Intersol' 2011 International Conference-Exhibition on Soils, Sediments and Water

# Ecotoxicological risk assessment of a scenario of terrestrial quarries filled with marine sediments using short-term and long-term laboratory microcosm assays

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**Harbour marine sediments :**

- French coast : 6500 km
- Harbour dredging : maintenance, deepening, construction of new areas = $50.10^6$ t/year (among which $10.10^6$ t/year contaminated)
- Clapping is not allowed for highly contaminated sediments
- Hence sediments must be managed on land
- Treatment and valorization, or dumping

One of re-use options : filling of former terrestrian cavities (quarries, diggings, mines, industrial wastelands, …)

**SEDIGEST**, standing for GESTion durable des SEDIments des ports (Sustainable management of harbour sediments), aims to develop a methodology of ecological risk assessment relative to a scenario of quarry infill and restoration schemes.

**SEDIGEST PROJECT PARTNERS :**

**Research centres :** ENTPE, INSA Lyon, BRGM, INERIS, CETMEF

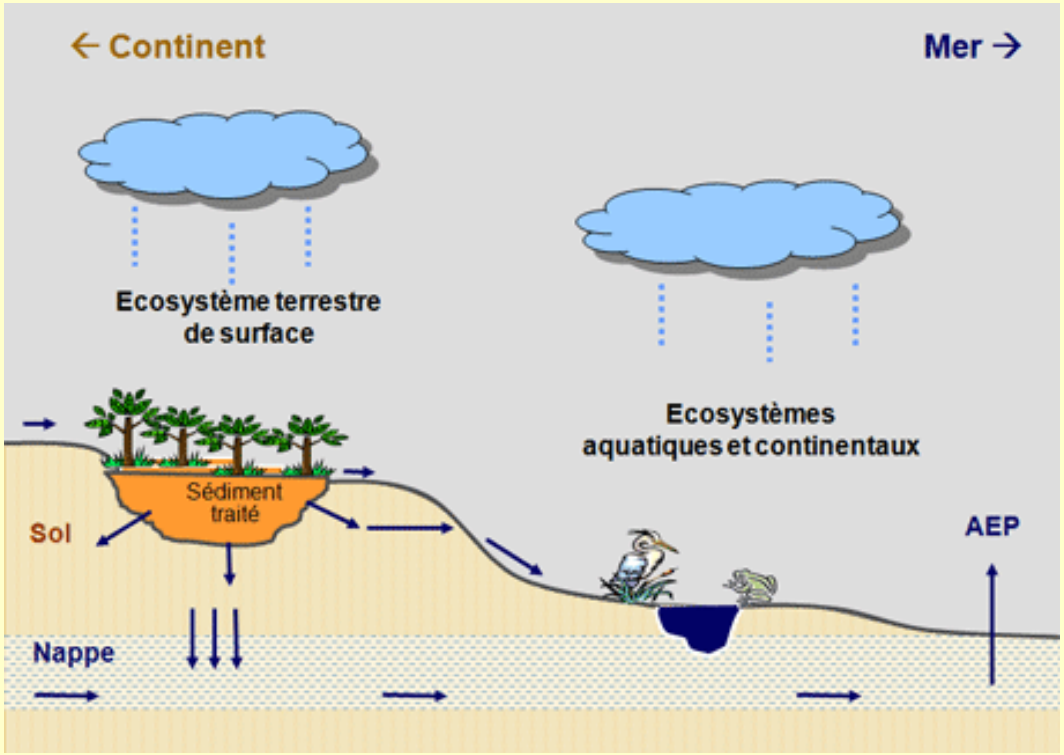
**Companies :** IN VIVO Environnement, EEDEMS, POLDEN-INSAVALOR

**Local authorities** : Var departmental council, Finistère departmental council

**SEDIGEST scientific objectives :**

To study ecological impacts of this option in terms of :

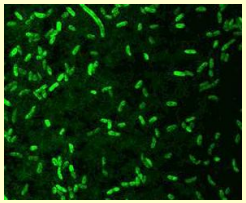
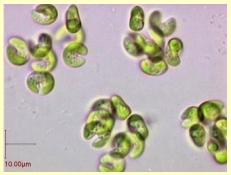
- pollutant flux emissions (leachates)
- pollutant transfer towards soils and ground waters
- ecotoxicological impacts on terrestrian and aquatic ecosystems



## Assessing effects on aquatic ecosystems

## (Workshop 3, Task 8)

- short-term single-species tests (Bacteria, Daphnids, Rotifers, Algae)

- cyto- and genotoxicity tests (fish cell lines)

- 21-day laboratory 2-L microcosm assays (3 leachates)
- 60-day laboratory 40-L microcosm assays (1 leachate)

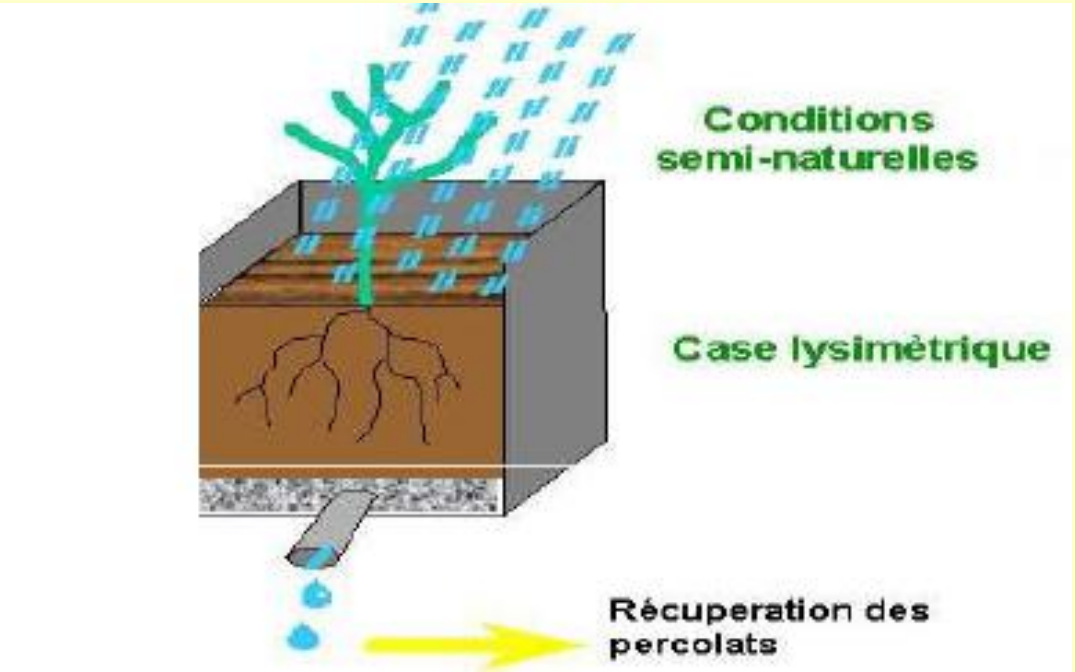
# Studied sediments

| Sediments | Contamination level | Treatment |
|---|---|---|
| SEDIMENT 1 | contents > N2 in trace metallic elements, PAHs, BPC | 5-month bioremediation |
| SEDIMENT 2 | contents > N2 in trace metallic elements, PAHs, BPC | Sand removal + 4-month bioremediation |
| SEDIMENT 3 | contents > N2 in trace metallic elements, PAHs<br>N1 < BPC contents < N2 | 5-month bioremediation + storing + lime and hydraulic binder treatment |

