Chemicals of Emerging Concern in the Bay of Fundy Watershed: What Are the Risks?

Karen A. Kidd and Angella Mercer

Canadian Rivers Institute and Biology Department

University of New Brunswick, Saint John, New Brunswick

BoFEP Technical Report No. 7

December 2012

This project was undertaken with the financial support of the Government of Canada.

Ce projet a été réalisé avec l'appui financier du gouvernement du Canada.

This publication should be cited as:

Kidd, K.A. and A. Mercer. 2012. *Chemicals of Emerging Concern in the Bay of Fundy Watershed: What Are the Risks?* Bay of Fundy Ecosystem Partnership Technical Report No. 7. Bay of Fundy Ecosystem Partnership, Tantallon, NS. 16p. + Appendices

For further information contact:

Secretariat
Bay of Fundy Ecosystem Partnership
PO Box 3062
Tantallon, Nova Scotia, Canada
B3Z 4G9

E-mail: secretariat@bofep.org

www.bofep.org

ISBN 978-0-9783120-4-6

1.0 Introduction

Hundreds of chemicals are present in the cleaning and personal care products and pharmaceuticals that we use every day in our homes (Figure 1). These chemicals include the active ingredients in pharmaceuticals (e.g. antibiotics, blood pressure regulators, hormonal contraceptives), and additives in personal care products (i.e. shampoos, soaps, lotions, cosmetics) and cleaners to make them smell better, last longer or be more effective. Pharmaceuticals are excreted in urine and faeces by people taking these medications and flushed down the toilet, while other chemicals are washed down the drain in sinks and showers. All of these chemicals end up in municipal wastewaters, and are often collectively referred to as "Chemicals of Emerging Concern" or CECs.

CECs = Chemicals of Emerging Concern

Although the use of chemicals in products in Canada is regulated by Health Canada under the Food and Drugs Act, there are no regulations or guidelines for the discharge of CECs into the aquatic environment from municipal wastewater treatment plants. In addition, little is known about how long these chemicals persist in the environment and the effects they have on fish and other aquatic life. They are of "recent concern" or "emerging concern" because we have started to find them in the environment over the past decade and have recognized that some can affect the health of wildlife.

Sewage treatment plants (STPs) were designed to remove bacteria, solids, and nutrients from sewage before it is discharged into streams, rivers, lakes, estuaries or coastal marine areas. Because STPs were not designed to remove CECs, some of these chemicals are found in the final effluents from STPs and in waters downstream of these outfalls. It is only recently that the technology has been available to measure these chemicals in sewage or in the environment since many are present at very low parts per trillion (ppt or ng/L) concentrations. In the last 5 to 10 years we have gained much more information on what is present in household sewage, what is or is not removed by STPs, and the types and levels of CECs that are present in the environment.

1 ppt = 1/20th of drop water in an Olympic-size swimming pool

Hundreds of CECs have been measured in household wastewaters. Herein we report on 31 CECs from several broad classes of chemicals that are used in households, as well as on 3 of the natural hormones excreted by humans that also affect aquatic life (Table 1 and Appendix A). All of the CECs listed in Table 1 occur in untreated and treated municipal wastewaters. The individual CAS numbers (unique chemical identifiers) are included for tracking purposes as each of these chemicals has many different names in the literature. These CECs include several types of human pharmaceuticals (antibiotics, antiepileptics, antidepressants, analgesics, blood lipid regulators, heart and blood pressure medications) and several chemicals found in personal care products and household cleaners (fragrances, preservatives, plasticizers, solvents, sunscreens, insect repellents). They were also chosen because of their potential risk to aquatic organisms and because they have a range of chemical properties (i.e. affinity to accumulate in lipids or remain in water, environmental persistence). Some are persistent in the environment (weeks to months) whereas others are broken down easily and persist only for hours to days. Some CECs will accumulate in fatty tissues of aquatic animals whereas others will stay mainly in the water. This report does not include chemicals found in houses but mainly used outside (e.g. pesticides), or chemicals that are present in homes in electronics, furniture, carpets, or building materials (e.g. PBDEs used as flame retardants in furniture and carpets, metals in electronics). Here we present information on the occurrence of CECs in influents, effluents and surface waters, removal efficiencies in different types of sewage treatment, potential risks to aquatic organisms with respect to their toxicity and ability to disrupt the hormone system (endocrine disruptors). The report includes information from Atlantic Canada (when available), studies from other locations in Canada, and some international data when Canadian data were unavailable. At the end of the report we discuss what is not known.

