Canadian Water Network

Canada's Challenges and Opportunities to Address Contaminants in Wastewater

Supporting Document 2

Wastewater Treatment Practice and Regulations in Canada and Other Jurisdictions

March 2018

Contents

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de:

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Acronyms and abbreviations

AEP	Alberta Environment and Parks
BAFU	Das Bundesamt für Umwelt
BNR	Biological nutrient removal
BOD_5	Biochemical oxygen demand, based on 5-day measurement
$cBOD_5$	Carbonaceous biochemical oxygen demand, based on 5-day measurement
CCME	Canadian Council of Ministers of the Environment
CEPT	Chemically enhanced primary treatment
COD	Chemical oxygen demand
CSO	Combined sewer overflow
CWA	Clean Water Act
DOC	Dissolved organic carbon
ECCC	Environment and climate change Canada
EE2	17 α-ethinylestradiol
EEA	European Environmental Agency
ERRIS	Effluent regulatory reporting information system
EU	European Union
MOECC	Ministry of Environment and Climate Change
m^3/day	Cubic meters per day
mg/L	Milligram per liter
µg/L	Microgram per liter
MWWS	Municipal water and wastewater survey
ng/L	Nanogram per liter
NPDES	National Pollutant Discharge Elimination System
NPRI	National pollutant release inventory
p.e.	Person equivalent
PAC	Powdered activated carbon
PPCP	Pharmaceuticals and personal care products
SS	Suspended solids
TBEL	Technology-based effluent limit
TN	Total nitrogen
TP	Total phosphorus
TRC	Total residual chlorine
TSS	Total suspended solids
UWWD	Urban Waste Water Directive
WFD	Water framework directive
WPA	Waters Protection Act
WPO	Waters Protection Ordinance
WQBEL	Water quality-based effluent limit
WQG	Water quality guideline
WQT	Water quality trading
WSER	Wastewater Systems Effluent Regulations
WSP	Waste stabilization pond
WWTP	Wastewater treatment plant

Preface

As the list of chemicals we generate as a society grows, many find their way into wastewater and ultimately into our natural ecosystems. Some of these substances are contaminants that can be harmful to human health, fish and wildlife, and to Canada's waterways. To put into clearer context the ability and opportunities to deal with wastewater contaminants in Canada, Canadian Water Network (CWN) led a national review of known contaminants and contaminants of emerging concern in municipal wastewater and our options to deal with them.

Supported by a $400,000 investment from Environment and Climate Change Canada, and leveraging CWN's extensive network of research and practitioner communities, CWN convened a national expert panel from October 2017 to March 2018. The panel's mandate, as established by CWN, was to assess Canada's needs and opportunities in dealing with multiple contaminants in municipal wastewater through consideration of the following critical questions:

- Which wastewater contaminants do we need to worry about most, now and in the future?
- What are the options for our diverse Canadian communities to address these contaminants through wastewater treatment?
- What are the important opportunities and trade-offs involved in those treatment choices, including resource recovery, cost implications, socio-economic and cultural fit, and implications for related issues like greenhouse gas emissions?

The expert panel was composed of a group of eight leading experts from across Canada with diverse expertise in municipal wastewater treatment, conventional contaminants and contaminants of emerging concern, environmental and ecosystem impacts, wastewater resource recovery, and the broader legal and socioeconomic implications of wastewater effluent discharges. The panel was chaired by Dr. Donald Mavinic of the University of British Columbia, an internationally recognized expert in wastewater treatment.

The expert panel's primary task was to generate a synthesis report providing a credible and useful framing of where we are, what we know and don't know, and a 'blueprint' for how we can move forward to achieve benefits through more effective wastewater treatment in Canada. This blueprint was developed through research and discussions that were augmented by incorporating perspectives from an extended group of experts from across Canada. A broad range of geographic and topic-area insights were solicited from expert contributors with knowledge of municipal wastewater practice, environmental impacts and assessments associated with wastewater, as well as legal and community perspectives. The extended expert input included both invited participation at panel working meetings, as well as broader national input through an online questionnaire.

As a supporting document to the expert panel's report, the current document provides a high-level overview of wastewater treatment practice and regulations in Canada and other jurisdictions.

Purpose and Scope

This supporting document is intended to provide a high-level overview of the current state of the practice of wastewater treatment across Canada, in addition to providing a summary of the regulatory structure surrounding wastewater treatment in Canada and other comparable jurisdictions. This information provides context and support for the findings and recommendations of the expert panel, and elaborates on the Canadian regulatory framework and regional perspectives summarized in the expert panel report.

This overview begins with summary of wastewater treatment practices across Canada and a description of the existing federal regulatory structure. This is followed by a brief review of provincial regulations for wastewater effluents, as well as a capture of the current state of regulatory oversight in northern regions as well as in Indigenous communities. United States national and state regulations, European Union and Swiss regulations, and an overview of Australian wastewater effluent regulations are included. A brief analysis and comparison of trends in wastewater regulations across jurisdictions are provided.

1. Canada

1.1 The state of wastewater treatment in Canada

The majority of Canadians have access to sewage collection systems, but the treatment of wastewater varies nationally from no treatment to advanced facilities. According to the 2009 Municipal Water and Wastewater Survey (MWWS), 87% of Canada's population is served by sewerage connected to some type of treatment, and this proportion has remained stable since the late 1980s (MWWS: Environment Canada, 2011).The remaining population is served by septic systems (12%) or sewage haulage (0.5%). Of the population receiving some form of wastewater treatment, the majority (79%) had their wastewater effluent treated at a secondary level or higher. The most common form of secondary treatment was mechanical treatment (~55%), 7% of the population receive secondary treatment in waste stabilization ponds (often termed "lagoons" or "aerated facultative lagoons"). Approximately 17% of population receives tertiary-level (or "advanced") treatment, while 18% of the population receives primary treatment, and 3% receives no or preliminary wastewater treatment (such as screening and grit removal). Note that for the MWWS, treatment levels are self-reported, and therefore some variation exists within broad treatment categories.

Across Canada, considerable variation exists in the level of wastewater treatment. In general, large and densely populated areas tend to have higher levels of treatment than sparsely populated regions (Holeton et al., 2011). In addition, areas discharging wastewater effluent to inland waters typically have higher levels of wastewater treatment than those discharging to marine waters or large rivers flowing directly to the coast. For example, Québec and the Atlantic provinces have <50% of their population served with secondary treatment or better, while Ontario and Manitoba have > 90% of population served with at least secondary wastewater treatment (Figure 1.1). Moreover, where access to large bodies of water is limited and demands on water resources are highest, there is typically a high level of wastewater treatment. For example, the Prairie Provinces have the highest water use per unit streamflow (Statistics Canada, 2009), and most major cities in the prairies provide tertiary treatment of wastewater effluents using biological nutrient removal (BNR) technology. In Saskatchewan and Alberta, the majority of the population is served with tertiary treatment (Figure 1.1).

