

Changes to the Numbering of Regulations

Please be advised that the numbers of one or more of the regulations listed below have been changed since this document was originally published. Following the adoption of the *Act respecting the Compilation of Québec Laws and Regulations*, RSQ, c R-2.2.0.0.2, the ministère de la Justice began on January 1, 2010 to change the numbering of selected regulations, including those related to the *Environment Quality Act*, RSQ, c Q-2.

Please visit <http://www.mddep.gouv.qc.ca/publications/lois-reglem-en.htm> for more details about this change.



Calculation and Interpretation of Effluent Discharge Objectives for Contaminants in the Aquatic Environment

2nd Edition

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FOREWORD

The Ministère du Développement durable, de l'Environnement et des Parcs (the Department) has a mission to “contribute to the well-being of present and future generations by ensuring the protection of the environment and natural ecosystems.”

The recommendations and evaluations of the Department are based, among others, on water quality criteria, which it has defined for the main uses of surface water. Water quality criteria are one of the reference tools that can be used to evaluate the quality of aquatic environments and the health of aquatic ecosystems. Water quality criteria also form the basis for calculating environmental discharge limits for contaminants present in wastewater discharged into aquatic environments.

The Department presents its water quality criteria in a document entitled *Critères de qualité de l'eau de surface au Québec*, available on the Department's Web site: http://www.mddep.gouv.qc.ca/eau/criteres_eau/index.htm. This document contains published and recognized narrative and chemical criteria for over 300 contaminants. It also sets the limits for acute and chronic whole effluent toxicity. In addition, the Department has adopted a method for determining the water quality criteria that it uses when there are no existing recognized water quality criteria for a contaminant, but for which toxicity data are available. This method is outlined in a document entitled *Méthodologie de calcul des critères de qualité de l'eau pour les substances toxiques* (MENVIQ 1990, rev. 1992, in revision).

In Quebec, wastewaters discharged into aquatic environments are not regulated on a large scale. Discharge standards stipulated in the regulations are usually based on the performance of typical wastewater treatment technology. They constitute a basic level of protection without considering the location of discharges. However, aquatic environments present highly variable vulnerabilities as a function of uses and hydrodynamic conditions. The standards determined by the technological approach can thus occasionally be insufficient to permit compliance with environmental water quality criteria. Consequently, different measures, such as more restrictive discharge limits or project modifications, can be taken to ensure adequate environmental protection.

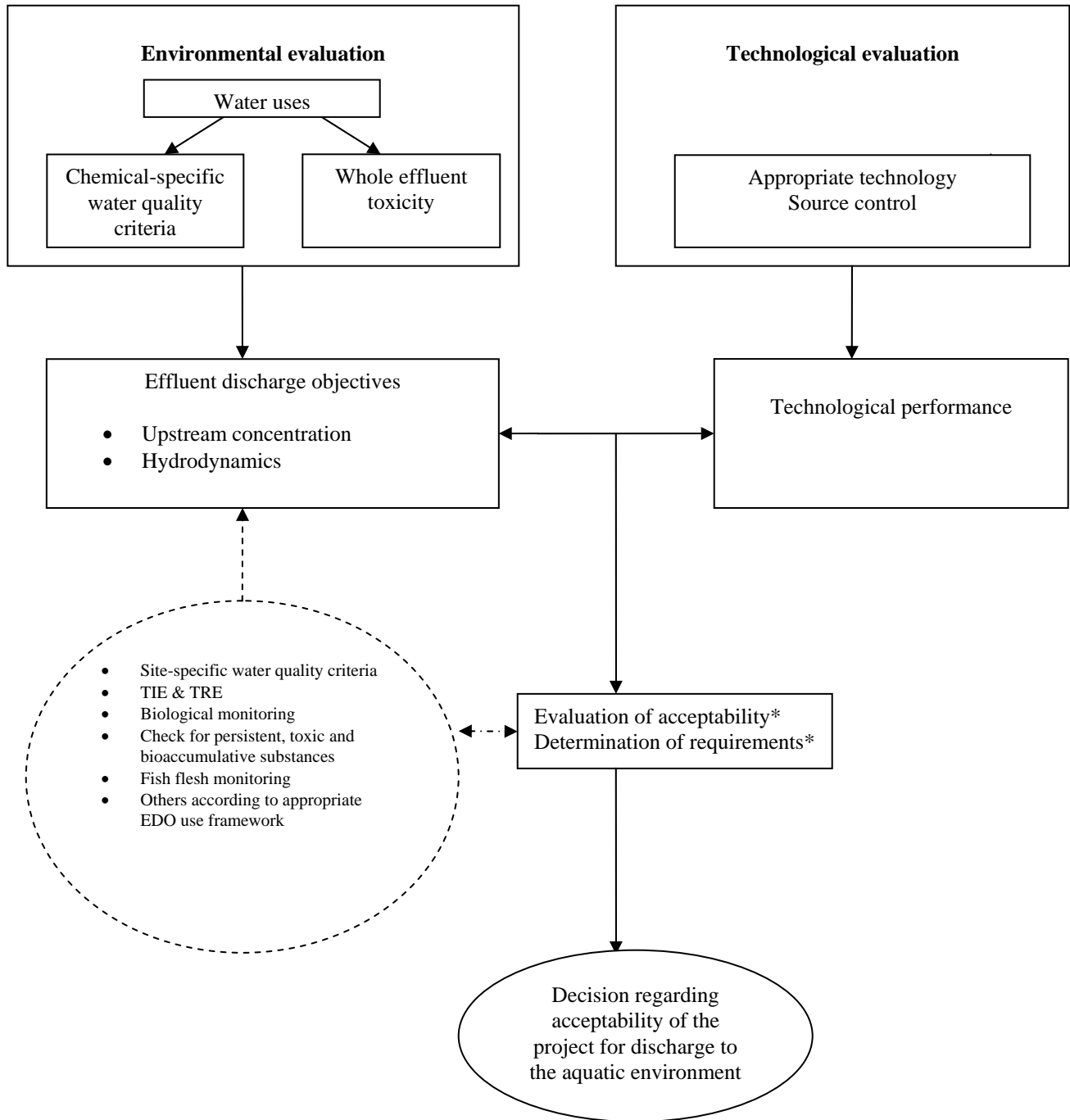
The Department has developed a method for determining effluent discharge objectives (EDOs), specific to each contamination source, based on surface water quality criteria, hydrodynamic conditions and the uses supported by the aquatic environment. This method is presented in the document.

The effluent discharge objectives constitute the basis for the process leading to the determination of discharge limits, designed to better protect the receiving environment. The diagram on page vi illustrates that the environmental evaluation is used in a complementary manner to the technological evaluation which itself ensures a base level of protection even for less vulnerable environments. This process is used to ensure that activities likely to have an impact on surface water quality comply with the principles of pollution prevention and reduction. It is used

specifically in municipal wastewater treatment projects, environmental impact assessments, depollution attestations, and the analysis of applications for statutory instruments (e.g., permits, authorization certificates). It can be accompanied or completed by other actions, such as an aquatic organism flesh/tissue quality evaluation, biological community assessment or sediment quality investigation.

Finally, the *Guide d'évaluation et de réduction des toxiques* (MEF, 1996, in revision) completes the series of documents by providing a tool for dischargers who must reduce their whole effluent toxicity. This guide outlines a structured method for performing a toxicity identification evaluation (TIE) and a toxicity reduction evaluation (TRE).

Diagram of the approach used to protect aquatic environments receiving point source discharges



* According to appropriate EDO use framework.

NOTE TO THE READER

The 2007 version of this document contains information never published before. It replaces the document entitled *Méthodologie de calcul des objectifs environnementaux de rejet pour les contaminants du milieu aquatique* (1991) and all previous versions.

An understanding of water quality and effluent evaluation tools and their limitations is essential before using the EDO calculation method that follows. For this reason, it is recommended that the readers familiarize themselves with the explanatory chapters in the document *Critères de qualité de l'eau de surface au Québec* http://www.mddep.gouv.qc.ca/eau/criteres_eau/index.htm and more specifically, the general usage rules for these criteria.

The method described in this document is based on the approach employed by the U.S. Environmental Protection Agency (U.S. EPA). The key technical document on which the U.S. and several Canadian provinces have based their approaches is the *Technical Support Document for Water Quality-Based Toxics Control* (U.S. EPA, 1991*b*). Effluent discharge objectives (EDO) are similar to U.S.EPA's Water Quality Based Effluent Limits (WQBEL).

This is not an official document. In case of disagreement between its content and the original document, the later should prevail. For the original document and updates please visit: <http://www.mddep.gouv.qc.ca/eau/oer/index.htm>.

TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	iv
NOTE TO THE READER	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	x
LIST OF FIGURES	x
ACRONYMS	xi
1 GENERAL DESCRIPTION OF THE APPROACH	1
2 SURFACE WATER USES	3
2.1 General.....	3
2.2 Drinking water sources	4
2.3 Consumption of fish and shellfish	5
2.4 Recreational activities	5
2.5 Aquatic life	5
2.6 Terrestrial piscivores.....	6
2.7 Other uses	6
3 NARRATIVE/CHEMICAL-SPECIFIC QUALITY CRITERIA AND WHOLE EFFLUENT TOXICITY CRITERIA	7
3.1 General.....	7
3.2 Narrative quality criteria	7
3.3 Chemical-specific quality criteria	8
3.3.1 Concentration and duration	8
3.3.2 Physical-chemical characteristics for the calculation of water quality criteria	10
3.3.3 Site-specific criteria	11
3.3.4 Sediment quality criteria	11
3.3.5 Biocriteria and biological monitoring.....	11
3.4 Whole effluent toxicity	11
3.4.1 Acute whole effluent toxicity.....	12
3.4.2 Chronic whole effluent toxicity.....	13
3.4.3 Whole effluent toxicity for discharges into marine environments	13
4 MIXING ZONES	14
4.1 General.....	14
4.2 Mixing zones in rivers	16
4.3 Mixing zones in lakes, reservoirs and enclosed bays.....	18
4.4 Mixing zones in estuaries and coastal waters	19
5 EFFLUENT DISCHARGE OBJECTIVES: SINGLE DISCHARGE APPROACH	20
5.1 General.....	20
5.2 EDO calculation equations for chemical contaminants	22
5.3 EDO calculation equations for whole effluent toxicity.....	24
5.3.1 Acute whole effluent toxicity.....	24
5.3.2 Chronic whole effluent toxicity.....	25

6	EFFLUENT DISCHARGE OBJECTIVES: MULTIPLE DISCHARGE APPROACH.....	25
6.1	Multiple discharge approach for phosphorus and fecal coliforms	25
	6.1.1 Phosphorus.....	27
	6.1.2 Fecal coliforms.....	28
6.2	Multiple discharge approach for BOD ₅	28
6.3	Multiple discharge approach for toxic contaminants	29
7	CALCULATION ELEMENTS OF EFFLUENT DISCHARGE OBJECTIVES	31
7.1	Stream critical low flow	31
7.2	Hydrodynamic modeling and diffusion tests	33
7.3	Effluent flow	34
7.4	Upstream concentration	35
7.5	Elevated upstream concentrations.....	37
7.6	Concentration and load EDOs	38
7.7	EDO application period	38
8	SPECIAL CASES OF ACUTE TOXICITY.....	40
8.1	Short-duration discharges	40
8.2	Continuous discharges	41
8.3	Physico-chemical characteristics for the calculation of effluent final acute values	41
9	ELEMENTS OF INTERPRETATION AND COMPLEMENTARY STUDIES RELATED TO THE EXCEEDANCE OF EFFLUENT DISCHARGE OBJECTIVES	42
9.1	General.....	42
9.2	Drinking water and fish flesh surveys	43
9.3	Form of metals	43
9.4	Site-specific water quality criteria	44
9.5	Toxicity identification evaluation	46
9.6	Verification of concentrations of highly bioaccumulative substances.....	47
	BIBLIOGRAPHY.....	48
	GLOSSARY	51
Appendix 1	Recommended toxicity tests	1
Appendix 2	Persistent, bioaccumulative and toxic substances.....	1
Appendix 3	Development of equations for calculating EDOs	1
Appendix 4	Examples of EDO calculations	1

LIST OF TABLES

Table 1 Mixing zone boundaries and maximum dilution allotted for different types of environments	21
Table 2 Conditions for using the single discharge and multiple discharge approaches according to contaminant	30
Table 3 Critical low flows applied to different uses	32
Table 4 Typical concentrations in agricultural and forested regions	37
Table 5 EDO application periods according to use and type of contaminant	39

LIST OF FIGURES

Figure 1 Representation of a back calculation performed when determining EDOs	2
Figure 2 Examples of different possible mixing zones for the same discharge	16
Figure 3 Elements of the loading mass balance	23

ACRONYMS

CALC	Chronic aquatic life criteria
CCME	Canadian Council of Ministers of the Environment
CEAEQ	Centre d'expertise en analyse environnementale du Québec
CEHQ	Centre d'expertise hydrique du Québec
CFU	Colony forming unit
CORMIX	Cornell Mixing Zone Expert System (hydrodynamic modeling software)
CPC(F)	Contamination prevention criteria for fish only
CPC(WF)	Contamination prevention criteria for water and fish consumption
DBO ₅	Biochemical oxygen demand (in 5 days)
EDO	Effluent discharge objectives
FAVe	Effluent final acute value
Fd	Dilution factor
IC ₂₅	Concentration that inhibits functioning in 25% of the organisms tested
LC ₅₀	Concentration that is lethal for 50% of organisms
MDDEP	Ministère du Développement durable, de l'Environnement et des Parcs
MEF	Ministère de l'Environnement et de la Faune
MENVIQ	Ministère de l'Environnement du Québec
MRNF	Ministère des Ressources naturelles et de la Faune
MSSS	Ministère de la Santé et des Services sociaux
NOEC	No observed effect concentration
PAH	Polycyclic aromatic hydrocarbons
PBTs	Persistent, bioaccumulative and toxic substances
PCB	Polychlorinated biphenyls
P _{tot}	Total phosphorus
QC	Quality criterion
QUAL2E	Enhanced Stream Water Quality Model
RAAC	Recreational activity and aesthetics criteria
SSQC	Site-specific quality criterion
TIE	Toxicity identification evaluation
TPC	Terrestrial piscivore criteria
TRE	Toxicity reduction evaluation
TSS	Total suspended solids
TU _a	Acute toxicity unit
TU _c	Chronic toxicity unit
U.S. EPA	United States Environmental Protection Agency
V/V	Volume to volume
WER	Water effect ratio
WET	Whole effluent toxicity

1 GENERAL DESCRIPTION OF THE APPROACH

One of the mandates of the Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) is the preservation and recovery of aquatic environmental uses. In this context, the Department has a responsibility to evaluate projects submitted to it, while taking into account the protection of human health and biological resources. To achieve this objective, the Department has adopted a method that allows it to evaluate the current impacts or predict the foreseeable impacts of wastewater discharges into aquatic ecosystems. This method permits the evaluation of concentrations and loads of contaminants potentially discharged into an aquatic environment without compromising water uses. These concentrations and loads, called *effluent discharge objectives* or *EDOs* are determined from:

- the characteristics of the receiving environment;
- the level of quality necessary to maintain water uses.

The characteristics of the receiving environment are represented by the natural quality and the actual quality of the waterbody, as well as its vulnerability and its dilution and attenuation capacity. Thus, a small waterbody cannot receive as large a load of contaminants as a large waterbody without experiencing a deterioration in quality. In the same manner, a lake with a slow renewal rate is less able to support a load than a fast-flowing river. The EDO approach is designed to take into account these differences. It also evaluates whether the capacity of a waterbody to receive contaminants has already been exceeded.

The level of quality necessary to maintain water uses is defined by water quality and whole effluent toxicity. The absence of acute toxicity of discharges must be respected. To ensure there are no lethal effects for aquatic organisms exposed to the effluents, discharges must not be acutely toxic. The absence of long-term effects on water uses must be satisfied over the entire waterbody so as to not compromise the ecological and human uses.

Several parameters are involved in establishing EDOs: the quality of water upstream of a discharge, the flow or volume of water available for dilution during critical conditions, the effluent flow rate, the whole effluent toxicity and the water quality criteria for each use. Calculation of EDOs is based on a load assessment applied to a segment of a waterbody. This assessment is carried out so that, for each contaminant, the load present upstream is added to the effluent load so that the maximum tolerable load is not exceeded at the end of a restricted mixing zone. This zone is allotted only if it does not harm the whole of the waterbody.

