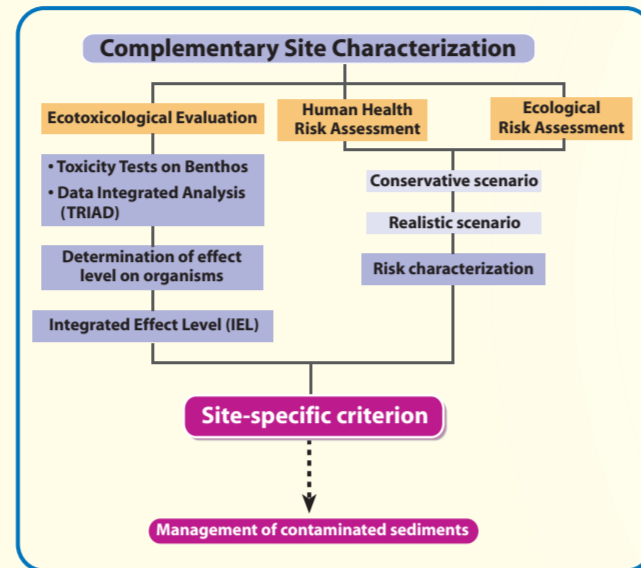


1 ABSTRACT

Recent studies have shown the presence of elevated copper concentrations in marine sediments over a large area surrounding the Gaspé commercial wharf, Quebec, Canada. A scientific committee integrating private (Noranda) and governmental stakeholders (Transport Canada) was formed to oversee a study related to the ecotoxicological, ecological and human health risk posed by those sediments and to define a site specific target level for remediation. The results suggested that copper mobility was low in sediments. Benthic community was found to be independent of the contamination gradient. Field-collected invertebrates, as well as transplanted blue mussels were found to bioaccumulate more copper in the exposed area compared with the reference sites. No toxic responses of amphipods and polychaetes were measured when testing sediment of any station while inhibition of the blue mussel larvae development and inhibition of bacterial bioluminescence (*Microtox*[®] solid-phase) were measured at some of the more contaminated stations. Based on realistic exposure scenarios, the actual copper and PAHs concentration in the sediment do not pose any significant risk neither to marine fauna nor to health human. The integration of all the information has led to the determination of site specific criteria for decontamination.

3 MATERIALS AND METHODS

GENERAL METHODOLOGY

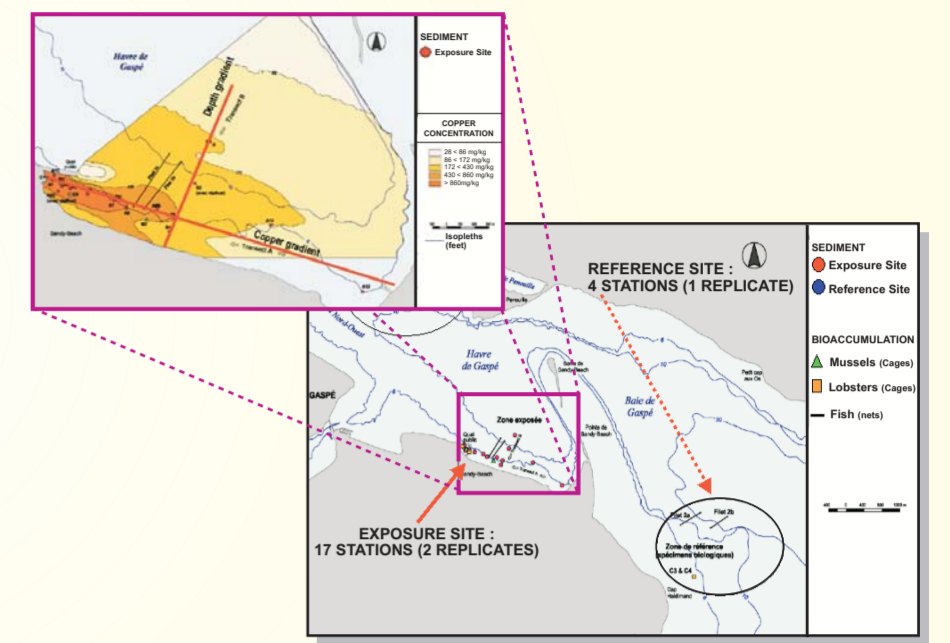


CHARACTERIZATION METHODOLOGY

- Sampling design for site characterization was based upon:
 - ✓ copper gradient
 - ✓ depth gradient
- Physico-chemical and biological analysis were made on exposure and reference site samples.

