4-dichlorophenoxyacetate, bifenox and dichlorprop herbicides,;further chlorinated to pentachlorophenol, a wood preservative; may be released to the environment in effluents from its manufacture and use as a chemical intermediate and from chlorination processes involving water treatment and wood pulp bleaching		Spectrum Laboratories 2005

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropane (1,2-)	78-87-5	Livestock (in DD mixture); solvent in plastics, resins and metals industry, intermediate in rubber processing, oil and fat solvent, in dry cleaning fluids, in degreasing, in insecticidal fumigant mixtures. Intermediate for perchloroethylene and carbon tetrachloride; lead scavenger for antiknock fluids; solvent for waxes, gums; solvent mixtures for cellulose esters and ethers, scouring compound; spotting agent; metal degreasing agent; soil fumigant for nematodes.		Spectrum Laboratories 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropene (1,2-) (cis and trans)	10061-02-6/542-75-6	use not identified		
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop	120-36-5	32532 - Pesticide mfg, herbicide	diffuse, non-point;	Spectrum Laboratories 2005; per Makepeace et al. (1995)
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	51338-27-3	32532 - Pesticide mfg, herbicide; 311420 - Fruit & Vegetable Canning	diffuse, non-point;	Cornell University, 2005; per Makepeace et al. (1995)
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	60-57-1	diffusive, non-point; Banned in Canada since end of 1995		ITK 2005; per Makepeace et al. (1995)
Organic	Pesticide - Organophosphorus	Dimethoate	60-51-5	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning	diffusive, non-point crop and animal spraying)	ITK 2005
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	571-61-9	production of creosote for wood preservative and water-proofing agent for structures on land and in marine and fresh waters and for railway crossing timbers and sleepers (railroad ties), bridge and pier decking, poles, log homes, fencing, and equipment for children's playgrounds. Non-wood uses include anti-fouling applications on concrete marine pilings. Creosote can be a component of roofing pitch, fuel oil, and lamp black and a lubricant for die moulds. Other uses reported include animal and bird repellent, insecticide, animal dip, and fungicide		Inchem. 2005
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	84-74-2	325 - chemical mfg; 4145 - pharmaceuticals, toiletries & related wholesalers		Health Canada 2005
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene	many congeners each has CAS No.	diffusive, non-point; NitroPAHs originate primarily as direct or indirect products of incomplete combustion, e.g., diesel exhaust		Inchem. 2005
Organic	Pesticide - Dintrophenol derivative	Dinoseb	88-85-7	32532 - Pesticide mfg, herbicide; 311420 - Fruit & Vegetable Canning		Health Canada 2005
Organic	Pesticide - Bipyridylium	Diquat	85-00-7	32532 - Pesticide mfg, herbicide		Inchem. 2005
Organic	Pesticide - Urea-based	Diuron	330-54-1	32532 - Pesticide mfg, herbicide		Health Canada 2005
Organic	Pesticide - Quaternary Ammonium	Didecyl dimethyl ammonium chloride	7173-51-5	325410- pharmaceutical & medicine mfg		Health Canada 2005
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	115-29-7	32532 - Pesticide mfg, 311420 - Fruit & Vegetable Canning		Inchem. 2005
Organic	Pesticide - Chlorinated hydrocarbon	Endrin	72-20-8	diffusive, non-point ; Banned in Canada since 1994		ITK 2005;
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)		domestic		Qureshi and Dutka (1979)
Emerging	Pharmaceuticals - Hormone	Estradiol	50-28-2	domestic; 325410- pharmaceutical & medicine mfg		Servos et al. (2005)
Organic	Alkyl benzene	Ethylbenzene	100-41-4	811119 - automotive maintenance mechanical & electrical (other); 325190 - chemical mfg (other basic organic); 81232 - dry cleaning & laundry Services (except coin-operated); 622111 - hospitals general (except pediatric); 541380 - Laboratories (testing); 812330 - linen & uniform supply; 562920 - material recovery facilities; 32411 - petroleum refineries; 562910 - remediation services; 221330 - steam & air (conditioning & supply); 562990 - waste management services (all other); 562210 - waste treatment & disposal		CWWA. 2000
Organic	Oxygenate - Alcohol	Ethylene glycol	107-21-1	481110 - Air transportation (scheduled); 488119 - airport operations (other); 336110 - automobile & light-duty motor vehicle mfg; 811199- automotive repair & maintenance (all other); 325999 - chemical product mfg (all other misc.); 33111 - iron & steel mills and ferro-alloy mfg; 325610 - soap & cleaning compound mfg		CWWA. 2000
Organic	Oxygenated - Epoxide	Ethylene oxide	75-21-8	used as an intermediate in the production of various chemicals; used in the manufacture of surfactants; alone or in combination with other gases, such as carbon dioxide and nitrogen, is used to sterilize instruments from the health care, publication, and wood products sectors. is also used in other industries where heat-sensitive goods are sterilized, and in the manufacture of choline chloride, glycol ethers, and polyglycols Ethylene oxide is used for the control of insects in stored products and for the control of bacteria in spices and natural seasonings. Other minor uses worldwide include its application in the manufacture of rocket propellant and petroleum demulsifiers. as a formulant or component of a formulant in pest control products at concentrations up to 0.4%. The formulants include fungicides, insecticides, herbicides		Inchem. 2005
Biological	Pathogen - Bacteria	Fecal coliforms		domestic; 56174 - carpet & upholstery cleaning services		CWWA. 2000; Qureshi and Dutka (1979)
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	206-44-0	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 -	diffusive, non-point (auto tire particles, road oils, atmos.deposition)	CWWA. 2000; Hydromantis staff professional judgment

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation		
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	86-73-7	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos.deposition)	CWWA. 2000; per Makepeace et al. (1995)
Inorganic	Anion	Fluoride	13709-49-4	325189 - chemical mfg (other basic inorganic); 325190 - chemical mfg (other basic organic); 334110 - computer & peripheral equipment mfg		CWWA. 2000
Organic	Oxygenate - Acetaldehyde	Formaldehyde	50-00-0	327910 - abrasive product mfg; 32552 - adhesive mfg; 324122 - asphalt shingle & coating material mfg; 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 334110 - computer & peripheral equipment mfg; 325920 - explosives mfg; 332999 - metal product mfg(all other misc.);327990 - mineral product mfg (all other non-metallic); 325320 - pesticide & other agricultural chemical mfg; 324190 - petroleum & coal products mfg; 322291 - sanitary paper product mfg; 325610 - soap & cleaning compound mfg		CWWA. 2000
Biological	Pathogen - Protozoan	*Giardia* sp.		domestic		
Organic	Pesticide - Phosphoroglycine	Glyphosate	1071-83-6	325320 - Pesticide and Other Agricultural Chemical Mfg, herbicide	diffusive, non-point[l]	Inchem. 2005;
Organic	Halocarboxylic acids	Haloacetic acids	many congeners each has CAS No.	domestic; diffusive, non-point; chemical byproduct from water disinfection with chlorine; may form in atmosphere over industrialized nations		NWRI 2005;
Organic	Haloacetonitrile	Haloacetonitriles	many congeners each has CAS No.	domestic; chemical byproduct from water disinfection with chlorine		
Non-specific	Physical/Chemical	Hardness				
Organic	Pesticide - Chlorinated hydrocarbon	Heptachlor + Heptachlor epoxide	76-44-8	diffusive, non-point Banned in Canada since 1990		ITK 2005;
Organic	Aliphatic Hydrocarbon - Halogenated	Hexachloro-1,3-butadiene	87-68-3	325189 - chemical mfg (all other basic inorganic)		CWWA. 2000
Organic	Chlorobenzene	Hexachlorobenzene	118-74-1	325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (all other basic organic); 325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, diffusive, non-point; Banned as pesticide since 1981; used to treat seeds, also kills fungi that affect food crops		ITK 2005;
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene	193-39-5	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Pesticide - Carbamate	Iodo-2-propynyl butyl carbamate (3-)	55406-53-6	32532 - Pesticide mfg, fungicide; 321114 - wood preservation; Fungicide used in the sawmill industry to prevent mould (fungus) from growing on the sap of the wood, staining the surface of the wood a blue colour (sapstain)		University of British Columbia 2005.
Inorganic	Metal/Metalloid	Iron	39331-38-9	488119 - airport operations (other); 331317 - aluminum rolling, drawing, extruding & alloying; 415110 - automobile & light duty truck wholesaler-distributors; 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 331221 - cold-rolled steel shape mfg; 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - Manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal window & door mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 51111 - newspaper publishers; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 32311 - printing; 562910 - remediation services;		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31331 - textile and fabric finishing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Organic	Pesticide - Urea-based	Isoproturon	34123-59-6	325320 - Pesticide and Other Agricultural Chemical Mfg, herbicide;	diffusive, non-point	http://www.itass.dk/pestdb.htm;
Inorganic	Metal/Metalloid	Lead	7439-92-1	488119 - airport operations (other); 336110 - automobile & light-duty motor vehicle mfg; 415110 - automobile & light duty truck wholesaler-distributors; 811119 - automotive maintenance mechanical & electrical (other); 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199- automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (all other basic organic); 33422 - communications broadcasting equipment mfg; 334110 - computer & peripheral equipment mfg; 332314 - concrete reinforcing bar mfg; 212233 - copper-zinc ore mining; 621210 - dental offices; 81232 - dry cleaning and laundry services (except coin-operated); 332113 - forging; 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 331511 - iron foundries; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - Manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 212299 - metal ore mining (all other); 331490 - metal processing & alloying (except Fe, Cu, and Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal window & door mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 2122232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 85110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation parts wholesaler-distributors (other new); 2122232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 32311 - printing; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, show case, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 85110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	58-89-9	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	CWWA. 2000;
Organic	Pesticide - Urea-based	Linuron	330-55-2	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, herbicide	diffusive, non-point	Cornell University, 2005;
Inorganic	Metal/Metalloid	Lithium	7439-93-2	Lithium aluminum hydride (LiAlH4) is an important reagent in organic chemistry. Lithium also forms numerous organic compounds. One compound of major importance is lithium stearate, produced by cooking tallow (or other animal fat) with lithium hydroxide; lithium stearate is used to transform oil into lithium-base lubricating greases, which have found extensive use in the automotive industry. Lithium carbonate is used in special glasses and ceramic glazes. Lithium chloride and bromide are used as brazing and welding fluxes; they are also used in air conditioning systems because they are very hygroscopic, i.e., they absorb moisture. Lithium hydroxide is used to increase the capacity of alkaline storage cells. Lithium compounds are used in the nuclear energy industry, in the preparation of plastics and synthetic rubber, and in the synthesis of vitamin A. Lithium is added in small amounts to magnesium, aluminum, or lead-base alloys; it is also used as a degasifier in iron, steel, and copper refining. In addition, lithium is used to scavenge small amounts of oxygen and nitrogen in electronic vacuum tubes. Trace amounts of lithium and its compounds color a flame bright red; they are used in pyrotechnics. Lithium in the salt form has recently come into use as a medical treatment for manic depression. used to scavenge small		Factmonster. 2005

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				amounts of oxygen and nitrogen in electronic vacuum tubes. Trace amounts of lithium and its compounds color a flame bright red; they are used in pyrotechnics. Lithium in the salt form has recently come into use as a medical treatment for manic depression.		
Inorganic	Metal/Metalloid	Magnesium	7439-95-4	Used as an alloying agent for aluminum, for die-casting of automotive parts, as a de-oxidizing and desulphurizing agent in the ferrous industry, in pharmaceutical products, perfumes, and pyrotechnics (fireworks and flares).		Natural Resources Canada 2005.
Organic	Pesticide - Organophosphorus	Malathion	121-75-5	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, insecticide;	diffusive, non-point	Cornell University, 2005;
Inorganic	Metal/Metalloid	Manganese	7439-96-5	488119 - Airport operations (other); 333317- Aluminum rolling, drawing, extruding and alloying; 415110 - automobile and light duty truck wholesalers/distributors; 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 331221 - cold-rolled steel shape mfg; 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (Mainline); 4832112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - Hotels (except casino hotels) and motels; 33111 - iron and steel mills and ferro-alloy mfg; 541380 - Laboratories (testing); 812310 - laundries (coin-operated) & dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other misc.); 488320 - marine cargo handling; 562920 - material recovery facilities; 625510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg; 331490 - metal processing and alloying (except Fe, Cu and Al); 332999 - metal products mfg (all other misc.); 331410 - metal smelting and refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332321 - metal window and door mfg; 332810 - metals-coating and allied activities; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 33637 - motor vehicle metal stamping; 336390 - motor vehicle parts mfg - other; 415290 - motor vehicle parts wholesaler/distributors (others-new); 332329 - ornamental metal products mfrs (others); 322121 - paper (excepts newsprint) mills; 812930 - parking lots & garages; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services; 562910 - remediation services; 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition and locker mfg; 321112 - shingle and shake mills; 332611 - spring (heavy gauge) mfg; 332118 - stamping; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 485110 - urban transit systems; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		CWWA. 2000
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	94-74-6	325320 - Pesticide and Other Agricultural Chemical Mfg, herbicide;	diffusive, non-point; herbicide used for controlling grasses & broadleaf weeds, mainly in cornfields	Cornell University, 2005
Inorganic	Metal/Metalloid	Mercury	7439-97-6	415110 - automobile & light duty truck wholesaler-distributors; 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (all other basic organic); 621210 - dental offices; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 722 - food services & drinking places; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 562910 - remediation services; 221330 - steam & air (conditioning and supply); 562990 - waste management services (all other); 562210 - waste treatment & disposal		CWWA. 2000
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	72-43-5	325320 - Pesticide and Other Agricultural Chemical Mfg, insecticide;	diffusive, non-point[n]	ATSDR 2005.
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	74-83-9	325190 - chemical mfg (other basic organic)		CWWA. 2000
Organometals	Alkyl mercury	Methyl mercury	22967-92-6	diffusive, non-point; methylation of mercury by bacteria in aquatic sediments under anaerobic conditions		
Organic	Oxygenate - Ether	Methyl t-butyl ether	1634-04-4	325190- chemical mfg (all other basic organic); 44719 - gasoline stations (other); gasoline stations with convenience stores;	diffusive, non-point	ATSDR 2005.
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)	101-14-4	industrial		Spectrum Laboratories 2005
Organic	Pesticide - Bipyridylium	Methyl-parathion	298-00-0	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning;	diffusive, non-point	ATSDR 2005.
Organic	Pesticide - Chloroacetanilide	Metolachlor	51218-45-2	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning		EPA 2005
Organic	Pesticide - Triazinone	Metribuzin	21087-64-9	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning,	diffusive, non-point	Cornell University, 2005;
Organic	Pesticide - Chlorinated hydrocarbon	Mirex	2385-85-5	Banned in Canada; diffusive, non-point		ITK 2005;