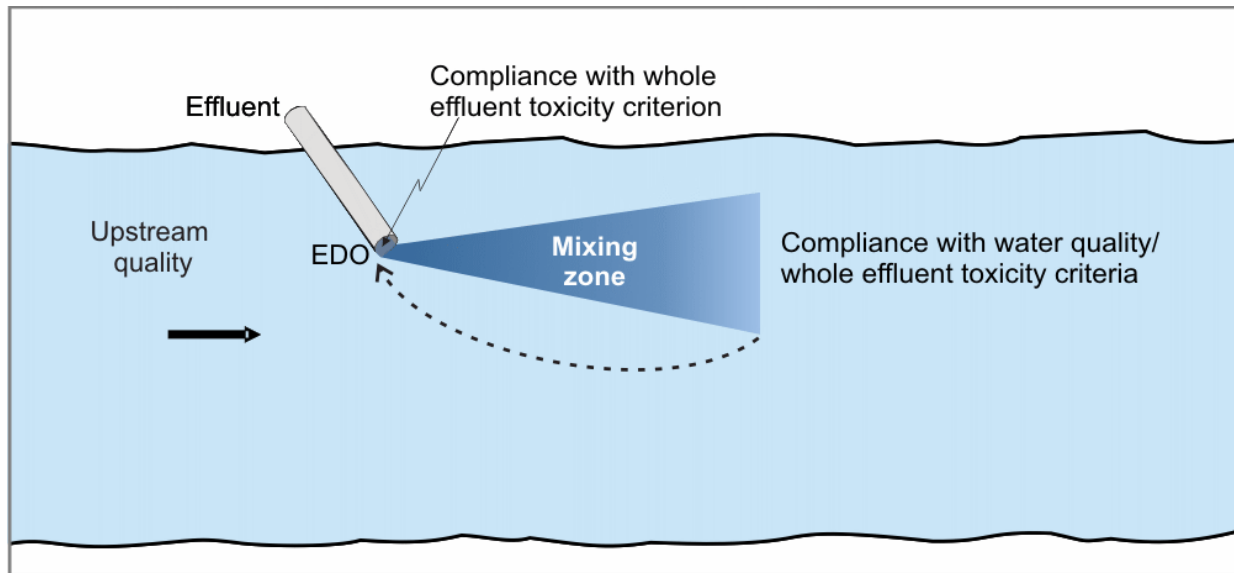


Figure 1 Representation of a back calculation performed when determining EDOs

Using a back calculation, the concentration and load (EDO) allotted for a discharge are determined based on the water quality criteria that must be respected downstream from the discharge and the mixing zone. All EDOs, chronic and acute, apply directly at the effluent source (Figure 1).

Water quality criteria and whole effluent toxicity limits are good predictive tools of the effects of contaminants on aquatic life and water uses (U.S. EPA, 1991*b*). However, considerations such as the health of the ecosystem, habitat degradation, the cumulative effects of several discharges or even the presence of a specific use or of a threatened species may necessitate additional interventions. Therefore, other evaluation tools can be used to take into account the effects not directly or indirectly considered by water quality criteria (e.g., biological monitoring, fish flesh surveys, sediment quality studies). The complementarity of these tools is what enables an overall assessment of the chemical, biological and physical integrity of ecosystems.

The method for determining EDOs is part of the Department's general approach to controlling pollutants from discharged wastewater, as explained in the foreword. The determination of EDOs differs from the determination of regulatory standards in that EDOs take into account the differences between receiving environments. While regulatory standards ensure equity between industrial discharges on the basis of a similar treatment level, the EDO approach aims to ensure equity between discharges on the basis of the sensitivity of the environment. Its main advantages reside in its predictive nature, since it can evaluate a future discharge, and in its preventive nature, since it enables stakeholders to take action before an observable effect is seen in the environment. It is also relatively simple in comparison to other tools and can be used to make quantitative recommendations, in line with the various wastewater treatment programs. It does, however, have its limits. The EDO approach does not target discharge in municipal

wastewater systems, soil seepage, agricultural non-point sources and urban run-off, nor is it suitable for evaluating the impacts of accidental discharges.

EDOs do not consider analytical, economic or technological constraints. They evaluate the environmental acceptability of existing or future discharges and can be used to justify additional interventions or modifications to projects. EDOs can also be used to identify the most problematic substances for an environment, identify replacement products or justify the use of more advanced treatment technologies, if required. They can result in the relocation of a discharge point in order to protect certain sensitive receiving environments and, ultimately, they can contribute to the refusal of a project.

EDOs must not be used as is (i.e., copied directly in a Departmental statutory instrument) without a preliminary analysis of existing treatment technologies. They must be included and used within usage frameworks developed for the activity sector in question. A procedure combining EDOs and technology has already been defined for certain sectors, and general guidelines on the use of EDOs for industrial effluent are being prepared by the Department. Therefore, this aspect will not be discussed in this document.

The method described in this document covers the majority of point-source aquatic discharge cases. However, this method does not purport to cover all possible situations. If justified by the particular circumstances, the cases that require a specific approach can be studied by the Department as long as the principles set forth in this document are respected. The following chapters outline each of the elements involved in the calculation of EDOs and certain concepts useful to their interpretation.

2 SURFACE WATER USES

2.1 General

The approach used to determine EDOs for wastewater discharged into the aquatic environment aims to protect existing surface water uses and to recover uses that have been lost.

The expressions *surface water* and *waterbody* refer to any waterway, including lakes, reservoirs, ponds, marshes and peat bogs. A *waterway* is defined as being any water mass that runs in a bed at a regular or intermittent flow rate, including those created or modified by human intervention, as well as the St. Lawrence River and Gulf and any seas surrounding the province of Quebec, with the exception of ditches along public or private roadways, dividing ditches and drainage ditches.¹

¹ The definition of waterway used is that indicated in the “Identification et délimitation des écosystèmes aquatiques, humides et riverains – projet” of the *Guide d’analyse des projets d’intervention dans les écosystèmes aquatiques, humides et riverains assujettis à l’article 22 de la Loi sur la qualité de l’environnement*.

Water uses refers to all uses needed for the development, growth and reproduction of living organisms, as well as recreational and utilitarian human uses. The expression *designated uses* indicates the uses applied by the Department for a segment of a particular waterbody. Designated uses include existing uses, those to be recovered and those planned for the near future. Certain uses are designated to prevent or reduce human health risks, and others to protect the integrity of ecosystems.

To prevent human health risks, surface water uses to be protected or recovered are:

- Drinking water sources;
- Consumption of fish and shellfish;
- Recreational activities.

To protect living organisms, surface water uses to be protected or recovered are:

- Aquatic life;
- Terrestrial piscivores.

Even when the water quality is adequate, certain uses may not be present on a waterbody, due to physical constraints (access, water depth, substrate, current speed). This is the case, among others, for certain recreational activities and for drinking water sources. Other uses, like aquatic life, are present or should be present in all surface waters. When evaluating the quality of a discharge into an aquatic environment, the existing uses or those to be recovered are designated by the Department after consultation with multiple sources and according to the terms described in sections 2.2 to 2.4.

2.2 Drinking water sources

Most of Quebec's population—in fact, over 5.3 million people—gets their drinking water from surface water, by way of municipal water supply systems (MDDEP, 2004).

The presence of certain contaminants in crude water is likely to increase the health risks for consumers if drinking water treatment processes are not sufficiently effective. Protecting sources of water destined to become drinking water tends to minimize treatment costs and reduce disinfection problems related to poor-quality source water. Moreover, the deterioration of water quality, even if only organoleptic in nature (taste, smell, colour), constitutes a loss of use since consumers may turn to other sources. For this reason, organoleptic constraints as well as those based on health risks are considered when determining EDOs.

This use is considered for all waterbodies where there is a source of drinking water. It is not considered where there is no source of drinking water.

2.3 Consumption of fish and shellfish

The quality of the flesh of aquatic organisms that are consumed by humans can be degraded by organoleptic effects (unpleasant taste or smell) or by an increase in health risks (toxic substances, toxins, bacteria). Certain substances can accumulate in the tissues of aquatic organisms (fish and shellfish) to levels that are harmful to consumers, thereby requiring restrictions or bans on their consumption.

Sport fishing is a wide-ranging water use. In 2005: “The province of Quebec count[ed] 813,590 fishermen” and “1.6 million Quebecers claimed to be interested in fishing at some point in time” (MRNF, 2004). Fishing is practised in all types of waterbodies. For this reason and because certain bioaccumulative substances are toxic and persistent, transferring from one compartment of the ecosystem to another (water, small fish, predatory fish, sediments, wild fowl), any increase that raises background levels in the environment, must be avoided.

With respect to toxic substances, consumption of fish and shellfish is a use designated in all waterbodies when determining EDOs. In addition, the zones conducive to shellfish harvesting must be free of microbial contamination. This aspect is taken into account in protecting shellfish-rich waters.

2.4 Recreational activities

Protection of recreational activities aims to prevent the health risks associated with direct or indirect contact with water. Direct-contact activities are those that may involve complete immersion of the body, including the head, in the water. This includes swimming, windsurfing or river kayaking. Indirect-contact activities are those that involve partial or less frequent contact with the water. Fishing, canoeing and pleasure boating are examples of activities from this second category.

Aesthetics aspects (colour, floating debris, turbidity, algae and aquatic plant overgrowth) are also considered and play an integral role in the protection of recreational activities by preserving the appeal of the sites where these activities are practised. Even in the absence of activities with water contact, the presence of riverbank development such as parks, rest stops or campgrounds requires that this aspect be taken into consideration.

The protection of recreational activities is ensured at use sites and generally not on waterbodies as a whole.

2.5 Aquatic life

Aquatic organisms are ubiquitous and are indicators of the health of aquatic ecosystems. Several phenomena processes associated with water pollution can have negative effects on aquatic populations or even create imbalances in communities by

favouring the development of harmful or undesirable species. Toxic substances, decreases in dissolved oxygen, spawning ground silting, and environmental enrichment by nutrients are changes that can disrupt the development of aquatic organisms.

Aquatic life is sensitive to variations in environmental conditions; it experiences the effects of these fluctuations even if the latter are short term. To protect aquatic life, the impacts of both short- and long-term discharges are considered.

The protection of aquatic life is considered in all waterbodies. Aquatic life includes all communities of fish, invertebrates, zooplankton, algae and macrophytes. In Quebec, the presence of coldwater species, salmonids for example is considered throughout the territory.

2.6 Terrestrial piscivores

The survival of terrestrial wildlife is dependent on water quality and the quality of the organisms they consume. Substances that accumulate in the tissues of aquatic organisms can have significant effects on the wildlife that consume them, particularly if they eat the whole fish, including the viscera and fat, where certain substances tend to accumulate. For species whose diet is principally comprised of fish, such as mink, kingfisher, otter and other piscivores, the risk of effects from bioaccumulative substances is greater.

The use of water by terrestrial piscivores is considered in all waterbodies when determining EDOs.

Surface water uses	
Drinking water sources	At drinking water source
Consumption of fish and shellfish	Everywhere
Recreational activities	At use site
Aquatic life	Everywhere
Terrestrial piscivores	Everywhere

2.7 Other uses

In addition to the uses already mentioned, other water uses include irrigation and livestock watering, which can be considered on a case-by-case basis. However, in most situations, the protection of the uses listed in the previous sections also ensures the protection of these specific uses.

When wastewater is discharged into a ditch along a public or private roadway, a dividing ditch or a drainage ditch, the uses to be protected are those designated for the first downstream environment corresponding to the definition of a waterway. However, if the ditch water is used for irrigation purposes, this use can be taken into consideration directly in the ditch. This same principle applies in avoiding sanitary problems related to poor bacteriological quality of the water in open ditches (e.g. in a residential area).

3 NARRATIVE/CHEMICAL-SPECIFIC QUALITY CRITERIA AND WHOLE EFFLUENT TOXICITY CRITERIA

3.1 General

Water quality criteria means any detailed statement or numerical value that describes the quality necessary to maintain a use. Three types of water quality criteria can be used when developing EDOs: narrative quality criteria, chemical-specific quality criteria and whole effluent toxicity criteria.

The water quality can be evaluated using narrative, chemical and whole effluent toxicity criteria as well as biological studies of the environment. The uses and limitations of each indicator are explained in *Critères de qualité de l'eau de surface au Québec* (MDDEP, 2006), which contains the water quality criteria recognized by the Department.

To calculate EDOs, only narrative, chemical-specific and whole effluent toxicity criteria are used. They are used to define values at the effluent source and to predict the effects of existing or future discharges before these effects occur and are detectable in the environment. Sediment quality criteria can be used to complete the evaluation of the impacts of a discharge on the aquatic environment (Section 3.3.4).

3.2 Narrative quality criteria

Narrative quality criteria are mainly tied to the protection of the esthetic quality of a waterbody. They also include a general recommendation on the banning of all substances at concentrations toxic to human health, aquatic life or terrestrial wildlife. Narrative criteria are listed in *Critères de qualité de l'eau de surface au Québec* (MDDEP, 2006). They are used to define qualitative discharge objectives, as follows: "The mixing zone must be free of debris, oil, foam or other floating materials present in sufficient quantities so as to be harmful or appear unesthetic." Narrative criteria can also be used to formulate objectives to ensure the maintenance of the physical and biological integrity of ecosystems.

3.3 Chemical-specific quality criteria

3.3.1 Concentration and duration

A water quality criterion is comprised of two parts: concentration and duration. The concentration is defined based on the potential effects of a contaminant—toxicity, health risk, organoleptic nature, esthetic or microbiological degradation, or eutrophication potential. Water quality criteria are defined specifically for each contaminant and for each water use. They are established based on recognized procedures that take into account the mechanism of action of each substance. These procedures are summarized in MDDEP (2006) and detailed in *Méthodologie de calcul des critères de qualité de l'eau pour les substances toxiques* (MENVIQ, 1990, rev. 1992, in revision). The quality criteria represent the predetermined effect level (e.g. 50% mortality) or the no-effect or no-risk level of a contaminant based on an organism/human exposure scenario specific to each use.

Chemical water quality criteria are expressed as total concentration for each contaminant, with the exception of metals, which are expressed as total recoverable metal concentration. The total recoverable form of a metal is that contained in an unfiltered sample and corresponding to the sum of dissolved metal and particulate metal, with no digestion of the silicate matrix (CEAEQ, 2006).

The EDOs are mainly established based on the chemical water quality criteria used to ensure the protection of the uses identified in Chapter 2. For continuous discharges, the water quality criteria used are:

- Contamination prevention criteria for water and fish* consumption;
- Contamination prevention criteria for fish consumption only;
- Recreational activities and aesthetics criteria;
- Chronic aquatic life criteria;
- Terrestrial piscivore criteria.

* includes shellfish

For each contaminant, EDOs are calculated based on each water quality criterion. The chronic aquatic life protection, aquatic organism contamination prevention, and terrestrial piscivore protection criteria must be respected at the end of the mixing zone. The criteria associated with aesthetics/recreational activities and protection of drinking water sources apply at the use site. The contamination prevention criteria

Water uses and quality criteria		
Drinking water sources	Contamination prevention criteria (water and fish consumption)	CPC(WF)
Consumption of fish and shellfish	Contamination prevention criteria (fish only)	CPC(F)
Recreational activities	Recreational activities and aesthetics criteria	RAAC
Aquatic life	Chronic aquatic life criteria	CALC
Terrestrial piscivores	Terrestrial piscivore criteria	TPC

for water and fish consumption (CPC(WF)) and the contamination prevention criteria for fish only (CPC(F)) are based on human exposure. CPC(WF)s serve to prevent the contamination of drinking water sources and the flesh of edible aquatic organisms. They are defined so as to protect an individual who draws his/her drinking water directly from the waterway in question, or who eats one meal per week of fish or shellfish for his/her entire life. CPC(F)s are defined to prevent the contamination of the flesh of edible fish and shellfish. They are determined for bioaccumulative substances, so as to protect an individual who eats one meal per week of fish for his/her entire life.

Two levels of protection are necessary to prevent effects on aquatic life: an acute effects level (severe short-term effects) and a chronic effects level (sublethal medium- and long-term effects). Chronic effects on aquatic life are evaluated based on the chronic aquatic life criteria (CALC) as well as on chronic whole effluent toxicity (Section 3.5). Acute toxicity of a discharge is evaluated based on the acute whole effluent toxicity (Section 3.5). When an evaluation of acute whole effluent toxicity is not appropriate, for example, for a one-time short-term discharge or to predict the acute toxicity of effluent from a new project, the effluent final acute values (FAVe), defined for specific contaminants, can be used (Section 8). For the protection of aquatic life, water quality criteria are determined separately for fresh and salt water environments (MDDEP, 2006).

The terrestrial piscivore criteria (TPC) are determined for substances that have a high propensity to bioaccumulate in the tissues of aquatic organisms. These quality criteria can be translated into concentrations in the tissues of whole fish (mg/kg) and can be used if environmental checks are required (Section 9.6).

The duration associated with a water quality criterion is the period of time over which organisms or people may be exposed to an average or maximum concentration without suffering any harmful effects. All environmental concentrations in excess of a criterion, when it is maintained consistently, are likely to result in the complete or partial loss of the use for which the water quality criterion was originally determined. However, slight variations can occur without necessarily inducing effects if their duration and frequency are limited. Consequently, the duration associated with water quality criteria is defined so as to limit the duration and frequency of a slight exceedance of a criterion.