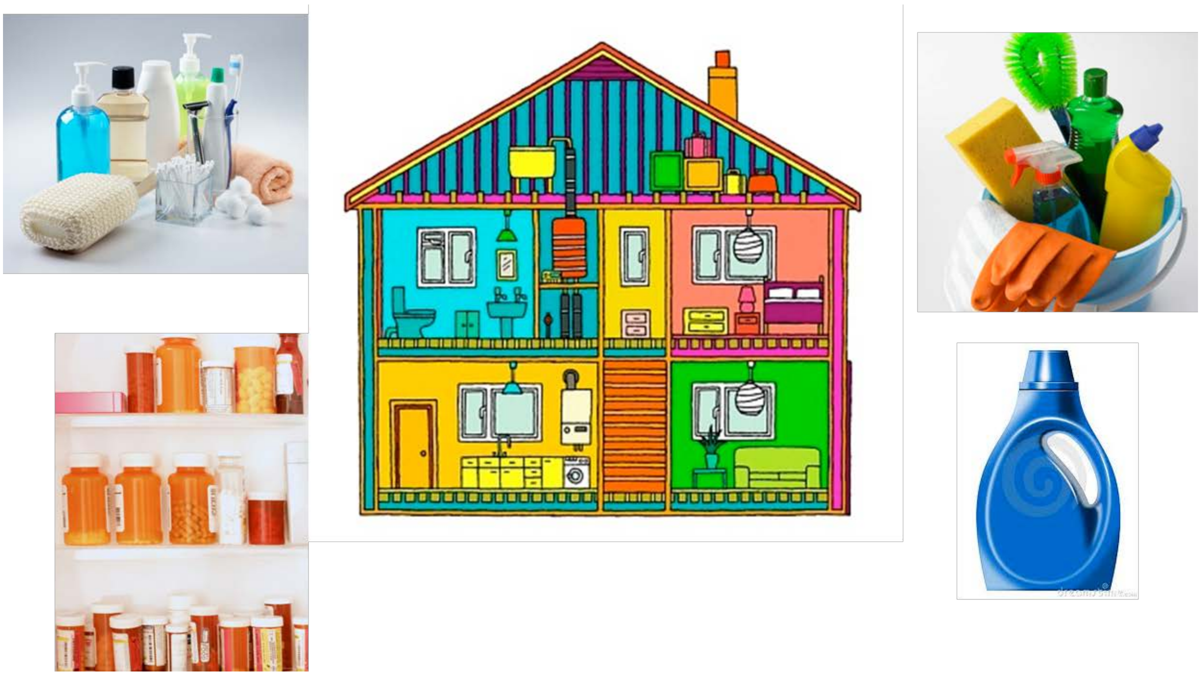

Figure 1: Sources of chemicals of emerging concern in households.

The detailed information used for this report is available as appendices.

The objectives of this report are to:

- Summarize data from Atlantic Canada, supplemented with data from elsewhere in Canada, on representative CECs in municipal wastewaters and receiving waters (Section 2)
- Summarize the types of sewage treatment used in Atlantic Canada (Section 3)
- Describe the efficiency of removal of CECs during sewage treatment (Section 4)
- Assess the risks of CECs to aquatic life (Section 5) and the unknowns for CECs for the Bay of Fundy and its watershed (Section 6)

Table 1: Select chemicals of emerging concern (CECs) present in municipal wastewaters (summary of Appendix A).

