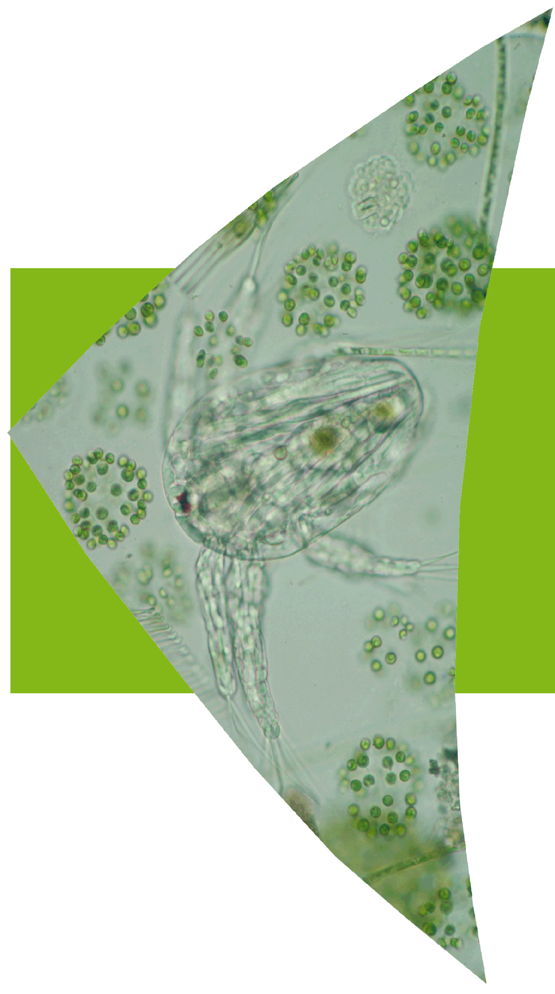

Sediment quality assessment in Ho Chi Minh City canals

T-K L Bui[1], LC Do Hong[1], T Combi[2], PA Lara-Martin[3], MC Casado-Martínez[4], I Werner[4]

[1]Vietnam National University Ho Chi Minh City, VN. [2] University of Bologna, Ravenna, IT.

[3]University of Cadiz, , ES. [4] Swiss Centre for Applied Ecotoxicology Eawag/EPFL. Lausanne, CH.

Contact: carmen.casado@centreecotox.ch

Introduction

- **Context of the study:**
  - Ho Chi Minh City metropolitan region is the largest urban and industrial hub of South Vietnam, with more than 6 million inhabitants and a large number of big factories and artisanal plants.
  - The area is characterized by a complex system of canals that play a vital role for the region and its inhabitants. They act as reservoirs for water run-off and drainage but also natural resources, and they are used for transportation.
  - Due to public health concerns an important sanitation program has been undertaken in the last decade for the reduction of wastewater pollution and flooding. At present, the main canals are recovering after clean-up and fish stock repopulation initiatives.
- **Objective:** In 2015 we carried out a pilot study to assess the quality of recent sediments from Ho Chi Minh City canals.

Figure 1: Surface sediments were collected from 6 canals, 4 of them located in the metropolitan area and 2 from suburban areas.

Material and Methods

STUDY SITES

- Tan Hoa-Lo Gom (KLG): Wastewater from industrial zone, small enterprises densely located along the canal
- Tau Hu-Ben Nghe (KTH): Domestic and industrial wastewater from small enterprises and cottage handicraft industries
- Doi (KD): Domestic and industrial wastewater from residential area, small enterprises and ship repairing workshops
- Nhieu Loc-Thi Nghe (KNL): Domestic wastewater
- Thay Cai (KTC): Wastewater from agricultural, industrial and domestic activities
- An Ha (KAH): Wastewater from domestic and agricultural activities

SEDIMENT CHARACTERISATION

- **Physico-chemistry:**
  - Granulometry, total carbon, total inorganic and total organic carbon.
  - Metals analysis
  - Organic micropollutants [1]: PCBs (#52, 101, 138, 153, 180), PAHs (16 US EPA), 16 organochlorine pesticides, 16 other pesticides, 6 organophosphate flame retardants, 13 fragances, 10 UV filters, and 4 other chemicals (triclosan, methyl-triclosan, DEET, nonylphenol).
- **Ecotoxicity:** *Myriophyllum aquaticum* (ISO 16191) macrophyte growth, 10 days; *Heterocypris incongruens* (ISO 14371) ostracod mortality and growth, 6 days; *Chironomus riparius* (AFNOR 90-339) midge larvae emergence, 28 days.