	Sediment	Porewater	Aquatic Organisms
Sampling Methods	Buylrite & stainless steel cores (diver)	Extraction from sediment (centrifugation)	Benthos: Grab (Ponar) Mussel: Transplanted Lobster: Cages Fish: Nets
Physico-Chemical Parameters	As*, Cd, Cu, Ni, Pb, Zn PAHs (16) Cu speciation TOC, grain size	Cu, Cu, Ni, Pb, Zn PAHs (16)** DOC	Cd, Cu, Ni, Pb, Zn PAHs (16)** (mussel, lobster, fish)
Biological Parameters	not applicable	not applicable	Relative Density, Richness, Regularity and Diversity indexes (benthos)
Ecotoxicity Tests	Amphipods (2), Polychaetes (2), <i>Microtox</i>	Blue mussel larvae	not applicable

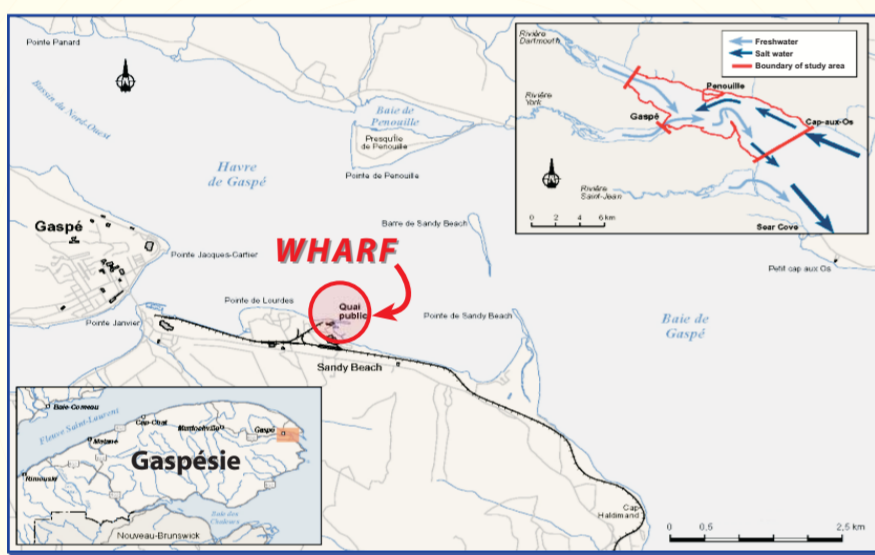
* Estimated from 1997 data. No measurement in 2001
** Estimated from partition (K_{oc}) and TOC
*** For lobster hepatopancreas only (not meat), no measurement in fish (only small catch)



2 CONTEXT AND OBJECTIVES

SITE LOCALISATION AND HISTORICAL USES

The site is located on the gaspian peninsula in the province of Quebec, Canada.



Commercial activities have taken place at Gaspé wharf for more than 50 years (sea products, oil, etc.).

Copper and sulfuric acid had been transhipped at the wharf until recently.

OBJECTIVES OF THIS STUDY

- ➔ Assess Human Health Risk (HHRA) and Ecological Risk (ERA) related to copper contamination in sediments.
- ➔ Determine an integrated effect level (IEL) based on ecotoxicity tests.
- ➔ Define site-specific criteria for copper to manage the contaminated sediments based upon HHRA, ERA and IEL.

4 SITE CHARACTERIZATION

SEDIMENT CHARACTERIZATION

- Fine particles > 75%
- Total Organic Carbon (TOC) = 2%
- 90% Cu strongly bound to particles (F4-F5)

POREWATER

- Dissolved Organic Carbon (DOC) < limit of detection
- Metals highly correlated with sediment (solid phase), TOC and % fine particles (r² > 88%)

BIOLOGICAL INDICATORS

- Spatial distribution of benthic community is related to sediment texture and depth, not to Cu gradient.
- Only Cu shows significant difference (p < 0.05) in bioaccumulation in mussels (meat), polychaetes (depurated organisms) and lobsters (hepatopancreas) between Reference and Exposure zones.