Bioremediation on SEDIMARD platform

# MATERIALS & METHODS

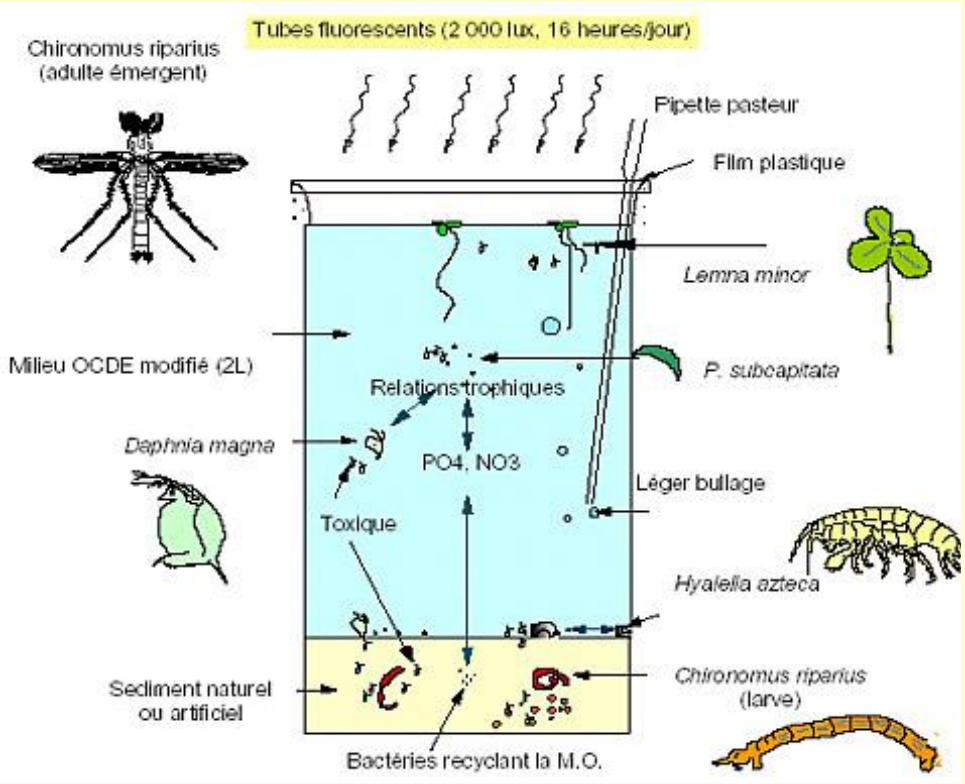
# Production of leachates using lysimeters




Weekly collection of leachates and mixing of percolates of same month

Physico-chemical analyses (salts, ETM, organic contaminants, …)

# Methodology of 2-L laboratory microcosm assays




**Benefits :**

* Exposure 21 days
* Interactions between populations
* Several acute/chronic endpoints
* 3 replicates/concentration
* Protocol validated on MSW percolates, contaminated sediments, toxic substances

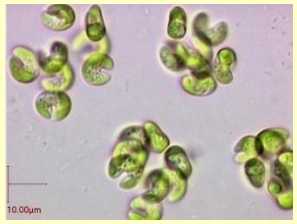
**Study of first-month leachates**

**Tested concentrations :**

* 1-5-10% (vol/vol) leachates SED1 and SED2
* 0.1-0.5-1.0% leachate SED3

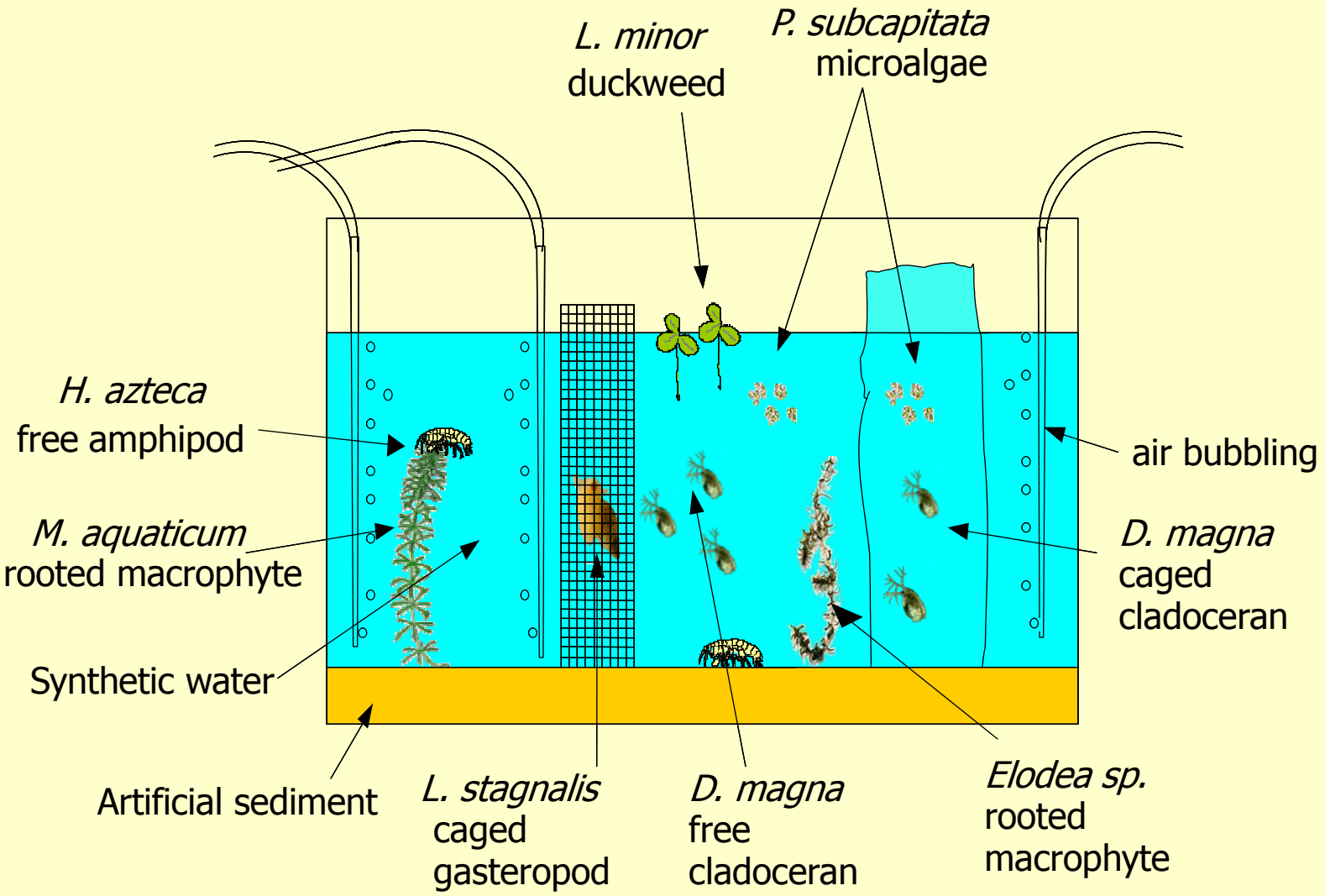
# Methodology of 2-L laboratory microcosm assays