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Inorganic	Metal/Metalloid	Molybdenum	7439-98-7	811119 - automotive maintenance mechanical & electrical (other); 325 - chemical mfg; ; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (all other basic organic); 33422 - communications broadcasting equipment mfg; 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 33111 - iron & steel mills and ferro-alloy mfg; 812330 - linen & uniform supply; 562920 - material recovery facilities; 332810 - metals coating & allied products; 322121 - paper (except newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 562910 - remediation services; 322291 - sanitary paper product mfg; 321112 - shingle & shake mills; 221330 - steam & air (conditioning and supply); 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation		CWWA. 2000
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene (vinyl chloride)	75-01-4	325190 - chemical mfg (other basic organic); 32511 - petrochemical mfg		ATSDR 2005.
Organic	Aromatic Hydrocarbon - Polycyclic	Naphthalene	91-20-3	325190 - chemical mfg (other basic organic); 331511 - iron foundries; 331514 - steel foundries		CWWA. 2000
Inorganic	Metal/Metalloid	Nickel	7440-02-0	488119 - airport operations (other); 415110 - automobile & light duty truck wholesaler-distributors; 441310 - automobile parts & accessories stores; 811119 - automotive maintenance & mechanical & electrical (other); 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 331221 - cold-rolled steel shape mfg; 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 212233 - copper-zinc ore mining; 6212101 - dental offices; 81232 - dry cleaning and laundry services (except coin-operated); 332113 - forging; 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - Hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 331511 - iron foundries; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other); 488320 - marine cargo handling; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 212299 - metal ore mining (all other); 331490 - metal processing & alloying (except, Fe, Cu & Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal windows & doors mfg; 332810 - metals coating & allied products; 333634 - motor vehicle brake system mfg; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 212232 - nickel-copper ore mfg; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 32411 - petroleum refineries; 81292 - photo finishing services; 323119 - printing (other); 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 331514 - steel foundries; 331222 - steel wire drawing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 332619 - wire product mfg (all other); 321114 - wood preservation iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other); 488320 - marine cargo handling; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 212299 - metal ore mining (all other); 331490 - metal processing & alloying (except, Fe, Cu & Al); 332999 - metal product mfg (all other misc.); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal windows & doors mfg; 332810 - metals coating & allied products; 333634 - motor vehicle brake system mfg; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 212232 - nickel-copper ore mfg; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 32411 - petroleum refineries; 81292 - photo finishing services; 323119 - printing (other); 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 331514 - steel foundries; 331222 - steel wire drawing; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 332619 - wire product mfg (all other); 321114 - wood preservation		CWWA. 2000
Inorganic	Nutrient	Nitrate	14797-55-8	336110 - automobile & light-duty motor vehicle mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 334110 - computer & peripheral equipment mfg; 311515 - dairy products (dry & condensed) mfg; 339990 - manufacturing (all other); 311511 - milk mfg (fluid); domestic	domestic source from nitrification of ammonia during wastewater treatment	CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid	139-13-9	325610 - soap & cleaning compound mfg	domestic source is laundry detergents	CWWA. 2000
Inorganic	Nutrient	Nitrite		325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); domestic	domestic source from nitrification of ammonia during wastewater treatment	CWWA. 2000
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	62-75-9	formed as an unintentional by-product in industries such as tanneries, pesticide manufacturing plants, rubber and tire manufacturing plants, alkylamine manufacture/use industries, fish processing industries, foundries, and dye manufacturing plants		ATSDR 2005.
Organic	Alkylphenol & Ethoxylates	Nonylphenol	84852-15-3	used eg in detergents, resins, plastics, stabilisers in the polymer industry, phenolic oximes, and paints.		European Parliament 2005.
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	9016-45-9, 26027-38-3	31611 - leather & hide tanning & finishing; 32411 - petroleum refineries; 31331 - textile & fabric finishing		CWWA. 2000
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene	EDF-151	325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic)		CWWA. 2000
Organic	Alkylphenol & Ethoxylates	Octylphenol	1806-26-4	widely used in detergents, emulsifiers, solubilizers, wetting agents, and dispersants		FindArticles 2005
Non-specific	Physical/Chemical	Oil and grease		32552 - adhesives mfg; 488119 - airport operations (other); 333317- aluminum rolling, drawing, extruding and alloying; 311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 324122 - asphalt shingle & coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; 811121 - automotive body, paint & interior repair & maintenance; 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 231220 - building construction (non-residential); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325 chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 31192 - coffee and tea mfg; 331221 - cold-rolled steel shape mfg; 332314 - concrete reinforcing bar mfg; 31134 - confectionery mfg (non-chocolate); 311821 - cookie and cracker mfg; 331420 - copper rolling, drawing, extruding and alloying; 311515 - dairy products (dry & condensed) mfg; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 231390 - engineering construction (other); 325920 - explosives mfg; 311211 - flour milling; 311822 - flour mixes & dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 722 - food services & drinking places; 413110 - food wholesaler-distributors (general-line); 413190 - food wholesaler-distributors (specialty-line); 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (mainline); 4832112 - freight rail transportation (short-haul); 311420 - Fruit & Vegetable Canning, pickling & drying; 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 33251 - hardware mfg; 622111 - hospitals general (except pediatrics); 721111 - hotels (except casino hotels) andmotels; 31152 - ice cream & frozen dessert mfg; 33111 - iron and steel mills and ferro-alloy mfg; 541380 - laboratories (testing); 812310 - laundries (coin-operated) & dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other misc.); 562920 - material recovery facilities; 625510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg; 332999 - metal products mfg (all other misc.); 331410 - metal smelting and refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal window and door mfg; 332810 - metals-coating and allied activities; 311511 - milk mfg (fluid; 327990 - mineral product mfg (all other non-metallic); 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg - other; 415290 - motor vehicle parts wholesaler/distributors (others-new); 311224 - oilseed processing; 332329 - ornamental metal products mfrs (others); 812930 - parking lots & garages; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg (other); 32411 - petroleum refineries; 81292 - photo finishing services; 311615 - poultry processing; 413160 - red meat & meat product wholesaler-distributors; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 325210 - resin & synthetic rubber mfg; 311811 - retail bakeries; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 337215 - shelving, showcase, partition and locker mfg; 311919 - snack food mfg (other); 325610 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; 332611 - spring (heavy gauge) mfg; 221330 - steam & air (conditioning and supply); 331222 - steel wire drawing; 31193 - syrup & other flavouring concentrates mfg; 31183 - tortilla mfg; 485110 - urban transit systems; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)	1910-42-5	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point[J]	Cornell University, 2005
Organic	Pesticide - Organophosphorus	Parathion	56-38-2	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point[J]	PMRA 2005

