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A RISK ASSESSMENT APPROACH TO PRIORITIZE CONTAMINANTED SEDIMENT SITES

PROPOSAL BY A TECHNICAL BOARD ESTABLISHED BY ENVIROMENTAL MINISTRY ON JANUARY 2014 FOR RISK ASSESSMENT OF AN ITALIAN CONTAMINATED SITE(SIN)

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RAMBOLL ENVIRON

Environmental Risk Assessment (ERA) for a contaminated aquatic ecosystem

Analysis of sediments and water in the aquatic ecosystem

Evaluation of pollutant contamination in sediment and waters

Direct effects on biota

Conceptual Site Model

Definition of screening benchmarks

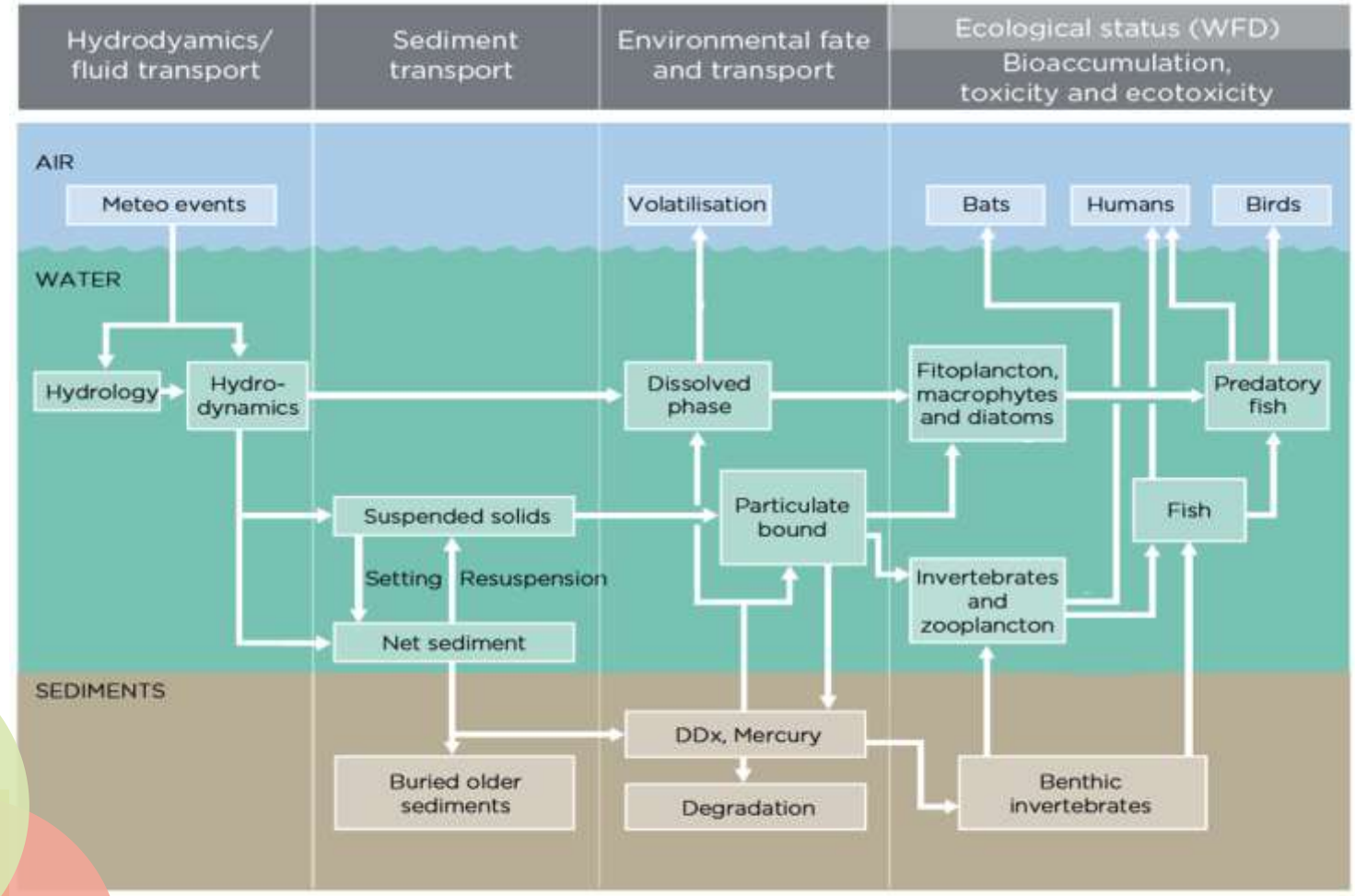
Definition of risk benchmarks

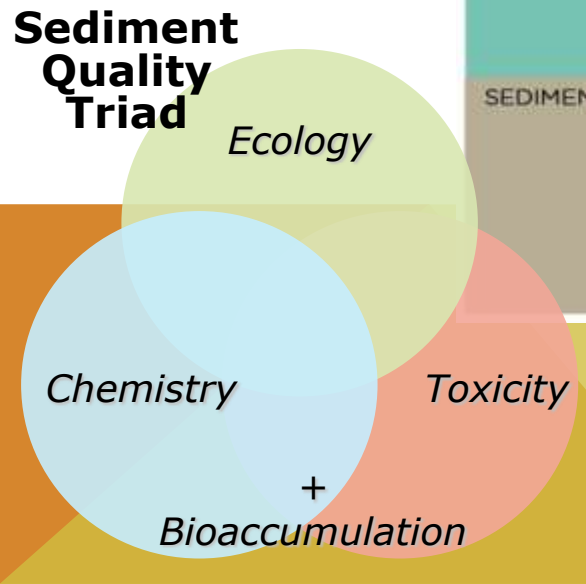
Analysis of bioavailability for biota

Evaluation of contaminant in benthic organisms

Direct effects on aquatic biota and secondary poisoning

CONCEPTUAL MODEL OF AQUATIC SITES





TIERED APPROACH

Phase I : DEFINITION OF SCREENING BENCHMARKs: comparison of on-site specific data with Environmental Quality Standards (EQS) for water, sediment and biota. If on-site data are lower than EQS, risk must be considered not relevant.

EQS for water and biota are defined by European Directive 2013/39/UE

For sediments, on-site concentrations were compared with TEC for organics and TEL values for trace metals (MacDonald et al., 2000).

Phase II : if water, sediment and/or biota concentrations overcome screening benchmarks, Environmental Risk must be re-assessed, considering risk benchmarks for different environmental compartments (water, sediment and biota).

DEFINITION OF RISK BENCHMARKS

RISK BENCHMARK is the concentration of a specific contaminant that may cause with a high probability adverse effects on ecological receptors (ROI)

