Application of a sediment quality triad approach to ascertain the causes of cadmium exceedance in the Charleroi-Brussels canal (Belgium)

***Marneffe Yves**, Carole Chalon, Aurore Claessens, Matthieu Hémart, Patricia Naport, Vincent Rollin, Corinne Verbruggen, Vicky Wrona*

Institut Scientifique de Service Public, Cellule Ecotoxicologie, rue du Chéra, 200, 4000 Liège, Belgium
(y.marneffe@issep.be)

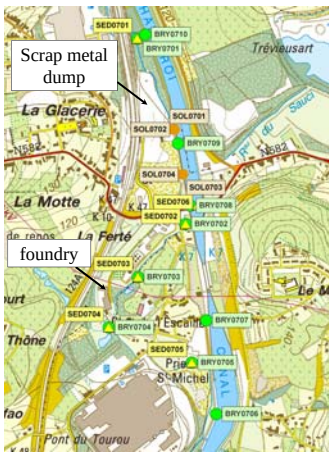
Introduction

The Daughter Directive on priority substances lays down environmental quality standards (EQS) for priority substances with the aim of achieving good surface water chemical status. In the Charleroi-Brussels canal, the cadmium concentrations measured near Gosselies often exceed the EQS in the water column (right figure). The presence of contaminated sediments acting as stock of cadmium could be an obstacle to achieve "good ecological status" for the waterbody. Moreover, in this area, the canal receive the water of two tributaries (the Piéton and the Saucy stream). Upstream of the confluence with the canal, the Piéton is canalized under a scrap metal dump and flows along a foundry. It could be a source of episodic pollution, although cadmium concentrations are not high in this tributary. To ascertain the causes of the cadmium exceedances, a sediment quality triad approach was used with the simultaneous observations of sediment chemistry, toxicity tests and the benthic community.

Material and methods

Ten stations along the canal and two tributaries were studied. Moreover, mosses that have been shown to have a good correlation between tissue concentrations of metals and the concentrations occurring in the surrounding water were placed. Sediment bioassays (*Chironomus riparius*, *Hyalella azteca* for whole samples and *Vibrio fischeri*, *Pseudokirchneriella subcapitata* and *Brachionus calyciflorus* for pore waters) were conducted to determine the potential impact of contaminated sediment. Oligochaetes were used for the evaluation of the biological quality of sediments (IOBS index, percentage of Tubificidae with and without hair setae, worm densities).

Investigative monitoring network along the canal and its tributaries

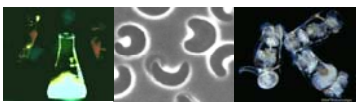


Legend
- Bryophytes caging + water sampling
- Sediment sampling sites
- Soil sampling sites

Bioassays were carried out on 4 sediment samples (3 samples from the Piéton - SED0701, SED0702, SED0705 - and 1 sample from the Canal- SED0706) except for the *Hyalella azteca* test (1 sample from the Piéton - SED0705 and 1 sample from the canal - SED0706).

Triad approach :

Test battery on pore water & **on whole sediment**



Vibrio fischeri | *Pseudokirchneriella subcapitata* | *Brachionus calyciflorus*

Chironomus riparius | *Hyalella azteca* (this test was carried out by VITO)

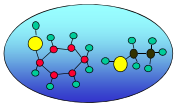
Bioindication & **caging (bioaccumulation)**

IOBS (biotic index based on Oligochaetes)

Fontinalis antipyretica

IOBS were carried out on 2 sampling sites ((1 sample from the Piéton - SED0705 and 1 sample from the canal - SED0706). Bryophytes were placed during 2 weeks at 11 points in the canal and its tributaries and heavy metals were analysed.

Chemistry



Chemical analyses were carried out on 5 sediment samples (heavy metals, PAHs, MAHs, PCBs, pesticides, inorganic substances, etc.) and twice on 11 water samples (only heavy metals). Heavy metals were also analysed in 4 soil samples from the canal bank.