General Category	Class	Chemical	Uses	CAS#
Personal care and household products	Antimicrobials	Triclocarban[4]	Soaps, deodorants, cleaning products	101-20-2
		Triclosan[4]	Soaps, deodorants, cleaning products	3380-34-5
	Fragrances	Galaxolide[5]	Cosmetics, soaps, shampoos	1222-05-5
		Vanillin[4]	Cosmetics, soaps, shampoos	121-33-5
		Camphor[4]	Household cleaners	76-22-2
	Insect repellent	DEET[1,4]		134-62-3
	Plasticizers	Bisphenol A[4]		80-05-7
		Dibutyl phthalate[4]		84-74-2
	Preservatives/ antioxidants	BHA[2]		25013-16-5
		BHT[3]		128-37-0
		Propylparaben[4]		94-13-3
	Sunscreens	3-benzylidene camphor[5]		
		4-methylbenzylidene camphor[5]		36861-47-9
	Solvents	Cyclic methyl siloxanes (D4, D5, D6)	Various (lotions, shampoos, cleaners)	
Pharmaceuticals	Analgesics/anti-inflammatories	Naproxen[6,13]		22204-53-1
		Salicylic acid[6]	Metabolite of acetylsalicylic acid	69-72-7
	Antibiotics	Amoxicillin[6]		26787-78-0
		Doxycycline		17086-28-1
		Erythromycin[6]		114-07-8
		Sulfacetamide[6]		144-80-9
		Sulfamethoxazole[4,6]		723-46-6
		Sulfapyridine[6]		144-83-2
		Trimethoprim[6,7]		738-70-5
	Blood cholesterol/ lipids regulators	Atorvastatin[8,9]		134523-00-5
		Gemfibrozil[6,11]		25812-30-0
	Antihypertensive/angina medication	Metoprolol[6,8]		37350-58-6
	Hormonal contraceptives	Ethinylestradiol[5,6]	Synthetic estrogen	57-63-6
		Levonorgestrel[10]	Synthetic progesterone	797-63-7
	Antidepressants	Citalopram[6]		59729-33-8
		Fluoxetine[6,7]		59333-67-4
	Anti-epileptics	Carbamazepine[6,8,12]		298-46-4
Other CECs	Natural hormones	Estradiol[5,6]		50-28-2
		Estrone[5,6]		51-16-7
		Testosterone[5,6]		58-22-0

[1]N,N-diethyl-meta-toluamide; [2]Butylated hydroxyanisole; [3]Butylated hydroxytoluene; [4]Drewes, J., et al., 2009; [5]Jjemba, P., 2008; [6]The Merck Index, 1989; [7]Batt, A., et al., 2008; [8]EC1; [9]DB1; [10]DB2; [11]DB3; [12]A1; [13]DB4

2.0 CECs in Influent, Effluent and Surface Waters in Atlantic Canada and Elsewhere in Canada

The measurement of CECs in sewage is difficult to do because often the concentration of CECs are very low and close to the ability of the equipment to measure them (analytical detection limits). Also, many studies will measure only a few of the hundreds of chemicals that are known to be in sewage because several different chemical techniques are needed to measure the diverse range of CECs (e.g. see Stephenson and Oppenheimer 2007). For these reasons, studies that report CECs in sewage or receiving waters will report results for only a select few chemicals, making it difficult to know everything that is present in these wastewaters.

Table 2 shows the concentrations of some CECs in sewage influent, effluent and surface waters (both fresh and marine) from several studies in Atlantic Canada and elsewhere in the country. These results are from a variety of locations that have different types of sewage treatment (see Appendix B for details). The concentrations vary and can sometimes be higher in the effluent than influent because the influent values and the effluent values may come from different locations or times. It is well known that concentrations of CECs will change from one day to the next within an STP depending on water flows and operating conditions. In addition, in some reports both the influent and effluent of the same sewage treatment plant were not tested. For the CECs that have not been measured in Atlantic Canada, we show data from elsewhere in Canada. It was assumed that sewage in Atlantic Canada will have similar concentrations to other locations across the country.

Levels of CECs in untreated sewage vary considerably from one location to another and from one CEC to another. Some pharmaceuticals like pain killers or anti inflammatories (aspirin and naproxen) are widely used and very commonly found in sewage. Salicylic acid (a breakdown product of aspirin) and naproxen found at much higher concentrations than other drugs because of their high use (Table 2). STPs that service larger communities can have higher CECs in the influent than STPs that service a smaller population. Finally, the type of sewage system in a community can influence the concentrations of CECs in influent. If stormwater is also collected for treatment, then this will dilute the amount of CECs in sewage. Table 2 shows that there is a wide range of CEC concentrations in untreated sewage from low ppt (e.g. estradiol) to low ppm (salicylic acid) concentrations. For many CECs, data for Atlantic Canada are not available.

Conversion of Concentrations

1 mg/L = 1000 µg/L = 1,000,000 ng/L

mg/L = parts per million (ppm); µg/L = parts per billion (ppb); ng/L = parts per trillion (ppt)

Table 2: Influent, effluent and surface water concentrations of select CECs in Atlantic Canada or other regions of Canada (ND means non- detectable, means that the chemical was not measured). Bolded values are from studies outside of Canada (U.S. mainly). This table is a summary of Appendix B.