SEDIMENT CONTAMINATION

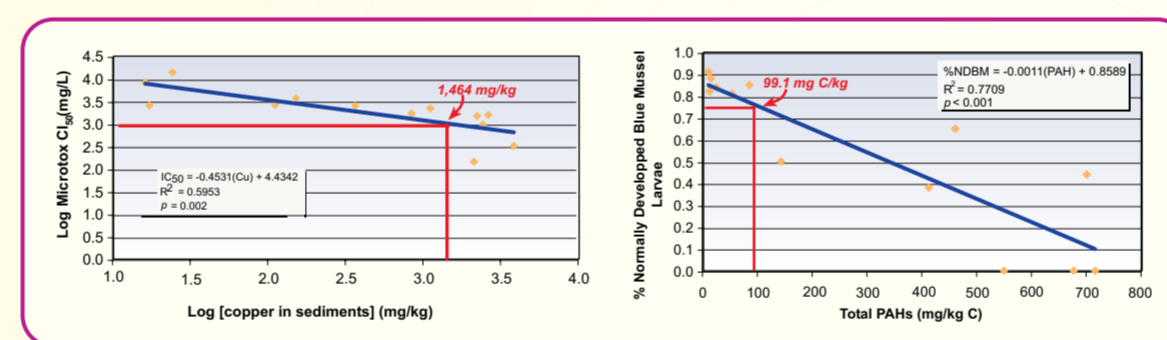
Parameter	Threshold Effect Level (TEL) (mg/kg)	Proportion of sample > TEL (%)	
		Exposure zone n=17	Reference zone n=4
Polycyclic aromatic hydrocarbons			
Benzo(a)anthracene (mg/kg)	0.5	29%	0%
Benzo(a)pyrene (mg/kg)	0.7	6%	0%
Chrysene (mg/kg)	0.8	6%	0%
Fluoranthene (mg/kg)	2	6%	0%
Naphthalene (mg/kg)	0.8	0%	0%
Phenanthrene (mg/kg)	0.8	24%	0%
Pyrene (mg/kg)	1	24%	0%
Inorganics			
Arsenic (mg/kg)	17	35%	0%
Cadmium (mg/kg)	3	0%	0%
Copper (mg/kg)	86	100%	0%
Nickel (mg/kg)	61	53%	50%
Lead (mg/kg)	170	6%	0%
Zinc (mg/kg)	540	0%	0%

* Sediment Quality Guidelines (CCME, 2003)

5 ECOTOXICOLOGICAL EVALUATION

DEVELOPMENT OF INTEGRATED EFFECT LEVEL (IEL)

- ➔ Toxicity tests were realized on sediments and porewater to obtain site-specific threshold concentrations for different species and endpoints.
- ➔ Only blue mussel and microtox tests showed a significant effect (p < 0.05).
- ➔ Both Cu and PAHs concentrations were associated with these effects.



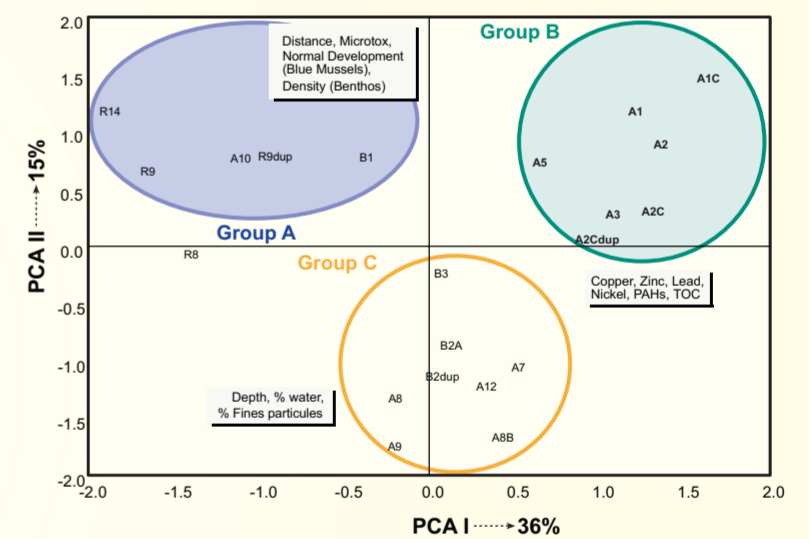
- ➔ IEL was defined as the 10th percentile of all threshold concentrations obtained from toxicity tests (6).

Toxicity test	Assesment Endpoint	Measured Effect	Threshold concentration	
			Copper (mg/kg)	Total PAHs (mg/kg)
Amphipods (<i>Eohaustorius estuarius</i>)	Survival	no	3,800*	25
	Reburrowing	no	3,800*	25
Polychaetes (<i>Neanthes</i>)	Survival	no	3,800*	25
	Growth	no	3,800*	25
Microtox (<i>Photobacterium phosphoreum</i>)	Bioluminescence	yes	1,464	8
Blue mussel (<i>Mytilus edulis</i>)	Larval development	yes	not defined	2
			IEL = 10th percentile	2,398

* Highest tested value

TRIAD APPROACH

- ➔ Principal Component Analysis (PCA) showed 3 groups of sampling stations.



- ➔ Group A and group B are segregated by IEL.