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Polyhalogenated Polyphenyl	PCBs	1336-36-3	diffusive, non-point[i] ;manufacture, import and most non-electrical uses of PCBs has been banned in North America since 1977		EcoInfo 2005
Organic	Dioxins and Furans - Polychlorinated	PCDD	many congeners each has CAS No.	Dioxins are byproducts of a wide variety of industrialized activities, such as chlorine bleaching in kraft pulp and paper mills and incineration of municipal and industrial wastes; diffusive, non-point		EcoInfo 2005
Organic	Dioxins and Furans - Polychlorinated	PCDF	39001-02-0	Furans are byproducts of a wide variety of industrialized activities, such as chlorine bleaching in kraft pulp and paper mills and incineration of municipal and industrial wastes.		EcoInfo 2005
Organic	Chlorobenzene	Pentachlorobenzene	608-93-5	325189 - chemical mfg (all other basic inorganic); 33111 - iron & steel mills & ferro-alloy mfg		CWWA. 2000
Organic	Chlorophenol	Pentachlorophenol	87-86-5	PCP is used as a fungicide, insecticide, mollusicide, algicide, disinfectant, and as an anti-fouling paint ingredient. However, it is primarily used as an industrial and commercial wood preservative for such things as fence posts, utility poles, boats, furniture and log homes.		University of Waterloo 2005.
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	198-55-0	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000
Non-specific[a]	Physical/Chemical	pH		325181 - alkali & chlorine mfg; 311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 811121 - automotive body, paint & interior repair & maintenance; 331814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 31212 - breweries; 327310 - cement mfg; 325 chemical mfg; 31192 - coffee and tea mfg; 31132 - chocolate & confectionery mfg; 334110 - computer & peripheral equipment mfg; 31134 - confectionery mfg (non-chocolate); 311821 - cookie and cracker mfg; 332210 - cutlery & hand tool mfg; 311515 - dairy products (dry & condensed) mfg; 221112 - electricity - fossil-fuel power generation; 311211 - flour milling; 311822 - flour mixes & dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 31152 - ice cream & frozen dessert mfg; 541380 - Laboratories (testing); 331490 - metal processing & alloying (except, Fe, Cu and Al); 311224 - oilseed processing; 325410 - pharmaceutical & medicine mfg; 311615 - poultry processing; 323119 - printing (other); 311614 - rendering & meat processing from carcasses; 311811 - retail bakeries; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 311919 - snack food mfg (other); 311310 - sugar mfg; 31193 - syrup & other flavouring concentrates mfg; 31183 - tortilla mfg		CWWA. 2000
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	85-01-8	325190 - chemical mfg (other basic organic)		CWWA. 2000
Organic	Aromatic Hydrocarbon	Phenols, Total	108-95-2	32552 - adhesives mfg; 488119 - airport operations (other); 324122 - asphalt shingle & coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 56174 - carpet & upholstery cleaning services; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 325920 - explosives mfg; 722 - food services & drinking places; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (mainline); 4832112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - hotels (except casino hotels) and motels; 331511 - iron foundries; 541380 - laboratories (testing); 812310 - laundries (coin-operated) & dry cleaners; 562920 - material recovery facilities; 812930 - parking lots & garages; 482114 - passenger rail transportation; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg (other); 32411 - petroleum refineries; 562910 - remediation services; 325210 - resin & synthetic rubber mfg; 322291 - sanitary paper product mfg; 311940 - seasoning & dressing mfg; 325610 - soap & cleaning compound mfg; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 321217 - waferboard mills; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation services; 311614 - rendering & meat processing from carcasses; 311811 - retail bakeries; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 311919 - snack food mfg (other); 325610 - soap & cleaning compound mfg; 31193 - syrup & other flavouring concentrates mfg; 31331 - textile and fabric finishing; 31183 - tortilla mfg		CWWA. 2000
Organic	Pesticide - Organophosphorus	Phorate	298-02-2	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, diffusive, non-point[i]		Inchem. 2005
Inorganic	Nutrient	Phosphorus (total)		32552 - adhesives mfg; 311119 - animal food mfg (other); 324122 - asphalt shingle & coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 56174 - carpet & upholstery cleaning services; 325 chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 325999 - chocolate & confectionery mfg; 31192 - coffee and tea mfg; 31134 - confectionery mfg		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				(non-chocolate); 311821 - cookie and cracker mfg; 311515 - dairy products (dry & condensed) mfg; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 325920 - explosives mfg; 311211 - flour milling; 311822 - flour mixes & dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 622111- hospitals general (except pediatrics); 721111 - hotels (except casino hotels) and motels; 31152 - ice cream & frozen dessert mfg; 541380 - laboratories (testing); 812310 - laundries (coin-operated) & dry cleaners; 31611 - leather & hide tanning & finishing; 625510 - medical & diagnostic laboratories; 331490 - metal products & alloying (except, Fe, Cu & Al); 332999 - metal products mfg (all other misc.); 331410 - metal smelting and refining (non-ferrous except aluminum); 311511 - milk mfg (fluid; 327990 - mineral product mfg (all other non-metallic); 51111 - newspaper publishers; 311224 - oilseed processing; 812930 - parking lots & garages; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg (other); 812922 - photo finishing services; 311615 - poultry processing; 32311 - printing; 562910 - remediation		
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters	many compounds each has CAS No.	Phthalate esters are chemicals used in the production of polyvinyl chloride (PVC), polyvinylacetates, cellulosics and polyurethanes and are thus used in a wide variety of consumer products		Health Canada 2005
Organic	Pesticide - Pyridine carboxylic acid	Picloram	2/1/1918	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	Health Canada 2005
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls	PJL335	mainly used as flame retardants in moulded thermoplastics, mostly in small appliances and automotive applications. Earlier applications in synthetic fibres have been discontinued	diffusive, non-point	Inchem. 2005; per Makepeace et al. (1995)
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers	many congeners each has CAS No.	PBDEs have been used extensively over the past two decades as flame retardants in most types of polymers. They are used in textiles, polyurethane foam, plastics, computers, wire and cable insulation, furniture, building materials, carpets and in vehicles	diffusive, non-point	EcoInfo 2005
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls	61788-33-8	Main uses were as dielectrics in transformers and large capacitors (considered to be closed systems); in heat transfer and hydraulic systems (nominally closed systems); in the formulation of lubricating and cutting oils; as plasticizers in paints, carbonless copying paper, adhesives, sealants, and plastics.	diffusive, non-point	Inchem. 2005
Organic	Aromatic Hydrocarbon - Polycyclic	Polycyclic hydrocarbons	130498-29-2	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos. deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	57-55-6	322211 - box mfg (corrugated & solids fibre)		CWWA. 2000
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	57-55-6	322211 - box mfg (corrugated & solids fibre)		CWWA. 2000
Biological	Pathogen - Protozoan	Protozoa		domestic		
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	129-00-0	811199- automotive repair & maintenance (all other); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 482114 - passenger rail transportation; 32411 - petroleum refineries; 485110 - urban transit systems; 321114 - wood preservation	diffusive, non-point (auto tire particles, road oils, atmos.deposition)	CWWA. 2000; per Makepeace et al. (1995)
Organic	Hydrocarbons with N,P,S substitution	Quinoline	91-22-5	used mainly as an intermediate in the manufacture of other products, but has also used as a catalyst, a corrosion inhibitor, in metallurgical processes, in the manufacture of dyes, as a preservative for anatomical specimens, in polymers and agricultural chemicals, and as a solvent for resins and terpenes. It is also used as an antimalarial medicine.		EPA.2005.
Organic	Oxygenate- Carboxylic Acid	Resin Acids	many compounds each has CAS No.	Resin acids constitute a major class of polar organics and environmental toxins derived primarily from pulp and paper processing of softwoods.		National Institutes of Health 2005.
Inorganic	Metal/Metalloid	Selenium	7782-49-2	325189 - chemical mfg (all other); 326210 - tire mfg		CWWA. 2000
Inorganic	Metal/Metalloid	Silver	7440-22-4	333317- Aluminum rolling, drawing, extruding and alloying; 811199- automotive repair & maintenance (all other); 56174 - carpet & upholstery cleaning services; 621210 - dental offices; 33422 - die-casting foundries (non-ferrous); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (Mainline); 4832112 - freight rail transportation (short-haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 622111 - hospitals general (except pediatrics); 721111 - hotels (except casino hotels) and motels; 812330 - linen & uniform supply; 562920 - material recovery facilities; 332810 - metals-coating and allied activities; 322121 - paper (excepts newsprint) mills; 482114 - passenger rail transportation; 32411 - petroleum refineries; 81292 - photo finishing services;		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				562910 - remediation services; 322291 - sanitary paper product mfg; 221330 - steam & air (conditioning and supply); 485110 - urban transit systems; 541940 - veterinary services; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 321114 - wood preservation		
Organic	Pesticide - Triazine	Simazine	122-34-9	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	Health Canada 2005
Inorganic	Metal/Metalloid	Sodium	7440-23-5	31611 - leather& hide tanning & finishing; domestici; Used in many home and personal care products; road salt applications in winter	diffusive, non-point	CWWA. 2000
Organic	Aromatic Hydrocarbon	Styrene	100-42-5	488320 - marine cargo handling; 32411 - petroleum refineries		CWWA. 2000
Inorganic	Anion	Sulphate		32552 - adhesives mfg; 324122 - asphalt shingle & coating material mfg; 325 chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 33422 - communications broadcasting equipment mfg; 325920 - explosives mfg; 33111 - iron and steel mills and ferro-alloy mfg; 488320 - marine cargo handling; 332999 - metal products mfg (all other misc.); 331410 - metal smelting and refining (non-ferrous except aluminum); 332321 - metal window and door mfg; 332810 - metals-coating and allied activities; 327990 - mineral product mfg (all other non-metallic); 336320 - motor vehicle electronic equipment mfg; 332329 - ornamental metal products mfrs (others); 325320 - pesticide & other agricultural chemical mfg; 324190 - petroleum & coal products mfg (other); 32411 - petroleum refineries; 322291 - sanitary paper product mfg; 311940 - seasoning & dressing mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition and locker mfg; 321112 - shingle & shake mills; 325610 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; 331222 - steel wire drawing; 31193 - syrup & other flavouring concentrates mfg; 312210 - tobacco stemming & redrying; 332619 - wire product mfg (all other); 321114 - wood preservation		CWWA. 2000
Inorganic	Miscellaneous	Sulphide (as H_2S)	18496-25-8	311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 325189 - chemical mfg (all other basic inorganic); 3325190 - chemical mfg (other basic organic); 31192 - coffee & tea mfg; 31134 - confectionery mfg (non-chocolate); 311821 - cookie & cracker mfg; 311515 - dairy products (dry & condensed) mfg; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning & laundry services (except coin-operated); 311211 - flour milling; 311822 - flour mixes& dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (mainline); 482112 - freight rail transportation (short-haul); 33251 - hardware mfg; 31152 - ice cream & frozen dessert mfg; 812330 - linen & uniform supply; 488320 - marine cargo handling; 562920 - material recovery facilities; 332810 - metals coating & allied activities; 311511 - milk mfg (fluid); 311224 - oilseed processing; 482114 - passenger rail transportation; 32511 - petrochemical mfg; 32411 - petroleum refineries; 311615 - poultry processing; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 311811 - retail bakeries; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 311919 - snack food mfg (other); 221330 - steam & air (conditioning and supply); 311310 - sugar mfg; 31193 - syrup & other flavouring concentrates mfg; 31183 - tortilla mfg; 562990 -waste management services (all other); 562210 - waste treatment & disposal		CWWA. 2000
Organic	Pesticide - Urea-based	Tebuthiuron	34014-18-1	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	Cornell University, 2005
Organic	Pesticide - Organophosphorus	Temephos	3383-96-8	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	Inchem. 2005
Non-specific [a]	Physical/Chemical	Temperature		3313131 - aluminum primary production; 31212 - breweries; 331420 - copper rolling, drawing, extruding and alloying; 221112 - electricity fossil-fuel power generation; 33111 - iron & steel mills & ferro-alloy mfg; 331511 - iron foundries; 331440 - metal smelting & refining (non-ferrous; except Al); 311511 - milk mfg (fluid); 211113 - oil & gas - conventional extraction; 311224 - oilseed processing; 32511 - petrochemical mfg; 331514 - steel foundries; 311310 - sugar mfg; 313 - textile mills		CWWA (2000)
Organic	Pesticide - Organophosphorus	Terbufos	13071-79-9	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning,	diffusive, non-point	Health Canada 2005
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,4-)	634-66-2	325189 - chemical mfg (all other basic inorganic); 33111 - iron & steel mills & ferro-alloy mfg; 32411 - petroleum refineries		CWWA. 2000
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,5-)	634-90-2	325189 - chemical mfg (all other basic inorganic); 33111 - iron & steel mills & ferro-alloy mfg; 32411 - petroleum refineries		CWWA. 2000
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,4,5-)	95-94-3	325189 - chemical mfg (all other basic inorganic); 33111 - iron & steel mills & ferro-alloy mfg; 32411 - petroleum refineries		CWWA. 2000
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	630-20-6	no data found; believed similar to 1,1,2,2-tetrachloroethane	diffusive, non-point	
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,2,2-)	79-34-6	no longer produced in Canada; may be a by-product of other chemical production such as vinyl chloride monomer dichloroethane. May enter in leachate from waste disposal sites treated by municipal treatment facilities, and from atmospheric transport	diffusive, non-point	Health Canada 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	127-18-4	325190 - chemical mfg (other basic inorganic); 812310 - laundries (coin-operated) & dry cleaners; 812330 - linen 7 uniform supply; 323119 - printing (other)		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloromethane	56-23-5	325189 - chemical mfg (all other basic inorganic (325190 - chemical mfg (other basic organic)		CWWA. 2000
Organic	Chlorophenol	Tetrachlorophenol (2,3,4,6-)	935-95-5	Used mostly as wood preservatives, possibly also in pesticide formulation		Health Canada.2005
Organometals	Alkyl lead	Tetraethyl lead	78-00-2	325190 - chemical mfg (other basic organic)		CWWA. 2000
Organometals	Alkyl lead	Tetramethyl lead	75-74-1	325190 - chemical mfg (other basic organic)		CWWA. 2000
Inorganic	Metal/Metalloid	Thallium	7440-28-0	now mainly used in the electrical and electronic industries and in the production of special glasses. Another important field of application is the use of radioisotopes in medicine. released into the environment, mainly from mineral smelters, coal-burning power plants, brickworks and cement plants		Inchem. 2005
Inorganic	Metal/Metalloid	Tin	7440-31-5	325 - chemical mfg		CWWA. 2000
Organic	Alkyl benzene	Toluene	108-88-3	811199- automotive repair & maintenance (all other); 325189 - chemical mfg (all other basic inorganic); 81232 - dry cleaning & laundry services (except coin-operated); 622111 - hospital general (except pediatric); 541380 - laboratories (testing); 812330 - linen & uniform supply; 562920 - material recovery facilities; 32411 - petroleum refineries; 562910 - remediation services; 221330 - steam & air (conditioning & supply); 562990 - waste management services (all other)		CWWA. 2000
Non-specific	Physical/Chemical	Total dissolved solids				
Non-specific	Physical/Chemical	Total organic carbon		numerous industrial sources (see biochemical oxygen demand); domestic		
Non-specific	Physical/Chemical	Total residual chlorine	7782-50-5	domestic	wastewater disinfection	
Non-specific	Physical/Chemical	Total suspended solids		327910 - abrasive product mfg; 32552 - adhesives mfg; 488119 - airport operations (other); 333317- aluminum rolling, drawing, extruding and alloying; 311611 - animal (except poultry) slaughtering; 311119 - animal food mfg (other); 324122 - asphalt shingle & coating material mfg; 415110 - automobile and light duty truck wholesalers/distributors; 811121 - automotive body, paint & interior repair & maintenance; 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199 - automotive repair & maintenance (all other); 311814 - bakeries (commercial) fresh & frozen mfg; 31123 - breakfast cereal mfg; 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 327310 - cement mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 31132 - chocolate & confectionery mfg; 31192 - coffee and tea mfg; 331221 - cold-rolled steel shape mfg; 323113 - commercial screen printing; 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 31134 - confectionery mfg (non-chocolate); 311821 - cookie and cracker mfg; 212233 - copper-zinc ore mining; 325991 - custom compounding of purchased resins; 315210 - cut & sew clothing contracting; 332210 - cutlery & hand tool mfg; 311515 - dairy products (dry & condensed) mfg; 331523 - die-casting foundries (non-ferrous); 312140 - distilleries; 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 231390 - engineering construction (other); 325920 - explosives mfg; 311211 - flour milling; 311822 - flour mixes & dough mfg from purchased flour; 311990 - food mfg (all other); 311111 - food mfg (dog & cat food); 722 - food services & drinking places; 413110 - food wholesaler-distributors (general-line); 413190 - food wholesaler-distributors (specialty-line); 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation (mainline); 4832112 - freight rail transportation (short-haul); 311420 - Fruit & Vegetable Canning, pickling & drying; 44719 - gasoline stations (other); 441711 - gasoline stations with convenience stores; 212220 - gold& silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatrics); 721111 - hotels (except casino hotels) and motels; 31152 - ice cream & frozen dessert mfg; 33111 - iron and steel mills and ferro-alloy mfg; 331511 - iron foundries; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) & dry cleaners; 31611 - leather & hide tanning & finishing; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other misc.); 488320 - marine cargo facilities; 562920 - material recovery facilities; 625510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg; 212299 - metal ore mining (all other); 332999 - metal products mfg (all other misc.); 331410 - metal smelting and refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332810 - metals coating & allied activities; 311511 - milk mfg (fluid; 327990 - mineral product mfg (all other non-metallic); 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg - other; 415290 - motor vehicle parts wholesaler/distributors (others-new); 51111 - newspaper publishers; 212232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots & garages; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg (other); 32411 - petroleum refineries; 325410 -		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				pharmaceutical & medicine mfg; 81292 - photo finishing services; 231330 - pipelines (oil & gas) construction; 311615 - poultry processing; 32311 - printing; 323119 - printing (other);413160 - red meat & meat product wholesaler-distributors; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 325210 - resin & synthetic rubber mfg; 311811 - retail bakeries; 322291 - sanitary paper product mfg; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition and locker mfg; 311919 - snack food mfg (other); 325610 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; 332611 - spring (heavy gauge) mfg; 332118 - stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 31193 - syrup & other flavouring concentrates mfg; 31331 - textile & fabric finishing; 312210 - tobacco stemming & redrying; 31183 - tortilla mfg; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 541940 - veterinary services; 321217 - waferboard mills; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 31213 - wineries; 332619 - wire product mfg (all other); 321114 - wood preservation 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 336390 - motor vehicle parts mfg - other; 415290 - motor vehicle parts wholesaler/distributors (others-new); 51111 - newspaper publishers; 212232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots & garages; 482114 - passenger rail transportation; 325320 - pesticide & other agricultural chemical mfg; 32511 - petrochemical mfg; 324190 - petroleum & coal products mfg (other); 32411 - petroleum refineries; 325410 - pharmaceutical & medicine mfg; 81292 - photo finishing services; 231330 - pipelines (oil & gas) construction; 311615 - poultry processing; 32311 - printing; 323119 - printing (other);413160 - red meat & meat product wholesaler-distributors; 562910 - remediation services; 311614 - rendering & meat processing from carcasses; 325210 - resin & synthetic rubber mfg; 311811 - retail bakeries; 322291 - sanitary paper product mfg; 311710 - seafood product preparation & packaging; 311940 - seasoning & dressing mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition and locker mfg; 311919 - snack food mfg (other); 325610 - soap & cleaning compound mfg; 312110 - soft drink & ice mfg; 332611 - spring (heavy gauge) mfg; 332118 - stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 31193 - syrup & other flavouring concentrates mfg; 31331 - textile & fabric finishing; 312210 - tobacco stemming & redrying; 31183 - tortilla mfg; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 541940 - veterinary services; 321217 - waferboard mills; 562990 -waste management services (all other); 562210 - waste treatment & disposal; 31213 - wineries; 332619 - wire product mfg (all other); 321114 - wood preservation		
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	8001-35-2	diffusive, non-point; Toxaphene was banned in Canada in 1985		ITK 2005
Organic	Pesticide - Thiocarbamate	Triallate	2303-17-5	325320 - Pesticide and Other Agricultural Chemical Mfg, diffusive, non-point		Agriculture Canada. 2005
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride	81741-28-8	used as a corrosion inhibitor in industrial cooling systems; as a pesticide and as a phase transfer catalyst		Environment Canada 2005
Organometals	Alkyl Tin	Tributyltin	688-73-3	used as molluscicides,as antifoulants on boats, ships, quays, buoys, crab pots, fish nets, and cages, as wood preservatives, as slimicides on masonry, as disinfectants, and as biocides for cooling systems, power station cooling towers, pulp and paper mills, breweries, leather processing, and textile mills		Inchem. 2005
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	120-82-1	33111 - iron & steel mills & ferro-alloy mfg		CWWA. 2000
Organic	Chlorobenzene	Trichlorobenzene (1,2,4-)	87-61-6	33111 - iron & steel mills & ferro-alloy mfg		CWWA. 2000
Organic	Chlorobenzene	Trichlorobenzene (1,3,5-)	108-70-3	33111 - iron & steel mills & ferro-alloy mfg		CWWA. 2000
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	71-55-6	mainly used in metal degreasing and as a solvent in many industrial and consumer products, including adhesives, spot removers, and aerosol cans. It is also a chemical intermediate		Inchem. 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,2-)	79-00-5	an impurity in the manufacture of 1,1,1-trichloroethane		Inchem. 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethylene	79-01-6	325190 - chemical mfg (other basic organic)		CWWA. 2000
Organic	Chlorophenol	Trichlorophenol (2,4,6-)	88-06-2	Used mostly as wood preservatives, possibly also in pesticide formulation		Health Canada 2005
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	55491-33-3	2,4,5-T is no longer on the market, diffusive, non-point		PMRA 2005
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)	93-72-1	banned in U.S .in 1985; diffusive, non-point		EPA 2005; Hydromantis staff professional judgment
Organometals	Alkyl Tin	Tricyclohexyltin	13121-70-5	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning, insecticide;	diffusive, non-point	Ortepa 2005
Organometals	Alkyl lead	Triethyl lead	56267-87-9	325190 - chemical mfg (other basic organic)		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
Organic	Pesticide - Dinitroaniline-based	Trifluralin	1582-09-8	325320 - Pesticide and Other Agricultural Chemical Mfg,	diffusive, non-point	Inchem. 2005
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)	many compounds each has CAS No.	industrial; domestic		see entries on chloroform, bromoform, dibromochloromethane and dichlorobromomethane; as chemical byproducts from disinfection of potable water and municipal wastewaters with chlorine
Organo-metals	Aromatic Tin	Triphenyltin	668-34-8	325320 - Pesticide and Other Agricultural Chemical Mfg, 311420 - Fruit & Vegetable Canning,	diffusive, non-point	Ortepa 2005
Non-specific	Physical/Chemical	Turbidity		domestic; many potential industrial contributors		
Inorganic	Metal/Metalloid	Uranium	7440-61-1	Domestic from potable water sources ;	diffusive, non-point	Nova Scotia 2005
Inorganic	Metal/Metalloid	Vanadium		325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 33111 - iron & steel mills & ferro-alloy mfg		CWWA. 2000
Biological	Pathogen - Virus	Viruses		domestic	diffusive, non-point	
Organic	Aromatic Hydrocarbon	Xylene	1330-20-7	811119 - automotive maintenance mechanical & electrical (other); 541380 - laboratories (testing); 812330 - linen & uniform supply; 562920 - material recovery facilities; 32411 - petroleum refineries; 323119 - printing (other); 562910 - remediation services; 221330 - steam & air (conditioning & supply); 562990 - waste management services (all other); 562210 - waste treatment & disposal		CWWA. 2000
Inorganic	Metal/Metalloid	Zinc	7440-66-6	488119 - airport operations (other); 331317 - aluminum rolling, drawing, extruding & alloying; 336110 - automobile and light-duty motor vehicle mfg; 415110 - automobile & light duty truck wholesaler-distributors; 811119 - automotive maintenance mechanical & electrical (other); 441310 - automotive parts and accessories stores; 811111 - automotive repair (general); 811199-automotive repair & maintenance (all other); 44111 - car dealers (new); 56174 - carpet & upholstery cleaning services; 325 - chemical mfg; 325189 - chemical mfg (all other basic inorganic); 325190 - chemical mfg (other basic organic); 325999 - chemical product mfg (all other misc.); 33422 - communications broadcasting equipment mfg; 332314 - concrete reinforcing bar mfg; 331420 - copper rolling, drawing, extruding and alloying; 212233 - copper-zinc ore mining; 621210 - dental offices; 331523 - die-casting foundries (non-ferrous); 81232 - dry cleaning and laundry services (except coin-operated); 611 - educational services; 332113 - forging; 331529 - foundries (non-ferrous except die-casting); 482113 - freight rail transportation - mainline); 482112 - freight rail transportation (short haul); 44719 - gasoline stations (other); 44711 - gasoline stations with convenience stores; 212220 - gold & silver ore mining; 33251 - hardware mfg; 622111 - hospitals general (except pediatric); 721111 - hotels (except casino hotels) and motels; 33111 - iron & steel mills and ferro-alloy mfg; 331511 - iron foundries; 21221 - iron ore mining; 541380 - laboratories (testing); 812310 - laundries (coin-operated) and dry cleaners; 335120 - lighting fixture mfg; 812330 - linen & uniform supply; 339990 - manufacturing (all other); 488320 - marine cargo handling; 562920 - material recovery facilities; 621510 - medical & diagnostic laboratories; 339110 - medical equipment & supplies mfg; 332439 - metal container mfg (other); 212299 - metal ore mining (all other); 331490 - metal processing & alloying (except Fe, Cu and Al); 331410 - metal smelting & refining (non-ferrous except aluminum); 33242 - metal tank (heavy gauge) mfg; 332910 - metal valve mfg; 332321 - metal window & door mfg; 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 33637 - motor vehicle metal stamping; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 212232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32511 - petrochemical mfg; 32411 - petroleum refineries; 81292 - photo finishing services; 562910 - remediation services; 326220 - rubber & plastic hose & belting mfg; 326290 - rubber product mfg (other); 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 - spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 326210 - tire mfg; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation 332810 - metals coating & allied products; 33633 - motor vehicle chassis components (except spring) mfg; 336320 - motor vehicle electronic equipment mfg; 336310 - motor vehicle gasoline mfg; 33637 - motor vehicle metal stamping; 336390 - motor vehicle parts mfg (other); 415290 - motor vehicle parts wholesaler-distributors (other new); 212232 - nickel-copper ore mining; 332329 - ornamental metal products mfg (other); 322121 - paper (except newsprint) mills; 812930 - parking lots and garages; 482114 - passenger rail transportation; 32511 - petrochemical mfg; 32411 - petroleum refineries; 81292 - photo finishing services; 562910 - remediation services; 326220 - rubber & plastic hose & belting mfg; 326290 - rubber product mfg (other); 322291 - sanitary paper product mfg; 334410 - semiconductor mfg; 337215 - shelving, showcase, partition & locker mfg; 321112 - shingle & shake mills; 332611 -		CWWA. 2000