Compound	KTH	KD	KNL	KAH	KLG	KTC	SQG
PCB-101	**0.5**	**0.9**	0.1	0.1	**4.9**	**0.6**	0.5
PCB-138	**1.0**	**2.4**	0.7	0.6	**26.2**	**1.6**	1.0
PCB-153	**2.6**	**3.0**	1.0	0.8	**20.1**	**2.6**	1.5
PCB-180	**2.6**	**2.7**	**1.0**	**0.7**	**16.1**	**3.6**	0.4
PCB-52	**0.4**	**1.2**	0.1	0.0	**2.2**	**4.6**	0.1
Anthracene	24.5	37.5	11.8	29.7	**222**	**38.8**	40
Acenaphtene	0.0	6.6	0.0	0.4	12	0.4	40
Benzo a anthracene	10.3	12.5	2.0	13.1	91.5	19	120
Benzo a pyrene	35.9	137	0.0	51	97.8	55	150
Benzo b fluoranthene	31.5	53.7	19.4	36.3	**193**	46.5	170
Benzo ghi perylene	15.8	26.6	9.8	24.7	**118**	55.4	110
Benzo k fluoranthene	11.6	22.3	7.4	7.2	**82.8**	16.4	80
Chrysene	25.0	31.6	11.1	33.8	**217**	30	150
Dibenzo ah anthracene	5.3	11.5	2.9	**20.9**	**43.1**	**57.7**	20
fluoranthene	33.5	65.1	16.6	107	**331**	78.5	250
Fluorene	4.5	10.7	0.1	2.7	36.3	10.5	40
Indeno 123 cd pyrene	23.3	40.5	14.7	12.4	**164**	54.7	120
Naphtalene	18.5	21	11.4	10.8	101	16.9	176
Phenanthrene	23.9	37.8	11.8	30	**219**	38.1	180
Pyrene	37.7	72	18.4	60.4	**387**	74.2	240
Acenaphtylene	1.1	2.8	0.8	0.5	24.4	4.4	30
Alpha-BHC	0.6	0.4	0.4	0.4	0.5	0.6	
Alpha-Endosulfan	0.3	0.7	0.2	1.0	**3.5**	1.7	2.1
Alpha-HCH	2.3	2.2	2.3	2.4	**2.9**	2.2	2.9
Beta-Endosulfan	0.9	2.2	0.8	1.5	0.0	0.9	14
cis-Chlordane	**0.9**	**0.8**	**0.7**	**0.6**	**3.0**	**0.6**	0.1
Dieldrin	0.7	**2**	1.6	0.9	**5.2**	1.2	1.9
EndosulfanSulfate	1.0	1.7	1.4	1.3	**3.3**	1.4	2.1
Endrin	**3.0**	**3.3**	0.7	**2.8**	0.0	**3.2**	2.2
Gamma-BHC	0.5	0.3	0.4	0.4	0.5	0.5	2.4
Heptachlor	0.4	0.1	0.1	0.1	0.3	0.1	68
Heptachlor epoxide	0.4	0.7	0.5	0.6	1.0	0.7	2.5
Lindane	0.5	0.3	0.4	0.4	0.4	0.5	2.4
p,p'-DDD	**2.0**	**2.7**	**2.1**	**2.5**	**30.9**	**1.2**	0.6
p,p'-DDE	**1.9**	**3.4**	**1.9**	**2.1**	**21**	**0.6**	0.3
p,p'-DDT	0.0	0.0	0.0	0.0	**22.1**	0.0	5.3
trans-Chlordane	**0.8**	**0.8**	**0.6**	**0.4**	**2.7**	**0.6**	0.1
Ametryn	1.0	1.2	1.2	1.2	0.0	2.1	
Bifenthrin	**22.6**	**17.9**	**8.6**	**142**	**39.3**	**477.6**	0.2