Results and discussion

Bioassays and bioindication (IOBS)

	SED0701 Piéton uptream	SED0702 Piéton downstream scrap metal dump	SED0705 Piéton upstream confluence with canal	SED0706 canal WFD sampling point	
C. riparius – mortality	0%	22%	16%	46%	Whole sediment
C. riparius – growth inhibition (7 days)	-2%	19%	41%	38%	
H. azteca – mortality	-	-	45% light acute impact	77% severe acute impact	
V. fischeri – EC50 - pore water	NT	NT	13,73%	NT	pore water
P. subcapitata – g rowth inhibition EC10 - pore water	> 97,71%	7,77 %	> 97,71%	28,63 %	
P. subcapitata – growth inhibition EC50 - pore water	> 97,71%	31,31%	> 97,71%	> 97,71%	
B. calyciflorus – reproduction inhibition EC50 - pore water	> 90%	56,67%	> 90%	> 90%	
IOBS	-	-	1.6	0.2	
Quality class	-	-	bad	very bad	
Suspected pollution	-	-	Heavy metals PCB + PAH, ammonium	Heavy metals PCB	

Bioassays show that sediments sampled upstream in the Piéton (SED0701) are not toxic, whereas they are toxic downstream from the scarp metal deposit (SED0702) and the foundry (SED0705). However, the most important toxic impact is observed in the canal (SED0706) (77 % mortality of *Hyalella azteca* and 46 % mortality of *Chironomus riparius*). In the same way, IOBS (biotic index based on oligochaetes community) shows that the quality is bad in the Piéton and very bad in the canal.

	units	BRYO0700 reference Ourthe	BRYO0701 Piéton	BRYO0702 Piéton	BRYO0704 Piéton	BRYO0705 Piéton	BRYO0706 canal	BRYO0707 Canal	BRYO0708 Canal WFD sampling point	BRYO0709 Canal	BRYO0710 Canal	BRYO0711 Saucy stream
Arsenic	mg/kg	6.45	14.13	20.38	8.16	6.73	13.57	26.08	18.12	12.00	11.91	19.56
Cadmium	mg/kg	2.02	5.25	3.10	1.93	2.05	10.00	16.94	11.72	4.14	5.47	1.93
Mercury	mg/kg	0.08	0.10	0.11	0.08	0.07	0.10	0.14	0.09	0.08	0.09	0.06
Chromium	mg/kg	16.0	21.0	18.4	16.6	17.6	20.8	32.1	23.7	18.7	20.6	15.5
Copper	mg/kg	17.5	32.8	30.7	34.3	22.7	21.2	28.5	23.0	18.2	28.0	21.6
Nickel	mg/kg	79.9	101.9	47.3	70.4	55.1	67.1	354.3	241.9	128.1	173.0	82.5
Lead	mg/kg	18.5	27.5	27.4	23.6	21.1	46.7	66.9	47.6	39.4	42.1	21.9
Zinc	mg/kg	428	855	1603	731	554	408	1111	751	459	590	444

SEQ-Eau quality classes: Very good | good | medium | poor | bad

Cd in Bryophytes

Heavy metals bioaccumulation

The heavy metal concentrations (see left table) were usually higher in the bryophytes placed 15 days in the canal than in those placed in the tributaries. Based on the french classification system (SEQ-Eau), the quality is bad for Cadmium and Nickel in the canal (BRYO0707) with a decreasing gradient upstream and downstream from this point. In the Piéton, the quality is medium to good.

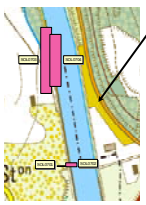
Cd in water samples

Cd in sediments	Contamination
SED0701 – Piéton upstream from the scrap metal deposit	PAH, MAHs, halogenated solvents
SED0702 – Piéton downtream from the scrap metal deposit	CN-, non polar hydrocarbons, PAH, MAHs, halogenated solvents
SED0704 – Piéton upstream from the foundry	F-
SED0705 – Piéton upstream from the confuence	F-, PAHs, MAHs
SED0706 – Canal Ch-Bxl WFD sampling point	Cadmium, non polar hydrocarbons, PAH, MAHs

Chemistry

All the sampled sediments (left table) are contaminated with hydrocarbons and micropollutants and the highest concentrations are found in the canal. Very high concentrations in cadmium (310 mg/kg DW) are measured in SED0706 whereas in the Piéton, they are about 100 times lower. In the water (right map), concentrations in removable cadmium are higher in the canal (max 23 µg/l).

In the soil samples, concentrations are locally high in the canal bank, especially downstream from the scrap metal dump (69 – 86 mg/kg DW compared to 6-10 mg/kg DW upstream). At this point, the soil is also heavily contaminated with lead, zinc and copper.



Cd in soil samples

Conclusion

The crosschecking of the ecotoxicological, bioindication and chemical data allows us to conclude that even if it is polluted, the Piéton is not the main source of the canal contamination by cadmium. The origin of the cadmium seems to be historical with a stock of polluted sediment acting as source for the contamination of the water column, without new inflow from tributaries. The contaminated canal bank could also contribute to this chronic pollution.

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