Effects may start to appear when CALCs are not respected for an average of more than 4 days, which is the shortest period in which effects are occasionally observed for certain species and certain contaminants. This period is safe even for the most reactive substances. The CPC(WF)s, CPC(F)s and TPCs are evaluated based on an average exposure time of 30 days, since they are based on lifelong exposure or on stable long-term exposure conditions. RAACs are applied so as to prevent the effects that occur after short exposure times. These durations are used to define the critical low

flows used in Section 7.1 to calculate EDOs, so as to prevent impairment of uses most of the time. These durations do not refer to a follow-up frequency for effluent.

Water quality criteria are contaminant-specific. As such, the cumulative effect of several contaminants present simultaneously is not taken into account. For the protection of aquatic life, the best method for considering the cumulative effect of contaminants found in the same effluent is to measure acute and chronic whole effluent toxicity (Section 3.5). It is also occasionally possible, when interactions between certain contaminants of the same type are well documented, to take this into account when formulating EDOs. The effects can be considered cumulative if the substances cause the same response by the same method of action (MDDEP, 2006). When toxic equivalency factors (TEF) are defined for the contaminants, they can be used to weight the effects of substances that have the same method of action but variable toxicity.

3.3.2 Physical-chemical characteristics for the calculation of water quality criteria

The toxicity of certain contaminants on aquatic life is influenced by the physical-chemical characteristics that prevail in the environment, such as pH, temperature, hardness, dissolved organic carbon, salinity or chloride concentration. For several of these contaminants, the water quality criteria vary as a function of one or several water characteristics.

The resulting EDOs are calculated based on the physical-chemical characteristics of the waterbody. Representative characteristics of the waterbodies are identified, i.e. values corresponding to the area directly upstream from the point of discharge, excluding direct contamination sources. According to available data, the following options are chosen:

- The annual median of ambient data for a waterbody, measured upstream or outside the zone of influence of a discharge;
- The seasonal medians, if it is justified (e.g., total ammonia) and the data permit, or if, for a particular effluent, the EDOs are formulated on a seasonal basis as an exception (Section 7.3) in which case the onus is on the discharger to provide the data required;
- The median of the data for a waterbody with similar characteristics when the data for the waterbody receiving the discharge are unavailable;
- Default conservative values.

For hardness, high medians in small tributaries located in agricultural regions must be considered with caution, because they can occasionally be attributed to agricultural practice (liming).

A discharger who deems that the physical-chemical characteristics used to calculate water quality criteria are not representative of the receiving environment can ask the

Department what minimal data are required to provide specific values for the target environment.

Phosphorus belongs to the category of contaminants whose effects depend on certain environmental characteristics. As such, the main physical factors generally mentioned are the type of substrate, water depth, water transparency, water temperature, current speed and shading (Environment Canada, 2003). These characteristics are not taken into account by water quality criteria. This is why phosphorus is subject to certain specific conditions in determining EDOs (Section 6.1.1).

3.3.3 Site-specific criteria

Surface water quality criteria in Quebec are designed to be sufficiently protective for all waterbodies, and can be used to calculate EDOs in most situations.

Nevertheless, special procedures exist that allow for the transition from a province-wide water quality criterion to a site-specific criterion (Section 9.3). This is the case, for example, when a specific characteristic of the water is not taken into account by the water quality criterion but is known to have an influence on the toxicity of a contaminant (such as a high concentration of dissolved organic carbon), or when natural concentrations are high, or in the presence of a particularly sensitive threatened or endangered species.

3.3.4 Sediment quality criteria

Compliance with water quality criteria cannot always prevent the accumulation of contaminants in the sediment downstream from a discharge. As yet, there is no formal approach for formulating EDOs based on sediment quality criteria. However, sediment quality criteria (Environment Canada and MENVIQ, 1992) can be used to complete the information on the potential impact of a discharge when there is a risk of contamination of a sedimentation zone located downstream. Among others, these quality criteria and the natural and ambient sediment concentrations can define the no-effect concentration or the quality of the sediment, at zero time, before implementation of a new project.

3.3.5 Biocriteria and biological monitoring

Criteria based on biological effects measured directly in the environment (biocriteria) are not yet standardized. Data from biological monitoring or *in situ* toxicity test demonstrating effects on aquatic life can serve to support the need to determine EDOs or to identify areas where environmental capacity is already exceeded.

3.4 Whole effluent toxicity

Whole effluent toxicity (WET) is a measure of the toxic potential of an effluent, determined by exposing aquatic organisms to an effluent and predetermined dilutions

thereof. The measurement of whole effluent toxicity rests on standardized toxicity tests. It is not designed to represent the exact conditions of the receiving environment.

The measure of WET is a strategy to detect toxic contaminants or combinations of contaminants that would otherwise have been ignored. When combined with toxicity identification or reduction evaluations (Section 9.5), it is used to establish the origin of the toxicity and select avenues for its elimination. WET takes into account the combined effects of several substances and takes into account unknown substances or those for which there are no chemical-specific criteria for the protection of aquatic life. However, it does not give any information on potential effects on other water uses.

WET is expressed in % of effluent that produces an effect (e.g. 16% V/V of effluent kills 50% of organisms exposed). The lower the V/V percentage of effluent that causes an effect, the greater the toxicity of the effluent. WET is also expressed in toxicity units (TU). Toxicity units are an inversion of the % effluent; as toxicity values increase, effluent toxicity increases.

Sample calculation of toxicity units

$$\frac{100\%}{16\% \text{ V/V}} = 6.6 \text{ TU}$$

$$\frac{100\%}{60\% \text{ V/V}} = 1.7 \text{ TU}$$

The EDOs for WET are determined based on:

- an acute WET criterion that applies directly to the effluent before dilution in the environment;
- a chronic WET criterion that applies at the end of a mixing zone.

These criteria are expressed in toxicity units.

3.4.1 Acute whole effluent toxicity

The lack of acute whole effluent toxicity is defined by a maximum of 50% mortality in undiluted effluent. The objective is to obtain a residual ambient concentration, inside the allotted mixing zone, that produces little or no mortality of organisms. By respecting this 50% mortality limit, there will be little or no mortality of exposed organisms in the mixing zone. The acute WET criterion, expressed in toxicity units, is one acute toxicity unit (1 TUa).

Toxic units are obtained by dividing 100% by the effluent concentration that is lethal for 50% of the organisms tested (LC₅₀).

$$\text{TUa} = \frac{100\%}{\text{LC}_{50} (\% \text{ V/V})}$$

To ensure a good representation of the range of sensitivities of species found in the ecosystem, three indicator species (two fish and one invertebrate) should be tested. The recommended tests are presented in Appendix 1.

Acute WET limits must be respected at all times to avoid the effects of all contaminants, including those that are fast-acting, such as total ammonia, and chloride.

3.4.2 Chronic whole effluent toxicity

To avoid the long-term effects of a discharge on aquatic life, an effluent must not cause, at the limit of the allotted mixing zone, long-term effects on the growth, development or reproduction of each of the indicator species tested. The water quality criterion for chronic WET, expressed in toxicity units, is one chronic toxicity unit (1 TUc).

Toxic units are obtained by dividing 100% by the highest concentration of effluent that has no effect. This value was originally defined as 100% divided by the no-observed-effect concentration (100 %/NOEC (% V/V)). It is now generally defined as the effluent concentration that inhibits functioning in 25% of the organisms tested.

$$\text{TUc} = \frac{100\%}{\text{IC}_{25} (\% \text{ V/V})}$$

To ensure a good representation of the range of sensitivities of species found in the ecosystem, a minimum of two indicator species from different trophic levels (1 fish, 1 invertebrate or 1 alga) should be tested. The recommended tests are presented in Appendix 1.

Chronic WET is associated with an average organism exposure time of 4 days, the shortest period in which effects are occasionally observed for certain species and certain contaminants. This period is safe even for fast-acting substances. As with chemical contaminants, this duration is used to determine the critical low flow that will ensure protection of the use most of the time (Section 7.1).

3.4.3 Whole effluent toxicity for discharges into marine environments

For freshwater discharges in marine environments, the toxicity tests in Appendix 1 are also recommended. If a discharger wishes to proceed with standardized tests on marine species, this may be proposed if appropriate quality controls are implemented.

Discharges of saline effluents or brines are evaluated on a case-by-case basis and may require the use of final acute values (FAVe) defined for marine environments to verify the potential acute effluent toxicity (Section 8).

4 MIXING ZONES

4.1 General

The calculation of EDOs constitutes the application of surface water quality criteria to point-source discharges of wastewater into waterbodies. In the presence of a discharge, water quality criteria based on chronic exposure may be exceeded locally without compromising the chemical integrity of the environment. An impact zone adjoining a discharge point, called the *mixing zone*, is usually tolerated. Water quality criteria can be exceeded in the mixing zone as long as there is no acute toxicity for aquatic organisms and no use is affected. At the end of this zone, which determines the volume of water allotted for effluent dilution, the water quality criteria must be respected.

The allocation of a mixing zone rests on the principle that a small zone of degradation can exist without harming the sustainability of the ecosystem as a whole. However, the mixing zone must be as limited as possible to ensure that it:

- Does not interfere with spawning zones and the development of early life history stages, nor with shellfish harvesting zones;
- Does not interfere with migration corridors of aquatic organisms, or with habitats of threatened or endangered species;
- Does not create barriers inhibiting the movement of fish at the entrance of a tributary;
- Does not overlap with another mixing zone unless the combined effects of both discharges have been considered;
- Does not attract fish in a manner that increases the exposure of organisms to bioaccumulative substances;
- Does not induce high concentrations over long distances when mixing is slow;
- Does not create a toxic barrier over the entire width of a waterway so as not to hinder the movement of mobile organisms.

To satisfy the previous statements, mixing zones are defined for each discharge based on the physical limits, the hydrodynamics of the natural environment and best professional judgment. The physical limits are applied to the so-called “critical” conditions of the effluent/receiving environment interface, so as to ensure compliance with water quality criteria in the majority of situations. These conditions correspond to the period during which the environmental risk of the discharge is the greatest. This risk is not defined based on very short-term transitory conditions but rather on conditions that are maintained over a certain period of time, depending on the impact to be prevented.

For designated uses that apply throughout a waterbody (e.g., protection of aquatic life), general limits exist to restrict the length of the mixing zone, the proportion of the flow to apply, and the maximum dilution used. Accordingly:

- When the effluent mixes slowly with the environment, high concentrations of contaminants can spread over several kilometres. To prevent this, the mixing zone is limited to a maximum length of 300 m;
- When the effluent mixes quickly with the environment, the entire volume of the waterway dilutes the effluent well before it reaches a distance of 300 m. To avoid allotting the entire flow of the waterway to a single discharge, the mixing zone is limited to a maximum portion of 50% of the flow of the waterway for toxic contaminants;
- The dilution is calculated at one of the two preceding boundaries, that is the one that is reached first. If this dilution is greater than 1 in 100, the dilution allotted to calculate the EDOs is limited to 1 in 100.

For the same discharge, several mixing zones may be delineated as a function of the targeted contaminants and designated uses (Figure 2). In the example illustrated in Figure 2, the contamination prevention criteria for water and fish consumption (CPC(WF)) and the recreational activities and aesthetics criteria (RAAC) apply directly at the drinking water source or the recreational activity zone. Dilution of the discharge is therefore estimated at the actual use site. Consequently, no maximum dilution limit is used to calculate the EDOs based on these criteria.

In rivers, it is possible that complete mixing of the effluent in the environment occurs rapidly. The volume of water allotted to the mixing of the effluent is thus defined based on the critical low flow. In all other environments, modeling allows for simulation of the mixing conditions, from which the volume of water allotted for dilution is established. The critical conditions and physical limits of mixing zones for different types of environments are presented in sections 4.2 to 4.4.

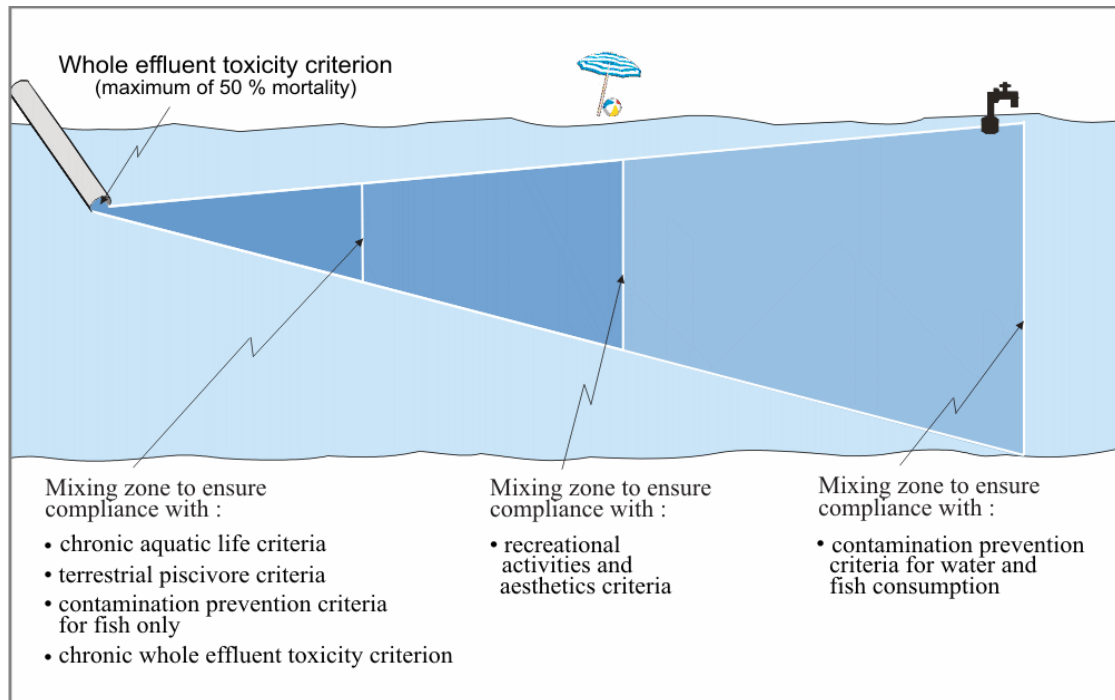


Figure 2 Examples of different possible mixing zones for the same discharge

Moreover, the mixing zone can be reduced or eliminated:

- When the water quality criteria for a contaminant are already exceeded in the environment;
- When aquatic organisms are already contaminated beyond the reference limits;
- For the discharge of persistent, bioaccumulative and toxic substances (PBTs) (Appendix 2), since there is very little natural attenuation of these substances. Accordingly, for new discharges, no mixing zone will be considered for PBTs. For existing facilities, the allocation of a mixing zone will be gradually phased out;
- For multiple discharges located on the same river segment;
- For discharges that constitute a major portion of the flow of a waterway.

4.2 Mixing zones in rivers

Rivers are waterbodies with continuous or intermittent flow that do not present a natural density gradient. In this type of environment, the critical conditions of the effluent/receiving environment interface generally correspond to low flow periods.

Mixing zone boundaries differ in rivers depending on how quickly or slowly the effluent is mixed into the environment. Complete mixing will occur rapidly over a short distance in a small river with turbulent flow. On the other hand, complete mixing will occur slowly and create a visible plume over a very long distance in large rivers

with laminar flow. An understanding of the hydrodynamics and the geomorphology of the environment, combined with professional judgement, will help to determine the type of mixing in a given environment.

The allotted dilution for the calculation of EDOs is fixed at a maximum limit of 1 in 100 for all contaminants, except phosphorus and fecal coliforms, since dilution must not be considered a form of treatment. This limit prevents the creation of zones of pollution in large environments where it is difficult to take into account the contaminant contributions of numerous discharges. It does establish some equity between the dischargers in both large and small environments.

For phosphorus and fecal coliforms, dilution is often limited by the use of a global approach, which takes into account the cumulative effects of several discharges of the same contaminant in one segment of a waterway (sections 6.1, 6.2 and 6.3).

Rapid mixing

When an effluent mixes rapidly with the entire waterbody, the mixing zone is based on the estimated critical low flow at the discharge point. No modeling is needed on the assumption that the mixing is uniform throughout the water volume. The mixing zone is thus limited by the most restrictive of the following boundaries:

- For toxic contaminants, the maximum flow allotted for dilution is 50% of the critical low flow;
- For conventional contaminants (phosphorus, fecal coliforms, biochemical oxygen demand and total suspended solids), the maximum flow allotted for dilution is 100% of the critical low flow;
- For the reasons described in 4.1 or to take into consideration the presence of several discharges in the same segment of a waterway, a smaller percentage of the critical low flow may be allotted.
- For all contaminants except phosphorus and fecal coliforms, the maximum dilution allotted is 1 in 100;
- For EDOs calculated using contamination prevention criteria for water and fish consumption (CPC(WF)), the maximum flow allotted for dilution is 100% of the critical low flow directly at the drinking water source, with no dilution limits.

Different hydrological flows are used to prevent impacts on each water uses. Reference critical low flows are stated in Section 7.1.