**Parameters monitored :**

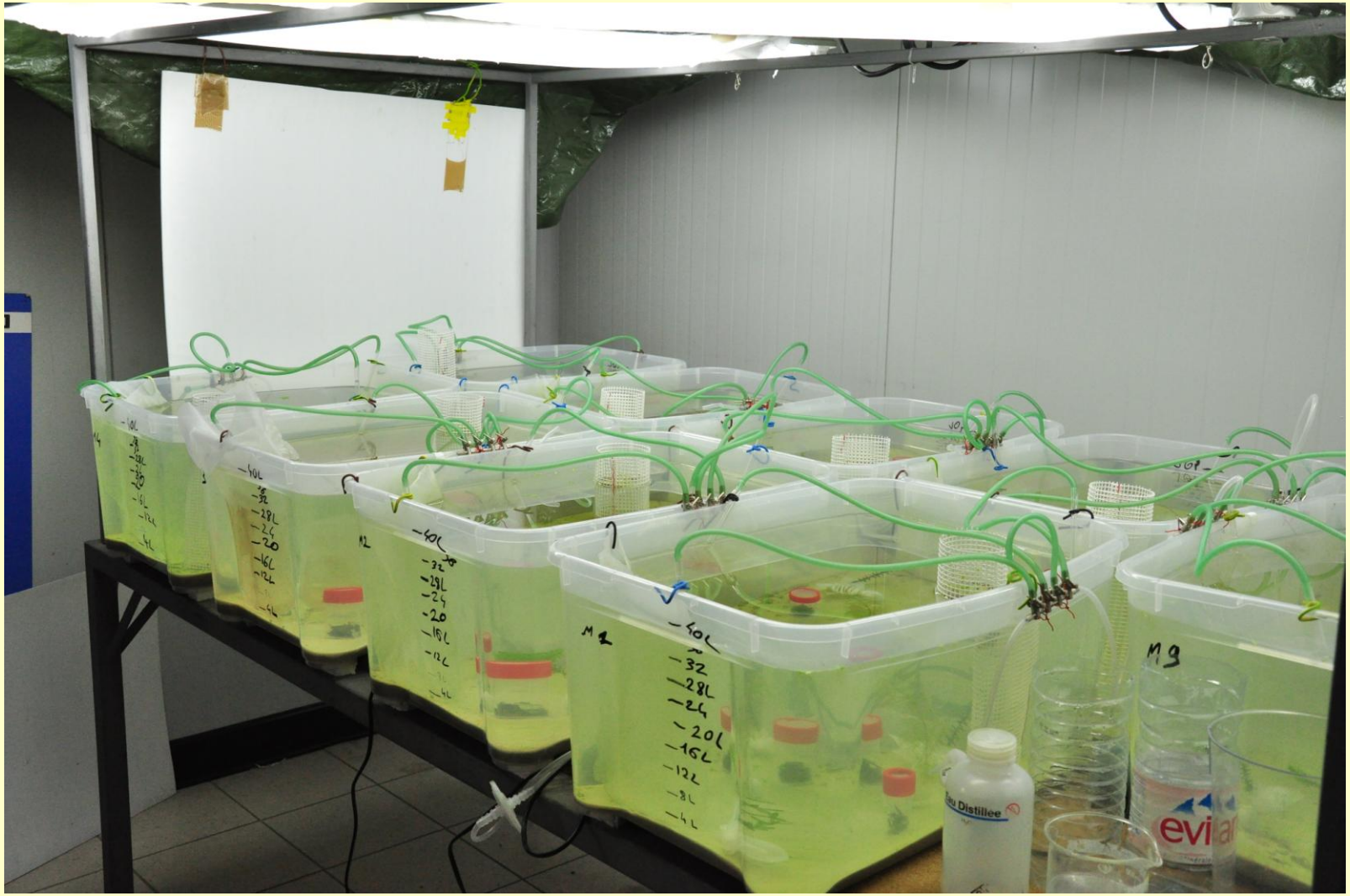


* pH, O2, cond, trace metallic elements
* Algae water column : growth (A685)
* Duckweeds : growth
* Daphnids : growth, reproduction, survival
* Amphipods : growth, survival
* Chironomids : growth, emergence

# Methodology of 40-L laboratory microcosm assays



# Methodology of 40-L laboratory microcosm assays



# Methodology of 40-L laboratory microcosm assays

| | |
|---|---|
| Sediment | artificial |
| Water | synthetic |
| Duration | 2 months |
| Number of replicates | 5 controls + 4 "1%" |
| *In situ* daphnids | Population monitored 2 months |
| *Ex situ* daphnids | Survival and reproduction on 3 generations |
| *In situ* amphipods | Population monitored 2 months |
| Pond snails | Survival, growth and reproduction 2 months |
| Microalgae | Growth at the beginning |
| Duckweeds | Growth 2 months |
| Rooted macrophytes | Growth 2 months |