Category	Compound	Canada			Atlantic Canada[1,2]		
		Influent ranges (ng/L)	Effluent ranges (ng/L)	Surface water (ng/L)	Influent ranges (ng/L)	Effluent ranges (ng/L)	Surface water (ng/L)
Analgesics/anti-inflammatories	Naproxen	ND-611000[11,15]	ND-33900[11,15]	ND-2700[10, 16,19]	ND-110	ND-91000	ND-4500
	Salicylic acid	13700-874000[8,11,15]	ND-59600[11,15]	80[19]	36-56	ND-35000	ND-17000
Antibiotics	Amoxicillin	-	**4.7[13]**	8019	-	-	-
	Doxycycline	-	ND-102[16]	**ND-80[13]**	-	-	-
	Erythromycin	-	838[12]	590[19]	-	-	-
	Sulfacetamide	-	ND-151[12,16]	ND[16]	-	-	-
	Sulfamethoxazole	-	193-3278[16]	ND-510[16,19]	-	-	-
	Sulfapyridine	-	81-707[12,16]	ND-61[16]	-	-	-
	Trimethoprim	-	9-3528[10,16]	ND-150[16,19]	-	-	-
Antidepressants	Citalopram	-	-	**4.53-219[14]**	-	-	-
	Fluoxetine	-	ND-799[10,16]	ND-46[10]	-	-	-
Anti-epileptic	Carbamazepine	100-1900[11,15]	7-3287[10,16]	2-350[10,19]	-	ND-240	ND-170
Antihypertensive/ angina medication	Metoprolol		**10-2200[13]**	**30-2200[13]**	-	-	-
Antimicrobials	Triclocarban	**49-6750[5,17]**	**26-130[17]**	**33-5600[5]**	-	-	-
	Triclosan	1930[8]	108[8]	110[19]	-	-	-
Blood cholesterol/ lipids regulators	Atorvastatin	166[7]	ND-77[7,10]	ND-15[10]	-	-	-
	Gemfibrozil	ND-2100[11,15]	ND-1493[10,15]	ND-4200[10,19]	ND-8	ND-13000	ND-580
Fragrances	Galaxolide	2031[8]	751[8]	**77-794[3]**	-	-	-
	Vanillin	**1600-2100[17]**	**150-470[17]**		-	-	-
Hormonal contraceptives	Ethinylestradiol	75-90[18]	ND-8.5[16]	ND[16]	-	-	-
	Levonorgestrel	150-170[18]	30[18]	ND[16]	-	-	-
Insect repellent	DEET	**54-600[18]**	**100-260[18]**	490[20]	-	-	-
Natural hormones	Estradiol	2.5-125[11,15,18]	ND-90[16,18]	ND-9[16,18]	-	-	ND–1.8
	Estrone	19-80[11,15]	ND-100[11,15,16]	ND[16,18]	5.7-20.0	-	1.4-6.6
	Testosterone	**5.4-13.3[9]**	ND[16]	**ND-214[6,9]**	-	-	-
Plasticizers	Bisphenol A	**200-530[17]**	1.29-194.6[16]	ND-1527[16]	-	-	-
	Dibutyl-phthalate	**390-3100[17]**	16.1-1385[16]	ND-169[16]	-	-	-
Preservatives/antioxidants	BHA	**52-230[17]**	**ND-39[17]**	-	-	-	-
	BHT	**43-410[17]**	**ND-240[17]**	**178[4]**	-	-	-
	Propylparaben	**760-2000[17]**	**ND-3.7[17]**	**ND-207[20]**	-	-	-
Sunscreens	Camphor	**160-1800[17]**	**ND[17]**	-	-	-	-

[1] Data from Brun, G., et al., 2006; Comeau, F., et al., 2008; and Saravanabhavan, G., et al. 2009. [2] These results are from Halifax, NS; Springhill, NS; Fredericton, NB; Sussex, NB; Charlottetown, PE; Summerside, PE; Gander, NL; St. John's, NL; and Nova Scotia watersheds (Halifax, Pictou and Cocagne); [3] Chase, D., et al., 2012; [4] Fries, E. and W. Püttmann, 2004; [5] Halden, R. and Paull, D., 2004; [6] Kolpin, D., et al., 2002; [7] Lee, H-B., et al., 2009; [8] Lishman, L., et al., 2006; [9] Liu, S., et al., 2011; [10] Metcalfe, C., et al., 2003a; [11] Metcalfe, C., et al., 2003b; [12] Miao, X., et al., 2004; [13] Monterio, S. and Boxall A., 2010; [14] Schultz, M., et al., 2010; [15] Servos, M., et al., 2005; [16] Sosiak, A., 2005; [17] Trenholm, R., et al., 2008; [18] Viglino, L., et al., 2008; [19] Waiser, M., et al., 2011; and [20] Yamamoto, H. et al., 2011.