Slow mixing

When an effluent does not mix rapidly with the entire waterbody, as is often the case in large rivers, the allotted mixing zone is restricted by a maximum distance, and the dilution is determined by hydrodynamic modeling. The modeling inputs must reflect

the critical low flow conditions in the environment. The mixing zone is then delineated by the most restrictive of the following limits:

- For toxic contaminants, BOD₅ and TSS, a maximum length of 300 m is allotted for dilution;
- For toxic contaminants, the maximum width of a plume is limited to half the width of the river, and the flow allotted for dilution must not exceed 50% of the river's critical low flow;
- For all contaminants except phosphorus and fecal coliforms, the maximum dilution allotted is 1 in 100;
- For EDOs calculated using contamination prevention criteria for water and fish consumption (CPC(WF)), the maximum flow allotted for dilution is 100% of the critical low flow directly at the drinking water source, with no maximum dilution limits.

In certain specific cases, the discharger may wish to conduct a dispersion test in the environment. Modeling inputs and the test conditions must reflect the critical low flow conditions in the environment as accurately as possible.

4.3 Mixing zones in lakes, reservoirs and enclosed bays

Lakes, reservoirs and enclosed bays constitute environments especially sensitive to the addition of contaminants. Their hydrodynamics generally favour sedimentation and slow effluent mixing. Discharge dilution in lakes, reservoirs or enclosed bays is determined from a hydrodynamic model, or if the discharger desires, a dispersion test. Identification of critical mixing conditions must take into account the water level, wind and current speed and direction, seasonal variations in temperature, and the presence of stratification. The presence of a thermocline at certain times of the year is an important element to consider, since it is a factor that considerably limits effluent mixing.

Once the critical effluent/receiving environment mixing conditions are identified, the mixing zone is then determined by the most restrictive of the following limits:

- For all contaminants, except phosphorus and fecal coliforms, the length that corresponds to the distance between the point of discharge and the surfacing point of the plume. If the plume does not surface, the length of the mixing zone is limited to the initial dilution zone (which corresponds to the limit of the *near-field region* in a model);
- For all contaminants, except phosphorus and fecal coliforms, a dilution estimated by modeling not exceeding that which would be allotted to the outlet of the lake during the critical low flow period; if it exceeds this, the dilution at the outlet of the lake is then retained to calculate the EDOs;
- For all contaminants, except phosphorus, a maximum dilution of 1 in 10;

- For EDOs calculated using contamination prevention criteria for water and fish consumption (CPC(WF)), the distance between the discharge and the drinking water source, with no maximum dilution limits.

For phosphorus, an analysis of all the inputs determines the load that can be allotted for a discharge. This approach is explained in Section 6.2.2. For fecal coliforms, the location of the use to be protected determines the mixing zone.

No wastewater discharge is allowed in lakes without outlets.

4.4 Mixing zones in estuaries and coastal waters

Estuaries and coastal waters are environments characterized by the presence of currents that fluctuate in intensity and direction under the influence of tides. In many of these regions, the direction of the currents reverses several times a day. The hydrodynamics are also influenced by the inflow of freshwater, the wind intensity and direction, the depth, the nature of the substrate and the stratification of the water column. The mixing of an effluent in estuaries and coastal waters is thus often difficult to determine. Vertical mixing of the discharge often occurs only after a few kilometres.

Although certain parts of estuaries are located in freshwater areas (in Quebec, the St. Lawrence river estuary extends from Trois-Rivières to the eastern tip of Île d'Orléans), estuaries and coastal waters are usually considered to be marine environments. A freshwater effluent discharged into salt water generally forms a plume that emerges rapidly and then floats on the surface around the discharge point. The initial mixing speed depends on several factors such as the water depth and the turbulence of the discharge. Once at the surface, the mix will be limited to the superficial layer until the relative densities of the two water masses allow it to spread throughout the water column.

Discharge dilution in these environments is determined with the help of a hydrodynamic model or a tracer studies, if desired. When the available data permit, the dispersal analysis in a large number of conditions will identify the critical mixing conditions (seasonal conditions). Once this period is defined, the determination of the dilution factor must take into account the average exposure level of organisms over a complete tidal cycle. To this end, computer simulations are performed at the slacks of high and low tide, as well as when the tide rises and falls. If the current reverses, the redirecting of the plume must be taken into account when evaluating the dilution factor. The results of different tests are then analyzed in a manner that represents the average dilutions of a tidal cycle.

The critical conditions in estuaries and coastal waters are often associated with periods of slower currents and low winds. Ideally, local or regional currents will have been studied, and modeling will be done in low wind conditions.

In this type of environment, the mixing zone is delineated by the most restrictive of the following limits:

- For all contaminants, except phosphorus and fecal coliforms, a maximum radius of 300 m from the discharge point;
- For all contaminants, except phosphorus and fecal coliforms, a maximum dilution of 1 in 100;
- In freshwater, for EDOs calculated using contamination prevention criteria for water and fish consumption (CPC(WF)), the distance between the discharge and the drinking water source, with no maximum dilution limits.

Phosphorus and fecal coliforms are not subjected to any maximum dilution limits. For fecal coliforms, the location of the use to be protected determines the mixing zone. For phosphorus, a case-by-case analysis is necessary to take into account certain specific conditions of a receiving environment, such as the confluence of salt and freshwaters, which can favour eutrophication.

5 EFFLUENT DISCHARGE OBJECTIVES: SINGLE DISCHARGE APPROACH

5.1 General

Effluent discharge objectives are calculated for chemical contaminants and for acute and chronic whole effluent toxicity. The calculation of EDOs according to the single discharge approach is based on a mass balance evaluated for a segment of the waterbody. In fact, since the degradation of the contaminants mainly responsible for the toxicity of effluents tends to be negligible near the discharge point (U.S. EPA, 1991*b*), the contaminants are considered conservative within the mixing zone. This mass balance is established in such a manner that, for a given contaminant, the effluent load added to the existing load upstream from the discharge does not exceed the maximum load based on the water quality criterion at the limit of the mixing zone. The calculation of EDOs integrates the quantity of water allotted for effluent dilution, the effluent flow, the water quality upstream from the discharge, and the water quality criteria ensuring protection of designated uses. A similar calculation is done for whole effluent toxicity.

Table 1 Mixing zone boundaries and maximum dilution allotted for different types of environments

	Fast-mixing river	Slow-mixing river	Lake, reservoir and enclosed bay	Estuary and coastal waters
Dilution determination	Critical low flow	Modeling	Modeling	Modeling
For uses to be designated everywhere	<ul style="list-style-type: none"> • 1 in 100 • 50% of the critical low flow (toxic) • 100% of the critical low flow (conventional) 	<ul style="list-style-type: none"> • 1 in 100 • length of 300 m • 50% of the critical low flow (toxic) • 100% of the critical low flow (conventional) 	<ul style="list-style-type: none"> • 1 in 10 • distance at the surfacing point • dilution at the outlet (for lakes) 	<ul style="list-style-type: none"> • 1 in 100 • radius of 300 m
For drinking water source CPC(WF)	<ul style="list-style-type: none"> • 100% of the critical low flow • distance to use 		<ul style="list-style-type: none"> • distance to use 	<ul style="list-style-type: none"> • distance to use
For uses affected by phosphorus	<ul style="list-style-type: none"> • 100% of the critical low flow • distance to the end of the river segment 		N/A ²	Case by case
For uses affected by fecal coliforms	<ul style="list-style-type: none"> • 100% of the critical low flow • distance to use 		<ul style="list-style-type: none"> • 1 in 10 • distance to use 	<ul style="list-style-type: none"> • distance to use
<p>¹ Boundaries not applicable to contamination prevention criteria for water and fish consumption (CPC(WF)) and to phosphorus and fecal coliform criteria.</p> <p>² Calculation of the EDOs is based on an analysis of all inputs and not on dilution at the end of a mixing zone.</p>				

EDOs can also be calculated using a multiple discharge approach when several sources of the same contaminant are discharged into the same segment of the waterway. The multiple discharge approach is described in Section 6, and the conditions of use for both approaches are summarized in Table 2 at the end of this section.

5.2 EDO calculation equations for chemical contaminants

The following equations illustrate the mass balance used to calculate the effluent discharge objectives for chemical contaminants. Only the main equations are presented in this section. For detailed equations, see Appendix 3.

upstream load + load allotted for = maximum load allowed
 effluent at the limit of the mixing zone

$$C_s Q_s + C_e Q_e = C_c (Q_s + Q_e) \quad (1)$$

where: C_s = upstream concentration of contaminant in the receiving water environment.

Q_s = upstream flow that corresponds to the portion of the upstream flow allotted for effluent mixing. Q_{am} takes into account the fraction of the effluent flow drawn from the receiving water upstream from the discharge point (f).

$$Q_s = Q_r - fQ_e$$

C_e = concentration allotted to the effluent for a given contaminant. It is expressed in total concentration or total recoverable metal concentration. It corresponds to the EDO concentration.

Q_e = effluent flow.

C_c = concentration corresponding to the water quality criterion used for a given contaminant and use. It is expressed in total concentration or total recoverable metal concentration.

Q_r = receiving water flow rate allotted for effluent mixing.

f = fraction of the effluent flow removed from the receiving water upstream from the discharge point. The factor f has a value of “1” if the water is drawn entirely from the waterway upstream from the discharge point, and a value of “0” if the water intake is underground or located in another watershed.

The load allotted to the effluent ($C_e Q_e$) corresponds to the load associated with compliance with the water quality criterion (maximum load permitted at the limit of the mixing zone), from which the load already present in the environment (upstream load) is subtracted. These loads, illustrated in Figure 3, are defined as follows:

$$C_e Q_e = C_c(Q_s + Q_e) - C_s Q_s \quad (2)$$

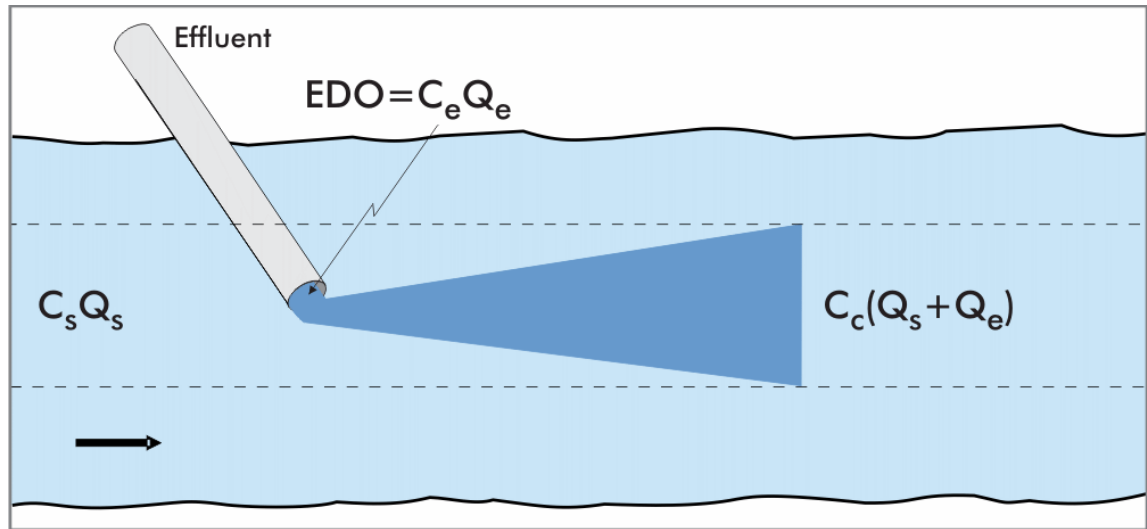


Figure 3 Elements of the loading mass balance

Equation 2 can be transformed by replacing Q_s with its definition ($Q_r - fQ_e$) and by isolating C_e :

$$C_e = \frac{C_c(Q_r - fQ_e + Q_e) - C_s(Q_r - fQ_e)}{Q_e} \quad (3)$$

C_e represents the EDO for a given contaminant expressed in concentration. It can also be calculated by rearranging the equations to include the dilution factor (Fd). The dilution factor is defined as the ratio between effluent flow and the flow that contributes to dilution, i.e. the sum of the upstream flow and the effluent flow. The dilution factor is always expressed as a fraction (e.g. $Fd = 0.01$ for a dilution of 1 in 100).

$$Fd = \frac{Q_e}{Q_s + Q_e} = \frac{Q_e}{(Q_r - fQ_e) + Q_e} \quad (4)$$

By substituting the dilution factor (Fd) into equation 3, the concentration allotted to the effluent becomes:

$$C_e = \frac{C_c - C_s}{Fd} + C_s \quad (5)$$

This simplified equation can be used to calculate EDOs in the case where the dilution factor was estimated by a hydrodynamic model or a diffusion test.

Once C_e is defined, the load allotted to the effluent corresponds to:

$$C_e \times Q_e \quad (6)$$

For a given contaminant, this calculation is repeated for all uses likely to be affected by the effluent, in each of the cases considering the mixing zone specific to the use. The most stringent EDO is then used, so as to ensure protection of all designated uses. An example of an EDO calculation is presented in Appendix 4.

When this calculation results in an EDO below the water quality criterion, the applicable EDO is the water quality criterion.

5.3 EDO calculation equations for whole effluent toxicity

5.3.1 Acute whole effluent toxicity

The acute whole effluent toxicity criterion of 1 TUa, equivalent to a maximum of 50% mortality, applies directly at the discharge point, before any dilution in the receiving water. The EDO for acute whole effluent toxicity is thus always one acute toxicity unit (1 TUa).

Each test performed with each of the recommended species must respect this limit of 1 TUa (Appendix 1).

5.3.2 Chronic whole effluent toxicity

The EDO for chronic whole effluent toxicity is calculated based on the criterion of one chronic toxicity unit (1 TUc), taking into account (as with individual contaminants) the mixing of the effluent in the receiving water. The following procedure illustrates the mass balance used to calculate the EDO for chronic WET. Equation 5 below is modified, considering that the toxicity of the natural environment, upstream from the discharge, is nil and that the criterion to be met at the end of the mixing zone is always 1 TUc.

$$C_e = \frac{C_c - C_s}{Fd} + C_s \quad (5)$$

Where:

C_e = chronic whole effluent toxicity allotted to the effluent (TUc).

C_c = chronic whole effluent toxicity criterion (1 TUc)

C_s = upstream concentration (nil by default)

Fd = dilution factor

The equation becomes:

$$C_e = \frac{1 \text{ TUc}}{Fd} \quad (6)$$

Each test performed with each of the recommended species must respect this limit of 1 TUc.

When this calculation results in an EDO below 1 TUc, the applicable EDO for chronic whole effluent toxicity is 1 TUc. The same value applies if the chronic whole effluent toxicity of the ambient environment is not nil (≥ 1 TUc).

6 EFFLUENT DISCHARGE OBJECTIVES: MULTIPLE DISCHARGE APPROACH

6.1 Multiple discharge approach for phosphorus and fecal coliforms

The multiple discharge approach takes into account several sources of the same contaminant on the scale of a predetermined segment. This segment can be limited to only a few kilometres of a waterway, up to a subwatershed or a complete watershed, depending on the issues associated with a given contaminant. This approach, which

rests on a simple segment distribution model, distributes the load allotted for a contaminant between point sources identified in this segment. It is mainly used for certain conventional contaminants (phosphorus and fecal coliforms) to prevent the expression of problems downstream from certain sources (beyond the mixing zone) and to take into account the conservative or non-conservative nature of certain contaminants.

The equation that allots the same concentration of contaminant to each effluent in a given segment of a waterway is the following:

$$C_e = (C_c - C_s) \frac{Q_r}{\sum_{i=1}^n Q_{e_i} e^{-kt_i}} \quad (7)$$

Where: n = number of effluents upstream from the use being considered

Q_{e_i} = flow of effluent i

k = decay rate of a contaminant
(if the contaminant is conservative, $k = 0$)

t_i = transit time between the discharge point i and the use being considered
(evaluated by the average current speed and the distance between the discharge point and the use)

The method can be applied downstream from each discharge point or at the site where a given use is to be protected. The concentration at the point where the dilution ($Q_r/\sum Q_{e_i}$) is minimal will determine the concentration to be respected for all discharge points located upstream from this point.

The flow rates of rivers used in the segment distribution model are the critical low flows that correspond to the uses to be protected, as presented in Table 3. The effluent flow rates are themselves determined according to the recommendations in Section 7.1. To ensure that the model accurately reflects the real conditions and to define realistic EDOs, it is critical to accurately estimate the average current speed and the decay rate of the contaminant, where applicable.

It is also possible to consider the contribution of non-point sources (if well documented) or to add a margin of safety to take into account future development of the segment modeled.

The segment distribution model is used to complement the single discharge approach. The most protective EDO obtained by either of the approaches is used. When this

calculation results in an EDO below the water quality criterion, the EDO retained is the water quality criterion. An example of an EDO calculation according to the multiple discharge approach is presented in Appendix 4.