# RESULTS

# Physico-chemical composition of tested leachates

| Percolate | SEDIMENT 1 | SEDIMENT 2 | SEDIMENT 3 |
|---|---|---|---|
| L/S cumulated (L/kg) | 0.083 | 0.061 | 0.052 |
| pH | 7.03 | 7.07 | 12.36 |
| Conductivity (µS/cm) | 33500 | 37700 | 23600 |
| Element (mg/L) | | | |
| Calcium | 734 | 834 | 834 |
| Cadmium | - | - | - |
| Chromium | - | 0.043 | 0.194 |
| Copper | 0.515 | 0.642 | 18.8 |
| Iron | 0.184 | 0.037 | - |
| Potassium | 328 | 340 | 428 |
| Magnesium | 1536 | 2119 | <0.01 |
| Molybdenium | 0.117 | - | 0.767 |
| Sodium | 6601 | 7691 | 4228 |
| Nickel | 0.045 | <0.06 | 0.522 |
| Lead | 0.137 | <0.25 | <0.25 |
| Phosphorus | 0.32 | 0.28 | 0.46 |
| Sulfur | 2781 | 3250 | 110 |
| Zinc | 3.51 | 2.27 | 0.036 |
| Chloride | 10890 | 12310 | 5842 |
| Nitrate | 6.97 | 265 | 10.2 |
| Sulfate | 6871 | 8443 | 64.3 |
| Ammonium | 1.09 | <0.2 | 2.17 |
| TOC | 157 | 416.5 | 1418.4 |

# Physico-chemical composition of tested leachates

**Organic contaminants (PAHs, BPC, MBT, DBT,TBT, pesticides)** :

* most often < Detection Limits

* except DBT and TBT for SED3 (respectively 7 and 119 µg/L)

# Response of 2-L microcosms

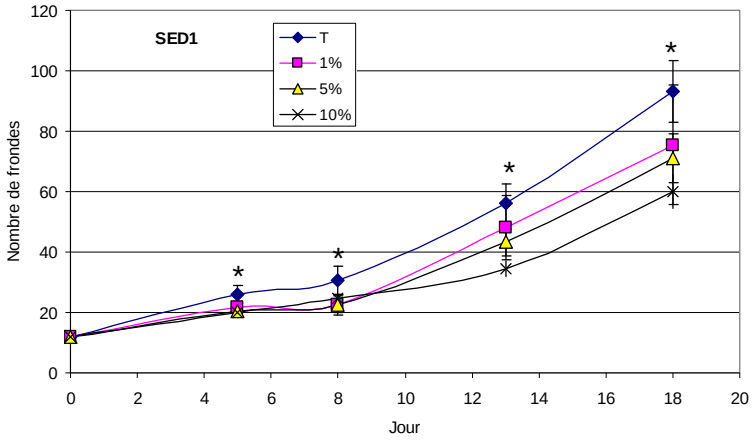
(1, 5 and 10% leachate of SED1 and SED2

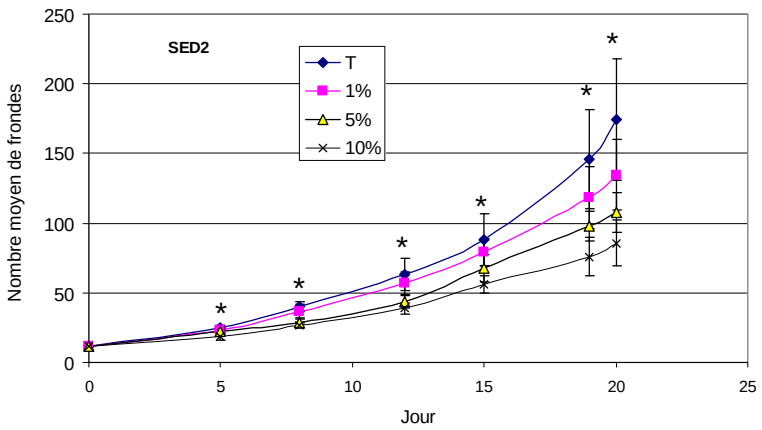
0.1, 0.5 and 1.0% leachate of SED3

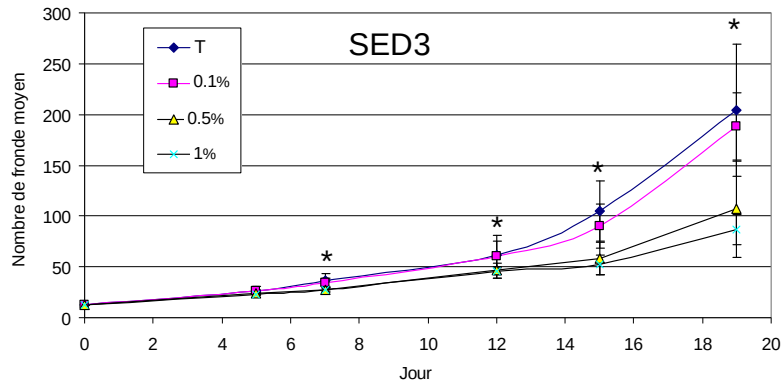
Exposure 3 weeks)