3.0 Types of Sewage Treatment in Atlantic Canada

The Bay of Fundy receives both treated and untreated sewage from the cities and towns in its watershed. Some of the sewage treatment plant effluents are discharged into rivers that drain into the Bay of Fundy (e.g. the Saint John River receives sewage from Edmundston, Woodstock, Fredericton, Gagetown and several other communities before the river discharges into the Saint John Harbour). Other discharges to the Bay of Fundy are into estuaries or coastal areas (e.g. treated and untreated sewage from the City of Saint John).

Table 3 summarizes the types of STPs that discharge into the Bay of Fundy in both Nova Scotia and New Brunswick (for more details see Appendix C). Between the two provinces there are 155 STPs discharging effluents either directly into the Bay or into waters that eventually flow into the Bay. In Nova Scotia, about half of the STPs use lagoons and half use secondary treatment. In contrast, STPs in New Brunswick use mainly lagoon treatment (71 of 88 STPs) and a much smaller number are secondary treatment. A small number of STPs in both provinces have tertiary treatment (10 and 1 % of plants in Nova Scotia and New Brunswick, respectively).

Nationally, 79% of STPs use lagoons or secondary treatment and smaller communities (<2000) tend to have lagoons whereas larger communities tend to use secondary treatment (Holton et al. 2011). Although municipal wastewater treatment has improved in Canada over the past decades, intentional and unintentional discharges of untreated sewage still occur in some communities due to a lack of treatment and when the capacity of treatment plants are exceeded during high storm events. These combined sewer overflows occur in communities where the stormwater and wastewater collection systems are not separated. CECs are also one of a number of water quality issues (i.e. excess nutrients, low dissolved oxygen, high ammonia, drinking water contamination, habitat loss) related to municipal wastewater discharges in Canadian waters (see Holton et al. 2011 for review).

Table 3: Numbers of STPs in New Brunswick and Nova Scotia that discharge directly into the Bay of Fundy or into rivers that flow into the Bay, the types of treatment used at these STPs, and the percent of total wastewater flow for each of these treatment types (data from Stefan Furey, Nova Scotia Environment (Water and Wastewater Branch) and Timothy LeBlanc, New Brunswick Department of Environment (Water and Wastewater Management Section), personal communication). Full table is available in Appendix C.

Province	Totals	Lagoon[1]	Primary[2]	Secondary[3]	Tertiary[4]
Nova Scotia – plant numbers	67	29	1	30	7
Flow (m^3/day)		35%	23%	34%	8%
New Brunswick – plant numbers	88	71	2	14	1
Flow (m^3/day)		48%	45%	3%	4%

[1] Aerated lagoon, facultative lagoon and aerated lagoon with sand filters.
[2] Primary, chemical assisted primary, and unknown.
[3] Rotating biological contactor (RBC), sequencing batch reactor (SBR), solar aquatics (operating as a SBR), contact stabilization, oxidation ditch, extended aeration, trickling filter, biogreen system and artificial wetland
[4] Activated biofilter, recirculating sand filters (RSF), dissolved air flotation (DAF), and DAF with activated sludge.

4.0 Removal of CECs by Sewage Treatment Plants

Even though STPs were not designed to remove CECs, levels of many of these chemicals are lower in the effluent than the influent because the processes used in wastewater treatment to remove nutrients, organics and bacteria can also remove some CECs (Stephenson and Oppenheimer 2007, Drewes et al. 2009). Also, other CECs will absorb to the solids (sludge) in the STP and not be discharged with the treated waters. Each STP is different in how well it removes these CECs and removal efficiencies will also vary within the same STP from one day to the next depending on the operating conditions. The influent and effluent levels of CECs from individual plants were used to calculate removal efficiencies and present the range in percent removal in Table 4 (for more details see Appendix D).

$$\% \text{ removal} = \frac{(\text{Concentration}_{\text{influent}} - \text{Concentration}_{\text{effluent}})}{(\text{Concentration influent})} \times 100$$

In general, the more treatment household sewage receives the higher the percent removal of CECs. STPs with tertiary treatment will typically have higher removal efficiencies than STPs with secondary or primary treatment. However, it is difficult to generalize because there are many different kinds of treatments used within each general category (see Table 3 for details), and this is why the removal efficiencies can vary from “poor” to “excellent” within each of these general categories. For example, the removal of the antiepileptic carbamazepine ranges from 0 to 100% within STPs with tertiary treatment (Table 4). It is difficult to generalize about how well certain classes of CECs are removed during sewage treatment because of the operational differences from one plant to another and from one day to another (see for example Drewes et al. 2009, Stephenson and Oppenheimer 2007).