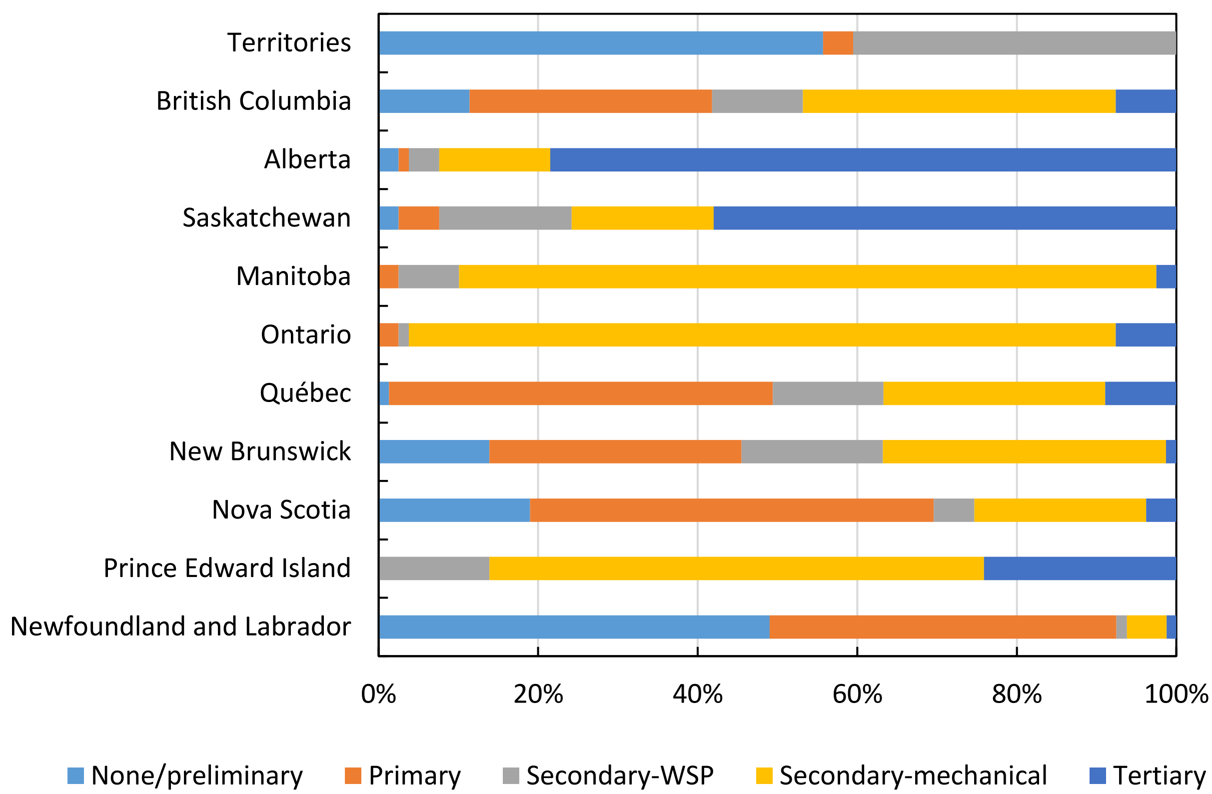

Figure 1.1 Levels of wastewater treatment across Canadian provinces and territories in 2009, based on population serviced by sewer systems (Adapted from Environment Canada, 2011). Secondary-WSP indicates secondary waste stabilization pond.

In several cities across Canada, even if wastewater treatment plants (WWTPs) treat effluent using secondary treatment or higher, untreated wastewater may be released into surface waters via combined sewers (Government of Canada, 2013). In collection systems with incomplete separation of stormwater and wastewater, stormwater flows that exceed the capacity of a wastewater treatment system can result in discharges of mixtures of stormwater and wastewater directly to a receiving environment. Discharges of untreated wastewater may threaten public and environmental health because of their high loads of pathogens, nutrients, and oxygen-depleting substances. Combined sewer systems are common in Canadian cities with parts of their sewer systems constructed before the mid-1940s, such as Ottawa, Montreal, Vancouver, and Toronto, but detailed data are not available on the proportion of the Canadian population serviced by combined sewer systems (Government of Canada, 2013). The quantities of both stormwater and CSOs vary temporally and with location, depending on climate and sewer design. Until recently, CSO discharges were not routinely monitored in Canada, and estimates of their volume and impact on receiving waters are rare (Government of Canada, 2013). However, many jurisdictions have implemented flow management and sewer separation programs, and new legislation will require CSO reporting, providing insights into the extent of CSO releases across Canada.

The 2009 MWWS data were obtained before recent federal wastewater regulations were implemented that legislate effluent standards consistent with secondary treatment. As a result, it is likely the rate of secondary treatment across Canada is presently higher than reported here. The MWWS program has been cancelled and has not been replaced with an equivalent national system of data collection for level of wastewater treatment in Canada and public reporting on results.

1.2 Regulatory structure for wastewater treatment

In Canada, wastewater management is a shared responsibility between federal, provincial, and municipal governments. The federal government uses legislative tools to stipulate minimum standards for wastewater effluents, while the provincial or territorial governments are primarily responsible for issuing permits or licenses to wastewater treatment plants to construct and operate under their regulatory frameworks. Issued permits may require increased stringency based on provincial legislation or local characteristics, such as the assimilative capacity of the receiving water, or the size of the serviced population. Operation of WWTPs is typically carried out by municipalities, who have provincial mandates to manage wastewater systems.

The primary federal tool to control the wastewater releases is the Fisheries Act. Within the Fisheries Act, Environment and Climate Change Canada (ECCC) administers the key pollution prevention provisions (subsections 36 (3) to (6)), which prohibit the deposit of deleterious substances in water frequented by fish, unless authorized by regulations (Environment and Climate Change Canada, 2017a). A deleterious substance may be any substance that degrades or alters water quality such that it could be harmful to fish, fish habitat, or the use of fish by people. Under the pollution prevention provisions, ECCC administers and enforces several regulations, such as those governing effluents from pulp and paper mills, metal mining operations, and municipal wastewater. The Wastewater Systems Effluent Regulations (WSER; SOR/2012-139) establish baseline municipal effluent quality standards for suspended solids (SS), carbonaceous biochemical oxygen-demanding material (CBOD), total residual chlorine, and un-ionized ammonia (NH_3), as outlined in Table 1.1. These regulations impose minimum standards for municipal effluent quality nationwide, and are intended to be achievable through secondary wastewater treatment or equivalent.

Table 1.1 Effluent quality standards established by the WSER (Government of Canada, 2012)

Effluent parameter	**Regulated concentration**
$CBOD_5$	Average 25 mg/L
SS	Average 25 mg/L
Total Residual Chlorine (TRC)	Average 0.02 mg/L
Un-ionized Ammonia (NH_3-N, 15°C)	Maximum 1.25 mg/L

For WSER-regulated compounds, maximum acceptable concentrations are based on yearly, quarterly or monthly averages of measured values for $CBOD_5$, SS, and TRC, based on facility parameters, such as discharge volume, continuity of discharge, and hydraulic retention time. The un-ionized ammonia standard is a maximum concentration. In addition to the regulated parameters, wastewater effluent must be not acutely toxic at the point of discharge based on 96-hour test for rainbow trout (Government of

Canada, 2012). Specific requirements for effluent monitoring, record-keeping, and reporting are specified in the WSER, and reporting to the federal government is required via the Effluent Regulatory Reporting Information System (ERRIS) (Government of Canada, 2017b). For example, the WSER also require reporting of the monthly volume and number of days each month effluent is discharged via combined sewers (Government of Canada, 2012). The WSER apply to wastewater systems that deposit effluent and that collect an average daily volume of >100 m^3. In addition, these Regulations do not apply to wastewater systems located in the Northwest Territories, Nunavut, and north of the 54th parallel in Québec or Newfoundland and Labrador.

The WSER came into force in June, 2012, with the effluent quality standards coming into force on January 1, 2015 (Government of Canada, 2012). Wastewater systems not meeting the standards needed to apply for transitional authorizations to continue discharging effluent. Those systems with authorizations must upgrade their wastewater treatment systems by the end of 2020, 2030, or 2040, depending on risk imposed on receiving waters by effluent and the characteristics of the receiving waters (Environment and Climate Change Canada, 2017b). In cases where provincial or territorial wastewater regulations are deemed to be equivalent to the WSER, a bilateral equivalency agreement may be established. In this case, the WSER no longer apply and the provincial/territorial regime becomes the sole regime applicable. An equivalency agreement is currently in place with Yukon (Government of Canada, 2017a), and several other provinces are working towards equivalency agreements (CCME, 2014). There are also bilateral administrative agreements for the WSER with New Brunswick and Saskatchewan, which establish a single window approach for the administration of the regulations.