6.1.1 Phosphorus

Phosphorus is an essential element in aquatic ecosystems. However, when present in excess, it can lead to eutrophication of an environment. Habitat and community modifications are also then likely to occur. Recreational activities may also be compromised due to esthetic degradation of the water. Finally, the excessive proliferation of cyanobacteria, some of which produce toxins, represents a health risk for those who enter into contact with the water or who consume it. Also called *algae blooms*, these proliferations are caused by excess phosphorus in the water.

For these reasons, certain uses are deemed “sensitive” to phosphorus. Specific wildlife habitats (e.g. spawning grounds), drinking water sources and beaches (due to direct-contact activities) fall into this category.

Certain environments are also deemed sensitive due to characteristics that would favour the expression of phosphorus. This is the case for lakes, reservoirs and closed bays.

Phosphorus in rivers

The segment distribution model (equation 7) for phosphorus in rivers is distinguished by:

- the use of a decay constant of 0 (phosphorus is considered conservative);
- the fact that it is located at the end of the segment at the opening of the waterway considered. The concentration allotted to discharges in a segment is therefore determined based on the critical low flow at the river mouth.

In rivers, when the mixing zone is not based on critical low flow, the single discharge approach is not used unless a sensitive use is located near a discharge point. The multiple discharge approach is used without the decay constant to determine the permissible phosphorus load.

Phosphorus in lakes, reservoirs and closed bays

Lakes, reservoirs and closed bays are environments sensitive to phosphorus additions and require maximum protective measures. The conditions in these environments (slow flow, slow renewal rate, water warming) are generally more favourable to the growth of aquatic plants and algae than those in continuous flow environments, but above all, these environments act as phosphorus traps. Thus, even when phosphorus

additions diminish, the impact of past discharges can continue to be felt for several years, due to accumulated phosphorus. Moreover, in this type of environment, an accelerated enrichment process may occur if there is anoxia at the water/sediment interface. Additional release of phosphorus is also frequently observed. This process is often irreversible and when recovery is possible, it may take many years.

In these environments, phosphorus is subjected to complex dynamics. Lakeshore capacity models are often used to estimate phosphorus loads that a lake can handle without harmful effects, all sources considered. The efficiency of these models, however, is increasingly contested.

Based on current tools, it is therefore difficult to predict the real impact of an addition of phosphorus on this type of environment. A case-by-case analysis is required. The results from lakeshore capacity models must be examined jointly with the observations and the data collected in the field. When there is uncertainty regarding the capacity of the environment to receive additional loads of phosphorus, the precautionary principle is applied.

6.1.2 Fecal coliforms

For the protection of uses sensitive to pathogenic micro-organisms, a calculation to determine the concentration of fecal coliforms is performed, for the segment of the watershed in question.

The segment distribution model (equation 7) applied to fecal coliforms is distinguished by:

- the use of a decay constant that determines the exportation of these pathogenic micro-organisms (by default, a value of 0.02 h^{-1} is recommended);
- the location of the end of a segment at the sensitive use (contact activities, drinking water sources, shellfish harvesting zones, etc.).

6.2 Multiple discharge approach for BOD₅

The establishment of EDOs for BOD₅ aims to protect the receiving environment from decreases in dissolved oxygen likely to harm aquatic life. Their calculation is based on conservative hypotheses that counterbalance the uncertainty of the behaviour of dissolved oxygen according to environmental conditions (oxidation of carbonated organic matter, nitrification, sediment oxygen demand, photosynthesis and respiration).

Several models exist (varying complexities) that simulate the processes that govern the concentrations of dissolved oxygen in rivers (U.S. EPA, 1997). These models also take into account the impact of BOD₅ discharges, single or multiple, in the environment. In the majority of cases, it is not necessary to use these models since current treatment

technologies are generally sufficient to ensure compliance with EDOs for BOD₅ calculated according to the single discharge approach.

In the opposite case, a discharger operator may use more elaborate models, such as QUAL2E (U.S. EPA, 1987), to determine whether the environment can receive concentrations and loads above the EDO without causing an oxygen deficit. The discharger may also use monitoring to demonstrate the absence of impacts for an existing discharge. However, this is not easy to demonstrate. A sampling plan is required, which takes into account a set of factors that influence dissolved oxygen values (fluctuations on a daily cycle, water temperature, presence of slow current zones, etc.). A discharger wishing to use this procedure must submit a proposal to the Department.

In certain large environments, particularly in the marine environment, verification by modeling or environmental measurements is practically impossible, because of the complexity of the environment. In such cases, the EDO calculated according to the local approach must be considered as a reference value for designing projects.

6.3 Multiple discharge approach for toxic contaminants

The single discharge approach is used for most discharges of toxic contaminants. However, a multiple discharge approach is needed if several effluents containing the same contaminants overlap within a 1-km segment or discharge into the same outfall. In such situations, the combined effect of the discharges is considered by allotting a single mixing zone for both discharges. The global dilution factor is then calculated based on the effluent flows, and the global load is established based on equations 5 and 6. The load allotted to the segment is then distributed between the effluents. Many wasteload allocations methods exist (U.S. EPA, 1991*b*).

The most common distribution method allots the same concentration of a contaminant to all the effluents; the loads are then calculated proportionally to the each effluent flow. The load distribution can take into account the quality of the water supply if it is shown that a significant difference exists between them and that this difference stems from the impact of the upstream discharge on the downstream discharge water supply.

When the multiple discharge approach is used for toxic contaminants, it is also generally used for BOD₅ and TSS.

Table 2 Conditions for using the single discharge and multiple discharge approaches according to contaminant

Contaminant	Single discharge approach generally used	Multiple discharge approach generally used	Details
Toxic	√		Multiple discharge approach used if several effluents within 1 km
BOD ₅	√		Possible use of simulation models for dissolved O ₂ in a river or environmental measurements to verify the EDO obtained using the single discharge approach; multiple discharge approach used if several effluents are discharged within 1 km
TSS	√		Multiple discharge approach used if several effluents are discharged within 1 km
Phosphorus		√	Single discharge approach also used if mixing zone based on critical low flows EDO used: the most stringent of the two approaches
Fecal coliforms		√	Single discharge approach also used if the use is located near the discharge point EDO used: the most stringent of the two approaches

7 CALCULATION ELEMENTS OF EFFLUENT DISCHARGE OBJECTIVES

7.1 Stream critical low flow

Critical river conditions generally occur during critical low flow periods. Critical low flow is defined as a periodic decrease in the flow of a waterway. Critical low flow occurs during dry periods when runoff is minimal or nil and only subterranean flow feeds surface waters (MDDEP, 2005). The EDOs calculated for these conditions ensure compliance with quality criteria in the environment most of the time.

A slight exceedance of water quality criteria in the natural environment will not necessarily cause effects if its duration and frequency are limited. The critical low flows have been selected so as to limit the duration and frequency of the exceedance. As such, various hydrological flows are applied to help prevent impacts on the uses to be protected (see Table 3).

- For the protection of aquatic life, on which the effects of contaminants are felt over relatively short periods of time, the critical low flow used for toxic contaminants is the flow 7Q10. This corresponds to the minimum average flow over 7 consecutive days with a probability of return of once every 10 years;
- For the protection of uses that consider the development of long-term effects, a critical low flow estimated for a longer period of time is more suitable while remaining safe. For the drinking water sources, the consumption of aquatic organisms and terrestrial wildlife, the flow $Q_{5,30}$ is used. This corresponds to the minimum average flow over 30 consecutive days with a probability of recurrence of once every 5 years;
- For conventional parameters (TSS, phosphorus, BOD_5) and fecal coliforms, the critical low flow 7Q2 is used, i.e. the minimum average flow over 7 consecutive days with a probability of recurrence of once every 2 years.

Table 3 presents the flows to be used in calculating the EDOs for different water uses. Even if these statistical flows are all calculated according to specific durations and returns, each one may occur several times per year over shorter periods. These episodes do not compromise the protection of the various uses.

Table 3 Critical low flows applied to different uses

Water quality criterion	Protected use or effect	Critical low flow	Compliance with criterion
CPC(WF) ¹	Water and aquatic organism contamination prevention	30Q5 annual	At drinking water source
CPC(F) ¹	Aquatic organism contamination prevention	30Q5 annual	At the end of the mixing zone
RAAC (fecal coliforms)	Recreational activities	7Q2 summer	At the use site
CALC (toxic)	Aquatic life, chronic	7Q10 annual ²	At the mixing zone limit
CALC (TSS, BOD ₅)	Aquatic life, chronic	7Q2 annual	At the mixing zone limit
CALC (phosphorus)	River eutrophication	7Q2 summer	In the sensitive zone or by segment
CALC (phosphorus)	Eutrophication in lakes, reservoirs or closed bays	Capacity model	In the lake, reservoir or closed bay
		7Q2 annual	At the opening of tributaries of the lake, reservoir or closed bay
TPC ¹	Terrestrial piscivores	30Q5 annual	At the mixing zone limit
Acute WET	Acute whole effluent toxicity		At the discharge point
Chronic WET	Chronic whole effluent toxicity	7Q10 annual	At the mixing zone limit
¹ For persistent, bioaccumulative and toxic substances, since no mixing zone is allotted, no critical low flow is allotted.			
² A seasonal EDO (summer) and an annual EDO are calculated for total ammonia on the basis of summer and annual critical low flows.			

Critical low flows are generally calculated based on data from the Department's hydrological database, according to the method presented in the document *Guide sommaire des méthodes d'estimation des débits d'étiage pour la province de Québec* (MDDEP, 2005). These basic data, as well as the critical low flow estimation service, are available from the Centre d'expertise hydrique du Québec. In the absence of an acceptable data series for the watershed being studied, the use of data originating from one or several similar watersheds (nature of the watercourse, slope, soil use, surface area) is possible.

If the protection of the use is limited to the summer season, a summer critical low flow is used for the calculation of EDOs. For example, this is the case for fecal coliforms, when the protection of recreational activities is targeted, and for phosphorus in rivers, if there is no lake downstream. When environmental characteristics vary as a function of season and significantly change the toxicity of a contaminant, as is the case for total ammonia, whose toxicity varies according to the temperature, seasonal critical low flows are used.

For continuous but seasonal discharges, the critical low flows of the receiving environment can be calculated from seasonal data series.

7.2 Hydrodynamic modeling and diffusion tests

Effluent dilution in the receiving environment can be estimated by hydrodynamic modeling. In this case, the Department recommends the use of the CORMIX software (Cornell Mixing Zone Expert System) (Jirka, Doneker and Hinton, 1996). This program is also one of the modeling tools recommended by the U.S. EPA.

The CORMIX software is an expert system comprising a complete series of analytical or empirical models describing the different mixing steps of an effluent in the receiving environment. Three subsystems of CORMIX are available to treat 1) simple submerged outfall (CORMIX1) (Doneker and Jirka, 1990), 2) submerged diffusers (CORMIX2) (Akar and Jirka, 1991) and 3) surface discharges (CORMIX3) (Jones, Nash and Jirka, 1996). In all cases, a user-friendly interface is used to specify the characteristics of the discharge and the receiving environment, the effluent flow, the geometry of the outflow, the water depth, its temperature, the current speed, etc. The CORMIX software then determines which series of models best applies and uses it to track the theoretical evolution of the mixing.

The results of the modeling done with CORMIX (or with other models) are always an oversimplification of reality. However, the complexity of certain receiving environments with specific geometries, uneven bottoms, curved channels, etc. can complicate the modeling. In these situations, it may be preferable to estimate the effluent dilution by means of a diffusion test performed in the environment.

Performing a diffusion test with a tracer is the most accurate way to determine the effluent dilution. However, this approach does have its limits. It is complex and expensive to carry out. The precision of the results depends on the precision of the injection, sampling and analysis techniques. It is especially difficult to represent a non-existent effluent or to complete dilution tests in critical conditions. Although the disadvantages often outweigh the benefits, dilution tests could nevertheless be useful in the following cases:

- for complex hydrodynamic conditions difficult to model;

- to confirm or refute concerns with respect to the impact of a discharge on a given use to be protected.

The Department does not perform diffusion tests. Dilution is evaluated according to critical low flows or with the assistance of the CORMIX model, as described in sections 2.2 to 4.4. Nevertheless, if a discharger disagrees with the dilution allotted, it must then provide a more representative estimate of reality. A diffusion test can be done to this end.

The Department does not recommend a particular method for performing such a test. In all cases, the choice of method must be justified based on the type of information needed to calculate the dilution, according to the type of environment and as a function of the basic principles of the approach. The precision of the results must also be evaluated. It is also possible to use a model to correct for the measured dilution factor, so as to better represent the desired critical conditions.

7.3 Effluent flow

For industrial wastewater, the average effluent flow is used when the discharge is relatively stable and when it corresponds to a representative and realistic production rate.

For municipal or domestic wastewater, the effluent flow used generally corresponds to the average design flow of wastewater treatment system or, if this is exceeded, to the average flow measured.

In situations where the effluent flow is variable (cyclical production, batch discharge, etc.), the correct choice of effluent flow is essential. In combination with the other elements of the mass balance, the flow chosen must protect aquatic life and the other water uses most of the time.

In situations where the effluent flow is recurrent but discontinuous (batch discharge), the total discharge flow is then calculated over 24 hours so as to maintain an average concentration for the water quality criteria at the end of the mixing zone. This approach applies for both toxic and conventional contaminants, with the exception of fecal coliforms. For fecal coliforms, the effect can be manifested even after only a short exposure. Consequently, the total discharge flow in a day is not spread over 24 hours but is considered on the basis of actual discharge time. Practically speaking, the dilution is calculated based on hourly flows (effluent flows and low flows in the environment).

In the case where indirect cooling waters or non-contaminated waters mix with the effluent before its final discharge point in the environment, EDOs are calculated on the basis of the process effluent flow, excluding all non-contaminated waters whose proportion exceeds 10% of the final effluent flow. The load present in the intake water

is thus allotted to the portion of non-contaminated water of the final effluent flow. This is added to the load allotted to the process effluent to obtain the load and the concentration allotted to the final effluent.

For continuous discharges that vary greatly in relation to precipitation, such as discharges from tailings, EDOs are first calculated according to the usual methods. Then, if the variability of the effluent flow is well documented and cannot be equalized, different effluent flows may be used according to the seasons. The EDOs are thus also calculated on the basis of seasonal effluent flows and low flows.

For discharges composed solely of contaminated rainwater (by atmospheric discharges or by the storage of raw or residual materials), an alternative approach may be considered according to the specific nature of the discharge (equalization, duration and frequency of the discharge, etc.).

Furthermore, any significant change in effluent flow must result in a revision of EDOs.

7.4 Upstream concentration

The level of a contaminant already present in the environment must be considered before determining the amount of contaminant that can be added without affecting the water uses. Values said to be *representative* of the waterbody are used as upstream concentrations of the receiving environment in EDO calculations. A concentration is representative if it corresponds to the quality of the segment immediately upstream from a discharge point while also excluding the influence of direct sources of contamination. A representative water quality value can be calculated from ambient data previously collected for the waterbody or from data for a waterbody with comparable topography, geology and land use.

Data are selected based on best professional judgment and by considering different elements such as sampling and analysis methods, detection limits and the location of the sampling site.

Via *Reseau-rivières*, the Department monitors water quality at more than 150 stations. This yields information on the spatial and temporal variability of water quality based on the main so-called conventional contaminants. Moreover, the Department implements *ad hoc* projects to evaluate the levels of certain trace or ultratrace organic and inorganic contaminants in surface water. These reports do not cover all rivers in Quebec, but do generate upstream concentrations for certain watersheds and determine more realistic default values for analyzed contaminants.

The specific treatment reserved for contaminants whose upstream concentration is higher than the water quality criterion is discussed in Section 7.5.

The general rules for attributing upstream concentrations are the following:

Upstream concentration in freshwater: toxic contaminants

- The median of representative data collected from the watershed or a comparable one;
- A conservative concentration defined based on existing data (e.g. for trace metals, the highest median observed in each of the segments sampled);
- In the absence of data, a default value is applied. This can correspond to:
 - a concentration equal to “0” for organic contaminants other than PCBs, chlorinated dioxins and furans, and polycyclic aromatic hydrocarbons (PAH) of group 1,²
 - a concentration equal to “0” for certain inorganic contaminants such as selenium, antimony and thallium,
 - a typical median value for Quebec (e.g. for fluorides 0.1 mg/l),
 - a concentration equal to half of the smallest detection limit if the results available for all of Quebec show that the concentrations are largely undetected (e.g. for cyanides),
 - a concentration equal to half of the smallest water quality criterion (e.g. for PAHs of group 1),
 - a concentration equal to “0” for whole effluent toxicity.

Upstream concentration in freshwater: conventional contaminants

- The median of representative data from the watershed;
- In the absence of data, a default value is retained for total suspended solids, biochemical oxygen demand, total ammonia and fecal coliforms. These are calculated in proportion to agricultural and forest surface areas of the drainage watershed and typical environmental concentrations (see Table 4);
- For phosphorus, the EDO is often calculated according to the global approach. The upstream concentration used is also the “natural” concentration since the beginning of a segment generally corresponds to the head of a watershed or a subwatershed. Two different values are used as upstream concentrations according to the region:
 - 0.011 mg/l P_{tot} (Appalachians, Canadian Shield and St. Lawrence Lowlands),
 - 0.017 mg/l P_{tot} (Abitibi).

