THE USE OF THE SEDIMENT QUALITY TRIAD FOR QUALITY ASSESSMENT OF FRESHWATER SEDIMENTS IN NORTHERN SPAIN

Zuriñe Maestre, Pilar Rodriguez and Maite Martinez-Madrid

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OBJECTIVES

- To provide a screening-level ecological risk assessment of freshwater sediments using 3 Lines of Evidence: Sediment Chemistry, In-situ Alteration and Sediment Toxicity

- To evaluate the contribution of sediment toxicity data and Sediment Quality Triad (SQT) to the Ecological Status assessment performed by Spanish Water Authorities

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Water Quality Surveillance Networks
- Environment and Territorial Planning Dept of the Basque Government
- Housing and Territorial Planning Dept of the Navarra Government
- Ebro Hydrographical Confederation
- Northern Hydrographical Confederation

Water Authorities provided data on sediment chemical concentration and/or benthic community data for 60 sites (2004-06)

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Sediment Chronic Toxicity Test

*Tubifex tubifex* (Annelida, Clitellata) 28-day sediment chronic bioassay

Endpoints:
- **%Survival**
- **CCAD** (N. of cocoons/adult)
- **%Hatch** (N. empty cocoons/N. total cocoons)
- **YGAD** (N. young/adult)
- **TGR** (Total Growth Rate, mg dw d⁻¹, somatic and reproductive biomass)

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Sediment Chronic Toxicity Test

*Tubifex tubifex* (Annelida, Clitellata) 28-day sediment chronic bioassay

**EXPOSURE CONDITIONS**
- 22.5 ± 0.5°C
- in the dark
- Test chamber: 250 ml
- Sediment volume: 100 ml, sieved through 500 µm mesh
- Overlying dechlorinated water: 100 ml. No water renewal

- Slight aeration
- 4 mature worms per chamber
- 6-7 weeks old
- Fed with trout flakes

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**LOE 1: *In situ* Alteration - Biota**

Ecological Quality Ratio (EQR) for IBMWP = \( \frac{\text{Observed value}}{\text{Reference Condition Value in each ecoregion}} \)

- **EQR close to 1**
  - **Very Good status**: No or very minor deviation from the reference condition (RC)
  - **Good status**: Slight deviation from the RC
  - **Moderate status**: Moderate deviation from the RC
  - **Poor status**: High deviation from the RC
  - **Bad status**: Very High deviation from the RC

- **EQR close to 0**

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LOE 1: *In situ* Alteration- Habitat

**METRICS**

- QBR: a riparian wood index (Munné et al. 1997) that includes both river-bed and riparian wood characteristics analyses.
- Hydro-morphological alterations (H-A): assess river continuity, hydrological regime, hydrodynamics, and so on.

<table>
<thead>
<tr>
<th>TRIAD ordinal ranking</th>
<th>-</th>
<th>±</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat Alteration</td>
<td>No or slight alteration</td>
<td>Moderate alteration</td>
<td>High or extreme alteration</td>
</tr>
</tbody>
</table>

In situations where habitat alterations are detected, reliance must be placed on the sediment toxicity (Chapman 2007)

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LOE 2: Sediment Toxicity

Procedure to establish the reference condition for the *T. tubifex* sediment bioassay endpoints:

**IBMWP - EQR**

**First step:** Select “Possible” reference sites

**Second step:** Apply criteria for excluding altered reference sites (Reynoldson et al. 2002):
- sites with less than 50% survival
- sites with 2 or more sublethal endpoints below the 5th percentile

**Third step:** Establish 3 categories of toxicity for each endpoint to classify test-sediments

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LOE 2: Sediment Toxicity

**CATEGORIES OF RESPONSE TO SEDIMENTS**

<table>
<thead>
<tr>
<th>Category</th>
<th>%Survival</th>
<th>CCAD</th>
<th>%Hatch</th>
<th>YGAD</th>
<th>TGR</th>
<th>TRIAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Toxic</td>
<td>&gt;76.0</td>
<td>&gt;6.5</td>
<td>&gt;11.2</td>
<td>&gt;2.8</td>
<td>&gt;0.83</td>
<td>-</td>
</tr>
<tr>
<td>Potentially Toxic</td>
<td>75.0-61.3</td>
<td>6.4-5.7</td>
<td>11.1-6.1</td>
<td>2.7-1.5</td>
<td>0.82-0.39</td>
<td>±</td>
</tr>
<tr>
<td>Toxic</td>
<td>&lt;61.2</td>
<td>&lt;5.6</td>
<td>6.0</td>
<td>1.4</td>
<td>0.38</td>
<td>+</td>
</tr>
</tbody>
</table>

Reference-sites endpoint values distribution

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LOE 3: Bulk-sediment metal concentration

No SQG for the study region

Test Effect-based SQG developed for other regions:

- Consensus-based PEC (USEPA, 2000; MacDonald et al. 2000),
- PEL (NOAA, 2006; Canadian Environmental Guidelines, 2003),
- RV-Y (Flanders, ANZECC, 1997-2008),

Consensus-based PEC was the SQG that best predicts samples as Non-toxic or Toxic

(following methodology described in Vidal & Bay 2005)

<table>
<thead>
<tr>
<th>Criteria (based in Chapman &amp; Anderson 2005)</th>
<th>Assessment</th>
<th>TRIAD ordinal ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Metal concentrations &lt; TEC</td>
<td>Adverse effects unlikely</td>
<td>-</td>
</tr>
<tr>
<td>≥1 metal concentration &gt; TEC</td>
<td>Adverse effects may / may not occur</td>
<td>±</td>
</tr>
<tr>
<td>≥1 metal concentration &gt; PEC</td>
<td>Adverse effects likely to occur</td>
<td>+</td>
</tr>
</tbody>
</table>