# Response of 2-L microcosms

**Inhibition of duckweed growth at 5 and 10% for SED1, SED2 and at 0.5 and 1.0% for SED3**



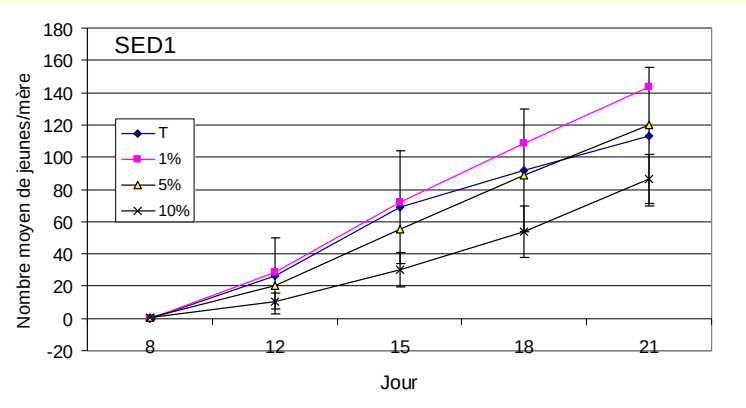



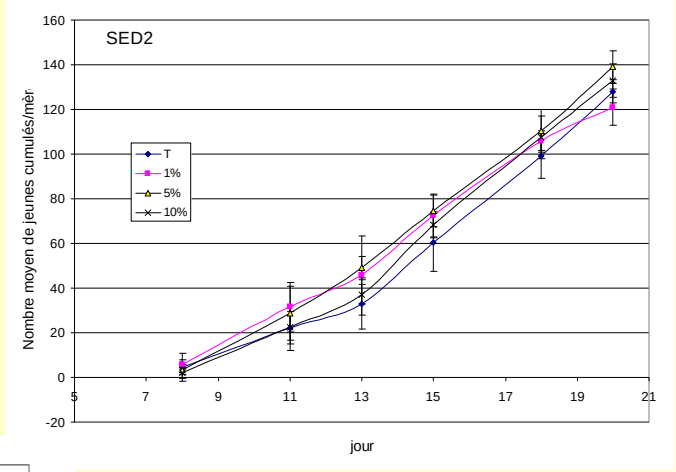



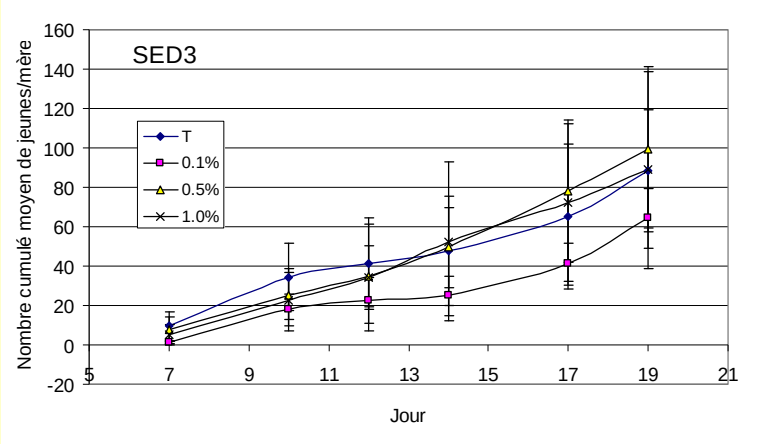

Duckweed growth in assays on SED1, SED2 and SED3

# Response of 2-L microcosms

## No effect on daphnids (survival, reproduction, growth)



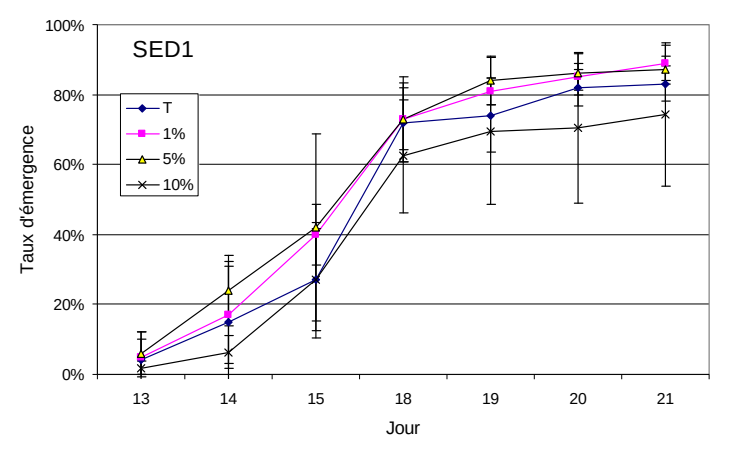



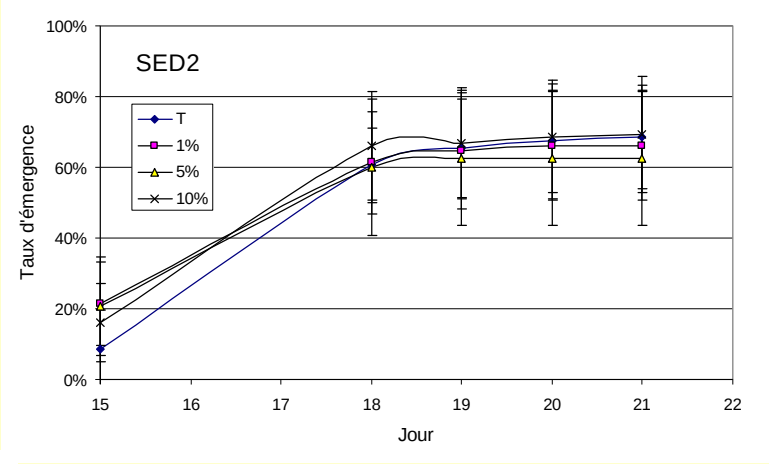



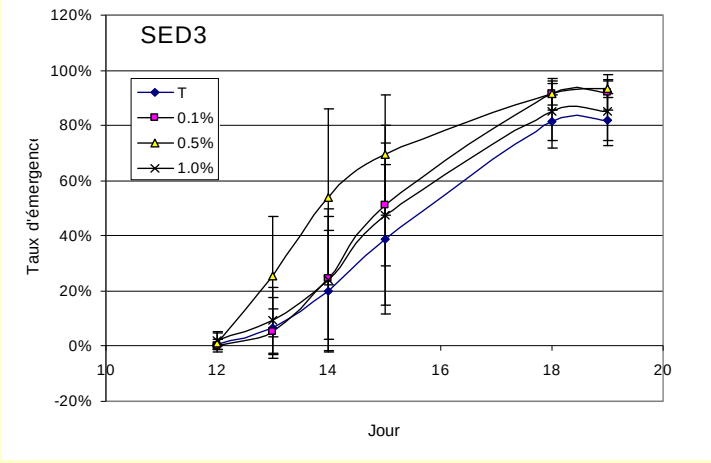

Daphnid reproduction in assays on SED1, SED2 and SED3