Table A.7. Sources of Contaminants in Municipal Wastewater

Main Class	Sub-class	Contaminant	CAS #	Industrial Source	Secondary Source	Reference
				spring (heavy gauge) mfg; 332118 stamping; 221330 - steam & air (conditioning and supply); 331514 - steel foundries; 331222 - steel wire drawing; 326210 - tire mfg; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation steel wire drawing; 326210 - tire mfg; 332720 - turned product & screw, nut & bolt mfg; 485110 - urban transit systems; 562990 - waste management services (all other); 562210 - waste treatment & disposal; 332619 - wire product mfg (all other); 321114 - wood preservation		

Note: Table is 11x17 inch format.

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Raw/Primary Treatment					Secondary/Tertiary Treatment															
				Raw Sewage Concentration (ug/L)[b]	Western Canada Plant #1 (ug/L)	Western Canada Plant #2 (ug/L)	Central Canada Plant #1 (ug/L)	Central Canada Plant #2 (ug/L)	Central Canada Plant #3 (ug/L)	Central Canada Plant #4 (ug/L)	Central Canada Plant #5 (ug/L)	Central Canada Plant #6 (ug/L)	Central Canada Plant #7 (ug/L)	Central Canada Plant #8 (ug/L)	EC - Confidential (ug/L)	Farre et al. 2000 (ug/L)	Bennie et al. 1998 (ug/L)	Braghetta et al. 2002 (ug/L	Scruggs et al. 2004 (ug/L)	Petrovic et al. 2003 (ug/L)	Scruggs et al. 2005 (ug/L)	Skadsen et al. 2004 (ug/L)	Brown 2004 (ug/L)	Cain et al. 2003 (ug/L)	Lee et al. 2004 (ug/L)
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)	1.5																					
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)	0/100mL																					
Biological	Pathogen - Bacteria	Fecal coliforms	0/100mL																					
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.																						
Biological	Pathogen - Protozoan	*Giardia* sp.																						
Biological	Pathogen - Protozoan	Protozoa																						
Biological	Pathogen - Virus	Viruses																						
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	0.7						<10	<10	<10	<10	<10	<10		8.4-13	1.7		25	0.1-350	25				3.2-81
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	0.009	7-790																				
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride																						
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate																		0.12-0.36				
Emerging	Pharmaceutical - Stimulant	Caffeine																nd-1.813	5.1		7	0.043-0.310	nd-4.0	0.2-3.6
Emerging	Pharmaceuticals - Hormone	Estradiol																			0.003-0.0099			
Inorganic	Anion	Bromate	10																					
Inorganic	Anion	Chlorate																						
Inorganic	Anion	Chloride	230000		55000	38000																		
Inorganic	Anion	Chlorite																						
Inorganic	Anion	Cyanide	5		0.5 WAD	0.5 WAD[e]																		
Inorganic	Anion	Fluoride	120		150[e]	90[e]																		
Inorganic	Anion	Sulphate	500000		11000	13000																		
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)	0.5																					
Inorganic	Disinfectant	Chlorine dioxide																						
Inorganic	Metal/Metalloid	Aluminum	5-100		1555	997			80	90	110	70	250	40	146.5									
Inorganic	Metal/Metalloid	Antimony	6		0.54	0.43																		
Inorganic	Metal/Metalloid	Arsenic	5		0.7	0.7																		
Inorganic	Metal/Metalloid	Barium	1000		52.68	38.23									9040									
Inorganic	Metal/Metalloid	Beryllium	11																					
Inorganic	Metal/Metalloid	Boron	200		180	110																		
Inorganic	Metal/Metalloid	Cadmium	0.0025-0.097	1.88	1.02	0.29			<0.2	0.1	0.04	0.02	0.2	0.02	1.9									
Inorganic	Metal/Metalloid	Calcium	1000000		19900	16700									47900									
Inorganic	Metal/Metalloid	Chromium (hexavalent)	1		3	2			<0.2	0.2	<0.2	0.2	1	3	2.9									
Inorganic	Metal/Metalloid	Chromium (trivalent)	8.9		4	2																		
Inorganic	Metal/Metalloid	Cobalt	0.9		1.06	0.58									12.3									
Inorganic	Metal/Metalloid	Copper	2-4		123.3	106			25	21	34	19	69	26	18.1									
Inorganic	Metal/Metalloid	Iron	300		1468	895			39	240	49	78	68	79	1172									
Inorganic	Metal/Metalloid	Lead	1-7		13	9.16			0.2	0.3	0.3	0.5	0.7	0.5	10.3									
Inorganic	Metal/Metalloid	Lithium	2500		2[e]	1.9[e]																		
Inorganic	Metal/Metalloid	Magnesium	200		6850	5360									14400									
Inorganic	Metal/Metalloid	Manganese	50		109	44			10	11	14	14	17	7	81.5									
Inorganic	Metal/Metalloid	Mercury	0.016	0.22	0.12	0.26									0.05									
Inorganic	Metal/Metalloid	Molybdenum	73		2.57	3.27									9.9									
Inorganic	Metal/Metalloid	Nickel	25-150		6.7	3			5.7	35	2.9	13	15	9.3	24.1									
Inorganic	Metal/Metalloid	Selenium	1		0.3																			
Inorganic	Metal/Metalloid	Silver	0.1		2.67	2.75									26.53									
Inorganic	Metal/Metalloid	Sodium	200000		48400	33600																		
Inorganic	Metal/Metalloid	Thallium	0.8																					
Inorganic	Metal/Metalloid	Tin			1.71	1.51																		
Inorganic	Metal/Metalloid	Uranium	5		0.05[e]	0.11[e]																		
Inorganic	Metal/Metalloid	Vanadium	6												10.8									
Inorganic	Metal/Metalloid	Zinc	30		103.7	68.2			27	34	29	22	89	33	30.8									
Inorganic	Miscellaneous	Cyanogen Chloride																						
Inorganic	Miscellaneous	Sulphide (as H_2S)	2		131 Total	96 Total																		
Inorganic	Nutrient	Ammonia	19		31,000[d]	22,000[d]																		
Inorganic	Nutrient	Nitrate	13000																					
Inorganic	Nutrient	Nitrite	60																					
Inorganic	Nutrient	Phosphorus (total)	0.1		6900	4700																		
Non-specific	Miscellaneous	Chlorinated wastewater effluents																						
Non-specific	Physical/Chemical	Biochemical Oxygen Demand			194000	180000																		
Non-specific	Physical/Chemical	Colour	15 TCU																					
Non-specific	Physical/Chemical	Hardness																						
Non-specific	Physical/Chemical	Oil and grease			297000	27000																		
Non-specific	Physical/Chemical	Total dissolved solids	500000																					
Non-specific	Physical/Chemical	Total organic carbon																						
Non-specific	Physical/Chemical	Total residual chlorine	2																					
Non-specific	Physical/Chemical	Total suspended solids			293000	173000																		
Non-specific	Physical/Chemical	Turbidity	1 NTU																					
Non-specific	Physical/Chemical	pH	6.5-8.5		7.1	7.04																		
Non-specific	Physical/Chemical	Temperature	15°C																					
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)																						
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane							<1	<1	<1	<1	<1	<1										
Organic	Aliphatic Hydrocarbon - Halogenated	Bromoform	60				ND	ND																
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes																						
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	1.8		2.5	3.2	ND	ND							2.16									
Organic	Aliphatic Hydrocarbon - Halogenated	Dibromochloromethane	40				ND	ND	<1	<1	<1	<1	<1	<1	0.43									
Organic	Aliphatic Hydrocarbon - Halogenated	Dichlorobromomethane	100						<1	<1	<1	<1	<1	<1	0.43									
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,1-)	200				ND	ND																
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	5				ND	ND	<1	<1	<1	<1	<1	<1	0.33									
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,1-)	14				ND	ND	<1	<1	<1	<1	<1	<1										
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,2-)	200				ND	ND	<1	<1	<1	<1	<1	<1	0.52									
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloromethane	50				ND	ND	<1	<1	<1	<1	<1	<1	2.69									
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropane (1,2-)	0.7				ND	ND																
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropene (1,2-) (cis and trans)	7				ND	ND	<1	<1	<1	<1	<1	<1	1.81									
Organic	Aliphatic Hydrocarbon - Halogenated	Hexachloro-1,3-butadiene	1.3				ND	ND																
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	0.9																					
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene	2																					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	20																					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,2,2-)	70				ND	ND	<1	<1	<1	<1	<1	<1	6.23									
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	30		3.4	10.6	0.43	ND	<1	<1	<1	<1	<1	<1	0.42				nd-0.5		nd-0.5			
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloromethane	5				ND	ND																
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	10				ND	ND	<1	<1	<1	<1	<1	<1	0.97									
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,2-)	800				ND	ND	<1	<1	<1	<1	<1	<1	0.38									
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethylene	21				ND	ND	<1	<1	<1	<1	<1	<1										