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## RESULTS

### SEDIMENT QUALITY TRIAD (SQT) decision matrix

<table>
<thead>
<tr>
<th>Bulk Sediment Metal Concentration</th>
<th>Adverse effects unlikely</th>
<th>Adverse effects may or may not occur</th>
<th>Adverse effects likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Toxicity (Survival, Growth &amp; Reproduction)</td>
<td>Negligible response</td>
<td>Potential response</td>
<td>Significant response</td>
</tr>
<tr>
<td>In-situ Alteration: Benthos (IBMWP) Habitat (QBR,H-A)</td>
<td>Equivalent to the reference condition</td>
<td>Possibly different from the reference condition</td>
<td>Different or very different from the reference condition</td>
</tr>
<tr>
<td>TRIAD ordinal ranking</td>
<td>-</td>
<td>±</td>
<td>+</td>
</tr>
</tbody>
</table>
## Decision matrix for WOE categorization: Examination of 5 scenarios

<table>
<thead>
<tr>
<th>Sediment</th>
<th>Metal Conc.</th>
<th>Toxicity</th>
<th>In situ Alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surv.</td>
<td>Growth</td>
<td>Reprod.</td>
</tr>
<tr>
<td>ZAY 018</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OKMA 040</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RCVA 178</td>
<td>±</td>
<td>-</td>
<td>A</td>
</tr>
<tr>
<td>OI 102</td>
<td>+</td>
<td>-</td>
<td>B</td>
</tr>
<tr>
<td>URS 34</td>
<td>±</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>SP 18</td>
<td>+</td>
<td>-</td>
<td>C</td>
</tr>
<tr>
<td>A 202</td>
<td>±</td>
<td>-</td>
<td>D</td>
</tr>
<tr>
<td>BA 558</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AS 160</td>
<td>+</td>
<td>±</td>
<td>-</td>
</tr>
<tr>
<td>SP 8</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

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Scenario A:  

ZAY 018

OKMA 040

Metals
Survival
Growth
Reproduction

IBMWP
H-A
QBR

SQT: Sediment unpolluted. No evidence of adverse biological effects.

Water Authorities (EWF): High or Good Ecological Status

SQT supports the Ecological Status category. No risk present. No further action required.

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**Scenario B:**

- (-) no significant adverse effect
- (±) potential adverse effect
- (+) significant adverse effect

**RCVA 178**

- Metals
- H-A
- QBR
- IBMWP

**Survival**

- Growth
- Reproduction

**Water Authorities (EWF):**

- **RCVA 178 High Ecological Status**
- **OI 102 Poor Ecological Status**

**SQT:** Contaminants present, but not available in current situation. No adverse biological effects

**SQT evidences that currently contaminants don’t represent an ecological risk**

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Scenario C:

- (-) no significant adverse effect
- (±) potential adverse effect
- (+) significant adverse effect

Water Authorities (EWF):

**URS34 High Ecological Status**

**SP18 Bad Ecological Status**

SQT: Contaminants present. Sediment Toxic, but there is no evidence of field community alteration.

SQT provides evidences of Potential Adverse effects. Further analyses required (e.g. *in situ* tests)

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**Scenario D:**

- (--) no significant adverse effect
- (±) potential adverse effect
- (+) significant adverse effect

**Water Authorities (EWF):**

**A202: Poor Ecological Status**

**BA558: Bad Ecological Status**

**SQT:** Contaminants present in the sediment are non-toxic. There is evidence of field community and habitat alteration.

SQT provides evidence of adverse effects occurring by unknown causes. Further analyses required (e.g. other test-species, in-situ tests).

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**Scenario E:**

- **AS 160:** (-) no significant adverse effect 
  (±) potential adverse effect 
  (+) significant adverse effect

**Metals Survival Growth Reproduction**

- **H-A**
- **QBR**
- **IBMWP**

**SP 8**

**Metals Survival Growth Reproduction**

- **H-A**
- **QBR**
- **IBMWP**

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**Water Authorities (EWF):**

**AS 160: Bad Ecological Status**

**SP 8: Poor Ecological Status**

**SQT:** Sediments highly polluted and toxic. Evidence of field community alteration.

SQT provides evidences of adverse effects and an unacceptable risk from sediment contamination. It supports the Ecological Status.

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Reference Condition Approach
(Reynoldson et al. 2002)

Toxicity data ordination (MDS) of reference sediments

90%, 99% Probability Ellipses

Toxicity categories:
- **Non-Toxic**: inside 90% probability ellipse
- **Possibly Toxic**: between 90% and 99% probability ellipses
- **Toxic**: outside 99% probability ellipse

Stress: 0.15

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CONCLUSIONS

- Problems for the integration of ALL databases:
  - Water Authorities measured different Organic Compounds in all sites. In consequence, they could not be included in the decision matrix.
  - Lack of standardization of the sediment fraction used for chemical analyses done by different Water Authorities.
  - Ecoregions shared by different Water Authorities had different values for the ecological reference condition, which was incongruent.

- The SQT provides an Ecological Risk Assessment that supports Ecological Status for sites in the extreme range of the risk assessment (+) and (-) (45% sites). In other intermediate situations, SQT has proved the utility of the Toxicity Line of Evidence as indicative of potential environmental risk (28% sites). In other sites (27%), further research is required because of insufficient information.

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