# Response of 2-L microcosms

## No effect on chironomid emergence



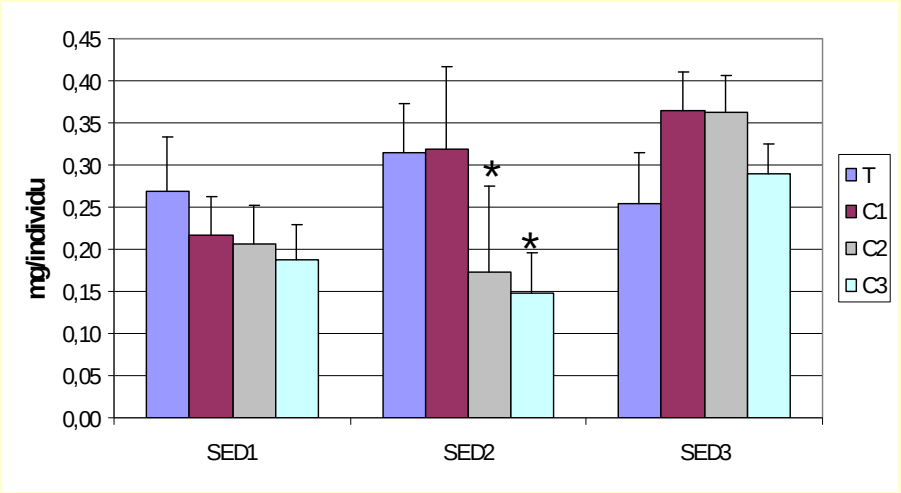



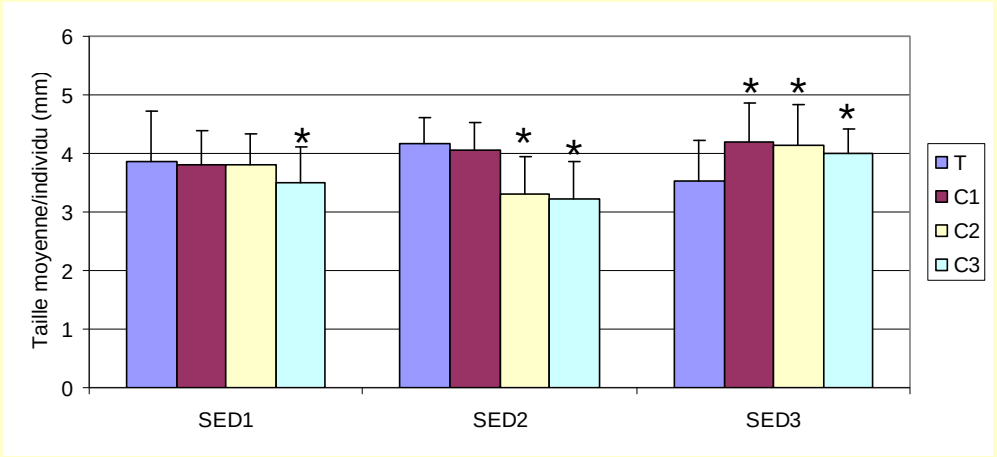




*Chironomus riparius* emergence rates in assays on SED1, SED2 and SED3

# Response of 2-L microcosms

**Amphipods : no effect on survival, but growth inhibited (SED1, SED2) or increased (SED 3)**




Final individual size and dry weight of *H. azteca* in assays on SED1, SED2 and SED3

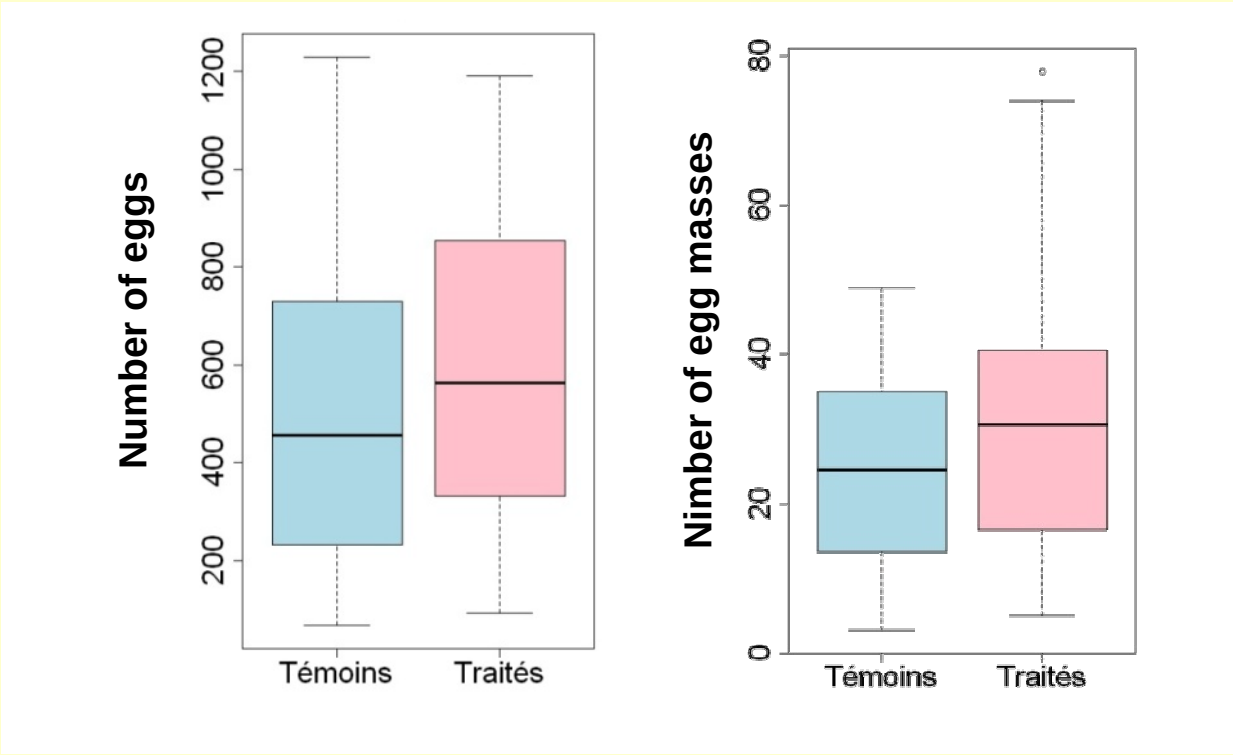
# Response of 40-L microcosms

(1% leachate of SEDIMENT2

Exposure 2 months)