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Raw/Primary Treatment					Secondary/Tertiary Treatment															
				Raw Sewage Concentration (ug/L) [b]	Western Canada Plant #1 (ug/L)	Western Canada Plant #2 (ug/L)	Central Canada Plant #1 (ug/L)	Central Canada Plant #2 (ug/L)	Central Canada Plant #3 (ug/L)	Central Canada Plant #4 (ug/L)	Central Canada Plant #5 (ug/L)	Central Canada Plant #6 (ug/L)	Central Canada Plant #7 (ug/L)	Central Canada Plant #8 (ug/L)	EC - Confidential (ug/L)	Farre et al. 2000 (ug/L)	Bennie et al. 1998 (ug/L)	Braghetta et al. 2002 (ug/L	Scruggs et al. 2004 (ug/L)	Petrovic et al. 2003 (ug/L)	Scruggs et al. 2005 (ug/L)	Skadsen et al. 2004 (ug/L)	Brown 2004 (ug/L)	Cain et al. 2003 (ug/L)	Lee et al. 2004 (ug/L)
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)	100																					
Organic	Alkyl benzene	Ethylbenzene	2.4			0.8	ND	ND	<1	<1	<1	<1	<1	<1	0.73									
Organic	Alkyl benzene	Toluene	2		0.7	2.6	ND	ND	<1	<1	<1	<1	<1	<1	0.48									
Organic	Alkylphenol & Ethoxylates	Nonylphenol	0.7						1.6	0.7	1.7	5.2	1	1.3		5.5-6.6	<0.020-4.8		16		16			0.5-9.1
Organic	Alkylphenol & Ethoxylates	Octylphenol														1.1-1.6								0.04-0.68
Organic	Aromatic Hydrocarbon	Benzene	5				ND	ND	<1	<1	<1	<1	<1	<1										
Organic	Aromatic Hydrocarbon	Phenols, Total	4		40	26	ND	<DL							0.42								0.067-2.2	
Organic	Aromatic Hydrocarbon	Styrene	72				ND	ND	<1	<1	<1	<1	<1	<1										
Organic	Aromatic Hydrocarbon	Xylene	2-40		0.8	5	ND	ND	<1	<1	<1	<1	<1	<1	0.61;0.37									
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime																						
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride																						
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	0.6																					
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene					ND	ND																
Organic	Aromatic Hydrocarbon - Polycyclic	Acenaphthene	5.8		0.1	0.11	0.81	<DL							0.93									
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	0.012	0.43	0.07	0.05	ND	ND																
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	0.018	0.65	0.1	0.04	<DL	<DL							0.25									
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	0.01	0.77	0.1	0.1	<DL	<DL							0.22									
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene		0.58	0.1	0.05	ND	ND							0.27									
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	0.00002	0.33			ND	ND							0.23									
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	0.0002	0.56	0.1	0.05	ND	<DL							0.25									
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene	0.1	0.72	0.1	0.05	ND	ND							0.21									
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	0.002	0.22			ND	ND																
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	0.02				ND	ND							0.2									
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	0.04	0.97			<DL	<DL																
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	3		0.12	0.12[e]	ND	<DL																
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene		0.54			ND	ND																
Organic	Aromatic Hydrocarbon - Polycyclic	Naphthalene	1.1		0.27[e]	0.35[e]	ND	0.12							0.38								0.05-0.14	
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	0.00007	0.69			ND	ND																
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	0.4	0.98	0.32	0.34	0.19	<DL																
Organic	Aromatic Hydrocarbon - Polycyclic	Total polycyclic aromatic hydrocarbons			1.17	0.97									0.36									
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	0.025	0.65			ND	<DL							0.18								0.05-0.11	
Organic	Chlorobenzene	Chlorobenzene	1.3																					
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	0.7				ND	ND	<1	<1	<1	<1	<1	<1										
Organic	Chlorobenzene	Dichlorobenzene (1,3-)	150				ND	ND	<1	<1	<1	<1	<1	<1										
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	5	1.55	1	0.6	ND	ND	<1	<1	<1	<1	<1	<1	1.56				nd-1		nd-1		0.06-0.09	
Organic	Chlorobenzene	Hexachlorobenzene	0.0065	0.002			ND	ND							0.002									
Organic	Chlorobenzene	Pentachlorobenzene	6				ND	ND																
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,4-)	1.8				ND	ND																
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,5-)	0.1				ND	ND																
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,4,5-)	0.1				ND	ND																
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	8																					
Organic	Chlorobenzene	Trichlorobenzene (1,2,4-)	24				ND	ND																
Organic	Chlorobenzene	Trichlorobenzene (1,3,5-)	0.65				ND	ND																
Organic	Chlorophenol	Chlorophenol	7													20								
Organic	Chlorophenol	Dichlorophenol (2,4-)	0.2		0.2		ND	ND								16				<20				
Organic	Chlorophenol	Pentachlorophenol	0.5	0.24	0.3	0.2	ND	ND							0.24									
Organic	Chlorophenol	Tetrachlorophenol (2,3,4,6-)	1				ND	ND																
Organic	Chlorophenol	Trichlorophenol (2,4,6-)	5		0.1	0.1	ND	<DL							0.42									
Organic	Dioxins and Furans	Dibenzofuran	0.3																					
Organic	Dioxins and Furans	Dibenzo-p-dioxin																						
Organic	Dioxins and Furans - Polychlorinated	PCDD		0.0038																				
Organic	Dioxins and Furans - Polychlorinated	PCDF		0.00012																				
Organic	Haloacetonitrile	Haloacetonitriles																						
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)																						
Organic	Halocarboxylic acids	Haloacetic acids																						
Organic	Haloether	Bis(chloromethyl)ether					ND	0.21							19.5									
Organic	Haloether	Chloromethyl methyl ether					ND	ND																
Organic	Hydrocarbons with N,P,S substitution	Acridine	4.4																					
Organic	Hydrocarbons with N,P,S substitution	Acrylamide																						
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile					ND	ND																
Organic	Hydrocarbons with N,P,S substitution	Aniline	2.2																					
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)					ND	ND																
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene																						
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)																						
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid	400																					
Organic	Hydrocarbons with N,P,S substitution	Quinoline	3.4																					
Organic	Oxygenate - Acetaldehyde	Acetaldehyde																						
Organic	Oxygenate - Acetaldehyde	Formaldehyde	0.8																					
Organic	Oxygenate - Alcohol	Ethylene glycol	192000																					
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	500000																					
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	500000																					
Organic	Oxygenate - Ether	Methyl t-butyl ether	20																					
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	16		54[e]	19	ND	ND							33.9								1.2-10	
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	19		2	1	ND	ND							1620									
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters																						
Organic	Oxygenate- Carboxylic Acid	Resin Acids																						
Organic	Oxygenated - Epoxide	Ethylene oxide																						
Organic	Oxygenated Compounds	Acrolein	0.03																					
Organic	Pesticide - Benzoic acid	Dicamba	10				ND	ND																
Organic	Pesticide - Bipyridylium	Diquat	0.5																					
Organic	Pesticide - Bipyridylium	Methyl-parathion																						
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)	10																					
Organic	Pesticide - Carbamate	Iodo-2-propynyl butyl carbamate (3-)	1.9				ND	ND																
Organic	Pesticide - Chlorinated hydrocarbon	Aldrin	0.7	0.005			ND	ND							0.01									
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	0.004	0.05																				
Organic	Pesticide - Chlorinated hydrocarbon	DDD					ND	ND							0.01									
Organic	Pesticide - Chlorinated hydrocarbon	DDE		0.01		0.195	ND	ND							0.01									
Organic	Pesticide - Chlorinated hydrocarbon	DDT	0.001	0.02			ND	ND							0.02									
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	0.0019																					
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	0.02				ND	ND							0.13									
Organic	Pesticide - Chlorinated hydrocarbon	Endrin	0.0023				ND	ND																

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Raw/Primary Treatment					Secondary/Tertiary Treatment																
				Raw Sewage Concentration (ug/L) [b]	Western Canada Plant #1 (ug/L)	Western Canada Plant #2 (ug/L)	Central Canada Plant #1 (ug/L)	Central Canada Plant #2 (ug/L)	Central Canada Plant #3 (ug/L)	Central Canada Plant #4 (ug/L)	Central Canada Plant #5 (ug/L)	Central Canada Plant #6 (ug/L)	Central Canada Plant #7 (ug/L)	Central Canada Plant #8 (ug/L)	EC - Confidential (ug/L)	Farre et al. 2000 (ug/L)	Bennie et al. 1998 (ug/L)	Braghetta et al. 2002 (ug/L	Scruggs et al. 2004 (ug/L)	Petrovic et al. 2003 (ug/L)	Scruggs et al. 2005 (ug/L)	Skadsen et al. 2004 (ug/L)	Brown 2004 (ug/L)	Cain et al. 2003 (ug/L)	Lee et al. 2004 (ug/L)
Organic	Pesticide - Chlorinated hydrocarbon	Heptachlor + Heptachlor epoxide	0.0036				ND	ND																	
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	0.01	0.02		0.012	ND	ND							0.01										
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	0.03																						
Organic	Pesticide - Chlorinated hydrocarbon	Mirex	0.001				ND	ND																	
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	0.0002																						
Organic	Pesticide - Chloroacetanilide	Alalchlor																							
Organic	Pesticide - Chloroacetanilide	Metolachlor	7.8																						
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	4				ND	ND												<20					
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop																							
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	6.1																						
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	2.6				ND	ND												20-400					
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	4				92	0.26																	
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)																							
Organic	Pesticide - Dinitroaniline-based	Trifluralin	0.2																						
Organic	Pesticide - Dintrophenol derivative	Dinoseb	0.05				<DL	ND																	
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	5																						
Organic	Pesticide - N-methyl carbamate	Aldicarb	0.15																						
Organic	Pesticide - N-methyl carbamate	Bendiocarb	40																						
Organic	Pesticide - N-methyl carbamate	Carbaryl	0.2																						
Organic	Pesticide - N-methyl carbamate	Carbofuran	1.8																						
Organic	Pesticide - Organophosphorus	Azinphos-methyl	20																						
Organic	Pesticide - Organophosphorus	Chlorfenvinphos																							
Organic	Pesticide - Organophosphorus	Chlorpyrifos	0.002																						
Organic	Pesticide - Organophosphorus	Diazinon	0.08																nd-1		nd-1				
Organic	Pesticide - Organophosphorus	Dimethoate	6.2																						
Organic	Pesticide - Organophosphorus	Malathion	0.1																						
Organic	Pesticide - Organophosphorus	Parathion	0.013																						
Organic	Pesticide - Organophosphorus	Phorate	2																						
Organic	Pesticide - Organophosphorus	Temephos																							
Organic	Pesticide - Organophosphorus	Terbufos	1																						
Organic	Pesticide - Phosphoroglycine	Glyphosate	65																						
Organic	Pesticide - Pyrethroid	Deltamethrin	0.0004																						
Organic	Pesticide - Pyridine carboxylic acid	Picloram	29																						
Organic	Pesticide - Quaternary Ammonium	Dodecyl dimethyl ammonium chloride	1.5																						
Organic	Pesticide - Substituted benzene	Chlorothalonil	0.18																						
Organic	Pesticide - Thiocarbamate	Triallate	0.24																						
Organic	Pesticide - Thiophthalinide	Captan	1.3																						
Organic	Pesticide - Triazine	Atrazine	1.8																						
Organic	Pesticide - Triazine	Cyanazine	2																						
Organic	Pesticide - Triazine	Simazine	10																						
Organic	Pesticide - Triazinone	Metribuzin	1																						
Organic	Pesticide - Uracil	Bromacil	5																						
Organic	Pesticide - Urea-based	Diuron	1.6																						
Organic	Pesticide - Urea-based	Isoproturon																							
Organic	Pesticide - Urea-based	Linuron	7																						
Organic	Pesticide - Urea-based	Tebuthiuron	0.27																						
Organic	Polyhalogenated Polyphenyl	Aroclor 1254																							
Organic	Polyhalogenated Polyphenyl	PCBs	0.014																						
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls																							
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers																							
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls																							
Organometals	Alkyl lead	Alkyl lead																							
Organometals	Alkyl lead	Tetraethyl lead	0.0007																						
Organometals	Alkyl lead	Tetramethyl lead	0.006																						
Organometals	Alkyl lead	Triethyl lead	0.4																						
Organometals	Alkyl mercury	Methyl mercury	0.004																						
Organometals	Alkyl Tin	Tributyltin	0.001																						
Organometals	Alkyl Tin	Tricyclohexyltin	250																						
Organometals	Aromatic Tin	Triphenyltin	0.022																						

Note: Table is 11x17 inch format

[a] See Table A.5 for details.

[b] Hydromantix 2004.

[c] Study included data from some facilities with only primary treatment.

[d] - estimates of unionized ammonia based on conversion from total ammonia following Francis-Floyd and Watson, University of Florida

[e] - 2002 data

Parameter exceeds benchmark.

