



Assessing sediment toxicity in the upper St. Lawrence estuary

**Ministère du Développement durable, de l'Environnement et de
la Lutte contre les changements climatiques**

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Introduction

In Quebec, criteria for the assessment of the chemical quality of sediments are the primary tool for assessing the potential environmental effects of chemical contamination present in sediments [1]. However, beyond applying the quality criteria, there was still work to be done to fully incorporate the various tools for assessing sediment quality, including toxicity tests. For instance, it was necessary to determine the type of studies required in each management context in order to complete the assessments of sediment contamination and its associated ecotoxicological risks.

Toxicity assessment tools

In the freshwater portion of the St. Lawrence, the assessment of the ecotoxicological risk of potentially contaminated sediment is partly based on the results of two survival and growth toxicity tests [2], one using *Chironomus riparius*, a dipteran insect whose larvae grow in sediment [3], and the other using *Hyalella azteca*, a small bottom-dwelling amphipod crustacean [4].

In marine environments, sediment toxicity can be assessed using the toxicity tests recommended under Environment and Climate Change Canada's Disposal at Sea Program [5, 6]. These are amphipod mortality (using one of the following: *Amphiporeia virginiana*, *Corophium volutator*, *Eohaustorius estuarius*, *Eohaustorius washingtonianus*, *Foxiphalus xiximeus*, *Leptocheirus pinguis* and *Rhepoxynius abronius*), sublethality as measured by bioluminescence inhibition in a bacterium (*Photobacterium phosphoreum*), sea urchin growth (using one of the following: *Strongylocentrotus droebachiensis*, *Strongylocentrotus purpuratus*, *Dendraster excentricus*, *Arbacia punctulata* and *Lytechinus pictus*), and polychaete growth (*Polydora cornuta*).

Toxicity tests are useful both for managing contaminated sites and for assessing dredging sediment. Although there are a number of tests for assessing the ecotoxicological risk of sediment in freshwater and saltwater, none are designed specifically for brackish water. No guides or guidelines recommend any toxicity tests that could be used to measure sediment toxicity in the upper St. Lawrence estuary, also referred to as the brackish estuary. This zone extends from the eastern tip of Île d'Orléans to the mouth of the Saguenay River on the North Shore and to the western tip of Île Verte along the South Shore [7] and covers a distance of approximately 150 km. In this part of the estuary, water salinity rises rapidly from less than 2‰ to approximately 20‰ between Cap Tourmente and Île aux Coudres, reaching 25‰ to 30‰ at Tadoussac [1, 7]. It was therefore necessary to determine which tests should be used to assess the toxicity of sediment in the brackish estuary. To that end, a study was conducted to answer the following question:

Which toxicity tests should be used to assess the potential impact of dredged or deposited sediment in the brackish estuary of the St. Lawrence?

Why amphipods?

This study focused on two amphipod species because amphipods are considered to be euryhaline organisms, meaning that they can tolerate and survive in a range of salinities.

Of the tests used in freshwater, the toxicity test on the amphipod *Hyaella azteca* might be suitable for assessing brackish sediment. It has been demonstrated that *Hyaella azteca* can be grown at salinities of up to 15‰ and subsequently be used in toxicity tests to assess estuarine sediment [8-11]. Other researchers have observed that this species can, if gradually acclimated, tolerate salinities of up to 30‰ [12]. However, another study indicated that not all strains of *Hyaella* exhibit the same degree of salinity tolerance [13]. Consequently, it was necessary to confirm whether this species could be used to assess sediment from the brackish estuary of the St. Lawrence.

As for the tests used in saltwater, the amphipod *Eohaustorius estuarius* is a species known for its tolerance of a very wide range of salinities (2 to 35‰ [6, 14, 15]). Consequently, it was necessary to confirm whether it could be used to assess sediment from the brackish estuary of the St. Lawrence.

Methods used

To assess the salinity tolerance of the two selected amphipod species, uncontaminated sediment samples were collected in the St. Lawrence brackish estuary, east of the North Traverse (MTM7-5223407, 292305), at a depth of 12 m. The sediment consisted of 100% medium and coarse sand containing very little organic matter (0.11%), and the salinity of the interstitial water—the water within the sediment matrix—was approximately 2‰.

In the toxicity tests, the sediment taken from the North Traverse was covered with water of varying salinities to simulate the brackish waters of the St. Lawrence and thus cover the entire range that can be found in this zone, namely 0‰ to 30‰.

Freshwater amphipods

The effect of salinity on survival and growth of the freshwater amphipod *Hyaella azteca* was assessed at the Centre d'expertise en analyse environnementale du Québec (ministère du Développement durable de l'Environnement et de la Lutte contre les changements climatiques). The approach used was an adaptation of method XP T 90-338-1, developed by the Association française de normalisation (AFNOR) [16], and method EPS 1/RM/33, developed by Environment and Climate Change Canada¹ [4]. The various salinities (0.5, 5, 10, 15 and 20‰) were obtained by diluting artificial seawater (34‰), supplied by the Aquarium du Québec, with freshwater (dechlorinated municipal water). The organisms used in the experiments came from the Centre d'expertise en analyse environnementale du Québec aquaculture facility. Salinity acclimation tests were performed: the amphipods were placed in water at 10‰ salinity, which was then

¹ Before December 2015, the applied title used for the department was Environment Canada.

increased by 2.5‰ per day to a maximum of 20‰. The amphipod survival rate at the increased salinities was calculated after four to seven days. Once the results of the acclimation tests were obtained, the standardized toxicity tests measuring survival and growth after 14 days of exposure were conducted at salinities ranging from 0‰ to 15‰ with new organisms that had not been acclimated [4].