# Response of 40-L microcosms : gasteropods

**No effects on snails survival, growth and reproduction (1st and 2nd generations)**

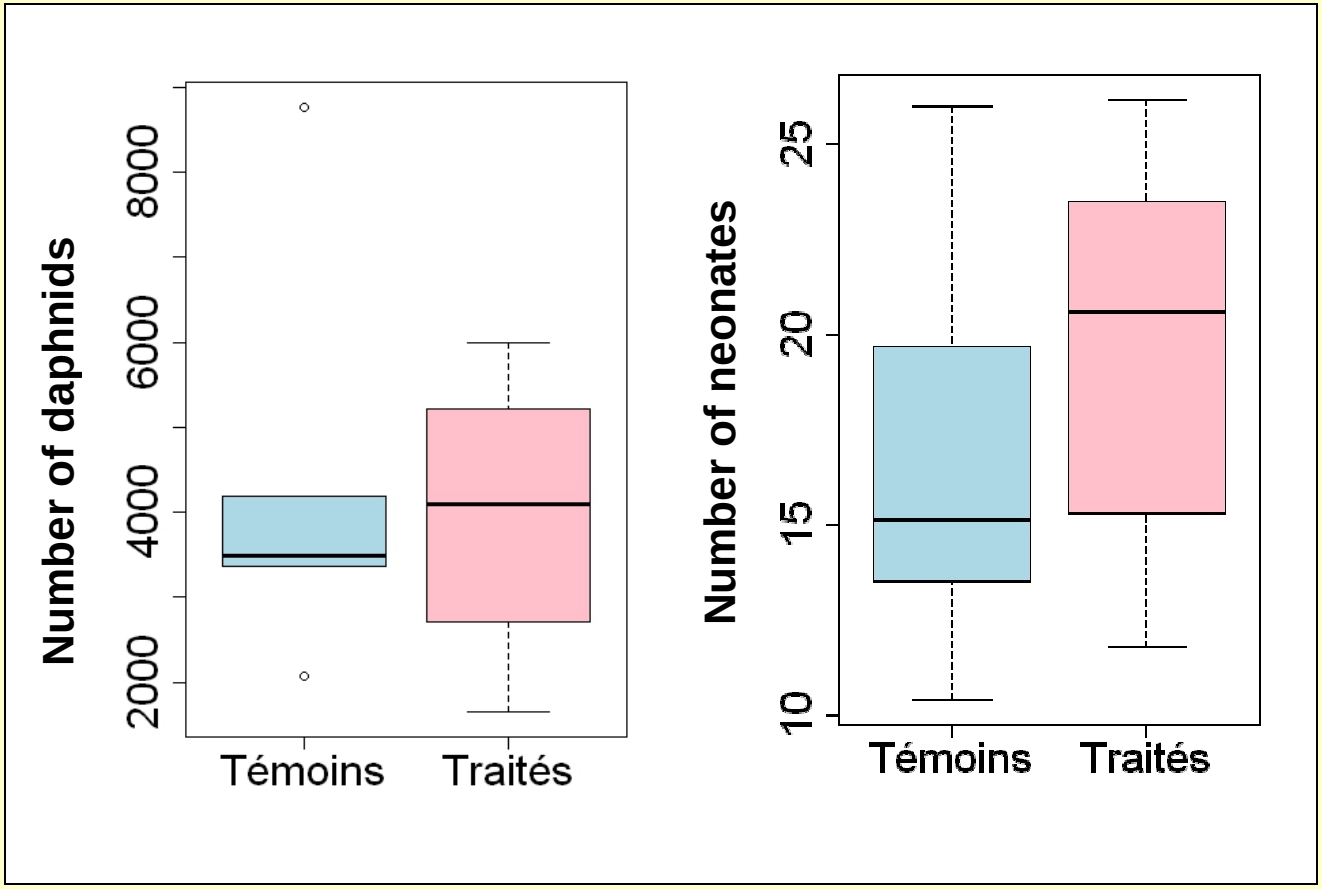



Controls

1% leachate

# Response of 40-L microcosms : daphnids

**No effects on population development in microcosms, no effects on reproduction of *ex situ* daphnids (mean on 3 generations)**