It is defined on the basis of a wide review of scientific papers, being particularly cautelative in this evaluation.

ATTENTION BENCHMARK is an intermediate value between screening values and risk benchmarks defined with the aim of evaluate possible temporal trend or to assess lower priority contaminated areas

The exceedance of attention benchmark may cause with low/moderate probability of adverse effects on specific ecological receptors

WHICH MANY BENCHMARKS ARE NECESSARY ?

For contaminants that can be bioaccumulated *screening*, *attention* and *risk benchmarks* are defined for the following Receptor Of Interest (ROI) in aquatic ecosystem :

- **Benthic organisms**
- *risk and attention benchmarks for sediments*
- *risk and attention benchmarks for biota (benthic invertebrates*)
- **Fish (and aquatic organisms)**
- *risk and attention benchmarks for water* (*Species Sensitivity Distribution)*
- *risk and attention benchmarks for biota* (fishes)
- **Fishing birds and bats**
- *risk and attention benchmarks based on intake doses* (diet)

Coregonus lavaretus

Crustacea-Gammaridae

HOW TO SELECT SCIENTIFIC PAPERS FOR THE EVALUATION OF ADVERSE EFFECTS?

Evaluation of the relevance of ecotossicological studies (Kase *et al*., 2012, 2013)

Biological Relevance	Are test specie relevant for the study?
	Are biological effects relevant ?
	Are the considered life stages relevant and appropriate?
	Are ecotoxicological test adeguate in respect to the environmental assessment?
Environmental Relevance	Is the exposure scenario of contaminant relevant for the considered case study?
	Are all parameters considered that may influence effects?
Exposure Rilevance	Is the exposure route relevant fot the considered specie?
	Is the test duration relevant and appropriate in respect to the considered effects?