Table 4: Removal efficiencies of select CECs for lagoons, primary, secondary and tertiary sewage treatment (data compiled from Drewes et al. 2009, Lee, H-B., et al, 2009, Lishman, L., et al., 2006, Monterio, S. and Boxall, A., 2010, and Servos, M., et al., 2005). Chemicals within each of the general categories are those listed in Table 1. Data to generate this table are found in Appendix D.

Substance Category	**Lagoon**	**Primary Treatment**	**Secondary**	**Tertiary**	**Misc.**
Antimicrobials			Good	Moderate-Good	
Fragrances	Excellent		Poor	Poor-Good	
Analgesics			Poor-Excellent	Poor-Excellent	
Antibiotics		Poor-Moderate	Poor	Poor-Excellent	
Antiepileptics			Poor	Poor-Excellent	
Antihypertensive, angina medication					Moderate
Blood cholesterol/lipid regulators			Poor-Excellent	Poor-Excellent	
Antidepressants				Poor-Excellent	
Insect repellent				Moderate	
Natural hormones	Moderate-Excellent	Excellent	Poor-Excellent	Good-Excellent	
Plasticizers				Moderate-Good	
Preservatives/antioxidants				Moderate-Excellent	
Sunscreens				Excellent	

Legend for Table 4: Range in removal efficiencies of CECs for the different categories.

Rating	**% Removal**	**Rating**	**% Removal**
Poor	<50%	Moderate-Good	50-94%
Poor-Moderate	<50-74%	Poor-Excellent	<50%->95%
Poor-Good	<50-94%	Moderate-Excellent	50->95%
Moderate	50-74%	Good-Excellent	75->95%
Good	75-94%	Excellent	≥95%

5.0 Risks of CECs to Aquatic Organisms

The chemical properties of CECs are very different from one group to another, and it is these properties (e.g. easily dissolved in water versus not easily dissolved in water) that determine where CECs go in the environment and how long they persist once discharged in the wastewaters. When CECs are released into surface waters, they may stay dissolved in the water or bind to particles in the water column or move into the sediments at the bottom of the river, lake or coastal area. The concentrations of CECs present in the water will depend on what is in the effluents and how quickly these effluents are diluted. Typically the highest levels of CECs are found closest to the wastewater outfall and then they rapidly decline downstream because of dilution or because they are degraded in the environment by sunlight or bacteria that are naturally present. Degradation can result in new chemicals in the environment which can be more or less toxic than the original ones. However, the CECs that stick to particles in the surface water and to the sediments tend to be more persistent in the environment and resistant to any degradation, and may also accumulate in the tissues of fish and other aquatic organisms. As examples, antidepressants, antimicrobials, antiepileptics, and fragrances have been found in the tissues of fish living downstream of STP discharges in other parts of Canada and in the United States (Metcalfe et al. 2010, Dann and Hontela 2011, Brooks et al. 2005, Ramirez et al. 2009).

Risks of chemicals to aquatic organisms depend on the concentrations and types of CECs to which they are exposed. Higher concentrations in the environment typically means higher risk to fish and other wildlife. Aquatic organisms are exposed to these chemicals directly from water or sediments, or through their food and both the level of exposure and route of exposure affects how toxic these chemicals are to an organism. Although fish and other organisms are exposed to complex mixtures of chemicals in effluents, the science is not advanced enough to be able to assess the total effects of these mixtures. For this reason, risks are examined using individual chemicals, maximum environmental exposures (worst-case scenarios), and lab toxicity experiments.

Very few surface water data for CECs exist for Atlantic Canada and these data are mainly from streams and not from the Bay of Fundy itself and for only a very small number of chemicals (Table 2). Only two out of eight sites are from marine environments in Atlantic Canada. The antiepileptic carbamazepine and the blood cholesterol regulator gemfibrozil were found at concentrations up to 170 and 580 ng/L, respectively. In contrast, anti-inflammatories and pain killers were found at much higher levels (naproxen 4,500 ng/L; salicylic acid 17,000 ng/L). Elsewhere in Canada, other CECs have been found in surface waters including plasticizers, antimicrobials, antibiotics, antidepressants and natural hormones (Table 2). It is likely that these CECs could also be found in surface waters in Atlantic Canada.

Because these CECs are very diverse in their properties and little is known about their effects on aquatic organisms, it is difficult to estimate the risk that they pose for species living in the Bay of Fundy or in waters flowing into the Bay. Some, like the natural and contraceptive hormones, are very similar to the hormones that are used by fish to control their reproduction and can be taken up from the water into the fish through their gills. Very low levels (~1 ng/L) of some hormones are enough to interfere with sexual development and reproduction in fish (Parrott and Blunt 2005). Other CECs like antibiotics can affect the growth of algae or the invertebrates (Daphnids or Daphnia) that fish eat.