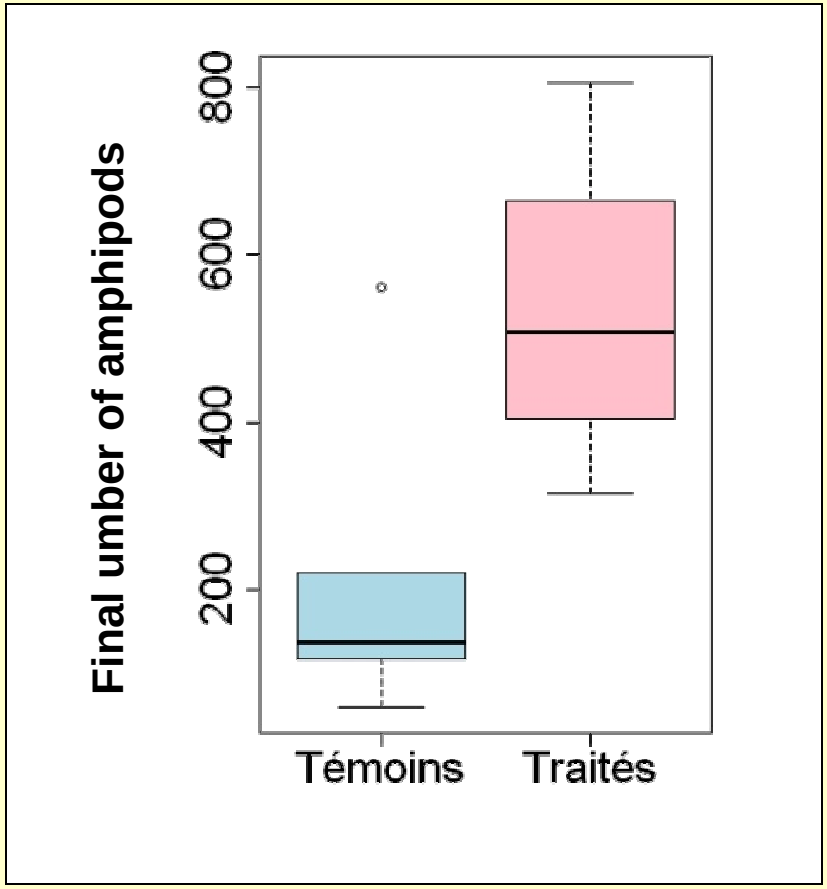



Controls

1% leachate

# Response of 40-L microcosms : amphipods

**No effects on population development in microcosms (means not different at p = 5%, Student test)**

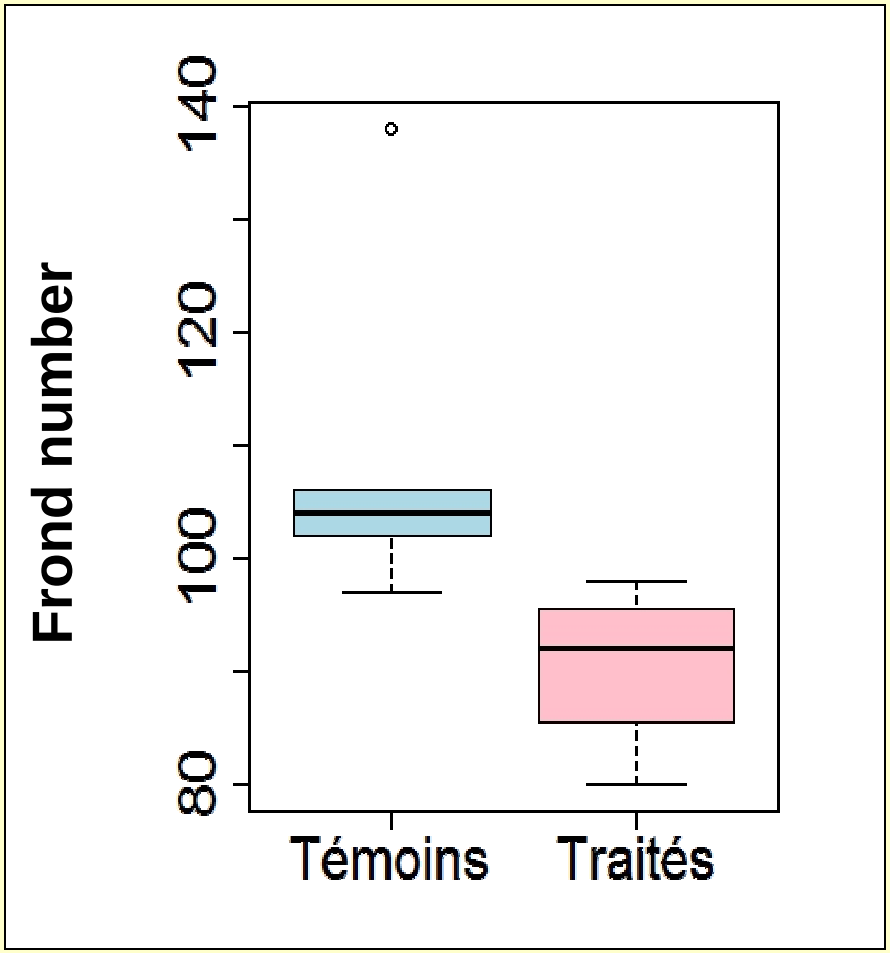



Controls

1% leachate

# Response of 40-L microcosms : duckweeds

No effects on duckweed frond number, but significantly lower number of colonies in contaminated microcosms

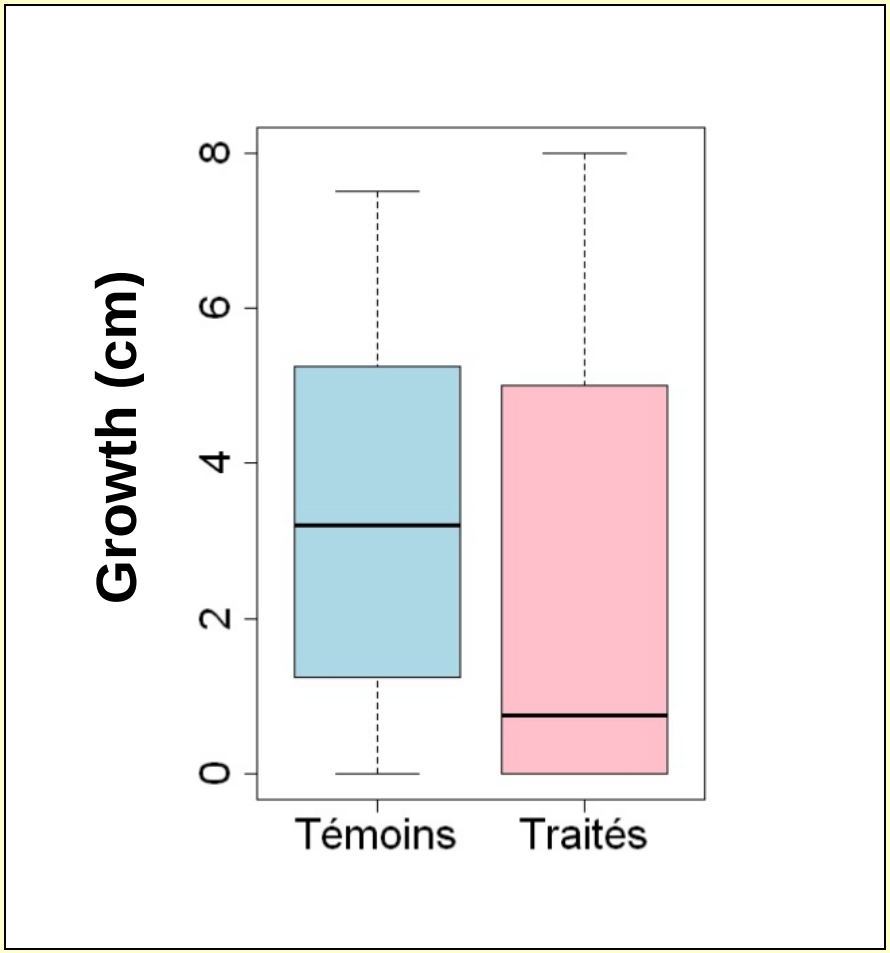



Controls

1% leachate

# Response of 40-L microcosms : rooted macrophytes

## No effects on growth of rooted macrophytes




Controls

1% leachate

# DISCUSSION

# Summary of microcosms results

## 2-L microcosms (conc 0.1- 10%, 3 leachates, 21 days)

- 2 species (duckweeds, amphipods) impaired out of 5
- NOEC microcosm : 1% for SED1 and SED2, 0.1% for SED3

## 40-L microcosms (conc 1%, 1 leachate, 2 months)

- 1 species (duckweeds) impaired out of 6
- NOEC microcosm : slightly < 1% (SED2)

# 2-L and 40-L microcosms for leachate of SED2 (1%)

| | 2 L | 40 L |
|---|---|---|
| Duration of exposure | 3 weeks | 8 weeks |
| Daphnid survival | No effect | No effect |
| Final size of daphnids | No effect | No effect |
| Final mass of daphnids | No effect | not measured |
| Daphnid reproduction | No effect | No effect |
| Amphipod survival | No effect | No effect |
| Final size of amphipods | No effect | not measured |
| Final mass of amphipods | No effect | not measured |
| Duckweed frond number | No effect | No effect |
| Duckweed colony number | No effect | Slight inhibition |
| Final mass of duckweeds | No effect | No effect |
| pH water column | No effect | No effect |
| Conductivity water column | multiplied by 2.7 | multiplied by 2.2 |
| Metals water column | No effect | slight increase Cu and Ni first week |
| Organics water column | nominal contents < DL | nominal contents < DL |
| Metals sediment | No effect | No effect |

# Links between contamination and effects ?

- toxicity of TBT for SED3 ? [TBT] = 0.2-2 µg/L > PNEC (0.02 µg/L)
- daphnids not sensitive to NaCl (LOEC : 7 g/L)
- but [Me] > PNEC (ex : Cu) : bioavailability reduced by complex matrix (calcium, magnesium, organic matter)
- chironomids not sensitive : sediment contamination low
- amphipods : impaired or improved growth ; [Me] > PNEC, pelagic and epibenthic invertebrate
- duckweeds : no direct effect of salinity ; joint effect of metals (Cu) and salinity ?

# CONCLUSION

* Risks for the peripheric ecosystems will depend on the characteristics of the sediments burried and the leaching behaviour

* But for the leachates a high salinity (chlorides, sodium, sulfates) and presence of heavy metals (Zn, Cu) and organic matter are in all cases expected

* For aquatic ecosystems receiving percolates, it seems that a dilution factor > 10 000x (conc 0.01%) will ensure their protection

* However, it is likely that repeated discharges will increase the risks due to accumulation of pollutants and increase of salinity (depending on the scenario)

# THANK YOU FOR YOUR ATTENTION

Site of this ANR project : www.sedigest.fr