Terbuthylazine	0.3	0.3	0.4	0.5	0.0	0.0	2.7
Terbutryn	0.7	0.6	0.7	0.9	2.5	0.5	8
Atrazine	0.7	1.7	0.7	0.7	0.0	1.1	6.6
Carbophenothion	2.6	4.2	3.8	3.4	6.8	3.4	
Parathion	4.2	5.8	4.1	5.7	10.4	6.5	
Permethrin-cis	**343**	**777**	**578**	0.0	0.0	**52.8**	0.4
Permethrin-trans	**181**	**178**	**266**	**1.5**	**3693**	**24.5**	0.4
Phenothrin	37.9	45.1	15.9	0.0	0.0	19.7	
Prometryn	3.8	2.3	1.4	0.9	28.6	2.0	400
Simetryn	1.0	1.0	0.9	1.0	1.3	1.3	
Chlorpyrifos	9.1	4.2	1.9	2.1	**38.8**	3.4	5.2
Irgarol	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	0.04
Fenvalerate-a	5.3	5.8	7.5	4.3	0.0	3.3	
Malathion	**2.0**	**2.6**	**2.5**	**2.4**	**3.2**	**2.4**	0.2
Tributylphosphate iso	1.0	1.0	1.4	1.2	1.8	1.4	
Triphenylphosphate (TPP)	3.8	7.3	4.7	2.1	48.7	2.3	1856
TRIS 2 ETHYL HEXYL PH	8.1	13.8	8.5	5.6	51.5	8.6	
TRIS O TOLYL PH	0.9	1.2	1.0	0.9	0.0	0.5	
TRIS P TOLYL PH	2.5	4.5	3.4	3.6	1.0	3.4	
TBP N	5.3	6.8	11.9	9.1	12.3	6.3	
OTNE	88.2	200	126	42.2	1293	38.2	
Galaxolide	96.4	166	47.9	6.5	2675	5.0	
Celestolide	1.7	1.7	1.6	0.9	21.8	0.9	
Cashmeran	5.5	4.7	21.7	4.7	24.2	6.8	
Muscone	0.0	0.0	0.0	0.0	0.0	0.0	
Musk R1	0.3	1.2	0.7	0.1	0.0	0.0	
Musk ambrette	2.1	1.6	1.3	1.3	2.0	2.2	
Musk ketone	2.1	2.1	1.4	1.5	6.1	1.6	
Musk moskene	2.4	3.1	2.6	2.7	3.5	2.6	
Musk tibeten	1.2	1.8	1.6	0.9	0.0	1.6	
Musk xylene	2.5	0.8	2.4	1.8	1.3	3.5	
Pantholide	2.6	3.8	2.6	2.8	33.2	2.8	
Tonalide	34.6	29.9	29.5	4.5	0.0	0.0	
2-EHDP	20.9	39.2	22.5	11.1	**205**	8.4	180
2-OHBP	0.0	0.0	0.0	0.0	0.0	0.0	
3-OHBP	1.4	1.6	1.5	1.6	1.2	0.8	
4-MBC	5.5	12.5	5.7	11.5	**55.7**	11	42.7
4-OHBP	0.9	2.9	0.0	2.7	0.0	3.4	
BP-10	0.1	0.7	1.2	1.6	0.0	0.0	
BP-3	0.3	0.8	1.4	1.6	0.0	0.0	
EHMC	14.9	21.6	13.2	10.1	341	16.2	
EHS	0.2	0.0	4.0	2.1	0.7	0.0	
Octocrylene	65.2	105.4	63.2	13.5	588	55.4	
Triclosan	22.7	7.9	13.6	2.1	**346**	1.6	23.1
Methyl triclosan	0.8	0.1	0.0	0.0	2.0	0.0	
Nonylphenol	**124**	**166**	**59.8**	**143**	**997**	21.4	24.9
DEET	1.7	0.7	1.4	1.8	3.9	1.7	298.3