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Secondary/Tertiary Treatment																			
				Tanaka et al. 2003 (ug/L)	Paxeus and Schroder 1996	Paxeus et al. 1992 (ug/L)	Nasu et al. 1999 (ug/L)	Drewes et al. 2004 (ug/L)	Suidan et al. 2004 (ug/L)	Ciek et al. 2004 (ug/L)	Emerick et al. 2004 (ug/L)	Sedlak et al. 2004 (ug/L)	Soroushian et al. 2004 (ug/L)	Jacobsen et al. 2004 (ug/L)	Kreuzinger et al. 2004 (ug/L)	Giger et al. 1987 (ug/L)	Hydromantis Confidential (ug/L)	MISA range OMOE 1988 (ug/L)	MISA mean OMOE 1988	Orr et al. 1992 (ug/L) [c]	Canviro 1991 (ug/L)	Vaughn et al. 2004 (cysts/100L)	Huffman et al. 2004 (cysts/100L)	Levine et al. 2004 (Cfu/100ml)
Biological	Algal Toxin	Cyanobacterial toxins (as Microcystin - LR)	1.5																				
Biological	Pathogen - Bacteria	*Escherichia coli* (*E. coli*)	0/100mL																				
Biological	Pathogen - Bacteria	Fecal coliforms	0/100mL																				20-4000
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.																				3-127	3.4-40.2	
Biological	Pathogen - Protozoan	*Giardia* sp.																				225-8152	191-320	
Biological	Pathogen - Protozoan	Protozoa																						
Biological	Pathogen - Virus	Viruses																						
Emerging	Alkylphenol & Ethoxylates	Nonylphenol ethoxylate	0.7	0.4-0.7			0.95-3																	
Emerging	Hydrocarbons with N,P,S substitution	N-Nitrosodimethylamine	0.009									0.046	0.043-0.8											
Emerging	Hydrocarbons with N,P,S substitution	Tributyltetradecylphosphonium chloride																						
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate																						
Emerging	Pharmaceutical - Stimulant	Caffeine			4	0.1-0.5																		
Emerging	Pharmaceuticals - Hormone	Estradiol		0.01			0.014	0.00018-0.00791	nd	0.00443														
Inorganic	Anion	Bromate	10																					
Inorganic	Anion	Chlorate																						
Inorganic	Anion	Chloride	230000																					
Inorganic	Anion	Chlorite																						
Inorganic	Anion	Cyanide	5															6-43	1.3					
Inorganic	Anion	Fluoride	120		1																			
Inorganic	Anion	Sulphate	500000																					
Inorganic	Disinfectant	Chloramines (mono-, di-, tri-; organic, inorganic)	0.5																					
Inorganic	Disinfectant	Chlorine dioxide																						
Inorganic	Metal/Metalloid	Aluminum	5-100								87							40-5800	101.7	<20-1150				
Inorganic	Metal/Metalloid	Antimony	6														0.6-9							
Inorganic	Metal/Metalloid	Arsenic	5								1.7						1-1.3			<10-23				
Inorganic	Metal/Metalloid	Barium	1000											319			47-53							
Inorganic	Metal/Metalloid	Beryllium	11																	<10				
Inorganic	Metal/Metalloid	Boron	200												1300	800-1200								
Inorganic	Metal/Metalloid	Cadmium	0.0025-0.097								0.014							3-14	2.1		<1-11			
Inorganic	Metal/Metalloid	Calcium	1000000																	2540-369000				
Inorganic	Metal/Metalloid	Chromium (hexavalent)	1								0.64			9.4				10-140	9	<5-33.5	6-108			
Inorganic	Metal/Metalloid	Chromium (trivalent)	8.9																					
Inorganic	Metal/Metalloid	Cobalt	0.9											15					6.4	<5-8.9				
Inorganic	Metal/Metalloid	Copper	2-4								3.3			8			46-53	10-190	13.1	<5-90	4-85			
Inorganic	Metal/Metalloid	Iron	300														300-430			66.3-5230				
Inorganic	Metal/Metalloid	Lead	1-7								0.24			2.8			6-<200	20-91	16.5	<10-18.1	<5-70			
Inorganic	Metal/Metalloid	Lithium	2500																					
Inorganic	Metal/Metalloid	Magnesium	200																	3540-25380				
Inorganic	Metal/Metalloid	Manganese	50														18-20			27.5-753				
Inorganic	Metal/Metalloid	Mercury	0.016								0.0065						0.07-0.16	0.1-0.36	0.03	<0.01-0.173				
Inorganic	Metal/Metalloid	Molybdenum	73															10-20	6.6	<5-47.0				
Inorganic	Metal/Metalloid	Nickel	25-150								2.1			13.5				10-900	22.1	<10-170	7-346			
Inorganic	Metal/Metalloid	Selenium	1											1.8			<1-1			<10-30.6				
Inorganic	Metal/Metalloid	Silver	0.1								0.12						<200-850	10-1250	6.9	<100				
Inorganic	Metal/Metalloid	Sodium	200000																					
Inorganic	Metal/Metalloid	Thallium	0.8																					
Inorganic	Metal/Metalloid	Tin																						
Inorganic	Metal/Metalloid	Uranium	5																					
Inorganic	Metal/Metalloid	Vanadium	6																	<20				
Inorganic	Metal/Metalloid	Zinc	30								19			70			140-160	10-1400	53.3	<10-100	12-312			
Inorganic	Miscellaneous	Cyanogen Chloride																						
Inorganic	Miscellaneous	Sulphide (as H_2S)	2																	<0.05-4.8				
Inorganic	Nutrient	Ammonia	19															50-27700		90-16000	<1000-17100			
Inorganic	Nutrient	Nitrate	13000															250-28400		<60-19800				
Inorganic	Nutrient	Nitrite	60															30-3300		5-4800				
Inorganic	Nutrient	Phosphorus (total)	0.1															190-5450			300-2460			
Non-specific	Miscellaneous	Chlorinated wastewater effluents																						
Non-specific	Physical/Chemical	Biochemical Oxygen Demand																3500-110000		900-30800	<2000-22000			
Non-specific	Physical/Chemical	Colour	15 TCU																					
Non-specific	Physical/Chemical	Hardness																						
Non-specific	Physical/Chemical	Oil and grease																						
Non-specific	Physical/Chemical	Total dissolved solids	500000																					
Non-specific	Physical/Chemical	Total organic carbon																2700-297000		4300-17100	6700-24200			
Non-specific	Physical/Chemical	Total residual chlorine	2																	<10-950				
Non-specific	Physical/Chemical	Total suspended solids																3500-242000		1100-33100	2000-51000			
Non-specific	Physical/Chemical	Turbidity	1 NTU															0.46-200						
Non-specific	Physical/Chemical	pH	6.5-8.5															6.38-8.18			7.05-7.8			
Non-specific	Physical/Chemical	Temperature	15°C																					
Organic	Aliphatic Hydrocarbon	Butadiene (1,3-)																						
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane																						
Organic	Aliphatic Hydrocarbon - Halogenated	Bromoform	60																					
Organic	Aliphatic Hydrocarbon - Halogenated	C10-13 chloroalkanes																						
Organic	Aliphatic Hydrocarbon - Halogenated	Chloroform	1.8														2.8-4.0				<0.5-3.6			
Organic	Aliphatic Hydrocarbon - Halogenated	Dibromochloromethane	40																					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichlorobromomethane	100																					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,1-)	200															2.2-2.3	1.01					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethane (1,2-)	5															2-10	1.3					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,1-)	14																					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloroethene (1,2-)	200																					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloromethane	50														0.5-2.5							
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropane (1,2-)	0.7																					
Organic	Aliphatic Hydrocarbon - Halogenated	Dichloropropene (1,2-) (cis and trans)	7																					
Organic	Aliphatic Hydrocarbon - Halogenated	Hexachloro-1,3-butadiene	1.3																					
Organic	Aliphatic Hydrocarbon - Halogenated	Methyl bromide	0.9																					
Organic	Aliphatic Hydrocarbon - Halogenated	Monochloroethene	2																					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,1,2-)	20																					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethane (1,1,2,2-)	70																					
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloroethylene	30														0.6-1.0	2.0-84	1.18		<0.5-120			
Organic	Aliphatic Hydrocarbon - Halogenated	Tetrachloromethane	5																					
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,1-)	10															2.10-27	1.18		<0.5-4.76			
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethane (1,1,2-)	800																					
Organic	Aliphatic Hydrocarbon - Halogenated	Trichloroethylene	21															2.0-14	1.12		<0.5-4.68			

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Secondary/Tertiary Treatment																			
				Tanaka et al. 2003 (ug/L)	Paxeus and Schroder 1996	Paxeus et al. 1992 (ug/L)	Nasu et al. 1999 (ug/L)	Drewes et al. 2004 (ug/L)	Suidan et al. 2004 (ug/L)	Ciek et al. 2004 (ug/L)	Emerick et al. 2004 (ug/L)	Sedlak et al. 2004 (ug/L)	Soroushian et al. 2004 (ug/L)	Jacobsen et al. 2004 (ug/L)	Kreuzinger et al. 2004 (ug/L)	Giger et al. 1987 (ug/L)	Hydromantis Confidential (ug/L)	MISA range OMOE 1988 (ug/L)	MISA mean OMOE 1988	Orr et al. 1992 (ug/L) [c]	Canviro 1991 (ug/L)	Vaughn et al. 2004 (cysts/100L)	Huffman et al. 2004 (cysts/100L)	Levine et al. 2004 (Cfu/100ml)
Organic	Aliphatic Hydrocarbon - Halogenated	Trihalomethanes (total)	100																				
Organic	Alkyl benzene	Ethylbenzene	2.4		1	<0.5											<0.5-2				<0.5-4.91			
Organic	Alkyl benzene	Toluene	2			<0.5											2.6-15				<0.25-4.55			
Organic	Alkylphenol & Ethoxylates	Nonylphenol	0.7	0.2		nd-0.4	0.4							0.32										
Organic	Alkylphenol & Ethoxylates	Octylphenol																						
Organic	Aromatic Hydrocarbon	Benzene	5			<0.5															<0.25-0.92			
Organic	Aromatic Hydrocarbon	Phenols, Total	4														16-20	7.5-17.3	1.65		<1-14.1			
Organic	Aromatic Hydrocarbon	Styrene	72																					
Organic	Aromatic Hydrocarbon	Xylene	2-40			<0.2											2-11;1.1-5.0	2.4-27;2.7-17	1.05		<0.25-9.58;<0.25-4.12			
Organic	Aromatic Hydrocarbon - Halogenated	(4-chlorophenyl) cyclopropylmethanone,O-[(4-nitrophenyl)methyl]oxime																						
Organic	Aromatic Hydrocarbon - Halogenated	Benzidine dihydrochloride																						
Organic	Aromatic Hydrocarbon - Halogenated	Dichlorobenzidene (3,3'-)	0.6																					
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene																						
Organic	Aromatic Hydrocarbon - Polycyclic	Acenaphthene	5.8																					
Organic	Aromatic Hydrocarbon - Polycyclic	Anthracene	0.012																		0.05-0.09			
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)anthracene	0.018																					
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(a)pyrene	0.01				nd-0.01										.006-.015							
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene															.008-.022							
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(g,h,i)perylene	0.00002																					
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(k)fluoranthene	0.0002														.008-.016							
Organic	Aromatic Hydrocarbon - Polycyclic	Chrysene	0.1														.012-.031							
Organic	Aromatic Hydrocarbon - Polycyclic	Dibenzo(a,h)anthracene	0.002																					
Organic	Aromatic Hydrocarbon - Polycyclic	Dimethylnaphthalene	0.02																					
Organic	Aromatic Hydrocarbon - Polycyclic	Fluoranthene	0.04																		<0.05-0.03			
Organic	Aromatic Hydrocarbon - Polycyclic	Fluorene	3																		<0.05-15.0			
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene															.019-.032							
Organic	Aromatic Hydrocarbon - Polycyclic	Naphthalene	1.1																					
Organic	Aromatic Hydrocarbon - Polycyclic	Perylene	0.00007																					
Organic	Aromatic Hydrocarbon - Polycyclic	Phenanthrene	0.4															0.10-0.68			<0.05-1.1			
Organic	Aromatic Hydrocarbon - Polycyclic	Total polycyclic aromatic hydrocarbons																						
Organic	Aromatic Hydrocarbon - Polycyclic	Pyrene	0.025											0.01							<0.05-0.28			
Organic	Chlorobenzene	Chlorobenzene	1.3																					
Organic	Chlorobenzene	Dichlorobenzene (1,2-)	0.7																		<0.5-4.61			
Organic	Chlorobenzene	Dichlorobenzene (1,3-)	150																					
Organic	Chlorobenzene	Dichlorobenzene (1,4-)	5														4.0-5.0				<0.5-4.61			
Organic	Chlorobenzene	Hexachlorobenzene	0.0065																					
Organic	Chlorobenzene	Pentachlorobenzene	6																					
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,4-)	1.8																					
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,3,5-)	0.1																					
Organic	Chlorobenzene	Tetrachlorobenzene (1,2,4,5-)	0.1																					
Organic	Chlorobenzene	Trichlorobenzene (1,2,3-)	8																					
Organic	Chlorobenzene	Trichlorobenzene (1,2,4-)	24															0.02-0.36	0.01					
Organic	Chlorobenzene	Trichlorobenzene (1,3,5-)	0.65																					
Organic	Chlorophenol	Chlorophenol	7																					
Organic	Chlorophenol	Dichlorophenol (2,4-)	0.2				nd-0.08																	
Organic	Chlorophenol	Pentachlorophenol	0.5																					
Organic	Chlorophenol	Tetrachlorophenol (2,3,4,6-)	1																					
Organic	Chlorophenol	Trichlorophenol (2,4,6-)	5																					
Organic	Dioxins and Furans	Dibenzofuran	0.3																					
Organic	Dioxins and Furans	Dibenzo-p-dioxin																						
Organic	Dioxins and Furans - Polychlorinated	PCDD																						
Organic	Dioxins and Furans - Polychlorinated	PCDF																						
Organic	Haloacetonitrile	Haloacetonitriles																						
Organic	Haloalcohol	Chloral hydrate (1,1-Ethanediol, 2,2,2-trichloro-)																						
Organic	Halocarboxylic acids	Haloacetic acids																						
Organic	Haloether	Bis(chloromethyl)ether																						
Organic	Haloether	Chloromethyl methyl ether																						
Organic	Hydrocarbons with N,P,S substitution	Acridine	4.4																					
Organic	Hydrocarbons with N,P,S substitution	Acrylamide																						
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile																						
Organic	Hydrocarbons with N,P,S substitution	Aniline	2.2																					
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)																						
Organic	Hydrocarbons with N,P,S substitution	Dinitropyrene																						
Organic	Hydrocarbons with N,P,S substitution	Methylenebis(2-chloroaniline) (4,4'-)																						
Organic	Hydrocarbons with N,P,S substitution	Nitrilotriacetic acid	400																					
Organic	Hydrocarbons with N,P,S substitution	Quinoline	3.4		18																			
Organic	Oxygenate - Acetaldehyde	Acetaldehyde																						
Organic	Oxygenate - Acetaldehyde	Formaldehyde	0.8																					
Organic	Oxygenate - Alcohol	Ethylene glycol	192000																					
Organic	Oxygenate - Alcohol	Propylene glycol (1,2-)	500000																					
Organic	Oxygenate - Alcohol	Propylene glycol (1,3-)	500000																					
Organic	Oxygenate - Ether	Methyl t-butyl ether	20																					
Organic	Oxygenate - Phthalic Ester	Bis(2-ethylhexyl)phthalate	16														9.9-<25							
Organic	Oxygenate - Phthalic Ester	Di-n-butyl phthalate	19				nd-0.3																	
Organic	Oxygenate - Phthalic Ester	Phthalic acid esters																						
Organic	Oxygenate- Carboxylic Acid	Resin Acids																						
Organic	Oxygenated - Epoxide	Ethylene oxide																						
Organic	Oxygenated Compounds	Acrolein	0.03																					
Organic	Pesticide - Benzoic acid	Dicamba	10																					
Organic	Pesticide - Bipyridylium	Diquat	0.5																					
Organic	Pesticide - Bipyridylium	Methyl-parathion																						
Organic	Pesticide - Bipyridylium	Paraquat (as dichloride)	10																					
Organic	Pesticide - Carbamate	Iodo-2-propynyl butyl carbamate (3-)	1.9																					
Organic	Pesticide - Chlorinated hydrocarbon	Aldrin	0.7																					
Organic	Pesticide - Chlorinated hydrocarbon	Chlordane	0.004															0.01-0.08	0.01					
Organic	Pesticide - Chlorinated hydrocarbon	DDD																						
Organic	Pesticide - Chlorinated hydrocarbon	DDE																0.01-0.04	0.01					
Organic	Pesticide - Chlorinated hydrocarbon	DDT	0.001																					
Organic	Pesticide - Chlorinated hydrocarbon	Dieldrin	0.0019																					
Organic	Pesticide - Chlorinated hydrocarbon	Endosulfan	0.02																					
Organic	Pesticide - Chlorinated hydrocarbon	Endrin	0.0023																					