The federal implementation of the WSER arose from recommendations that were part of a national strategy designed and endorsed by the Canadian Council of Ministers of the Environment (CCME). The CCME strategy was intended to create a standardized approach to municipal wastewater management across Canada, to both harmonize wastewater reporting into a one-window approach, and to ensure a baseline level of environmental protection (CCME, 2009). In addition to establishing National Performance Standards and timelines for achieving them, the CCME strategy includes requirements for compliance monitoring and reporting, and discusses an economic plan for associated upgrades. The strategy also encourages reduction of pollutants at the source, and indicates that environmental monitoring at the watershed level is important to confirm that the environment is protected. The harmonized approach to wastewater treatment intended by the CCME strategy and WSER has not yet been fully realized, and most provinces currently have duplication of reporting efforts. However, ECCC states that achieving bilateral agreements remains a priority (Government of Canada, 2017a).

In addition to the Fisheries Act, the Canadian Environmental Protection Act (CEPA) is also used to prevent and manage risks posed by toxic and harmful substance. This legal framework may contribute to improved wastewater effluents by controlling substances that are otherwise difficult to treat (CCME, 2009). Under CEPA, owners or operators of wastewater treatment facilities that meet reporting requirements are required to report discharges to the National Pollutant Release Inventory (NPRI), which is a publicly accessible inventory of pollutant releases. NPRI tracks releases of several substances associated with municipal wastewater, such as ammonia, chlorine, metals, phosphorus, and greenhouse gases. However, reporting to the NPRI is only mandatory for facilities in which employees work a total of ≥20,000 hours during the calendar year, thresholds for specific substances are met, or total discharges exceed 10 000 m^3/day (Environment and Climate Change Canada Change, 2016). Because only about 200 WWTPs (out of ~3500) across Canada meet these requirements (Holeton et al., 2011), the contaminant releases shown in this database represent only a subset of the total contaminant loads released into the environment from wastewater treatment facilities.

1.3 Provincial regulations for wastewater effluents

In addition to federal regulations, provinces and devolved territories (including Yukon and the Northwest Territories) also have the power to implement additional or more stringent requirements pertaining to wastewater effluents. As a result, there are several varying wastewater regulations and practices across Canada. For example, Manitoba regulates total nitrogen (TN) loads, and several provinces regulate or have requirements for total phosphorus (TP) on a province-wide or site-specific basis, such as British Columbia, Alberta, Manitoba, and Ontario (Oleszkiewicz et al., 2015). Additional regulations may also apply to sensitive waters, such as stringent total phosphorus limits (0.1 mg/L) for WWTPs discharging effluent to the Lake Simcoe Watershed in Ontario. Details of the regulatory structure within Canadian provinces are outlined below, with a focus on regulations that are supplementary to the federal WSER requirements.

1.3.1 British Columbia

In addition to the federal WSER, British Columbia has an Environmental Management Act that that is administered by the Ministry of Environment. Within this act, there is a Municipal Wastewater Regulation, which governs wastewater discharges to ground and surface waters (B.C. Reg. 87/2012) (Government of British Columbia, 2012). Effluent quality standards under British Columbia's Municipal Wastewater Regulation are based on the type and size of receiving environment, with differing stringencies for rivers, estuaries, lakes, and marine waters (Table 1.2). In addition to the federally regulated compounds, British Columbia has regulations for effluent pH, total phosphorus, and ortho-phosphate.

Regulations in British Columbia take daily flows into account, and relaxed interim standards exist when flows exceed twice the average dry weather flow. In addition to the parameters outlined in Table 1.2, more stringent phosphorus requirements of 0.25 mg/L exist for sensitive bodies of water, including the Okanagan Basin, the Christina Lake Basin, the Thompson River at Kamloops, the Cowichan River, the Nicola River at Merritt, and the Cheakamus River at Whistler.

Table 1.2 Municipal effluent quality requirements (Maximum Daily Flow > 50 m^3/d*)
(Modified from (Government of British Columbia, 2012)

Municipal effluent quality	**Streams, rivers, and estuaries**		**Lakes ≥ 100 ha**	**Marine Waters**	
	Dilution ratio ≥40:1	Dilution ratio ≥10:1	Surface area ≥ 100 ha	Open	Embayed
If daily flows are <2x Average dry weather flow					
BOD_5 & TSS (mg/L)	≤45	≤10	≤45	≤45	≤45
pH	6 – 9	6 – 9	6 – 9	6 – 9	6 – 9
Total phosphorus (mg/L)	≤1	≤1	≤1	n/a	n/a
Ortho-phosphate (mg/L)	≤0.5	≤0.5	≤0.5	n/a	n/a
If daily flows are ≥ 2x Average dry weather flow: interim standards					
BOD_5 & TSS (mg/L)	≤130	≤10	≤130	≤130	≤130

**for maximum daily flows < 50 m^3/d, less stringent regulations exist*

In addition to these contaminants, British Columbia Ministry of Environment has water quality guidelines (WQGs) for a wide variety of chemicals, including 17 α-ethinylestradiol (EE2), metals, and a variety of organic contaminants (British Columbia Ministry of the Environment, 2017). For example, these guidelines indicate that the 30-day average for EE2 should not exceed 0.5 ng/L in unfiltered water samples. The WQGs provide direction for decisions that affect water quality, and although they do not have legal force, they must be considered in any decision affecting water quality made by the Ministry of Environment, such as determining allowable limits in waste discharge authorization (British Columbia Ministry of the Environment, 2017)

In British Columbia, a wide variety of wastewater treatment levels exist, largely depending on the discharge location. In the mid-1980s, Kelowna installed the first full-scale BNR plant in North America, and following its success, BNR technology had widespread uptake across interior British Columbia and other western provinces. Conversely, levels of wastewater treatment tend to be lower in coastal plants. For example, Vancouver has three secondary level plants and two primary level plants. The Capital Regional District (CRD) in Victoria has no treatment and discharges untreated wastewater via a deep ocean outfall. As a result of the WSER, the CRD is now designing a single advanced WWTP (with resource recovery), and Metro Vancouver is upgrading its North Shore WWTP (formerly called Lion's Gate) from primary to conventional secondary.

1.3.2 Alberta

Under the Environmental Protection and Enhancement Act, Alberta Environment and Parks (AEP) has the regulatory mandate for wastewater systems. AEP's stated objective for wastewater treatment is to develop "comprehensive and scientifically defensible standards and guidelines that are effective, reliable, achievable and economically affordable" (Government of Alberta, 2013b). Alberta requires a minimum of secondary biological treatment for wastewater from municipalities serving <20,000, and tertiary treatment for facilities serving populations >20,000 (Government of Alberta, 2013a). Secondary treatment standards specify allowable concentrations of $CBOD_5$ and TSS in wastewater effluents, while tertiary treatment standards further specify effluent concentrations of phosphorus and ammonia (Table 1.3) (Government of Alberta, 2013a). High levels of wastewater treatment are common in Alberta for larger population centres, with the majority of the population being served by tertiary treatment. While mid- to large-sized WWTPs in Alberta typically use BNR technology for wastewater treatment, smaller communities typically rely on facultative lagoons, which are the most numerous types of systems in the province.

Table 1.3 Effluent regulations in Alberta (Government of Alberta, 2013a)

Parameter	Secondary standards (mg/L)	Tertiary standards (mg/L)
$CBOD_5$	25	20
TSS	25	20
TP	--	1
NH_3-N	--	Site specific

1.3.3 Saskatchewan

Prior to 2015, wastewater effluent discharges in Saskatchewan were regulated under the Water Regulations (2002) (Government of Saskatchwan, 2007). Following the release of the CCME strategy and the federal wastewater regulations, Saskatchewan repealed the Water Regulations and released The Waterworks and Sewage Works Regulations (Chapter E-10.22 Reg 3), effective as of June 1, 2015 (Government of Saskatchewan, 2015). These regulations contain the national performance standards from the CCME national strategy and the federal WSER as minimum requirements for discharged effluents (CCME, 2014). In addition to specifying a $CBOD_5$ concentration of 25 mg/L, Saskatchewan further specifies a total BOD_5 of 30 mg/L (Government of Saskatchewan, 2015).