Figure 1 : Freshwater amphipod (*Hyalella azteca*)

Marine amphipods

The effect of salinity on survival of the marine amphipod (*Eohaustorius estuarius*) was assessed at the Atlantic Laboratory for Environmental Testing (Environment and Climate Change Canada, in Moncton) according to the protocol EPS 1/RM/35 [6]. The various water salinities (0.5, 5, 10, 15, 2 and 25‰) were obtained by diluting artificial seawater (28‰), supplied by the Atlantic Laboratory for Environmental Testing, with freshwater (dechlorinated municipal water). The organisms were supplied by Northwestern Aquatic Sciences in Newport, (Oregon, United States) and had been taken directly from Yaquina Bay (Oregon), where the salinity is 22‰. The amphipods were gradually acclimated to the exposure salinities, with the salinity level variation by 5‰ per day until it reached the desired level. That level was maintained for two days before the toxicity tests were performed to measure survival after 96 hours of exposure [6].



Figure 2 : Marine Amphipode (*Eohaustorius estuarius*)

Amphipod response to salinity

The marine amphipod *E. estuarius* was successfully acclimated to salinities ranging from 0.5 to 30‰, with a survival rate of approximately 98%. During the toxicity testing, the survival rate of *E. estuarius* was greater than 96% at all salinity levels tested (Table 1).

The survival rate of the freshwater amphipod *H. azteca* was just 78% at 17.5‰ salinity and 16% at 20‰ salinity. Given these survival rates, the experiments were then performed with amphipods that had not been acclimated were therefore carried out for salinities ranging from 0 to 15‰. This range of salinities had no significant effect on the growth and survival of *H. azteca* at salinities ranging from 0 to 15‰, as survival exceeded 85% and growth inhibition or stimulation was below 12%.

Table 1: Percent survival and growth inhibition of *Hyalella azteca* and percent survival of *Eohaustorius estuarius* following exposure to various salinities

Salinity (‰)	<i>Hyalella azteca</i>		<i>Eohaustorius estuarius</i>	
	Survival (%)	Size (mm)	Growth inhibition (%)	Survival (%)
Control*	93.3 ± 5.8	2.24 ± 0.09	na	97.0 ± 6.7
0.5	96.7 ± 5.8	2.20 ± 0.02	1.8	98.0 ± 2.7
5	86.7 ± 15.3	2.50 ± 0.02	- 11.6	99.0 ± 2.2
10	100 ± 0	2.44 ± 0.07	- 8.9	99.0 ± 2.2
15	93.3 ± 11.5	2.01 ± 0.05	10.3	97.0 ± 4.5
20	na	na	na	100 ± 0
25	na	na	na	96.0 ± 2.2
30	na	na	na	96 ± 4.2

na: not applicable

*The salinity of the control environment was 0.14‰ for *H. azteca* and 28‰ for *E. estuarius*.

Recommendations

The main objective of this study was to determine which biological tests could be used to assess the toxicity and facilitate the management of contaminated sediment in the brackish estuary of the St. Lawrence.

According to the results obtained and a review of the literature, it appears that the physiology of the amphipod *H. azteca* makes it unsuitable for use at salinities greater than 15‰. However, the amphipod *E. estuarius* proved to be highly adaptable to a very wide range of salinities, from 0.5 to 30‰.

Consequently, the average salinity of the site to be studied must first be determined with the aid of the salinity gradient map in Figure 2 of *Criteria for the Assessment of Sediment Quality in Quebec and Application Frameworks: Prevention, Dredging and Remediation* [1].

If the salinity at the site under study is less than or equal to 15‰, the toxicity of dredged or deposited sediment in the brackish estuary of the St. Lawrence can be assessed using the following tests:

- Mortality of the amphipod *Eohaustorius estuarius* according to the Environment and Climate Change Canada method (EPS 1/RM/35, 1998) after acclimation to the salinity at the study site. This acclimation must be carried out gradually by varying the salinity by 5‰ per day and maintaining the desired salinity for 2 days before beginning the toxicity tests.
- Mortality and growth of the amphipod *Hyalella azteca* according to the AFNOR method (XP T 90-338-1, 2003) or the Environment and Climate Change Canada method (EPS 1/RM/33, 2013), after acclimation to the salinity of the site.

If the salinity at the site under study is greater than 15‰, the toxicity of the sediment can be assessed using the following tests:

- Mortality of the amphipod *Eohaustorius estuarius* according to the Environment and Climate Change Canada method (EPS 1/RM/35, 1998).
- Survival and growth of polychaete worms (*Polydora cornuta*) according to the Environment and Climate Change Canada method (EPS 1/RM/41). This toxicity test, not evaluated in this study, was added in the recommendations following a review of the scientific literature and expert's consultation.

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