Secondly evaluation of **the reliability** of ecotossicological studies (Klimisch, 1997)

Does the paper report detail about: • Ecotoxicologycal protocol? • Number of tested organisms? • Measurement of concentrations? • Exposure duration? • Considered Effects?	• Endpoints? • Statistical analysis? • Information on life cycles? • Feeding during the test? • National or International validation?

DEFINITION OF ECOLOGICAL RISK IN ERA APPROACH

BENTHIC ORGANISMS – SEDIMENTS

Risk and attention benchmarks for sediments :

- Paper review about ecotoxitogycal test with sediments according to Relevance and Reliability approaches considering:

  - "*spiked sediment toxicity test*": toxicity test in laboratory experiments using spiked sediments in controlled conditions. Spike tests can over-estimate contaminant bioavailability

  - "*case study*": toxicity test carried out using sediments collected in contaminated sites or ecological surveys in contaminated sites

- Evaluation of no-effect concentrations (NOEC) and lowest effect concentrations (LOEC), considering both *spiked test* and *case-study*. For each scientific paper only the most cautelative NOEC and LOEC values should be considered

Calculation of risk and attention benchmarks

DEFINITION OF ECOLOGICAL RISK IN ERA APPROACH BENTHIC ORGANISMS – SEDIMENTS

On the basis of NOEC and LOEC reported values, Risk benchmark is calculated using the equation proposed by MacDonald *et al*. (1996, 2003) and Canadian Council of Ministers of the Environment (1995) to define the lowest limit of the effective range (in this case of LOEC)

$$\boldsymbol{Risk\ benchmarch} = \sqrt{(P_{50}\ \text{Effect dataset} \times P_{85}\ \text{No Effect dataset})}$$

where P is percentile value

Attention benchmark was calculated using the equation proposed by MacDonald et al. (1996, 2003) and CCME (1995) to define the upper limit of the no-effective range

$$\boldsymbol{Attention\ benchmark} = \sqrt{(P_{15}\ \text{Effect dataset} \times P_{50}\ \text{No Effect dataset})}$$

where P is percentile value

Larvae of Heptageniidae

DEFINITION OF ECOLOGICAL RISK IN ERA APPROACH BENTHIC ORGANISMS – FISH AND BIRD TISSUES

Advantage s of *benchmark on biolta*:

- Biota integrate all the possible exposure route of organisms (thophic role, habitat conditions and so on)
- Concentrations in biota are dominated by on-site bioavailability and therefore are the most realistic and easily measurable

Scientific papers with similar scenario, following relevance and significativity approach, can be used to define pollutant concentrations characterized by no adverse effects for organisms

This approach was used for benthic organisms and fish tissues .

ID	Specie	Pollutant	Exposure route	Duration of exposure	Effects	Endpoint	Tissue concentration for each end-point		Source
							NOEC (mg THg/kg ww)	LOEC (mg THg/kg ww)	
Hg-Spiked-2	Chironomus riparius	Total Hg	sediment	21 – 35 g	Growth	Unbounded NOEC	6		Gremyatchikh et al. 2009

For fishing birds and bats risk benchmarks was defined following SSD approach for a daily diet normalized on body weight and compared with on-site exposure to DDx and Hg

Case study: Lake Maggiore

The main source of DDx and Hg pollution was a factory at Pieve Vergonte (near the Toce River).
In 1996 DDT production was stopped and the production building reclaimed.
The industrial activities were drastically reduced, underground waters and effluents were treated and contaminated soils were stabilized: DDx and Hg concentrations dropped significantly. Recently in 2017 soil restoration begins with on-site soil treatment.