Large plants in Saskatchewan (such as the Saskatoon WWTP and the new Regina WWTP) utilize BNR technology, resulting in removal of nutrients in addition to meeting WSER requirements. The Saskatoon wastewater treatment plant also has a phosphorus recovery facility which has decreased phosphorus discharges (City of Saskatoon, 2018). Similar to the other Prairie provinces, Saskatchewan has a higher proportion of wastewater systems by count which are lagoons versus mechanical treatment plants.

1.3.4 Manitoba

In Manitoba, minimum effluent standards are legislated in the Water Quality Standards, Objectives and Guideline Regulation under The Water Protection Act (Manitoba, 2017). Manitoba has minimum water quality standards that must be achieved, which are brought into force with licenses issued to individual wastewater treatment facilities. Standards for treated wastewater effluent include BOD_5, TSS, ammonia, chlorine, total phosphorus, total nitrogen, and fecal coliforms (Table 1.4). In addition, the water quality standards indicate that the best practical technology should be utilized when upgrading a facility. Site-specific effluent requirements outlined in individual licenses may be more stringent than the provincial standards, and may include limits for additional compounds (CCME, 2014). Manitoba has approximately 500 wastewater treatment systems, approximately 150 of which are mechanical WWTPs, while the rest are primarily facultative lagoons. BNR technology is common in large plants.

Table 1.4 Manitoba wastewater effluent regulations (Manitoba, 2017)

Parameter	**Regulation**
CBOD	25 mg/L
BOD*	25 mg/L
TSS	25 mg/L
NH3-N	Site specific (not to exceed 1.25 mg/L)
Chlorine	0.02 mg/L
Total phosphorus (TP)	1 mg/L
Total nitrogen (TN)	15 mg/L
Fecal coliforms	200 fecal coliforms/100 mL
Best practical technology**	All new or upgrading facilities

* *$CBOD_5$ is a subset of BOD_5 and is by definition lower than total BOD. Therefore, Manitoba's limits on oxygen-demanding substances are more stringent than national limits*

***Best practical technology for beneficial use of resources such as nutrients, organic matter and energy contained within biosolids and sludge.*

1.3.5 Ontario

The Ontario Ministry of Environment and Climate Change (MOECC) regulates wastewater effluents through the Ontario Water Resources Act (1990) and the Environmental Protection Act (1990), both of which require Environmental Compliance Approvals (ECAs), formerly referred to as Certificates of Approval (CofAs), for establishing a wastewater treatment facility or discharging wastewater effluents to ground or surface waters (Government of Ontario, 2017). The MOECC issues ECAs to individual wastewater treatment facilities stipulating effluent quality limits based on site-specific criteria. ECAs utilize minimum effluent quality parameters as specified by the WSER, but may specify more stringent or additional criteria based on site specific assessments (CCME, 2014). The procedures for establishing effluent requirements from discharges to surface waters are (Government of Ontario, 2017):

1. A site-specific assessment is conducted on the receiving water to assess existing conditions and establish its assimilative capacity.
2. Site-specific effluent requirements are compared to federal or provincial regulations or guidelines for effluent discharges and the most stringent requirement is applied.
3. An ECA indicating effluent requirements is issued to each WWTP.

In Ontario, most WWTPs use extended aeration with chemical precipitation of phosphorus using aluminum or iron salts. Nitrification is common, but most WWTPs do not attempt to remove nitrate (i.e., reduce total nitrogen). Phosphorus levels are regulated depending on the sensitivity of the receiving water, as assessed in the ECA process. Wastewater treatment facilities discharging to sensitive water bodies such as the Great Lakes and Lake Simcoe have increased stringency. For example, WWTPs discharging effluent in the Lake Simcoe Watershed have total phosphorus limits of 0.1 mg P/L, the most stringent in the country (Oleszkiewicz et al., 2015).

1.3.6 Québec

In Québec, the Environmental Quality Act (Government of Québec, 2017) includes a Regulation respecting municipal wastewater treatment works (Government of Quebec, 2013), which has arisen as a result of the CCME's Canada-wide Strategy for the Management of Municipal Wastewater Effluent (CCME, 2009). This Regulation is targeted at Québec municipalities located below the 54^{th} parallel that treat wastewater with average annual flow greater than 100 m^3/day, and is intended to provide protection for aquatic ecosystems and drinking water sources (Government of Québec, 2017). The Regulation specifies $CBOD_5$ and TSS values equal to the WSER, and also specifies an effluent pH range of 6.0—9.5 (Government of Québec, 2017). In addition, Québec's regulations prohibit any combined sewer overflows of municipal wastewater and diverting of untreated or partially treated wastewater under dry weather conditions, and forbid increasing the overall frequency of overflow events. However, this prohibition referred to in the first paragraph does not apply to overflows and diversions of wastewater occurring during the following events:

(1) In a case of emergency;

(2) The melting of snow;

(3) The realization of work to alter, repair or maintain a works;

(4) The infiltration of water into the works caused by spring thaw.

In Québec, most small communities are served by lagoons for wastewater treatment. The Jean-R. Marcotte treatment plant in Montreal is the second largest wastewater treatment plant in the world and receives nearly 40% all wastewater generated in the province of Québec. This plant currently uses chemically enhanced primary treatment (CEPT), but is in the process of upgrading facilities to include ozonation for disinfection and destruction of other trace organic contaminants.

1.3.7 Atlantic Provinces

The Atlantic Provinces primarily discharge wastewater effluents to marine waters and have traditionally had lower levels of secondary treatment than inland parts of Canada. For example, in 2009 approximately 50% of the population of Nova Scotia is connected to central treatment facilities, while 45% of the population relies on on-site sewage disposal systems (i.e., septic tanks), and 5% on untreated discharge (Government of Nova Scotia, 2015). Several Atlantic province communities have been issued transitional authorizations to extend the timeframe for meeting the national standards. New Brunswick has created a bilateral administrative agreements as a result of WSER.

1.3.8 Northern Regions

In northern regions, territorial water boards authorize effluent discharges and are responsible for local standards, monitoring, and reporting requirements. The North faces several unique challenges because of the cold climate, the small size of settlements, and the remoteness of these settlements. Most communities employ lagoons (with or without mechanical aeration) or oxidation ponds, which may be shallow aerobic, deep anaerobic, or seasonal facultative ponds (which rely on symbiosis between bacteria and algae to encourage photosynthesis and associated oxygen production). Some lagoons or ponds also employ wetlands for seasonal polishing of effluents before discharge. These types of simpler treatment technologies are especially common in small and remote communities. The federal WSER criteria are met in Yukon, which has a bilateral equivalency agreement with the federal government (Government of Canada, 2016). The federal Regulations do not currently apply to Nunavut, Northwest Territories, or communities in Québec and Newfoundland and Labrador located above the 54^{th} parallel. These regions were excluded because the CCME strategy determined that due to the climatic conditions and remoteness of Canada's North, careful consideration would be needed to produce a viable means of improving protection of human and environmental health through wastewater treatment (CCME, 2014). As a result, the governments of Northwest Territories, Nunavut, Québec, Newfoundland and Labrador, and Canada formed the Northern Working Group, who have worked collaboratively to undertake research into factors that affect performance of wastewater facilities in northern conditions. This group has completed work timelines for implementation, adapting risk level criteria in WSER, taking into consideration the challenges faced in the North, and examining the potential costs of building new facilities capable of achieving the WSER standards. However, no federal regulations pertaining to wastewater effluents have yet been established. In the interim, effluent quality requirements in existing water board authorizations continue to apply, in addition to the general prohibition of depositing deleterious substances of the federal Fisheries Act.