Another issue of concern for municipal wastewaters is the discharge of antibiotics into surface waters (e.g. Waiser et al. 2011). Because antibiotics are effective against bacterial infections in humans and livestock, once they are released into surface waters they may also affect the abundance of naturally-occurring bacteria and also cause antibiotic resistance in these organisms. While several reviews on this subject have been written (Kummerer 2009, Taylor et al. 2011) and fecal bacteria that are resistant to antibiotics are found, albeit at low levels, downstream of municipal wastewater discharges or livestock production (e.g. Lanthier et al. 2011), little is known about the effects of antibiotics on natural bacterial communities in the Canadian environment.

A preliminary assessment of the risk of these CECs to aquatic organisms is shown in Table 5. The highest surface water concentration that was measured in Atlantic Canada (from Table 2) was compared to the lowest concentration of the CEC that affects algae, invertebrates or fish either over the short term (acute) or longer term (chronic) or a toxicity value that was calculated from the properties of the chemical (U.S. Environmental Protection Agency's PBT Profiler, www.epa.gov/oppt/sf/tools/pbtprofiler.htm; PBT – Persistence, Bioaccumulation, Toxicity). For a few chemicals, no toxicity data were available and these chemicals were not included in Table 5 (see Appendix E). These effects ranged from decreased survival of algae, zooplankton or fish (lethal concentrations (LC) or effective concentrations (EC)) organisms to changes in growth using chronic studies. If no surface water concentrations were available for Atlantic Canada, data from elsewhere in Canada or outside of Canada were used. A risk quotient (RQ) was calculated as follows:

$$RQ = \frac{\text{Maximum surface water concentration (mg/L)}}{\text{Toxicity value for most sensitive organism (mg/L)}}$$

RQs > 1 indicate that there is a potential risk for aquatic organisms.

RQs < 1 indicate little or no risk of these CECs in the environment.

Based on the results shown in Table 5, all RQs were well below 1 and suggest that the measured levels of these CECs do not threaten the health of aquatic organisms (see Appendix F for data used to generate RQs). However, there are many limitations to this approach. First, very few aquatic organisms have been studied and for those that have, most are freshwater and not marine. Lab studies examine individual chemicals but wild animals are exposed to mixtures of CECs and other chemicals in these effluents. It is not known how these mixes of chemicals affect aquatic organisms. Finally, some of these CECs will affect the hormone (endocrine) systems of fish at much lower concentrations than the toxicity data shown in Table 5 so the risks may be underestimated. More specifically, male fish living downstream of wastewater discharges in heavily populated watersheds, like the Grand River in Ontario, are feminized because of the presence of estrogen mimics in the effluents (e.g. Tetreault et al. 2011). These effects on male fish occur at much lower concentrations of estrogens than those that cause effects on survival and growth. In spite of the unknowns related to CECs, many studies have shown that increased treatment of sewage decreases the risks to aquatic life. For example, the major upgrade of the City of Boulder, Colorado, STP from trickling filter to activated sludge decreased the concentrations of estrogens in the effluents and their subsequent effects on male fish (Barber et al. 2012).

6.0 Unknowns for CECs in Atlantic Canada

Few studies have been done on CECs in Atlantic Canada and limited data exist on only a small number of CECs for this region. At present, it is not known how widespread CECs are in surface waters and almost no measurements have been done in marine waters. None were found for the Bay of Fundy proper. It is possible because of the low densities of people in the region that most CECs will not be present at detectable levels or concentrations of concern but currently this is not known. Some CECs will concentrate in sediments and into fish tissues. However, no studies have been done as yet in the more populated parts of the Bay of Fundy watershed that have measured concentrations of CECs in water, sediments and biota, or effects of these effluents on the health of fish or other aquatic life.

Recommended study sites include the Saint John Harbour and the Saint John River near large centres like Fredericton, NB.

Table 5: Risk quotients (RQs) of select CECs in surface waters (see text for explanation) (- means no data available for calculation). The maximum surface water concentrations (mg/L) are from Table 2. See Appendix E for all toxicity data and Appendix F for all RQs.