These correspond to the median concentrations at the water quality monitoring stations not influenced by the different regions, except for the St. Lawrence Lowlands. In the latter case, there is a default value.

² PAH for which there is sufficient evidence of carcinogenicity (listed in Appendix 7 of MDDEP, 2006).

Table 4 Typical concentrations in agricultural and forested regions

Contaminant	Upstream concentration 100% agricultural (mg/l)	Upstream concentration 100% forest (mg/l)
BOD ₅	1.0	0.4
TSS	4.0	1.0
Fecal coliforms	310 CFU/100 ml	5 CFU/100 ml
Ammonia nitrogen	0.03	0.02

Upstream concentrations in brackish and salt waters

In brackish and salt waters, specific values for each waterbody, originating in the literature or determined in the field, are used for the contaminants.

A discharger who considers that the upstream concentrations used in the calculation of the EDOs are not representative of the receiving environment can ask the Department what minimal data would be required to provide specific values for the target environment. Taking into account the low concentrations of several toxic contaminants in surface waters (trace metals, organic compounds), specific sampling and analysis techniques may be necessary to generate acceptable results.

7.5 Elevated upstream concentrations

Some contaminants are already present in concentrations higher than the water quality criteria. These high levels may originate naturally or by human activity. For example:

- Phosphorus in concentrations exceeding water quality criteria in several rivers whose watersheds serve agricultural purposes;
- Metals may present high natural concentrations, especially in highly mineralized areas or in watersheds with a high clay content;
- Polychlorinated biphenyls, chlorinated dioxins and furans and occasionally mercury can present concentrations above water quality criteria, even in relatively untouched environments. These concentrations can be attributed to atmospheric contributions.

In the majority of cases, an exceedance of water quality criteria indicates that the environment has met or exceeded the level of quality desirable and that no additional load of contaminants can be added.

The EDOs take into account this particular situation, but they also take into consideration the water source. Thus, when a company draws its water from the

receiving environment, the EDO corresponds to a nil net load. Moreover, if the company uses non-contaminated water (groundwater, municipal water or from other sources), the EDO is then the water quality criterion.

For trace metals, certain upstream concentrations higher than the criterion may lead to the identification of a site-specific criterion (see Section 9.4).

7.6 Concentration and load EDOs

EDOs are established for both concentrations and loads, with the exception of EDOs for parameters that cannot be stated in terms of load (pH, whole effluent toxicity, fecal coliforms). The two are inseparable as the concentration to be respected in the environment is a function of the allotted effluent load.

Concentration EDOs are necessary to establish the risk of direct impacts in proximity to the discharge point. Such a limit is even more necessary when the effluent flow is significant with respect to that of the receiving waterway. The lower the dilution, the more the effluent concentration influences the resulting environmental concentration. In the extreme case where the effluent constitutes 100% of the flow of a waterway, the concentration in the environment is determined solely by the effluent concentration and not by its load.

Load EDOs are those used to ensure compliance with the water quality criterion in the environment when a dilution is allotted. Despite low concentrations, a high flow effluent adds a large quantity of contaminants that disperse into the environment and that can have long-term effects on water uses or on other compartments of ecosystems downstream from the discharge.

7.7 EDO application period

For certain contaminants, EDOs are evaluated for only part of the year, according to the use to be protected or the sensitivity of the receiving environment. In Table 5, EDO application periods are outlined for both conventional and toxic contaminants as a function of use.

Table 5 EDO application periods according to use and type of contaminant

CONTAMINANTS	PERIODS	USE OR EFFECT
CONVENTIONAL		
BOD ₅ and TSS	Yearly	Aquatic life
PHOSPHORUS	Yearly May 15 to November 14 (Western Québec) ¹ May 15 to October 14 (Eastern Québec) ¹	Eutrophication (upstream from a lake, reservoir, bay) Eutrophication (river with no downstream lake, reservoir or enclosed bay)
FECAL COLIFORMS	Yearly May 1 to November 30 May 1 to October 31 June 1 to September 30	Water/aquatic organism contamination prevention Public health Recreational activities (secondary contact) Recreational activities (primary contact)
TOXIC		
TOTAL AMMONIA ²	May 15 to November 14 (summer temp.) November 15 to May 14 (winter temp.)	Aquatic life Aquatic life
OTHER TOXIC CONTAMINANTS	Yearly	Water/aquatic organism contamination prevention/terrestrial piscivores/aquatic life
<p>¹ The period of May 15 to November 14 applies to all waterways in Quebec, with the exception of those on the north shore of the St. Lawrence River and emptying downstream of Saint-Pierre Lake. For those on the south shore situated east of the South River, the period of May 15 to October 14 is used.</p> <p>² Although the EDO for total ammonia applies over the whole year, two periods were established for its application due to temperature-related variations in toxicity.</p>		

8 SPECIAL CASES OF ACUTE TOXICITY

8.1 Short-duration discharges

Certain discharges occur only once and are of short duration (less than 30 days). In these cases, organisms are not chronically exposed to contaminants and will be able to recover, provided the effluent does not have any acute toxic effects on them. As such, for all discharges, including those of short duration, absence of acute effluent toxicity is the goal. Given the time required to perform toxicity tests, it is not always possible to evaluate the quality of short-duration discharges by determining whole effluent toxicity, as described in Section 3.5.

In this case, a chemical quality criterion determined for each of the contaminants is used to estimate the potential acute effects of an effluent before discharge. This is the effluent final acute value (FAVe), which corresponds

to a contaminant concentration that will kill 50% of the sensitive organisms exposed. This value is described in MDDEP (2006) and MENVIQ (1990, rev. 1992, in revision). For non-recurring short-duration discharges, the FAVE becomes the EDO. Like all EDOs, the FAVE does not take into account analytical, technological or economic constraints.

A different situation applies for short-duration recurring discharges. If the recurrence is frequent, the EDOs for chronic criteria are calculated in the same manner as for a continuous discharge. The absence of acute whole effluent toxicity during a discharge episode must also be ensured. For these intermittent discharges, the effluent flow used to determine the EDOs must reflect the average exposure of organisms in the environment (Section 7.3).

For persistent, bioaccumulative and toxic substances (PCBs, chlorinated dioxins and furans, mercury), all discharges, even of short duration, cause an increase in concentrations of these substances in the environment. Any addition, even periodic,

Evaluation of acute toxicity for different types of discharges			
Type of discharge	Example of discharge	Use of FAVE	EDOs defined for the chronic effects
Non-recurring discharge	Less than one month	√ ¹	
Recurring discharge	10 minutes per day ¹	√ ¹	
	Several days per month ¹	√ ¹	
	10 minutes several times per day	²	√
	Over one hour every day	²	√
Continuous discharge	More than one month	Acute WET ³	√
¹ For persistent, bioaccumulative toxic substances, the chronic criteria (CPC(F) and TPC) apply regardless of the duration of the discharge ² Acute WET must be verified at the time of a discharge episode ³ For a specific substance, when the relationship between its presence in an effluent and the acute effects measured by WET tests is well known, the FAVE can be used as an indicator of WET			

increases the possibility of long-term effects on various compartments of the ecosystem. Since the goal is to eliminate the mixing zone for these substances, the CPC(F) and TPC quality criteria or the upstream concentrations of these substances (Section 7.5) can be used as EDOs, even for short-duration discharges.

FAVeS are established for each contaminant. Where there is more than one contaminant in an effluent and measurement of acute WET cannot be done, the acute effects of toxic substances can be considered additive. To take into account the presence of several substances in an effluent, the following equation can be used :

$$\frac{[\text{substance}]_1}{FAVe_1} + \frac{[\text{substance}]_2}{FAVe_2} + \dots + \frac{[\text{substance}]_n}{FAVe_x} < 1$$

8.2 Continuous discharges

For continuous discharges, it is possible to estimate the potential acute toxicity of an effluent without doing toxicity tests when, for a given substance, the relationship between its presence in one type of effluent and the acute effects measured by whole effluent toxicity tests are well documented. This is the case for ammonia nitrogen in municipal and domestic effluents, or in any other similar effluent, such as effluent from the agrifood industry and septic tank sludge treatment plants. The effluent final acute values (FAVe) for ammonia nitrogen can also serve as indicators for acute whole effluent toxicity of this type of wastewater discharge.

FAVeS can also be used to predict the acute whole effluent toxicity of a future discharge of wastewater, for example, before the implementation of a new project.

8.3 Physico-chemical characteristics for the calculation of effluent final acute values

FAVeS of certain contaminants vary as a function of one or several physical-chemical characteristics (pH, temperature, hardness). As FAVEs serve to predict acute whole effluent toxicity, they are calculated from the physical-chemical characteristics of the effluent. Since an EDO is the absence of acute toxicity at all times, the physical-chemical characteristics chosen to prevent the most critical effects must be used. As an example, for a substance whose toxicity increases with increased pH, the maximum expected pH should be used. Conversely, for substances whose toxicity decreases with decreased pH, the minimum expected pH should be used.

9 ELEMENTS OF INTERPRETATION AND COMPLEMENTARY STUDIES RELATED TO THE EXCEEDANCE OF EFFLUENT DISCHARGE OBJECTIVES

9.1 General

Compliance with EDOs means that water quality is protected for aquatic organisms and wildlife the vast majority of the time. It also means that water quality is adequate for consumption or recreational activities, with no restrictions.³ The EDOs are designed to protect water uses and to prevent effects before they occur.

EDOs are objectives formulated on the basis of toxicological and hydrodynamic data. They do not take into account analytical, economic or technological constraints that must be considered during project analysis. As such, they can sometimes be exceeded. The exceedance of an EDO at the effluent source indicates the probable exceedance of a quality criterion in the environment. This exceedance will first be evident for the quality criterion for the most sensitive use and in critical conditions. Moreover, since quality criteria are determined based on generic exposure scenarios, it is possible that specific environmental conditions may influence the expected effects for a designated use.

The occasional exceedance of an EDO does not necessarily mean there is an immediate health or environmental hazard. The exceedance of an EDO means there is a risk of an effect or contamination, and that this risk increases as the range or frequency of the exceedance increases. This observation helps prioritize treatment interventions. The EDOs also help determine, for a given environment, the contaminants that represent a risk that justifies performing additional studies to assess this risk.

Questions are sometimes raised about the impacts of exceeding an EDO, particularly regarding human water uses. This section presents possible complementary studies and provides advice for individuals required to answer these questions or who wish to further specify the risk associated with a discharge.

These complementary studies are used to:

- specify the risk associated with the discharge of a contaminant:
 - ✦ drinking water and fish flesh monitoring,
 - ✦ form of metals,
 - ✦ site-specific quality criteria.
- determine the cause of the toxicity when its origin is not known:
 - ✦ toxicity identification evaluation (TIE).
- verify the concentrations of highly bioaccumulative contaminants.

³ Except regarding disinfection.

These studies, which are generally not necessary, can be quite costly. However, they could be considered when current or future available treatment technologies are insufficient to achieve the objectives.

9.2 Drinking water and fish flesh surveys

The exceedance of EDOs calculated based on contamination prevention criteria for water and fish consumption (CPC(WF)) or for fish consumption only (CPC(F)) indicates a risk of contamination of the water used to produce drinking water, or a risk of contamination of the flesh of edible fish or shellfish. However, it does not mean there is a health risk related to ingesting treated drinking water produced from this water, nor to consuming the fish.

The potential exceedance of CPC(WF) at a drinking water source can, in certain circumstances, trigger a verification of drinking water quality. The *Regulation respecting the quality of drinking water* (Quebec, 2006) is then used by the Department to evaluate the quality of consumers' drinking water.

Similarly, the anticipated exceedance of an CPC(F) downstream from a discharge can, in certain circumstances, trigger a fish flesh quality follow-up. The bioaccumulation of contaminants differs according to environmental conditions and species present. The real health risk can be evaluated based on these environmental data. It is then Health Canada advisories on the marketing of fishery products that dictate whether a consumption restriction alert should be issued. These directives are stated in the *Guide de consommation du poisson de pêche sportive en eau douce du Québec* (MDDEP and MSSS, 2005). The CPC(F) are scientific recommendations defining concentrations in water which, if not exceeded, will ensure long-term safe levels for the consumption of aquatic organisms. The advisories for the marketing of fishery products are the values used to prohibit sales or limit consumption when the pollutant content in the flesh of organisms exceeds these limits.

9.3 Form of metals

The exceedance of EDOs at the effluent source indicates an exceedance of quality criteria in the natural environment. However, the toxicity of metals can be influenced by the form of the metal and by the physical-chemical conditions in the environment (Section 9.4). The EDOs for metals are determined based on water quality criteria expressed in total recoverable metals (MDDEP, 2006) and are themselves also expressed in total recoverable metals. The total recoverable form is that contained in an unfiltered sample and corresponds to the sum of dissolved metals and particulate metals, with no digestion of the silicate matrix (CEAEQ, 2006).

For certain specific studies, it may only be of interest to evaluate the dissolved phase or even the free ions of a metal. In fact, in the natural environment, outside of the influence zone of a discharge, the dissolved form of metals can be a good

representation of the bioavailability of a metal. Water quality criteria, defined for the dissolved form of the metal (i.e. the form contained in a filtered sample), exist for a few metals (MDDEP, 2006, update in preparation). However, measures of dissolved metals are not appropriate in the influence zone of a discharge where the metals can still pass from one form to another depending on environmental conditions. Moreover, specific measures must be taken to measure dissolved metals without risking contamination.

For these reasons and the following ones, the total recoverable metal concentrations are those that need to be measured and evaluated at effluent sources as well as in the influence zone of a discharge.

- This measurement yields results comparable to those obtained within the framework of a regulatory follow-up;
- Depending on environmental conditions, a portion of the metal weakly bound to particulate matter can be released and become bioavailable downstream from a discharge;
- The particulate fraction of a metal can deposit in a lentic zone and contaminate sediments;
- The particulate fraction, although less toxic than the dissolved fraction, is not without toxicity.

9.4 Site-specific water quality criteria

The exceedance of EDOs defined based on chronic aquatic life criteria (CALC) is generally a good indicator of effects of contaminants on organisms in the environment. Nevertheless, there are procedures for determining site-specific criteria for a given site, by replacing provincial water quality criteria. These site-specific quality criteria are used to assess the risk associated with the discharge of a contaminant, when a discharger deems that the specific environmental conditions so require, and when other conditions specific to the discharge are evaluated. These procedures are mainly used to determine site-specific criteria for metals, but they can be used for other contaminants. They are detailed in U.S. EPA (1994 and 2001) and CCME (2003).

The establishment of site-specific quality criteria for the protection of aquatic life can be justified when:

- the specific local characteristics of the receiving environment, such as the pH, hardness, dissolved organic carbon or total suspended solids, may modify the toxicity or bioavailability of a substance;
- metal levels are naturally elevated at a particular site;
- the sensitivity of resident aquatic species at a specific site differs from that of the species tested thus far and used in the calculation of water quality criteria.

The “specific local characteristics” of receiving waters refers to the natural characteristics of waterbodies. In Quebec, it is these natural variations that are the most likely to result in the need for site-specific criteria.

“Resident” aquatic species at a given site means the species, genera, families, orders, classes and phyla that are usually present at that site, that are seasonal due to migration, that appear intermittently because their grounds extend to the site, that were once there, or that live in adjacent waters. Resident taxons cannot be determined simply by upstream or downstream sampling at a site at a given time. In Quebec, the differences between species sensitivity ranges from one region to another are unlikely to significantly modify the criteria.

Site-specific water quality criteria are rarely needed. The determination and subsequent adoption of site-specific water quality criteria is an option. Before the Department agrees to such a process, the discharger must ensure that it is relevant by:

- verifying if the methods used for sampling and analysis, particularly for metals, result in an exceedance of water quality criteria in the environment;
- evaluating the possibility of reducing the effluent concentration;
- defining limits for the segment of the waterway deemed particular;
- determining, based on the literature, if the physical-chemical characteristics specific to that site are known to modify the bioavailability or toxicity of the substance;
- verifying the limits related to water quality criteria for other water uses (CPC(WF), CPC(F) and TPC).

In several cases, these measurements negate the need for site-specific quality criteria.

A discharger wishing to define site-specific criteria for a segment of a given waterway must first submit a study plan to the Department in order to agree on implementation conditions with the latter.

From among existing procedures, the Department specifically recommends the water effect ratio (WER), which is described briefly below.

Water effect ratio (WER)

The WER takes into account the difference between the toxicity of a metal in solution in laboratory water and the toxicity of the same metal in natural environmental water. If there is in fact a difference in toxicity, the WER can increase or decrease the value of the water quality criterion (QC). The site-specific quality criterion (SSQC) is calculated as follows:

$$\text{SSQC} = \text{QC} \times \frac{\text{toxicity with ambient water}}{\text{toxicity with laboratory water}}$$

WERs are used to correct water quality criteria for aquatic life determined based on toxicity data from the laboratory. They do not apply to water quality criteria based on the potential bioaccumulation of a substance or to those derived from environmental data, as is the case with selenium.