1.3.9 Indigenous Communities

Responsibilities for wastewater management in Indigenous communities south of 60 degrees are shared by Indigenous communities and the federal government, and wastewater systems that collect more than 100 m^3 are subject to the WSER. North of 60 degrees, some responsibilities have been devolved to territorial governments or Inuit and First Nations as part of land-claims settlements in the North (Government of Canada, 2018). In general, a wide disparity has existed in local governance capacity, regulatory framework, funding per capita and methods of wastewater treatment from one community to another. In 2011, a national assessment of Indigenous water and wastewater systems was commissioned by INAC to identify deficiencies and short- and long-term needs. The assessment found that the types of systems employed vary by province, and that the most common types of treatment methods are facultative lagoons and municipal type agreement (MTA) systems (INAC, 2011). Facultative lagoons are commonly employed in Ontario, Saskatchewan, and Alberta, while communities in British Columbia, Yukon and the Atlantic commonly employ MTAs (INAC, 2011).

Out of 532 wastewater systems across 418 First Nations, 54% of homes are sewered, 8% of homes are on a truck haul, 36% of homes have individual wastewater systems and 2% of homes (representing 112,836 homes) have no service at all (INAC, 2011). The use of wastewater services differs between provinces; for example, 99% of wastewater services in Indigenous communities in Yukon employ truck haul systems, whereas only 5% of Ontario and 7% of Saskatchewan Indigenous communities use this system (INAC, 2011).

The risk assessment conducted by INAC of Indigenous wastewater systems across Canada is based on their risk level evaluation guidelines. Of the 532 wastewater systems tested, 14% were rated as high risk, 51% as medium risk and 35% as low risk (INAC, 2011). The greatest percentage of high risk systems are located in Ontario and the Atlantic, while the greatest percentage of low risk systems are located in the Northwest Territories, Yukon, and British Columbia (INAC, 2011). Based on this assessment, INAC recommended that infrastructure and system upgrades that are not meeting protocol should be the highest priority for improvement, including provision of basic service levels for existing non-serviced homes. The cost to upgrade wastewater systems in order to comply with current protocols is estimated to be $316 million, which would improve plant design capacity and provide standby power units for Indigenous communities that experience frequent power outages (INAC, 2011).

2. United States

2.1 National regulations

The Clean Water Act (CWA) was established in 1972 as a result of a significant reorganization and update to the 1948 Federal Water Pollution Control Act (US EPA, 2017d). The CWA regulates quality standards in surface waters in the Unites States and establishes the structure for regulating discharges of pollutants under the regulatory authority of the United States Environmental Protection Agency (US EPA). Under the CWA, it is unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained. Permits are granted to individual treatment facilities by state environmental protection agencies under the CWA's National Pollutant Discharge Elimination System (NPDES) permit program. This program establishes discharge limits for municipal wastewater treatment facilities (US EPA, 2017c).

The NPDES permit system takes into account both technology-based effluent limitations (TBELs) and water quality-based effluent limitations (WQBELs) (US EPA, 2010). TBELs require a minimum effluent quality that is attainable using existing technologies for reducing discharges of pollutants into surface water, and represent the minimum level of control that must be imposed with any NPDES permit (US EPA, 2010). The effluent standards specified by existing TBELs are consistent with secondary treatment and include limits for biochemical oxygen demand (BOD_5) or carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), and pH (Table 1.5).

Table 1.5 Secondary treatment standards (US EPA, 2010)

Parameter	30 day average	7 day average
BOD_5 or $CBOD_5$	30 mg/L or 25 mg/L	45 mg/L or 40 mg/L
TSS	30 mg/L	45 mg/L
BOD_5 and TSS removal	≥85%	--
pH (standard units)	Maintained within the limits of 6.0—9.0	

In addition to TBELs, NPDES permits take into account the impact of wastewater effluents on the quality of the receiving water (States Environmental Protection Agency, 2010). The CWA requires development of WQBELs, which add additional or more stringent effluent limitations (States Environmental Protection Agency, 2010). Before WQBELs can be established, individual states define water quality standards for their water bodies based on both the current condition and intended use. States then determine total maximum daily loads (TMDLs) on a watershed level, accounting for both point and non-point contributions. TMDLs are enforceable standards that specify the maximum load of a given substance that a water body can assimilate each day and still meet its desired water quality standards. TMDLs are used by permitting agencies when establishing WQBELS, which ensure that water quality standards are met and contribute to the CWA objective of maintaining or restoring the chemical, physical, and biological integrity of national waters.

Permit WQBELS often include specifications for nutrients, especially for phosphorus and/or nitrogen. Under the CWA, water quality trading (WQT) is an option for compliance with WQBELs in an NPDES permit (US EPA, 2016b). WQT can provide greater flexibility, reduce overall costs, encourage participation of non-point sources within the watershed, and decrease the total burden on a watershed (US EPA, 2016a). Under this framework, credits can only be traded only on a watershed basis, and NPDES permits facilitate trading consistent with the regulations of the CWA. WQT may be between WWTPs, which capitalizes on economies of scale, or between WWTPs and other nutrient sources. WQT is considered a good option for dischargers with regulated baselines for whom pollution reduction is expensive, for example because it requires large investments in infrastructure for a small community (Ogilvie Ogilvie & Company, 2013). WQT has the benefit of achieving the same (or often better) water quality targets at a lower overall cost. This system also incentivizes larger plants to invest in upgrades that can achieve greater nutrient reductions than stipulated by their permits, because they can then sell credits to smaller plants. A successful WQT program was used for nitrogen trading among WWTPs in Connecticut to meet regulated nutrient reductions, with an estimated capital cost savings of $200 million (US EPA, 2008).

2.2 State regulations

Under the CWA framework, individual states are integral in the permitting process because they set water quality standards, monitor and assess water bodies, and develop TMDLs required to achieve water quality goals (US EPA, 2017a, 2017b). State regulations and implementation vary considerably, with some states stipulating effluent requirements at a statewide level (e.g. Arizona, Illinois, Michigan, New York, Wyoming), and others delegating regulatory control locally to regional quality boards (e.g. California) or local health agencies (e.g. Colorado) (Oleszkiewicz et al., 2015).

States have the authority to set effluent standards that are broader or more stringent than those required by the CWA. Most states follow the federal effluent regulations for BOD_5 and TSS, with some having additional regulations. Under the EPA's National Strategy for Development of Regional Nutrient Criteria (US EPA, 1998), states are encouraged to establish numeric criteria for phosphorus and nitrogen in all bodies of water. Currently, approximately half of all states have at least partial phosphorus and/or nitrogen criteria for at least some types of water bodies (US EPA, 2018). Florida is the only state with statewide nitrogen and phosphorus criteria for all water body classifications, including estuaries, rivers/streams, and lakes/reservoirs. Florida has total phosphorus and nitrogen effluent limits of 0.7-1 mg P/L and 7-10 mg N/L, respectively (Oleszkiewicz et al., 2015). Wisconsin, Minnesota, and New Jersey have statewide phosphorus criteria for lakes/reservoirs and rivers/streams, and New York is expected to set statewide phosphorus criteria for lakes/reservoirs, and statewide nitrogen and phosphorus criteria for streams/rivers by the end of 2018.