Table 2: Average concentrations in ng/g dry weight (n=2). Sediment quality guidelines (SQG) from several sources included.

Results and Discussion

PHYSICO-CHEMISTRY AND RISK ASSESSMENT

- **Sediment properties (Table 1):**
  - Fine sediment content ranging from 49% (KNL) to 97% (KD) and TOC ranging from 1% (KNL) to more than 5% (KTC, KAH).
- **Metal concentrations (Table 1):**
  - C > PEC: KLG (Cr, Cu, Ni), KTC (Cr) and KD (Ni).
  - C > TEC: KTH (Cr, Cu, Ni), KAH (Cr)
  - C < TEC: KNL
- **Organic micropollutants (Table 2):**
  - PCBs > SQG: KLG >> KTC > KD > KTH > KNL ~ KAH
  - PAHs > SQG: KLG >> KTC ~ KD > KAH > KTH >> KNL
  - Highest concentrations of most other compounds at KLG.
  - C >> SQG: bifenthrin, permethrin, nonylphenol, at KLG also triclosan, chlorpyrifos and p,p'-DDT.
  - C > SQG: chlordane, p,p'-DDD, p,p'-DDE, irgarol, malathion
  - Fragances: higher concentrations of OTNE, galaxolide, cashmeran and tonalide (no available SQG)
  - UV filters: C > SQS for 2-EHDP and 4-MBC for KLG and high concentrations of octocrylene and EHMC (no SQG).

Table 1: Grain size distribution (%) and total organic carbon (TOC, %) and preliminary metal concentrations measured in whole sediment (mg/kg d.w.). TEC: threshold effect concentration; PEC: probable effect concentration [2].

Canal	Clay	Silt	Sand	TOC	Co	Cr	Cu	Ni	Zn
KD	54.9	42.1	2.9	3.02	23.9	**106**	**70.5**	**51.8**	**183**
KLG	21.9	56.8	21.3	2.72	17.6	**207**	**213**	**77.3**	**412**
KNL	30.7	18.3	51.0	1.08	9.6	31.7	21.7	8.5	89.7
KAH	55.5	30.7	13.8	5.21	14.4	**47.3**	27.7	21.2	67.5
KTH	36.5	26.6	36.9	2.88	13.5	**57.3**	**34.6**	**28.0**	116
KTC	42.7	29.5	27.8	5.11	25.2	**159**	**43.7**	**36.4**	**344**
TEC						43.9	31.6	22.7	121
PEC						111	149	48.6	459

Table 3: Average percentage of effect for each sample and endpoint. M: mortality; GI: growth inhibition; EI: emergence inhibition; TT: toxicity threshold used to classify samples as toxic. Toxicity is bolded. Color codes according to the % effect for each endpoint included below.

Species	Endpoint	TT	KD	KLG	KNL	KAH	KTH	KTC
H. incongruens	M	20	**80**	**92**	**23**	**100**	**45**	**100**
	GI	35 [3]	**55**	16	**38**	**100**	**31**	**100**
M. aquaticum	GI	20 [4]	-26	11	-17	-14	-41	-13
C. riparius	EI	67 [5]	13	22	17	17	3	**52**

% Effect	0-20	20-35	35-50	50-80	> 80
Class	Not toxic	Slightly toxic	Moderately toxic	Distinctly toxic	Highly toxic

ECOTOXICITY ASSESSMENT

- All sediments were toxic to the ostracod *H. incongruens*, with the lowest mortality for KNL, the sample with the lowest contamination level (Table 3).
- High mortality of ostracods exposed to KAH and KTC, this last sample being the only one causing significant effects in the *C. riparius* emergence test. These two samples had very high concentrations of the pyrethroid insecticide, bifenthrin.
- Higher growth rates of *M. aquaticum* exposed to all sediments than in controls except sample KLG, the canal with the highest contamination level.

Conclusion

✓ Levels of metals and organic micropollutants above quality criteria ⟶ risk to benthic communities.

✓ Incidence of toxicity is species specific, with highest sensitivity of crustacean ostracods.

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