A WER is calculated individually for each metal at each site; WERs cannot be extrapolated from one metal to another, from one effluent to another, or from one site to another.

9.5 Toxicity identification evaluation

The origin of exceedance of EDOs for acute or chronic WET and the substances in question can be determined. However, this is not always the case. The presence of unsuspected substances, relatively new and unstudied additives, or the simultaneous presence of several contaminants, even at concentrations within the quality criteria, are all causes that can explain a measured toxicity. A discharger may also want to determine the main contaminant causing the toxicity.

The discharger may conduct a toxicity identification evaluation when the origin of the toxicity is not known. In the *Guide d'évaluation et de réduction des toxiques* (GERT), the Department proposes a structured process for dischargers in an effort to facilitate the design of such studies (MEF, 1996, in revision). The guide presents the different steps in a toxicity reduction evaluation (TRE). A TRE helps guide the choice of corrective measures, evaluate their efficacy, and confirm the reduction of toxicity. The GERT closely follows the method recommended by the U.S. EPA, presented in several methodology documents (U.S. EPA 1989, 1991a, 1992, 1993, 1999).

The identification of toxicity origin is mainly based on the use of standard toxicity tests, so as to identify the physical-chemical fraction(s) of the effluent specifically responsible for the toxicity. It involves a set of effluent fractioning steps in a laboratory (e.g. filtration, pH adjustment, addition of a chelator to metals) combined with toxicity tests. This characterization helps focus on a restricted group of causal agents and maximize the effort invested in finding solutions to reduce toxicity. Specific chemical substances can also be identified if more precise analyses are performed on the different fractions. In both cases, the information generated helps determine the solutions.

9.6 Verification of concentrations of highly bioaccumulative substances

Compliance with EDOs for highly bioaccumulative substances is occasionally difficult to determine with certainty. Highly bioaccumulative substances tend to accumulate in the food chain. This explains why predatory organisms (pike, osprey, mink, humans, etc.) are more contaminated than those situated lower in the food chain (algae, minnows, etc.) and more contaminated than the water in the receiving environment. This phenomenon of bioaccumulation also provides insight into why quality criteria and EDOs for these contaminants can occasionally be lower than the detection limits of usual analytical methods. Other methods are needed to achieve the objective of gradually (virtually) eliminating several of these undesirable contaminants (Appendix 2). Several techniques are used to verify whether the EDOs are achieved when the detection limits of current analytical methods are not sensitive enough.

To achieve this, the discharger can use:

- high-resolution analytical methods with better detection limits;
- verify the concentrations in the tissues of exposed organisms. Terrestrial piscivore protection criteria (TPC) are defined for highly bioaccumulative substances. These criteria can be translated into concentrations in the tissues of fish (mg/kg) and used as reference values to evaluate the presence of these contaminants;
- verify concentrations of the target contaminant in process inputs (e.g. waste oil);
- draw up an inventory of products that can generate the target contaminant (e.g. organochlorides or halogens used in the process);
- any other adequate method, direct or indirect, ensuring compliance with EDOs before discharge into the receiving environment.

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GLOSSARY

- Primary contact recreational activity: Recreational activity in which the user is in direct or complete contact with the water, or is likely to be, such as swimming, windsurfing or water skiing. It involves possible immersion of the head.
- Secondary contact recreational activity: Recreational activity in which the user may be in partial, occasional or accidental contact with the water, such as pleasure boating, canoeing and fishing.
- Additivity: Interaction of two or more substances, which results in the global toxicity from the mixture of the latter being almost equal to the sum of the individual toxicities of these substances.
- Watershed: Area of land whose surface waters and groundwaters drain into the same waterbody.
- Bioaccumulation: Net accumulation of a substance in the tissues of an aquatic organism, resulting from direct exposure to water or food containing these substances.
- Bioavailability: Fraction of the total quantity of a substance in the environment that can be absorbed by living organisms.
- Physical-chemical characteristics: Characteristics of natural surface waters (pH, hardness, temperature, etc.) that can modify the toxicity of a substance for organisms.
- Total recoverable concentration: Concentration of a metal contained in an unfiltered sample and corresponding to the sum of dissolved metal and particulate metal, with no digestion of the silicate matrix.
- Total concentration: Concentration of a contaminant corresponding to the sum of dissolved and particulate fractions.
- Critical conditions: Set of conditions (e.g. flow, current, temperature) of the effluent/receiving environment mixture that corresponds to the moment at which the environmental risk associated with the discharge is the greatest. This risk is not defined based on very short-term transitory conditions but rather on conditions that are maintained over a certain period of time, depending on the impact to be prevented.
- Conservative: Said of contaminants that conserve their chemical properties after being discharged into the environment.
- Contaminant: Solid, liquid or gaseous matter, micro-organism, sound, vibration, rays, heat, odour, radiation or any combination of the latter likely to alter water or environmental quality in any manner.

- Conventional contaminants: Indicators, chemical substances (excluding toxic substances) or micro-organisms traditionally used to characterize the physical-chemical or bacteriological quality of water. Biochemical oxygen demand, total suspended solids, phosphorus and fecal coliforms are conventional contaminants.
- Contamination prevention criteria for water and fish consumption (CPC(WF)): Concentration of a contaminant in water that permits consumption of water and aquatic organisms, over a lifetime, with no harmful health effects and at which organoleptic properties are of good quality.
- Contamination prevention criteria for fish consumption only (CPC(F)): Concentration of a contaminant in water to which aquatic organisms can be exposed without bioaccumulation of the contaminant up to levels potentially harmful to human health. This criterion can also correspond to the limit at which the taste, odour or colour of the flesh of organisms begin to deteriorate.
- Terrestrial piscivore criteria (TPC): Concentration of a contaminant in water that, over several generations, does not cause a significant reduction in the viability or usefulness (commercial or recreational) of an animal population exposed through its water or food consumption (U.S. EPA, 1995). The TPC corresponds to the lower of the value calculated to protect avian species and that calculated to protect mammals.
- Chronic aquatic life criteria (CALC): The highest concentration of a contaminant that produces no harmful effect on aquatic organisms (and their progeny) when the latter are exposed on a daily basis over a lifetime. The quality criteria required to protect aquatic organisms from the indirect effects of conventional pollutants (including a decrease in oxygen, enrichment of waterbodies and spawning ground silting) are also included in CALCs.
- Critical low flow: Minimum flow of a waterway having a defined duration (number of consecutive days) and frequency of recurrence (years).
- Biochemical oxygen demand: Measurement of the quantity of oxygen (mg/l) used in biochemical oxidation of organic matter (plant and animal) and inorganic matter (sulfides, iron salts, etc.) during a given period and at a given temperature.
- Effluent: Discharge of wastewater or discharge of residual liquids into an aquatic environment from a point source, by wastewater treatment plants, industries, wastewater disposal systems, etc.
- Low flow: Periodic decrease in the flow of a waterway.
- Eutrophication: Long natural process by which an aquatic ecosystem, particularly a lake, becomes increasingly rich in nutrients (nitrogen and especially phosphorus), thereby

increasing the plant biomass. Among other things, this enrichment can lead to modifications in animal communities, an increase in organic matter and even a deficit of dissolved oxygen in the hypolimnion. Anthropogenic phosphorus inputs can accelerate this process and have perceptible effects over a relatively short time.

- Requirements: Standards, obligations, rules or conditions stipulated in statutory instruments, specifically requirements regarding follow-ups, surveys, research, pilot projects, etc.
- Discharger: Individual or legal entity who/that carries out an activity involving the discharge of wastewater.
- Drainage ditch: Long man-made depression dug into the ground used for the sole purposes of drainage and irrigation, and whose watershed has a surface area of less than 100 hectares.
- Ditch along a public or private roadway: Long depression dug into the ground, used solely to drain a public or private roadway. A public or private roadway can include any highway, road, street, alley, pedestrian path, bicycle path or railway.
- Dividing ditch: Long depression dug into the ground, used as a dividing line between neighbours, pursuant to Article 1002 of the Civil Code.
- Nutrients: Simple or compound substances crucial to the survival of plants and animals. In aquatic ecosystems, phosphorus and nitrogen are nutrients that can stimulate the growth of algae or aquatic plants when present in excess amounts.
- Virtual elimination: Defined as the total absence of toxic substances in the environment or as the absence of effects on the environment and the ecosystem.
- Receiving environment: Surface water into which effluent is discharged.
- Non-point source discharge: Discharge for which a single point of origin cannot be determined and which is discharged into an aquatic environment in a dispersed manner, as opposed to a point-source discharge (e.g. runoff from farmland).
- Point source discharge: Discharge into an aquatic environment confined to a single point, as opposed to a non-point source discharge.
- Drinking water source: Source of raw water which, after treatment, becomes fit for human consumption, i.e. preparation/processing of food, cooking and drinking water.
- Toxic substances: Substances or combinations of substances which, after being discharged into the environment and after exposure thereto, can (based on existing information) cause death, cancer or genetic mutations and all types of physiological, anatomical or behavioural anomalies in organisms or their progeny. Exposure can be through ingestion, inhalation or

assimilation by an organism, either directly in the environment (water, air) or indirectly in the food chain.

- Persistent, bioaccumulative and toxic substances: Substances named in the SLV 2000 agreement. In Quebec, six of these substances are likely to be present in liquid effluents. These are 2,3,7,8-TCDD, 2,3,7,8-TCDF, hexachlorobenzene, benzo(a)pyrene, PCBs and mercury.
- Whole effluent toxicity: Measure of the toxic potential of an effluent based on standardized toxicity tests, conducted by exposing aquatic organisms to predetermined dilutions of this effluent.
- Acute toxicity unit (TUa): Expression of acute toxicity obtained by dividing 100% by the concentration of effluent that is lethal to 50% of each of the organisms tested.

$$TUa = \frac{100\%}{LC_{50} (\% \text{ V/V})}$$

- Chronic toxicity unit (TUc): Expression of chronic toxicity obtained by dividing 100% by the concentration of effluent with no observable effect (NOEC) or by the concentration of effluent that inhibits a function (development, growth or reproduction) in 25% of the organisms tested (IC₂₅).

$$TUc = \frac{100\%}{NOEC (\% \text{ V/V})} \text{ or}$$

$$TUc = \frac{100\%}{IC_{25} (\% \text{ V/V})}$$

- Effluent final acute value: Concentration of a contaminant that can kill 50% of sensitive organisms exposed.

Appendices

Appendix 1 Recommended toxicity tests

To ensure representation of the range of sensitivity of species in the ecosystem, a minimum number of indicator species from different trophic levels had to be tested. The tests recommended by the Department for evaluating whole effluent toxicity of wastewater are as follows:

Acute toxicity tests

- Determining lethal toxicity in microcrustaceans (*Daphnia magna*)

CENTRE D'EXPERTISE EN ANALYSE ENVIRONNEMENTALE DU QUÉBEC (CEAEQ), 2005. *Méthode d'analyse. Détermination de la toxicité létale CL₅₀ 48h Daphnia magna*, MA 500 – D.mag. 1.0, Revision 4, Quebec, Ministère du Développement durable, de l'Environnement et des Parcs du Québec.

- Determining acute lethality in rainbow trout (*Oncorhynchus mykiss*)

ENVIRONMENT CANADA, 2000. *Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout*, Ottawa, Environment Canada, Conservation and Protection. (EPS1/RM/13, Second Edition).

- Determining acute lethality in the fathead minnow (*Pimephales promelas*)

U.S. EPA, 2002. *Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms*, 5th Edition, Washington, DC, U.S. EPA, Office of Water (EPA-821-02-012).

Chronic toxicity tests

- Test of larval growth and survival using fathead minnows (*Pimephales promelas*)

ENVIRONMENT CANADA, 1992. *Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows*, Ottawa, Environment Canada, Conservation and Protection (EPS1/RM/22; amended in November 1997).

- Determining toxicity – Growth inhibition in algae (*Pseudokirchneriella subcapitata*)

CENTRE D'EXPERTISE EN ANALYSE ENVIRONNEMENTALE DU QUÉBEC (CEAEQ), 2005. *Détermination de la toxicité – Inhibition de la croissance chez l'algue Pseudokirchneriella subcapitata*, MA 500 – P. sub. 1.0, Quebec, Ministère du Développement durable, de l'Environnement et des Parcs du Québec.

Other standardized chronic toxicity tests can be used, e.g. tests on *Ceriodaphnia dubia* survival and reproduction. These can be used when the algae growth inhibition test is not sensitive or shows growth stimulation. This is specifically the case with municipal effluent. It is also possible to use a version of the algae growth inhibition test modified by the CEAEQ, which distinguishes the stimulant effect of effluent rich in organic matter (e.g. pulp and paper effluent) from the toxic effect of some of its components.

The chronic test with *C. dubia* can also replace the fathead minnow test, i.e. when the latter is known to be minimally sensitive to a given type of effluent, or when, in the presence of volatile substances in the water, only small volumes of effluent should be used.

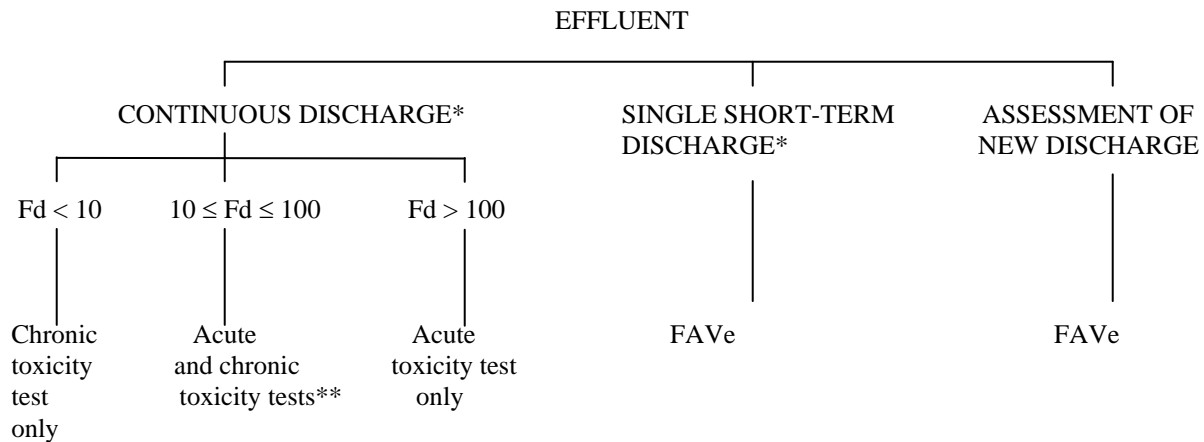
➤ Cladoceran *Ceriodaphnia dubia* survival and reproduction test

ENVIRONMENT CANADA, 1997. *Biological Test Method: Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia*. Ottawa, Environment Canada, Conservation and Protection (EPS1/RM/21; amended in November 2007).

The three acute toxicity tests and the two chronic toxicity tests should all be performed, to cover the entire sensitivity range of the species. Occasionally, only a few of these tests are recommended. For example, in the absence of dilution or in the case of very low dilution of an effluent, the EDO corresponds or is very close to the chronic quality criteria. In such a situation, only chronic toxicity tests could be ordered. Compliance with the EDOs for chronic WET ensures compliance with acute WET. Conversely, in situations of extreme dilution, compliance with acute WET ensures compliance with chronic WET.

Moreover, the simultaneous use of acute and chronic toxicity tests with the fathead minnow helps determine an acute-chronic ratio with the results from the two tests. Once well established, this ratio is used to perform only one of the two tests and to infer the results of the other. The acute-chronic ratio must be established based on at least 12 test results, i.e. one per month for 12 months, or equivalent.

**Possible scenarios for the selection
of toxicity tests at the time of
whole effluent toxicity (WET) characterization**



A minimum of two species from different trophic levels (fish, shellfish, algae) must be tested, unless a sufficient number of results (at least 12 results over one year, or equivalent) show that a species is still the most sensitive for a given effluent.

* A short-term but recurrent discharge can be considered either as a continuous discharge or as a short-term discharge, based on the frequency of the recurrence and best professional judgement (Section 8).

** One or the other, based on the acute-chronic ratio obtained after a series of acute and chronic toxicity tests with the same species (e.g. fathead minnow).

Appendix 2 Persistent, bioaccumulative and toxic substances

“A substance is said to be toxic, persistent and bioaccumulative if, once released into the environment as a result of human activities, it has harmful repercussions on environmental quality and human health, if it remains in the environment and decomposes very slowly, and if it accumulates in living organisms via the food chain.” (SVL2000, 1999).

The list was established based on that proposed by the Great Lakes International Joint Commission. This list, adopted by St. Lawrence Vision 2000 in 1997, includes 11 substances, several of which are no longer produced, sold or used in Canada. “In Quebec, only six of these substances are likely to be present in the effluents discharged (...). They are: hexachlorobenzene, 2,3,7,8-TCDD, 2,3,7,8-TCDF, benzo(a)pyrene, PCBs and mercury.”