Michigan has effluent limits of total phosphorus and total nitrogen limits of 2 mg P/L and 10 mg N/L, respectively (Oleszkiewicz et al., 2015). Wisconsin recently implemented regulatory changes to address phosphorus loading in surface waters, which seek to set limits such that phosphorus concentrations for a given body of water are near naturally occurring levels (Blair et al., 2015; Wisconsin State Legislature, 2010, 2016). Previously, effluent standards were 1.0 mg P/L, but are now an order of magnitude lower (i.e. 100 µg P/L) for the majority of WWTPs, with regulated concentrations as low as 50 µg P/L for some plants (Wisconsin State Legislature, 2016). New York has established a State Pollutant Discharge Elimination System (SPDES) program to protect surface and groundwater resources that is broader in scope than the CWA (New York State Department of Environmental Conservation, 2017). For example, the SPDES system regulates a variety of organic chemicals as well as water treatment chemicals, such as de-foamers and flocculants (New York State Department of Environmental Conservation, n.d.). The SPDES permit for the Syracuse Metropolitan Wastewater Treatment Plant (NY 0027081; New York State Department of Environmental Conservation, 2012) stipulates extremely stringent TP discharge limits of 20 µg/L, and specifies loadings for a variety of organic chemicals, such as tetrachloroethane, chloroform, and butyl benzyl phthalate.

3. European Union and Switzerland

3.1 European Union wastewater treatment and regulations

The European Union adopted the Water Framework Directive (WFD; EC 60/2000) in 2000, which defines a framework for integrated river basin management and requires management of water based on hydrological boundaries (i.e. at the watershed level) instead of administrative boundaries. Under the WFD, rivers are to be managed according to river basin management plans, which indicate water quality objectives and actions to reach them, and are updated every six years. The WFD required member states to achieve "good ecological status" for all fresh and coastal waters by 2015, although several member countries have not yet achieved this goal. Under the legal force of an EU Directive, all member countries must meet the outlined goals, but they may devise their own laws regarding how to accomplish this.

In addition to the WFD, the EU Urban Waste Water Directive (UWWD, 1991; EC 91/271) (European Union, 1991) outlines legal requirements for wastewater treatment and disposal within EU member states. According to this directive, all treatment facilities serving >2000 person equivalents (p.e.) must collect and treat wastewater using secondary (i.e. biological) treatment to reduce TSS, BOD_5, and chemical oxygen demand (COD) in wastewater effluents. For agglomerations of >10,000 p.e. in sensitive areas, more advanced treatment must be used to ensure removal of additional nutrients (including nitrogen and phosphorus) in addition to the parameters targeted by secondary treatment (Table 1.6). Sensitive areas include any freshwater, estuarine, or coastal environments that are eutrophic or in danger of becoming eutrophic, as well as surface waters intended for abstraction of drinking water. Member states may either designate and monitor sensitive areas, or apply the more stringent guidelines to all water bodies in their territory (Blöch, 2005). For the largest agglomerations (>100,000 p.e.), higher stringency exists for phosphorus and nitrogen concentrations in discharged effluent. In addition to specified effluent limits, the UWWD requires a percentage removal across a treatment plant for BOD_5, COD, nitrogen, and phosphorus (Table 1.6).

Table 1.6 European Union effluent regulations (European Union, 1991)

Parameter	**Regulated value (mg/L)**		**Reduction required (%)**
	10,000—100,000 p.e.	>100,000 p.e.	--
TSS	35	35	--
BOD_5	25	25	70-90%
COD	125	125	75%
TN	15	10	70-80%
TP	2	1	80%

Note: For TSS, BOD_5, and COD, a pre-defined number of samples (ranging from 4-24) must be collected each year based on WWTP size and previous performance. The indicated values represent the maximum allowable concentration in collected samples, but a pre-defined proportion of samples are permitted to fail to conform to regulated values. For samples that fail to conform, they must not deviate from the regulated value by >100%. For TN and TP, regulated values represents yearly averages.

In the EU, the degree of wastewater treatment varies regionally, with tertiary treatment (i.e., removal of nutrients) being the most common treatment level (European Environment Agency, 2017). In Central Europe, 97% of the population is connected to a sewage collection system, while in all other regions of Europe, approximately 75-85% of the total population is connected to collection systems (Figure 1.2). Approximately 80% of the total population in Central and Northern Europe receive tertiary treatment, while over half of the population in Southern and Eastern Europe receive tertiary treatment. In all regions of Europe except South-eastern, virtually all collected wastewater receives a minimum of secondary treatment. In South-eastern Europe, 34% of the population receives primary treatment or lower (Figure 1.2), but the overall rate of sewage collection and tertiary treatment have steadily increased between since 2005 and is expected to continue this upward trend (European Environment Agency, 2017).

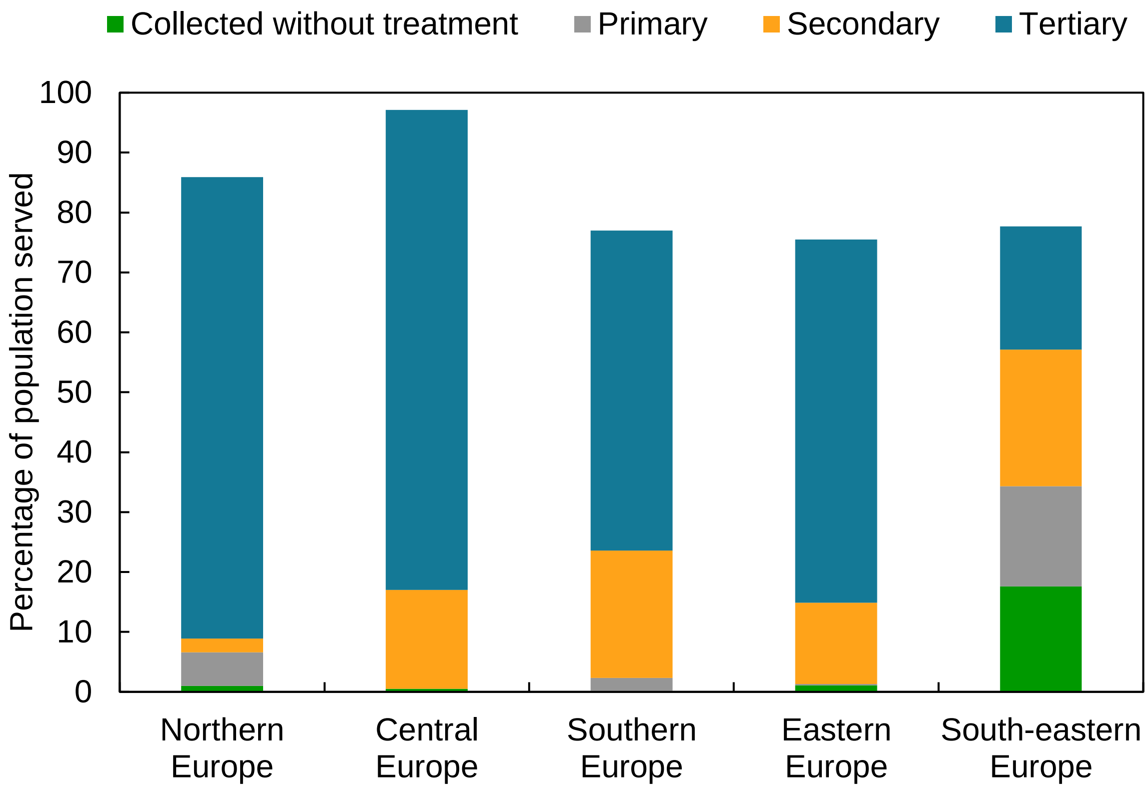

Figure 1.2 Levels of wastewater treatment in Europe in 2015. Data obtained from European Environment Agency, 2017. Bar totals indicate population with access to wastewater collection systems. *Northern Europe*: Norway, Sweden, Finland, and Iceland. *Central Europe*: Austria, Belgium, Denmark, Netherlands, Germany, Switzerland, Luxembourg, United Kingdom. *Southern Europe*: Greece, Italy, Malta, and Spain. *Eastern Europe*: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovenia. *South-eastern Europe:* Bulgaria, Romania, and Turkey.