Table A.8. Substance Concentrations in MWWEs

Main Class	Sub-class	Chemical Name	Lowest Benchmark (ug/L) [a]	Secondary/Tertiary Treatment																			
				Tanaka et al. 2003 (ug/L)	Paxeus and Schroder 1996	Paxeus et al. 1992 (ug/L)	Nasu et al. 1999 (ug/L)	Drewes et al. 2004 (ug/L)	Suidan et al. 2004 (ug/L)	Ciek et al. 2004 (ug/L)	Emerick et al. 2004 (ug/L)	Sedlak et al. 2004 (ug/L)	Soroushian et al. 2004 (ug/L)	Jacobsen et al. 2004 (ug/L)	Kreuzinger et al. 2004 (ug/L)	Giger et al. 1987 (ug/L)	Hydromantis Confidential (ug/L)	MISA range OMOE 1988 (ug/L)	MISA mean OMOE 1988	Orr et al. 1992 (ug/L) [c]	Canviro 1991 (ug/L)	Vaughn et al. 2004 (cysts/100L)	Huffman et al. 2004 (cysts/100L)	Levine et al. 2004 (Cfu/100ml)
Organic	Pesticide - Chlorinated hydrocarbon	Heptachlor + Heptachlor epoxide	0.0036																				
Organic	Pesticide - Chlorinated hydrocarbon	Lindane	0.01															0.01-0.79	0.02					
Organic	Pesticide - Chlorinated hydrocarbon	Methoxychlor	0.03																				
Organic	Pesticide - Chlorinated hydrocarbon	Mirex	0.001																				
Organic	Pesticide - Chlorinated hydrocarbon	Toxaphene	0.0002																				
Organic	Pesticide - Chloroacetanilide	Alalchlor																					
Organic	Pesticide - Chloroacetanilide	Metolachlor	7.8																				
Organic	Pesticide - Chlorophenoxy herbicide	2,4-D	4															0.02-34	0.08					
Organic	Pesticide - Chlorophenoxy herbicide	Dichlorprop																					
Organic	Pesticide - Chlorophenoxy herbicide	Diclofop-methyl	6.1																				
Organic	Pesticide - Chlorophenoxy herbicide	MCPA	2.6																				
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxyacetic acid (2,4,5-)	4															0.05-2.3	0.03					
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)																0.05-2.9	0.03					
Organic	Pesticide - Dinitroaniline-based	Trifluralin	0.2																				
Organic	Pesticide - Dintrophenol derivative	Dinoseb	0.05																				
Organic	Pesticide - Hydroxy benzonitrile	Bromoxynil	5																				
Organic	Pesticide - N-methyl carbamate	Aldicarb	0.15																				
Organic	Pesticide - N-methyl carbamate	Bendiocarb	40																				
Organic	Pesticide - N-methyl carbamate	Carbaryl	0.2																				
Organic	Pesticide - N-methyl carbamate	Carbofuran	1.8																				
Organic	Pesticide - Organophosphorus	Azinphos-methyl	20																				
Organic	Pesticide - Organophosphorus	Chlorfenvinphos																					
Organic	Pesticide - Organophosphorus	Chlorpyrifos	0.002																				
Organic	Pesticide - Organophosphorus	Diazinon	0.08																				
Organic	Pesticide - Organophosphorus	Dimethoate	6.2																				
Organic	Pesticide - Organophosphorus	Malathion	0.1																				
Organic	Pesticide - Organophosphorus	Parathion	0.013																				
Organic	Pesticide - Organophosphorus	Phorate	2																				
Organic	Pesticide - Organophosphorus	Temephos																					
Organic	Pesticide - Organophosphorus	Terbufos	1																				
Organic	Pesticide - Phosphoroglycine	Glyphosate	65																				
Organic	Pesticide - Pyrethroid	Deltamethrin	0.0004																				
Organic	Pesticide - Pyridine carboxylic acid	Picloram	29																				
Organic	Pesticide - Quaternary Ammonium	Dodecyl dimethyl ammonium chloride	1.5																				
Organic	Pesticide - Substituted benzene	Chlorothalonil	0.18																				
Organic	Pesticide - Thiocarbamate	Triallate	0.24																				
Organic	Pesticide - Thiophthalinide	Captan	1.3																				
Organic	Pesticide - Triazine	Atrazine	1.8																				
Organic	Pesticide - Triazine	Cyanazine	2																				
Organic	Pesticide - Triazine	Simazine	10																				
Organic	Pesticide - Triazinone	Metribuzin	1																				
Organic	Pesticide - Uracil	Bromacil	5																				
Organic	Pesticide - Urea-based	Diuron	1.6																				
Organic	Pesticide - Urea-based	Isoproturon																					
Organic	Pesticide - Urea-based	Linuron	7																				
Organic	Pesticide - Urea-based	Tebuthiuron	0.27																				
Organic	Polyhalogenated Polyphenyl	Aroclor 1254																					
Organic	Polyhalogenated Polyphenyl	PCBs	0.014																				
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls																0.04-0.19	0.02					
Organic	Polyhalogenated Polyphenyl	Polybrominated diphenylethers																					
Organic	Polyhalogenated Polyphenyl	Polychlorinated terphenyls																					
Organometals	Alkyl lead	Alkyl lead																					
Organometals	Alkyl lead	Tetraethyl lead	0.0007																				
Organometals	Alkyl lead	Tetramethyl lead	0.006																				
Organometals	Alkyl lead	Triethyl lead	0.4																				
Organometals	Alkyl mercury	Methyl mercury	0.004																				
Organometals	Alkyl Tin	Tributyltin	0.001																				
Organometals	Alkyl Tin	Tricyclohexyltin	250																				
Organometals	Aromatic Tin	Triphenyltin	0.022																				

Note: Table is 11x17 inch format

[a] See Table A.5 for details.

[b] Hydromantix 2004.

[c] Study included data from some facilities with only primary treatment.

[d] - estimates of unionized ammonia based on conversion from total ammonia following Francis-Floyd and Watson, University of Florida

[e] - 2002 data

Parameter exceeds benchmark.

Table A.9. Substances from Master List that were Measured in Effluent But Have No Benchmark

Main Class	Sub-class	Chemical Name	Raw/Primary Treatment					Secondary/Tertiary Treatment						
			Raw Sewage Concentration (ug/L)[b]	Western Canada Plant #1 (ug/L)	Western Canada Plant #2 (ug/L)	Central Canada Plant #1 (ug/L)	Central Canada Plant #2 (ug/L)	Central Canada Plant #3 (ug/L)	Central Canada Plant #4 (ug/L)	Central Canada Plant #5 (ug/L)	Central Canada Plant #6 (ug/L)	Central Canada Plant #7 (ug/L)	Central Canada Plant #8 (ug/L)	EC - Confidential (ug/L)
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.												
Biological	Pathogen - Protozoan	*Giardia* sp.												
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate												
Emerging	Pharmaceutical - Stimulant	Caffeine												
Emerging	Pharmaceuticals - Hormone	Estradiol												
Inorganic	Metal/Metalloid	Tin		1.71	1.51									
Non-specific	Physical/Chemical	Biochemical Oxygen Demand		194000	180000									
Non-specific	Physical/Chemical	Oil and grease		297000	27000									
Non-specific	Physical/Chemical	Total organic carbon												
Non-specific	Physical/Chemical	Total suspended solids		293000	173000									
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane						<1	<1	<1	<1	<1	<1	
Organic	Alkylphenol & Ethoxylates	Octylphenol												
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene				ND	ND							
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene	0.58	0.1	0.05	ND	ND							0.27
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene	0.54			ND	ND							
Organic	Aromatic Hydrocarbon - Polycyclic	Total polycyclic aromatic hydrocarbons		1.17	0.97									0.36
Organic	Dioxins and Furans - Polychlorinated	PCDD	0.0038											
Organic	Dioxins and Furans - Polychlorinated	PCDF	0.00012											
Organic	Haloether	Bis(chloromethyl)ether				ND	0.21							19.5
Organic	Haloether	Chloromethyl methyl ether				ND	ND							
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile				ND	ND							
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)				ND	ND							
Organic	Pesticide - Chlorinated hydrocarbon	DDD				ND	ND							0.01
Organic	Pesticide - Chlorinated hydrocarbon	DDE	0.01		0.195	ND	ND							0.01
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)												
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls												

Main Class	Sub-class	Chemical Name	Secondary/Tertiary Treatment											
			Farre et al. 2000 (ug/L)	Braghetta et al. 2002 (ug/L	Scruggs et al. 2004 (ug/L)	Petrovic et al. 2003 (ug/L)	Scruggs et al. 2005 (ug/L)	Skadsen et al. 2004 (ug/L)	Brown 2004 (ug/L)	Cain et al. 2003 (ug/L)	Lee et al. 2004 (ug/L)	Tanaka et al. 2003 (ug/L)	Paxeus and Schroder 1996 (ug/L)	Paxeus et al. 1992 (ug/L)
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.												
Biological	Pathogen - Protozoan	*Giardia* sp.												
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate				0.12-0.36								
Emerging	Pharmaceutical - Stimulant	Caffeine		nd-1.813	5.1		7	0.043-0.310	nd-4.0	0.2-3.6			4	0.1-0.5
Emerging	Pharmaceuticals - Hormone	Estradiol					0.003-0.0099					0.01		
Inorganic	Metal/Metalloid	Tin												
Non-specific	Physical/Chemical	Biochemical Oxygen Demand												
Non-specific	Physical/Chemical	Oil and grease												
Non-specific	Physical/Chemical	Total organic carbon												
Non-specific	Physical/Chemical	Total suspended solids												
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane												
Organic	Alkylphenol & Ethoxylates	Octylphenol	1.1-1.6								0.04-0.68			
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene												
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene												
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene												
Organic	Aromatic Hydrocarbon - Polycyclic	Total polycyclic aromatic hydrocarbons												
Organic	Dioxins and Furans - Polychlorinated	PCDD												
Organic	Dioxins and Furans - Polychlorinated	PCDF												
Organic	Haloether	Bis(chloromethyl)ether												
Organic	Haloether	Chloromethyl methyl ether												
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile												
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)												
Organic	Pesticide - Chlorinated hydrocarbon	DDD												
Organic	Pesticide - Chlorinated hydrocarbon	DDE												
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)												
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls												

Table A.9. Substances from Master List that were Measured in Effluent But Have No Benchmark

Main Class	Sub-class	Chemical Name	Secondary/Tertiary Treatment											
			Nasu et al. 1999 (ug/L)	Drewes et al. 2004 (ug/L)	Suidan et al. 2004 (ug/L)	Ciek et al. 2004 (ug/L)	Unknown (ug/L)	MISA range OMOE 1988 (ug/L)	MISA mean OMOE 1988 (ug/L)	Orr et al. 1992 (ug/L) [c]	Canviro 1991 (ug/L)	Vaughn et al. 2004 (cysts/100L)	Huffman et al. 2004 (cysts/100L)	Levine et al. 2004 (Cfu/100ml)
Biological	Pathogen - Protozoan	*Cryptosporidium* sp.										3-127	3.4-40.2	
Biological	Pathogen - Protozoan	*Giardia* sp.										225-8152	191-320	
Emerging	Pharmaceutical - Lipid Regulator	Clofibric acid/clofibrate												
Emerging	Pharmaceutical - Stimulant	Caffeine												
Emerging	Pharmaceuticals - Hormone	Estradiol	0.014	.00018-0.0079	nd	0.00443								
Inorganic	Metal/Metalloid	Tin												
Non-specific	Physical/Chemical	Biochemical Oxygen Demand						3500-110000		900-30800	<2000-22000			
Non-specific	Physical/Chemical	Oil and grease												
Non-specific	Physical/Chemical	Total organic carbon						2700-297000		4300-17100	6700-24200			
Non-specific	Physical/Chemical	Total suspended solids						3500-242000		1100-33100	2000-51000			
Organic	Aliphatic Hydrocarbon - Halogenated	Bromochloromethane												
Organic	Alkylphenol & Ethoxylates	Octylphenol												
Organic	Aromatic Hydrocarbon - Halogenated	Octachlorostyrene												
Organic	Aromatic Hydrocarbon - Polycyclic	Benzo(b)fluoranthene					.008-.022							
Organic	Aromatic Hydrocarbon - Polycyclic	Indeno(1,2,3-c,d)pyrene					.019-.032							
Organic	Aromatic Hydrocarbon - Polycyclic	Total polycyclic aromatic hydrocarbons												
Organic	Dioxins and Furans - Polychlorinated	PCDD												
Organic	Dioxins and Furans - Polychlorinated	PCDF												
Organic	Haloether	Bis(chloromethyl)ether												
Organic	Haloether	Chloromethyl methyl ether												
Organic	Hydrocarbons with N,P,S substitution	Acrylonitrile												
Organic	Hydrocarbons with N,P,S substitution	Biphenyldiamine (4,4'-)												
Organic	Pesticide - Chlorinated hydrocarbon	DDD												
Organic	Pesticide - Chlorinated hydrocarbon	DDE						0.01-0.04	0.01					
Organic	Pesticide - Chlorophenoxy herbicide	Trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)						0.05-2.9	0.03					
Organic	Polyhalogenated Polyphenyl	Polybrominated biphenyls						0.04-0.19	0.02					