Contaminants
Lead alkyls (air)
Dieldrin and aldrin
DDT (including DDD and DDE)
Mirex
Toxaphene
2,3,7,8-TCDD
2,3,7,8-TCDF
Polychlorinated biphenyls (PCBs)
Benzo(a)pyrene (air)
Mercury

Reference: St. Lawrence Vision 2000 (SLV2000), 1999. *The Virtual Elimination of toxic, persistent and bioaccumulative substances. A Reality with St. Lawrence Vision 2000*, 2nd edition, Environment Canada and Ministère de l'Environnement du Québec, Québec, 4 p.

http://slv2000.qc.ca/bibliotheque/centre_docum/phase2/elimination_virtuelle/fiche_a.pdf

Appendix 3 Development of equations for calculating EDOs

EDOs are determined based on the following mass balances:

upstream load + load allotted for effluent = maximum load allowed at the limit of the mixing zone

$$C_s Q_s + C_e Q_e = C_c (Q_s + Q_e) \quad (1)$$

where:

C_e = concentration allotted to the effluent for a given contaminant. It is expressed in total concentration or total recoverable metal concentration. It corresponds to the EDO concentration.

Q_e = effluent flow.

C_c = concentration corresponding to the water quality criterion used for a given contaminant and use. It is expressed in total concentration or total recoverable metal concentration.

C_s = upstream concentration of the contaminant in the receiving water.

Q_s = upstream flow that corresponds to the portion of the upstream flow allotted for effluent mixing. Q_{am} takes into account the fraction f of the effluent flow drawn from the receiving water upstream from the discharge point.

$$Q_{am} = Q_r - f Q_e.$$

Q_r = receiving water flow rate allotted for effluent mixing.

f = fraction of the effluent flow removed from the receiving water upstream from the discharge point. The f factor has a value of “1” if the water is drawn entirely from the waterway upstream from the discharge point, and a value of “0” if the water intake is underground or located in another watershed.

The load allotted to the effluent ($C_e Q_e$) corresponds to the load associated with compliance with the water quality criterion (maximum load permitted at the limit of the mixing zone), from which is subtracted the load already present in the environment (upstream load). These loads are defined as follows:

$$C_e Q_e = C_c (Q_s + Q_e) - C_{am} Q_{am} \quad (2)$$

Equation (2) can be transformed by replacing Q_{am} with its definition ($Q_r - fQ_e$):

$$C_e Q_e = C_c [(Q_r - fQ_e) + Q_e] - C_s (Q_r - fQ_e) \quad (2a)$$

It is possible to determine the concentration allotted to the effluent (C_e) by solving the following equation:

$$C_e = \frac{C_c (Q_r - fQ_e + Q_e) - C_s (Q_r - fQ_e)}{Q_e} \quad (3)$$

Or:

$$C_e = C_c \frac{(Q_r - fQ_e + Q_e)}{Q_e} - \frac{C_s (Q_r - fQ_e)}{Q_e} \quad (3a)$$

The equations can be rearranged to include the dilution factor (Fd). The dilution factor is defined as the ratio between effluent flow and the flow that contributes to dilution, i.e. the sum of the upstream flow and the effluent flow.

$$Fd = \frac{Q_e}{Q_s + Q_e} = \frac{Q_e}{(Q_r - fQ_e) + Q_e} \quad (4)$$

By substituting the dilution factor (Fd) into equation 3, the concentration allotted to the effluent becomes:

$$C_e = \frac{C_c}{Fd} - C_s \frac{Q_r - fQ_e}{Q_e} \quad (4a)$$

Knowing that, according to equation 4:

$$Q_r = \frac{Q_e}{Fd} + fQ_e - Q_e \quad (4b)$$

Equation 4a becomes:

$$C_e = \frac{C_c}{Fd} - \frac{C_s}{Q_e} \left(\frac{Q_e}{Fd} + fQ_e - Q_e - fQ_e \right) \quad (4c)$$

$$C_e = \frac{C_c}{Fd} - \frac{C_s}{Q_e} \left(\frac{Q_e}{Fd} - Q_e \right) \quad (4d)$$

$$C_e = \frac{C_c}{Fd} - \frac{C_s Q_e}{Q_e Fd} + \frac{C_s Q_e}{Q_e} \quad (4e)$$

$$C_e = \frac{C_c}{Fd} - \frac{C_s}{Fd} + C_s \quad (4f)$$

Hence the following simplified equation that can be used to calculate EDOs in the case where the dilution factor was estimated by a hydrodynamic model or a diffusion test:

$$C_e = \frac{C_c - C_s}{Fd} + C_s \quad (5)$$

Appendix 4 Examples of EDO calculations

This appendix describes two examples of EDO calculations. The first example presents an industrial effluent characterized by the presence of nickel and lead. It uses the local approach to calculate the EDOs for these metals and for the chronic whole effluent toxicity. The second example presents EDO calculations for total suspended solids (TSS) and fecal coliforms for two municipal effluents. The local approach is used for TSSs, whereas the global approach is used for fecal coliforms.

1. Industrial effluent – rapid mixing (local approach)

Metal Inc. is a medium-sized metal plating company. The effluent from Metal Inc. is treated by sedimentation and is decanted before being discharged into a river. The wastewater is characterized by the presence of lead and nickel. The average effluent flow is 10 l/s.

a. Determination of uses

Aquatic life (CALC), terrestrial piscivores (TPC) and consumption of fish and shellfish (CPC(F)) are uses considered for all waterways. There are no drinking water sources or recreational activity zones downstream from the discharge point.

b. Water quality criteria

To ensure an adequate level of water quality to maintain these uses, water quality criteria are applied relative to chemical contaminants and whole effluent toxicity. The two contaminants in question have a toxicity that varies according to the hardness of the environment. The aquatic life protection criteria are calculated based on the median hardness of the receiving environment upstream from the discharge, which is 50 mg/l of CaCO₃.

	Lead	Nickel	WET
FAVe	-----	-----	1 TUa
CALC	0.0013 mg/l	0.029 mg/l	1 TUc
TPC	-----	-----	-----
CPC(F)	-----	4.6 mg/l	-----

c. Calculation of EDOs for chemical contaminants (local approach)

The EDOs are calculated such that the quantity of lead and nickel discharged enables compliance with water quality criteria at the limit of the mixing zone in question. Using to the local approach, the mass balance takes into account the effluent flow, the characteristics of the environment, the upstream concentration of contaminants and the dilution in critical conditions.

Upstream concentration

The upstream concentration in the river is 0.0002 mg/l of lead and 0.002 mg/l of nickel.

Flow considered for the dilution

- The annual flows 7Q10 and 30Q5 are 500 l/s and 1,000 l/s, respectively.
- The company draws its water from the receiving environment ($f = 1$).
- Mixing occurs rapidly in the waterbody. For toxic contaminants, the maximum flow allotted for mixing of the effluent is 50% of the critical low flow, with a maximum limit of 1 in 100.

Calculation of EDOs

The EDOs are calculated according to basic equation 3 of the mass balance:

$$C_e = \frac{C_c (Q_r - fQ_e + Q_e) - C_s (Q_r - fQ_e)}{Q_e}$$

This results in:

$$EDO Pb_{CALPC} = \frac{0.0013 (250 - (1 \times 10) + 10) - 0.0002 (250 - (1 \times 10))}{10} = 0.0277 \text{ mg/l}$$

$$EDO Ni_{CALPC} = \frac{0.029 (250 - (1 \times 10) + 10) - 0.002 (250 - (1 \times 10))}{10} = 0.677 \text{ mg/l}$$

$$EDO Ni_{AOCPC} = \frac{4.6 (250 - (1 \times 10) + 10) - 0.002 (250 - (1 \times 10))}{10} = 230 \text{ mg/l}$$

The EDO for lead is 0.0277 mg/l. Based on C_e , the load allotted is determined by $C_e \times Q_e$, which corresponds to 0.024 kg/d.

The EDO for nickel is that which ensures the protection of all uses, i.e. EDO_{CALC} , which is 0.677 mg/l and 0.58 kg/d.

We can also calculate the EDOs based on the simplified EDO calculation equation 5. It is then necessary to calculate the dilution factors (Fd):

$$Fd = \frac{Q_e}{Q_s + Q_e} = \frac{Q_e}{(Q_r - fQ_e) + Q_e} \quad (4)$$

$$Fd_{CALPC} = \frac{10}{250 - (1 \times 10) + 10} = 1 \text{ in } 25 \text{ or } 0.04$$

$$Fd_{AOCPC} = \frac{10}{500 - (1 \times 10) + 10} = 1 \text{ in } 50 \text{ or } 0.02$$

According to simplified equation 5, the EDOs are calculated as follows:

$$C_e = \frac{C_c - C_s}{Fd} + C_s \quad (5)$$

$$EDO_{Pb_{CALC}} = \frac{0.0013 - 0.0002}{0.04} + 0.0002 = 0.0277 \text{ mg/l}$$

$$EDO_{Ni_{CALC}} = \frac{0.029 - 0.002}{0.04} + 0.002 = 0.677 \text{ mg/l}$$

$$EDO_{Ni_{CPC(F)}} = \frac{4.6 - 0.002}{0.02} + 0.002 = 230 \text{ mg/l}$$

These values correspond to the concentrations calculated previously.

d. EDO calculations for whole effluent toxicity

The acute whole effluent toxicity criterion of 1 TUa, equivalent to a maximum of 50% mortality, applies directly at the discharge point, before any dilution in the receiving water. The EDO for acute whole effluent toxicity is thus always one acute toxicity unit (1 TUa).

The EDO for chronic whole effluent toxicity is calculated such that the criterion of 1 TUC is respected at the end of the mixing zone in question. The basic equation for calculating the EDO for chronic whole effluent toxicity (6) is as follows:

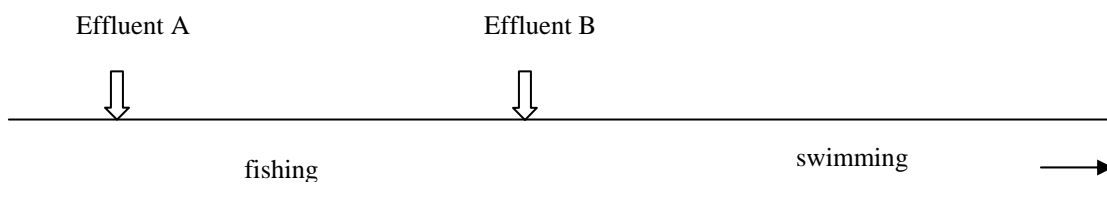
$$C_e = \frac{C_c}{Fd_{CALPC}} = \frac{1TUC}{Fd} \quad (6)$$

$$EDO = \frac{1TUC}{0.04} = 25 TUC$$

This means that if the chronic toxicity of the discharge from this company does not exceed 25 TUC, based on the quality criteria, the effluent will not cause chronic effects on the aquatic life at the limit of the mixing zone in question.

2. Municipal effluent – rapid mixing (local approach and global approach)

The treated effluent from municipality A is discharged into a river. The design flow rate at the wastewater treatment plant is 50 l/s. Total suspended solids (TSS) and fecal coliforms (f.c.) are two of the contaminants for which EDOs have been requested for this station. A second station, in municipality B, also discharges its effluent (200 l/s) into the river, 4 km downstream from the effluent from municipality A.



a. Determination of uses

Aquatic life (CALC), terrestrial piscivores (TPC) and consumption of fish and shellfish (CPC(F)) are uses considered for all waterways. There is also a fishing zone (RAAC) 1.8 km downstream from the effluent at station A, and a swimming area (RAAC) 8 km downstream from the effluent at station A.

b. Water quality criteria

	TSS	Fecal coliforms
CALC	Increase of 5 mg/l compared with the upstream concentration	-----
TPC	-----	-----
CPC(F)	-----	-----
RAAC	-----	200 CFU/100 ml (direct contact) 1,000 CFU/100 ml (indirect contact)

c. Calculation of EDOs for total suspended solids (local approach)

The EDOs are calculated such that the quantity of total suspended solids discharged enables compliance with water quality criteria at the limit of the mixing zone in question. According to the local approach, the mass balance takes into account the effluent flow, the characteristics of the environment, the upstream concentration of contaminants and the dilution in critical conditions.

Upstream concentration

There is no water quality monitoring station for TSSs upstream from the discharge by municipality A. The upstream concentration is estimated in proportion to agricultural and forest surface areas in the watershed. Since the surface area of the watershed at the discharge point is 10% agricultural and 90% forest, the default upstream concentration for TSSs is therefore:

$$C_s = 10\% (4 \text{ mg/l}) + 90\% (1 \text{ mg/l}) = 1.3 \text{ mg/l}$$

The upstream concentration for TSSs is therefore 1.3 mg/l. The CALC for the TSSs is therefore: $1.3 \text{ mg/l} + 5 \text{ mg/l} = 6.3 \text{ mg/l}$.

Flow considered for the dilution

- The river, at the discharge point from wastewater treatment plant A, has an annual critical low flow 7Q2 of 800 l/s.
- Municipality A draws its water from an underground well ($f = 0$).
- Effluent mixing occurs rapidly in the waterbody. For TSSs, 100% of 7Q2 is allotted for dilution, with a maximum limit of 1 in 100.

Calculation of EDOs

The EDO for TSSs is calculated according to equation 3 of the mass balance:

$$C_e = \frac{C_c (Q_r - fQ_e + Q_e) - C_s (Q_r - fQ_e)}{Q_e}$$

$$\text{EDO TSS}_{\text{CALC}} = \frac{6.3 (800 - 0 + 50) - 1.3 (800 - 0)}{50} = 86.3 \text{ mg/l}$$

Based on C_e , the load allotted is determined by $C_e \times Q_e$. The EDO for the TSSs in the effluent from municipality A is therefore 86.3 mg/l and 372.8 kg/d.

d. Calculation of EDOs for fecal coliforms (global approach)

To take into account the presence of the two effluents that influence recreational uses (fishing and swimming) and the decay of fecal coliforms, the global approach is used to calculate the EDOs for fecal coliforms from municipality A. Equation 7 is used:

$$C_e = (C_c - C_s) \frac{Q_r}{\sum_{i=1}^n Q_{e_i} e^{-kt_i}} \quad (7)$$

Upstream concentration

As with TSSs, the upstream concentration of fecal coliforms is calculated based on the percentages of agricultural and forest surface areas.

$$C_s = 10\% (310 \text{ CFU}/100 \text{ ml}) + 90\% (5 \text{ CFU}/100 \text{ ml}) = 36 \text{ CFU}/100 \text{ ml}$$

The upstream concentration of fecal coliforms is therefore 36 CFU/100 ml at the start of the segment.

Flows considered for dilution

Since recreational activities take place only in the summer, the critical low flows used are those of summer 7Q2. At the fishing site, the summer 7Q2 is 1,100 l/s and at the swimming site, it is 2,000 l/s.

Transit time between discharge point and the use

In the segment studied, the average speed of the river is 0.5 m/s. Therefore, the transit time between the discharge point and the uses can be determined by the simple formula:

$$\text{Time} = \text{distance}/\text{speed}$$

Accordingly, the time between the discharge point in municipality A and the fishing site is:

$$\text{time} = 1,800 \text{ m}/0.5 \text{ ms}^{-1} = 3,600 \text{ s} = 1 \text{ h}$$

The same equation applies for the transit time between the discharge point in municipality A and the swimming area, and for the time between effluent B and the swimming area.

Calculation of EDOs

Use	Discharge upstream from the use	Discharge-use transit time (h)	C _s (CFU/100 ml)	Q _r (l/s)	Q _e (l/s)
Fishing	Effluent A	1	36	1,100	50
Swimming	Effluent A	4.4	36	2,000	50
	Effluent B	2.2			200

The table above contains the data needed to calculate the EDOs used to ensure protection of fishing and swimming activities. The decay rate used for fecal coliforms is 0.02 h⁻¹.

$$C_e = (C_c - C_s) \frac{Q_r}{\sum_{i=1}^n Q_{e_i} e^{-kt_i}} \quad (7)$$

Only the effluent from municipality A is located upstream from the fishing site. Therefore, it is the only one included in the calculation of EDOs used to ensure protection of this use.

$$EDO_{f.c. \text{ FISHING}} = (1,000 - 36) \frac{1,100}{50 e^{-(0.02)(1)}} = 21,636 \text{ CFU} / 100 \text{ ml}$$

To ensure protection of the swimming site, the effluents from municipalities A and B must be considered:

$$EDO_{f.c. \text{ SWIMMING}} = (200 - 36) \frac{2,000}{50 e^{-(0.02)(4.4)} + 200 e^{-(0.02)(2.2)}} = 1,383 \text{ CFU} / 100 \text{ ml}$$

The EDO used for the effluent from municipality A is that which ensures the protection of all recreational uses downstream from the effluent, i.e. 1,383 CFU/100 ml (for fecal coliforms, the EDO is expressed as a concentration only). This EDO also applies to the effluent from municipality B.