3.2 European Union member states

The effluent quality standards regulated by the UWWD include up to tertiary treatment, but member states may also choose to enforce more stringent requirements (Table 1.7), and may use additional regulatory tools to incent improved effluent quality. For example, in Germany, the Netherlands, and Denmark, fees are charged to wastewater treatment systems based on total loads of discharged pollutants, which has resulted in achievement of better effluent quality than required by law.

Table 1.7 Wastewater effluent regulations in selected EU member states
(Adapted from Oleszkiewicz et al., 2015)

Country	BOD5 (mg/L)	COD (mg/L)	TSS (mg/L)	TN (mg N/L)	TP (mg P/L)	NH_4 (mg N/L)	p.e.*
EU	25	125	35	10	1	-	>100,000
France	25	125	20	10	1	-	>100,000
Poland	25	125	20	10	1	-	>100,000
Austria	15	75	-	70% removal	1	5	>50,000
Denmark	-	-	-	8	1.5	-	>5,000
Netherlands	20	125	30	10	1	-	>90,000
Germany	15	75	30	13	1	10	(>6000 kg BOD_5/d

**For countries whose effluent requirements varying by community population equivalents, the most stringent requirements are shown.*

3.2.1 Germany

In Germany, the goals of water protection policies are to achieve both good ecological and chemical quality for all bodies of water, and to ensure water quantity and quality for the common good, including drinking water, recreation, and energy production (Federal Ministry for the Environment, Nature Conservation, 2016). Water policies are intended to achieve these goals and are explicitly based on the precautionary principle, the polluter-pay principle, full-cost accounting, and cooperation among stakeholders (Federal Ministry for the Environment, Nature Conservation, 2016). The primary federal law concerning wastewater effluents is the Federal Water Act (Wasserhaushaltsgesetz), which was first introduced in 1957 and was substantially revised in 2010, with amendments to incorporate the EU's WFD into national law. These amendments created the legal basis for transboundary, sustainable water management in order to achieve good chemical and ecological status for all water bodies by 2027. River basin management organizations in Germany have been established for states (Länder) sharing river watersheds.

The Federal Water Act contains several ordinances, including the Waste Water Ordinance (Abwasserverordnung), which establishes general principles of sewage treatment and outlines sampling and analytical procedures that should be followed, in addition to specifying effluent standards (Federal ministry of the Environment, Nature Conservation, and Nuclear Safety, 2004). For municipal wastewater, minimum effluent standards are outlined in Table 1.8. In addition to national regulations, individual Länder may supplement federal laws with their own region-specific rules.

In addition to effluent quality regulations, Germany has a federal Waste Water Charges Act (Abwasserabgabengesetz), which requires that fees be paid when contaminant-containing wastewater is discharged into water bodies (Federal Ministry for the Environment, Nature Conservation, 2016). Charges levied vary depending on the noxiousness of the wastewater, which takes into account oxidizable substances, phosphorus, nitrogen, organohalogens, several heavy metals, and the toxicity of the effluent to fish (German Law Archive, 1998). These charges are based on the polluter-pays principle and are intended to provide economic incentives for reducing the impacts of effluents on receiving waters.

Table 1.8 Germany minimum effluent quality regulations (Federal ministry of the Environment, Nature Conservation, and Nuclear Safety, 2004)

WWTP Size category	COD (mg/L)	BOD_5 (mg/L)	NH_4 (mg N/L)	TN (mg N/L)	TP (mg P/L)
1: <60 kg/d BOD5 (raw)	150	40	--	--	--
2: 60-300 kg/d BOD5 (raw)	110	25	--	--	--
3: 300-600 kg/d BOD5 (raw)	90	20	10	--	--
4: 600-6000 kg/d BOD5 (raw)	90	20	10	18	2
5: >6000 kg/d BOD5 (raw)	75	15	10	13	1

3.2.2 Switzerland

Although Switzerland is not an EU member state, it collaborates closely with the EU on environmental matters and has been a full member of the European Environment Agency since April 2006 (Federal Office for the Environment, 2017). Through the legal force of the Water Protection Act (WPA; The Federal Assembly of the Swiss Confederation, 2016) and Waters Protection Ordinance (WPO; The Federal Assembly of the Swiss Confederation, 2017), Switzerland imposes wastewater effluent standards that are more stringent and more comprehensive than those of the EU (Table 1.9). For example, these regulations include limits for dissolved organic carbon (DOC), and organic trace contaminants, which include endocrine disruptors and selected pharmaceuticals. In addition to establishing effluent concentrations for regulated substances, Switzerland also specifies removal percentages that must be achieved through wastewater treatment.

Table 1.9 Wastewater effluent regulations in Switzerland (The Federal Assembly of the Swiss Confederation, 2017)

Parameter	**WWTP treating < 10,000 p.e.**	**WWTP treating > 10,000 p.e.**
TSS	20 mg/L	15 mg/L
COD	60 mg/L (80% removal)	45 mg/L (85% removal)
BOD_5	20 mg/L (90% removal)	15 mg/L (90% removal)
DOC	10 mg/L (85% removal; all WWTPs >2000 p.e.)	
Transparency	30 cm	
Total ammonium nitrogen (NH_4^+-N + NH_3-N)	2 mg/l (90% removal)	
Nitrite	0.3 mg N/L (guide value)	
Adsorbable organic halogen (AOX)	0.08 mg N/L	
Organic trace substances	>80% removal*	
TP[‡]	0.8 mg P/L (80% removal)	
TN[‡]	Concentrations and removal efficiencies are specified for individual WWTPs. Plants with no specified limits must be operated to remove as much nitrogen as possible. All structural modifications which are possible at no great cost must be undertaken.	

* *Applies to plants with a) ≥80 000 connected residents, b) ≥24 000 connected residents in the catchment area of lakes, c) ≥ 8000 connected residents that discharge into a watercourse containing more than 10% wastewater untreated for organic trace substances, d) ≥ 8000 connected residents if removal is required due to special hydrogeological conditions.*

‡ *Additional requirements for discharge into sensitive waters*

Note: A pre-defined number of yearly samples (4-24) must be taken depending on plant size and previous performance. Within these samples, the above values represent maximum acceptable concentrations. A pre-defined number of non-compliant samples is permissible (e.g. if 24 samples are taken, 4 may be non-compliant), but the following values must never be exceeded: TSS of 50 mg/l; COD of 120 mg/L; DOC of 20 mg/L; BOD_5 of 40 mg/L. For phosphorus, the indicated value is based on annual averages, and in WWTPs serving ≥10,000 p.e. must never have an annual average exceeded 0.8 mg/L.

Switzerland has recently revised the WPO to require nationwide implementation of advanced treatment processes in WWTPs serving large populations or those discharging to sensitive waters (Eggen, Hollender, Joss, Schärer, & Stamm, 2014). These revisions came into force on January 1, 2016, and require that WWTPs treating population equivalents greater than 80,000, discharging to receiving environments used for abstraction of drinking water, or contributing >10% of the total flow to a receiving stream, achieve 80% reduction of organic trace substances compared to raw sewage. These legislative changes were widely supported and were made following broad public consultation. As a result of this legislation, approximately 100 of the total of 759 Swiss wastewater treatment plants will be required to upgrade their facilities by 2040. The total cost of the upgrade program is expected to be 1.6 billion dollars, which will be supported by a federal fund (which covers 75% of total costs) and a sewerage tax paid by wastewater producers, according to the polluter-pays principle (BAFU, 2012; Swiss Federal Institute of Aquatic Sciences and Technology, 2015).