Compound	Max Surface Water (mg/L)	Toxicity Value (mg/L)	Surface Water RQs	Type of Toxicity Data	Toxicity Reference
Trimethoprim	0.00015	72.062	0.000002	Algae (Chronic)	1
Sulfapyridine	0.000061	3.5	0.00002	PBT Profiler	1
Amoxicillin	0.00008	2.2	0.00004	Algae (24h LC50)	2
Carbamazepine	0.00017	4.615	0.00004	Daphnid (Chronic)	1
Estradiol	0.0000018	0.044	0.00004	PBT Profiler	1
Citalopram	0.000219	3.9	0.00006	Daphnia (48th EC50)	3
DEET	0.00049	5.835	0.00008	Daphnid (Chronic)	1
Doxycycline	0.00008	0.86	0.00009	PBT Profiler	1
Estrone	0.0000066	0.074	0.00009	PBT Profiler	1
Erythromycin	0.000590	0.94	0.00011	Daphnia (48th EC50)	2
Fluoxetine	0.000046	0.398	0.00012	Fish (Chronic)	1
Testosterone	0.000214	1.34	0.00016	Daphnid (Chronic)	1
Metoprolol	0.0022	13.383	0.00016	Daphnid (Chronic)	1
Gemfibrozil	0.00058	0.889	0.00065	Fish (Chronic)	1
Triclosan	0.00011	0.13	0.00085	Daphnia (48th EC50)	2
Dibutyl·phthalate	0.000169	0.11	0.00154	PBT Profiler	1
Naproxen	0.0045	2.6203	0.00172	Algae (96h EC50)	2
Propylparaben	0.000207	0.078	0.00265	PBT Profiler	1
Salicylic acid	0.017	1.3	0.01308	PBT Profiler	1
BHT	0.000178	0.012	0.01483	PBT Profiler	1
Galaxolide	0.000794	0.05	0.01588	PBT Profiler	1
Sulfamethoxazole	0.000510	0.03	0.01700	Algae (LC5)	2
Bisphenol A	0.001527	0.05	0.03054	PBT Profiler	1
Triclocarban	0.0056	0.09	0.06222	PBT Profiler	1
BHA	-	0.046	-	PBT Profiler	1
Camphor	-	1.8	-	PBT Profiler	1
Vanillin	-	0.48	-	PBT Profiler	1

[1]Diamond et al. 2011, [2]Waiser et al. 2011 and [3]Henry, T.B., et al., 2004

As mentioned earlier, municipal wastewaters contain a mix of hundreds of different chemicals and the types and concentrations of these mixtures varies from one location to another. Some of these individual chemicals affect aquatic life in a similar and additive way. Others may interfere with different processes in the same organism, thereby affecting the overall health of the animal. Because of the many unknowns about how CECs affect aquatic life, it is not yet possible to know the total toxicity or risk that CECs pose to freshwater and marine organisms. The understanding of mixture effects has been identified as a big knowledge gap by the scientific community.

Most of the lab studies to assess the toxicity of CECs have been done on freshwater species. While this is useful for organisms living in the rivers draining into the Bay of Fundy, the risks to the species living in the Bay of Fundy proper are very difficult to assess. No lab studies are done on marine mammals and few exist for marine algae, invertebrates and fish. If they are exposed to CECs at all, levels are likely to be very low given the large dilution in the Bay of Fundy. However, this is also an unknown.

Some CECs like antibiotics used in livestock production or hormones excreted by the livestock themselves can be found in surface waters in agricultural areas when storms create runoff of manure into waterways. This runoff could contain elevated concentrations of CECs in areas where there is intense livestock production but information on this potential risk is not understood for Atlantic Canada and for the Bay of Fundy.

7.0 Summary

- Based on the current but limited data available for Atlantic Canada, there does not appear to be a risk of toxicity from individual CECs for the Bay of Fundy watershed.
- However, these data are available for only a limited number of sites and for a small number of chemicals compared to the hundreds known to be in sewage. As a result, there may be some CECs that pose a risk to aquatic life but they have not yet been identified because information on environmental concentrations or toxicity are missing.
- Risks from CECs will be greatest in areas where there is little dilution of the effluent and human populations are highest. These sites are recommended as priorities for future studies.
- There large data gaps for Atlantic Canada for CECs in effluents, surface waters, sediments and biota. More studies on CECs concentrations in the Bay of Fundy watershed are recommended to better understand their levels and fate, and the risks to this environment.
- In addition, wastewaters are a mix of CECs as well as other chemical and physical stressors to surface waters. Understanding the total risk of chemicals in wastewater (including CECs) to aquatic life is an ongoing challenge. However, it is clear that improved wastewater treatment has many benefits for organisms living downstream.

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