Table A.10. Additional Substances Identified in the Literature Review

Main Class	Sub-class	Chemical Name	Bennie et al 1998 (ug/L)	Braghetta et al 2002 (ug/L)	Brown 2004 (ug/L)	Cain et al 2003 (ug/L)	Canviro 1991 (ug/L)	Carballa et al 2004 (ug/L)	EC - Confidential (ug/L)	Giger et al 1987 (ug/L)	Jacobsen et al 2004 (ug/L)	Khan and Ongerth 2002 (ug/L)	Knepper 2001a (ug/L)	Kreuzinger et al. (ug/L)	Lee et al (2004)	Levine et al 2004 (Cfu/100 mL)	Miao et al 2004 (ug/L)	Metcalfe et al 2003 (ug/L)	MISA range (ug/L)	MISA mean (ug/L)	Mitjans et al 2004 (ug/L)
Emerging		Acenaphthylene					<0.05-1.8														
Emerging	Pharmaceuticals	Acetaminophen (paracetamol)		0.061-0.209								0.39-1.33									
Emerging	Pharmaceuticals	Albuterol		nd-0.018																	
Emerging		Atenolol																			
Emerging	Pharmaceuticals	Bezafibrate												nd-0.130				0.2			
Emerging		2-butanone (methyl ethyl ketone)																			
Emerging		B-BHC																	0.01-0.07	0.01	
Emerging		A-BHC							0.02										0.03-1.24	0.01	
Emerging		D-BHC							0.02												
Emerging	Aromatic Hydrocarbon	Bisphenol A													0.01-17.3						
Emerging	Pharmaceuticals	Captopril										nd-0.08									
Emerging	Pharmaceuticals	Carbamazepine		0.068-0.124								nd-8.04		0.73-1.67				0.5-2.3			
Emerging	Pharmaceuticals	Chlorotetracycline							0.01												
Emerging	Pharmaceuticals	Cholesterol				10-81															
Emerging	Pharmaceuticals	Cimetidine		nd-0.312																	
Emerging	Pharmaceuticals	Ciprofloxacin			0.5-2												0.118				
Emerging	Pharmaceuticals	Clarithromycin															0.087				
Emerging	Biological	Clostr. Perfringens														60-110					
Emerging	Pharmaceuticals	Coprostanol				7.5-90															
Emerging	Pharmaceuticals	Cotinine		nd-0.027																	
Emerging		m,p-cresol							1.96												
Emerging	Personal Care	DEET											~0.3								
Emerging		Diatrizoate																			
Emerging		Diazepam																			
Emerging		Dibutyltin																			
Emerging	Pharmaceuticals	Diclofenac		nd-0.011										1.18-3.00				nd			
Emerging	Sterol	Dihydrocholesterol																			
Emerging	Pharmaceuticals	Diltiazem		0.015-0.035																	
Emerging		4,5-Dinitro-o-cresol							3.54												
Emerging	Oxygenated Compound	1,4-Dioxane																			
Emerging	Pharmaceuticals	Diphenhydramine		nd-0.122																	
Emerging	Pharmaceuticals	Doxycyline															0.038				
Emerging		DSBP 4,4'-bis(2-sulfostyryl)-biphenyl) - fluoresent whitening agent																			
Emerging		DTDMAC - cationic surfactant as fabric softener																			
Emerging	Pharmaceuticals	Estrone													0.0087-0.075						
Emerging	Pharmaceuticals	17a-Ethinylestradiol																			
Emerging		3,4-Ethyltoluene							2.5												
Emerging	Pharmaceuticals	Equililenin																			
Emerging	Pharmaceuticals	Equilin																			
Emerging	Pharmaceuticals	Erythromycin-H2O															0.08				
Emerging	Personal Care	Galaxolide						0.49-0.6						0.270-0.530							0.205-1.4
Emerging	Pharmaceuticals	Gemfibrozil		0.21-0.653								nd-0.59						nd-1.3			
Emerging		Hexachloroethane																	0.01-0.05	0.01	
Emerging	Pharmaceuticals	16a-hydroxyestrone													<1						
Emerging	Pharmaceuticals	Ibuprofen										0.09-0.22		nd-0.035				nd-21.7			
Emerging		Indole							1.34												
Emerging		Iomeprol																			
Emerging		Iopamidol																			
Emerging	Pharmaceuticals	Iopromide						9.3													
Emerging	Pharmaceuticals	Ketporofen		nd-0.012																	
Emerging	Pharmaceuticals	Lincomycin			0.25-2	<1															
Emerging	Pharmaceuticals	Menstranol																			
Emerging	Pharmaceuticals	Metformin		0.245-0.409																	
Emerging	Pharmaceuticals	Methadone										nd-0.62									
Emerging		Metropolol																			
Emerging		Monobutyltin																			
Emerging	Pharmaceuticals	Morphine										0.01-5.46									
Emerging	Pharmaceuticals	Naproxen										0.25-0.80						nd-33.9			
Emerging		4-Nitrophenol							1.12												
Emerging	Hydrocarbons with N,P,S substitution	Nitrilotriacetate								2.5-860											
Emerging		N-nitroso-di-n-prpoylamine							0.29												
Emerging	Alkylphenol & Ethoxylates	Nonylphenol diethoxyacetic acid (NP3EC)																			
Emerging	Alkylphenol & Ethoxylates	Nonylphenol diethoxylate (NP2EO)	0.099-21																		
Emerging	Alkylphenol & Ethoxylates	Nonylphenol monoethoxyacetic acid (NP2EC)																			
Emerging	Alkylphenol & Ethoxylates	Nonylphenol monoethoxylate (NP1EO)	0.15-26																		
Emerging	Alkylphenol & Ethoxylates	Nonylphenol polyethoxylates (total)													3.2-81						
Emerging	Alkylphenol & Ethoxylates	Nonylphenoxyacetic acid (NP1EC)													1.1-35.4						
Emerging	Pharmaceuticals	Norfloxacin															0.05				
Emerging	Alkylphenol & Ethoxylates	Octylphenol monoethoxylate carboxylic acid													0.40-4.96						
Emerging	Pharmaceuticals	Ofloxacin			0.11-35												0.094				
Emerging	Pharmaceuticals	Oxytetracycline																			
Emerging	Pharmaceuticals	Paraxanthine		0.026-1.333																	
Emerging	Pharmaceuticals	Pentoxyfilline																nd-0.6			
Emerging	Pharmaceuticals	Phenytoin										nd-0.16									
Emerging		Propanolol																			
Emerging	Pharmaceuticals	Ranitidine		nd-0.028																	

Table A.10. Additional Substances Identified in the Literature Review

Main Class	Sub-class	Chemical Name	Bennie et al 1998 (ug/L)	Braghetta et al 2002 (ug/L)	Brown 2004 (ug/L)	Cain et al 2003 (ug/L)	Canviro 1991 (ug/L)	Carballa et al 2004 (ug/L)	EC - Confidential (ug/L)	Giger et al 1987 (ug/L)	Jacobsen et al 2004 (ug/L)	Khan and Ongerth 2002 (ug/L)	Knepper 2001a (ug/L)	Kreuzinger et al. (ug/L)	Lee et al (2004)	Levine et al 2004 (Cfu/100 mL)	Miao et al 2004 (ug/L)	Metcalfe et al 2003 (ug/L)	MISA range (ug/L)	MISA mean (ug/L)	Mitjans et al 2004 (ug/L)
Emerging	Pharmaceuticals	Roxithromycin												0.010-0.230			0.008				
Emerging	Pharmaceuticals	Salicylic Acid										0.09-0.38						nd-54.8			
Emerging	Pharmaceuticals	Sitosterol				6.9-32															
Emerging		Sotalol																			
Emerging	Pharmaceuticals	Stigmastanol				1.1-4.3															
Emerging	Pharmaceuticals	Stigmasterol				6.4-15															
Emerging		Strontium							410												
Emerging	Pharmaceuticals	Sulfacetamide															0.064				
Emerging	Pharmaceuticals	Sulfadiazine															0.019				
Emerging	Pharmaceuticals	Sulfadimethoxine				1-2.8															
Emerging	Pharmaceuticals	Sulfamethazine				<1-2											0.363				
Emerging	Pharmaceuticals	Sulfamethizole									1.7-3.2										
Emerging	Pharmaceuticals	Sulfamethoxasole		0.103-0.342																	
Emerging	Pharmaceuticals	Sulfapyridine															0.081				
Emerging	Pharmaceuticals	Sulfathiazole				<1-2															
Emerging	Pharmaceuticals	Sulfisoxazole															0.019				
Emerging	Pharmaceuticals	Testosterone													<1						
Emerging		2,3,5,6-Tetrachlorophenol							0.27												
Emerging	Pharmaceuticals	Tetracycline															0.151				
Emerging	Personal Care	Tonalide						0.15-0.2						0.100-0.190							0.03-0.292
Emerging	Pharmaceuticals	Trimethoprim		0.082-0.127																	
Emerging	Pharmaceuticals	Tylosin				<1															
Emerging		Titanium							7.7												
Emerging		2,3,5-Trichlorophenol							0.62												
Emerging		2,4,5-Trichlorophenol							0.46												

Note: Table is 11x17 inch format.

Table A.10. Additional Substances Identified in the Literature Review

Sub-class	Chemical Name	Bennie et al 1998 (ug/L)	Braghetta et al 2002 (ug/L)	Brown 2004 (ug/L)	Cain et al 2003 (ug/L)	Canviro 1991 (ug/L)	Carballa et al 2004 (ug/L)	EC - Confidential (ug/L)	Orr et al 1992 (ug/L)	Patterson et al 2000 (ug/L)	Paxeus et al 2003 (ug/L)	Paxeus 2004 (ug/L)	Petrovic et al 2003 (ug/L)	Skadsen et al. 2004 (ug/L)	Scruggs et al 2004 (ug/L)	Scruggs et al 2005 (ug/L)	Sedlak et al (ug/L)	Tanaka et al 2003 (ug/L)	Ternes et al (ug/L)	Hydromantis Confidential (ug/L)
	Acenaphthylene					<0.05-1.8														
Pharmaceuticals	Acetaminophen (paracetamol)		0.061-0.209											<0.002-0.0051						
Pharmaceuticals	Albuterol		nd-0.018																	
	Atenolol											0.19							0.4-0.7	
Pharmaceuticals	Bezafibrate												1.1-2.2							
	2-butanone (methyl ethyl ketone)																			5-15
	B-BHC																			
	A-BHC							0.02												
	D-BHC							0.02												
Aromatic Hydrocarbon	Bisphenol A																	0.02		
Pharmaceuticals	Captopril																			
Pharmaceuticals	Carbamazepine		0.068-0.124											0.21-0.36						
Pharmaceuticals	Chlorotetracycline							0.01												
Pharmaceuticals	Cholesterol				10-81									2.7-39.0						
Pharmaceuticals	Cimetidine		nd-0.312																	
Pharmaceuticals	Ciprofloxacin			0.5-2																
Pharmaceuticals	Clarithromycin																			
Biological	Clostr. Perfringens																			
Pharmaceuticals	Coprostanol				7.5-90									1.4-6.2						
Pharmaceuticals	Cotinine		nd-0.027																	
	m,p-cresol							1.96												
Personal Care	DEET																			
	Diatrizoate																		3.8-5.2	
	Diazepam																			
	Dibutyltin																			
Pharmaceuticals	Diclofenac		nd-0.011																	
Sterol	Dihydrocholesterol													0.60-6.90						
Pharmaceuticals	Diltiazem		0.015-0.035																	
	4,5-Dinitro-o-cresol							3.54												
Oxygenated Compound	1,4-Dioxane													1-3						
Pharmaceuticals	Diphenhydramine		nd-0.122																	
Pharmaceuticals	Doxycyline																			
	DSBP 4,4'-bis(2-sulfostyryl)-biphenyl) - fluoresent whitening agent																			
	DTDMAC - cationic surfactant as fabric softener																			
Pharmaceuticals	Estrone																	0.0054	<0.001-0.070	
Pharmaceuticals	17a-Ethinylestradiol																		<0.001-0.042	
	3,4-Ethyltoluene							2.5												
Pharmaceuticals	Equililenin																			
Pharmaceuticals	Equilin																			
Pharmaceuticals	Erythromycin-H2O																			
Personal Care	Galaxolide						0.49-0.6			0.035-0.152									0.2-0.6	
Pharmaceuticals	Gemfibrozil		0.21-0.653																	
	Hexachloroethane																			
Pharmaceuticals	16a-hydroxyestrone																			
Pharmaceuticals	Ibuprofen													0.011-0.051						
	Indole							1.34											<0.001-0.005	
	Iomeprol																		1.3-1.4	
	Iopamidol																		0.8-1.3	
Pharmaceuticals	Iopromide						9.3													
Pharmaceuticals	Ketporofen		nd-0.012																	
Pharmaceuticals	Lincomycin			0.25-2	<1									0.0015-0.0089						
Pharmaceuticals	Menstranol																			
Pharmaceuticals	Metformin		0.245-0.409																	
Pharmaceuticals	Methadone																			
	Metropolol										0.1	0.08							nd-2.4	
	Monobutyltin																			
Pharmaceuticals	Morphine																			
Pharmaceuticals	Naproxen																			
	4-Nitrophenol							1.12												
Hydrocarbons with N,P,S substitution	Nitrilotriacetate																			
	N-nitroso-di-n-prpoylamine							0.29												
Alkylphenol & Ethoxylates	Nonylphenol diethoxyacetic acid (NP3EC)																	3.1		
Alkylphenol & Ethoxylates	Nonylphenol diethoxylate (NP2EO)	0.099-21																		
Alkylphenol & Ethoxylates	Nonylphenol monoethoxyacetic acid (NP2EC)																	3.1		
Alkylphenol & Ethoxylates	Nonylphenol monoethoxylate (NP1EO)	0.15-26																0.7		
Alkylphenol & Ethoxylates	Nonylphenol polyethoxylates (total)																			
Alkylphenol & Ethoxylates	Nonylphenoxyacetic acid (NP1EC)																			
Pharmaceuticals	Norfloxacin																			
Alkylphenol & Ethoxylates	Octylphenol monoethoxylate carboxylic acid																			
Pharmaceuticals	Ofloxacin			0.11-35																
Pharmaceuticals	Oxytetracycline																			
Pharmaceuticals	Paraxanthine		0.026-1.333																	
Pharmaceuticals	Pentoxyfilline																			
Pharmaceuticals	Phenytoin																			
	Propanolol																0.01-0.7		0.1-0.3	
Pharmaceuticals	Ranitidine		nd-0.028																	

Table A.10. Additional Substances Identified in the Literature Review

Sub-class	Chemical Name	Bennie et al 1998 (ug/L)	Braghetta et al 2002 (ug/L)	Brown 2004 (ug/L)	Cain et al 2003 (ug/L)	Canviro 1991 (ug/L)	Carballa et al 2004 (ug/L)	EC - Confidential (ug/L)	Orr et al 1992 (ug/L)	Patterson et al 2000 (ug/L)	Paxeus et al 2003 (ug/L)	Paxeus 2004 (ug/L)	Petrovic et al 2003 (ug/L)	Skadsen et al. 2004 (ug/L)	Scruggs et al 2004 (ug/L)	Scruggs et al 2005 (ug/L)	Sedlak et al (ug/L)	Tanaka et al 2003 (ug/L)	Ternes et al (ug/L)	Hydromantis Confidential (ug/L)
Pharmaceuticals	Roxithromycin																		0.2-0.7	
Pharmaceuticals	Salicylic Acid																			
Pharmaceuticals	Sitosterol				6.9-32									0.94-16.0						
	Sotalol																		1.1-2.4	
Pharmaceuticals	Stigmastanol				1.1-4.3									<0.200-0.95						
Pharmaceuticals	Stigmasterol				6.4-15									0.47-9.0						
	Strontium							410	75-7550											
Pharmaceuticals	Sulfacetamide																			
Pharmaceuticals	Sulfadiazine																			
Pharmaceuticals	Sulfadimethoxine				1-2.8															
Pharmaceuticals	Sulfamethazine				<1-2															
Pharmaceuticals	Sulfamethizole																			
Pharmaceuticals	Sulfamethoxasole		0.103-0.342											0.35-0.86						
Pharmaceuticals	Sulfapyridine																			
Pharmaceuticals	Sulfathiazole				<1-2															
Pharmaceuticals	Sulfisoxazole																			
Pharmaceuticals	Testosterone																			
	2,3,5,6-Tetrachlorophenol							0.27												
Pharmaceuticals	Tetracycline																			
Personal Care	Tonalide						0.15-0.2			0.0266-0.0922					nd-1	nd-1			0.05-0.1	
Pharmaceuticals	Trimethoprim		0.082-0.127											0.16-0.61						
Pharmaceuticals	Tylosin				<1									<0.001-0.0023						
	Titanium							7.7												
	2,3,5-Trichlorophenol							0.62												
	2,4,5-Trichlorophenol							0.46												

; 11x17 inch format.