Legislative changes requiring reduction of organic trace contaminants followed multi-year studies by the Swiss Federal Office for the Environment (Das Bundesamt für Umwelt; BAFU), which determined that fish fertility and aquatic species diversity in Swiss surface waters were negatively impacted from by micropollutants in wastewater effluents (Joss, Schärer, & Abegglen, 2016). In addition, these upgrades contribute to the fulfillment of a 2013 Ministerial Declaration by the Rhine River Council that agreed relevant states would to take action to reduce micropollutant inputs to the Rhine (Internationale Kommission zum Schutz des Rheins, 2013).

A variety of advanced wastewater treatment processes were investigated using pilot-scale and full-scale studies for their ability to remove several indicator chemicals. Ozonation and powdered activated carbon (PAC) removed at least 80% of the assessed indicators, and were chosen as the most appropriate method to supplement biological treatment and remove organic trace contaminants (Swiss Federal Institute of Aquatic Sciences and Technology, 2015).

4. Australia

In Australia, wastewater is treated by approximately 580 publicly-owned WWTPs (Australian Government, 2017), and all major cities in Australia, with the exception of Canberra, are located on the coast and discharge wastewater effluent into the marine environment (ANZECC, 1997). There are more than 50 ocean outfalls from these cities and coastal communities, and the level of treatment prior to discharge varies from minimal to secondary treatment with nutrient removal. Discharge to inland waters is predominantly from smaller communities, and typically receives at least secondary treatment and disinfection.

Australia has a National Water Quality Management Strategy (NWQMS), which includes a variety of guideline documents pertaining to various aspects of water management, including the Australian Guidelines for Sewerage Systems Effluent Management (ANZECC, 1997). These guidelines provide advice on management of sewerage systems and municipal wastewater effluents, including setting minimum treatment levels for municipal wastewater based on the receiving water. For example, for inland waters, estuaries, and nearshore coastal waters, a minimum of secondary treatment is specified, while lower minimum treatment levels (i.e. preliminary or primary) may exist for coastal waters with extended outfalls.

In addition, the Australia and New Zealand Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000) provide a broad range of tools for the management of environmental water quality, which are intended to be adjusted to local conditions to achieve sufficient protection of water quality. These guidelines recommend implementing integrated approaches to water management by combining numerical values for chemical compounds, water quality monitoring, toxicity assessment, and biological monitoring. Numerical trigger values are derived from toxicity data and represent a threshold, above which there is considered to be elevated risk to the aquatic ecosystem (NSW Government, 2013). Triggers exist for a variety of compounds, such as total phosphorus, total nitrogen, ammonium, dissolved oxygen, and pH (ANZECC, 2000).

The roles of the states and territories are also outlined in the NWQMS. Individual states and territories are responsible for setting water quality goals and regulating discharges of wastewater to surface waters (see Table 1.10). Interestingly, New South Wales and Victoria have adopted a statistical approach in which limits are based on median and/or 90th percentile of average daily results (Oleszkiewicz et al., 2015). This approach allows for periodic excursions over the limit, which has a minimal impact on the receiving water and allows plants to avoid oversizing infrastructure in order to meet never-to-exceed limits.

Table 1.10 Effluent quality parameters in Australia (modified from Oleszkiewicz et al., 2015)

Parameter	**South Australia**	**New South Wales**	**Victoria**		**Queensland**	**Western Australia**
		90th percentile	median	90th percentile		
BOD_5 (mg/L)	<6	10	5	10	Site-specific	Site-specific
NH_4 (mg N/L)	0.02-0.03[a]	2	2	5		
TN (mg N/L)	0.1-0.75[a]	10	10	15		
TP (mg P/L)	0.01-0.1[a]	0.3	0.5	1		

[a] *This criterion relates to receiving water after mixing*

5. Trends in Wastewater Regulations across Jurisdictions

The Canadian WSER standards regulate traditional wastewater contaminants and necessitate secondary (i.e. biological) treatment of wastewater or equivalent. The United States and the European Union also use secondary treatment as a minimum baseline for wastewater effluent and use similar regulated effluent concentrations for BOD_5 and TSS (Table 1.11). In Europe, secondary treatment has been the minimum acceptable technology for 27 years, since the introduction of the Urban Waste Water Directive, while in the United States, secondary treatment has been the minimum acceptable technology for 46 years, since the enactment of the Clean Water Act in 1972. Given that the WSER have only been in place in Canada since 2012, and that all plants will not meet these regulations until 2040, Canada has trailed the United States and EU in moving to secondary treatment as a minimum baseline.

Table 1.11 Comparison of wastewater effluent regulations in Canada, the United States, and the European Union

Parameter	**Canada**	**United States***	**EU**	
Population trigger	n/a	n/a	10,000—100,000 p.e.	>100,000 p.e.
BOD5	--	30 mg/L	--	--
CBOD5	25 mg/L	25 mg/L	25 mg/L	25 mg/L
COD	--	--	125 mg/L	125 mg/L
TSS	25 mg/L	>85% removal	35 mg/L	35 mg/L
NH_3-N (unionized)	1.25 mg N/L	--	--	--
Chlorine	0.02 mg/L	--	--	--
pH	--	6.0—9.0	--	--
Total nitrogen	--	--	15 mg/L	10 mg/L
Total phosphorus	--	--	2 mg/L	1 mg/L

**values based on 30-day averages (not 7-day)*

In Europe, tertiary treatment is the norm and is regulated for large agglomerations and for communities discharging to sensitive waters (Figure 1.2, Table 1.11). Neither the United States nor Canada have national regulations for nutrients in wastewater effluents, although in both cases, individual states/provinces may choose to impose their own regulations. In addition, localized permitting authorities in both Canada and the United States may specify nutrient removal based on receiving water body characteristics. In the United States, water quality trading is an accepted method of meeting WQBELs, and has the benefit of reducing nutrient loading to a receiving water at a reduced cost. Regulations can support WQT by setting trading ratios that ensure that pollution reductions are at least as great as those that the credit buyer's facility would have otherwise been able to achieve, but in practice often exceed these reductions, resulting in an overall reduction in nutrient loading (Ogilvie Ogilvie & Company, 2013). Both Canada and the United States have special protections for designated bodies of water, such as the Great Lakes, which commonly include stringent phosphorus regulations for WWTPs discharging to these watersheds.

In addition to convention and known contaminants, such as oxygen-demanding substances, suspended solids, and nutrients, wastewater contains a wide variety of other pollutants, such as endocrine-disrupting substances (e.g. estrogens), pharmaceuticals and personal care products (PPCPs), and microplastics. These diverse pollutants are often collectively termed "contaminants of emerging concern". For PPCPs, wastewater has been identified as the primary source to surface waters (Clara et al., 2012; Reif, Santos, Judd, Lema, & Omil, 2011). However, with the exception of Switzerland (which requires an 80% reduction in organic trace contaminants), contaminants of emerging concern in wastewater are largely unregulated. Both the United States and EU have identified PCPPs as substances of concern that may require regulation (European Commission, 2012, 2013; US EPA, 2014), and the European Commission has proposed amending its list of priority substances (which are monitored and controlled) to include diclofenac, estradiol, and ethynilestradiol (European Commission, 2012, 2013).

Canadian federal regulations specify maximal acceptable concentrations in discharged effluent (i.e., "end-of-pipe" criteria), but do not take into account total loads discharged from a single source or watershed-based loads from multiple sources. Provinces do consider the assimilative capacity of the receiving water when issuing permits, but very few cases of watershed-based wastewater management exist in Canada, with phosphorus management in the Lake Simcoe watershed being a notable exception. In contrast, the EU WFD explicitly indicates that the watershed scale must be utilized for water management decision making, regardless of administrative boundaries. In the United States, TMDLs consider various sources when determining the maximum load any one discharger can emit per day. United States federal guidelines take into account water quality status and require goals and monitoring for each body of water. Consideration of different sources of a pollutants is necessary for assessing the overall impact of any given WWTP on the receiving environment, but Canada's regulations do not currently include this approach.

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