Station	Distance from shore near the wharf (m)	Total PAHs (mg/kg)	Copper (mg/kg)
Group B			
A1C	61	20.3	3,860
A1	69	21.6	2,100
A2C	140	25.2	2,600
A2	140	15.0	2,400
A3	196	9.0	2,200
A5	325	8.3	1,100
A7	519	2.8	830
A8	618	0.6	110
A8B	829	2.1	530
A9	970	1.1	360
A10	1,637	1.1	150
A12	2,394	1.7	210
R8	3,189	0.2	16
R9	3,462	0.1	24
R14B	3,977	0.1	17
Group A			

6 HUMAN HEALTH RISK ASSESSMENT (HHRA)

Using provincial guideline (MSSS, 2002), human health risk was estimated considering:

- ➔ 5 target groups (babies to adults)
- ➔ 18 chemicals of concern (COCs)
- ➔ Carcinogenic and non carcinogenic effects
- ➔ Ingestion of local seafood and fish (3 scenarios)

Parameter	Worst-case scenario	Conservative scenario	Site-specific scenario
COCs	12 PAHs, As, Cd, Cu, Ni, Pb, Zn		
Target groups	Babies, toddlers, children, teens and adults		
Food and water ingestion (background)	Drinking water, food, soil and dust		
Local fish and seafood ingestion	Fish	100%	20%
	Lobsters	100%	20%
	Mussels	100%	5%
Non Carcinogenic Risk	As, Cd, Cu, Zn	As, Cd	As (background)
Carcinogenic Risk	6 PAHs, As, Pb	6 PAHs, As	-

7 ECOLOGICAL RISK ASSESSMENT (ERA)

Using provincial guidelines (CEAEQ, 1998), ecological risk was estimated considering:

- ➔ 3 target organisms
- ➔ 10 chemicals of concern (COCs)
- ➔ 2 exposure scenarios

	American Plaice (fish)		Common Goldeneye (bird)		Doubled-Crested Cormorant (bird)	
	Conservative scenario (generic)	Realist scenario (site-specific)	Conservative scenario (generic)	Realist scenario (site-specific)	Conservative scenario (generic)	Realist scenario (site-specific)
COCs	4 PAHs, As, Cd, Cu, Ni, Pb, Zn		16 PAHs, As, Cd, Cu, Ni, Pb, Zn		16 PAHs, As, Cd, Cu, Ni, Pb, Zn	
Pathways	Direct contact with water		Mussels, marine worms and sediments intake		Fish intake	
Exposure to site	100%	5% (10 ha / 250 ha)	100%	11% (10 ha / 89 ha)	100%	not applicable
Endpoints	Reproduction inhibition / mortality		Growth inhibition		Reproduction inhibition / mortality	
Substances presenting a potential risk	Fluoranthene (PAH) copper		copper			

References

CCME - Canadian Council of Ministers of the Environment (2003). Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Summary tables. In: Canadian environmental quality guidelines, 1999, updated 2003, Winnipeg, Manitoba.
MSSS - Ministère de la Santé et des Services Sociaux (2002). Lignes directrices pour la réalisation des évaluations du risque toxicologique pour la santé humaine. Direction générale de la santé publique, Québec, Canada.
CEAEQ - Centre d'Expertise en Analyse Environnementale (1998). Procédure d'évaluation du risque écotoxicologique pour la réhabilitation des terrains contaminés. Ministère de l'Environnement et de la Faune, Québec, Canada.

8 CONCLUSIONS

- ➔ Generic sediment criteria and conservative exposure scenario (worst-case) show a potential risk for copper and PAHs for targeted ecological and human receptors in a large sector around the Gaspé wharf.
- ➔ Site-specific exposure scenarios indicate no significant risk for the human health and the environment.
- ➔ Site-specific ecotoxicity tests allowed the calculation of an IEL for copper and PAHs leading to a significant reduction of the area potentially affected near the Gaspé wharf.

Ecotoxicological Evaluation	Conservative approach (worst-case)		Realist approach (site-specific)	
	Copper and PAHs concentration in sediments > TEL		Copper and PAHs concentration in sediments > Integrated Effect Level	
Ecological Risk	Potential		Non significant	
Toxicological risk	Non Carcinogenic	Potential	Non significant	
	Carcinogenic	Potential	Non significant	

- ➔ The development of a site-specific criteria for Cu and PAHs allowed to determine a targeted area for remediation around Gaspé wharf, limiting the extent of potential secondary effects from remediation actions.

- ➔ Subsequent work:
 - ✓ Rehabilitation plan and complementary analysis
 - ✓ Environmental impacts study (EIS)
 - ✓ Public Hearings