SITE-SPECIFIC DATA: WATER AND SEDIMENTS

Lake sediments: collected with a gravity or vibro corer in the Pallanza Basin

River sediments: collected with a dredge or metallic spoon in different sites upstream and downstream the industrial site

SITE-SPECIFIC DATA: BIOTA

Benthic invertebrates: collected with grabs in the Pallanza Basin and with hand nets in the Toce river. Specimens were separated according to taxonomic groups

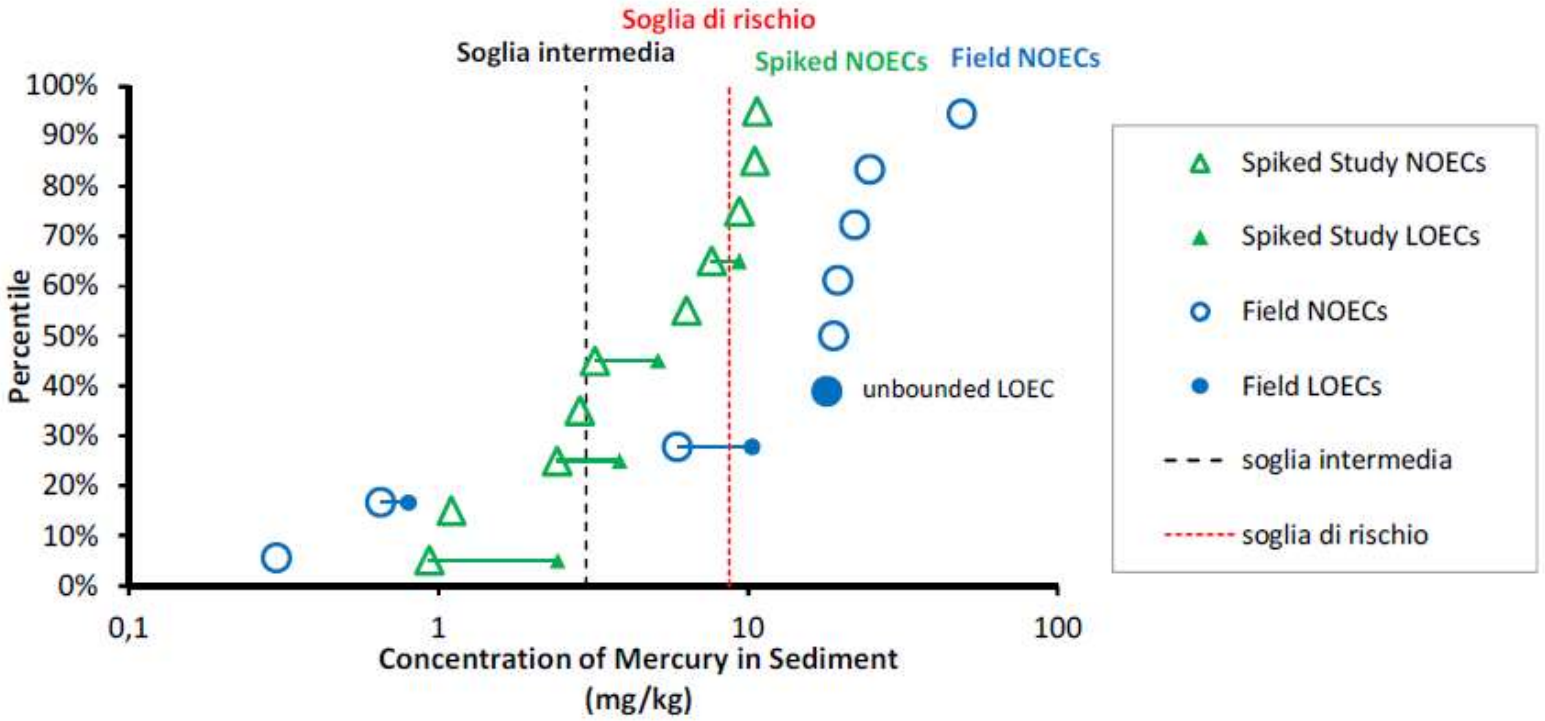
Alosa fallax lacustris

Fish: collected in the Pallanza Basin using gill nets:

- *Rutilus rutilus* (roach): littoral, bentophagic
- *Coregonus lavaretus* (common whitefish) : pelagic, planktophagic
- *Alosa fallax lacustris* (landlocked shad): pelagic, planktophagic

Calculation of risk and attention concentrations for total mercury in sediments

Risk benchmark was calculated s.s. using:
$\sqrt{(P_{50}}$ Effect dataset $\times P_{85}$ No Effect dataset)
Attention benchmark was calculated using $\sqrt{(P_{15}}$ Effect dataset $\times P_{50}$ No Effect dataset)



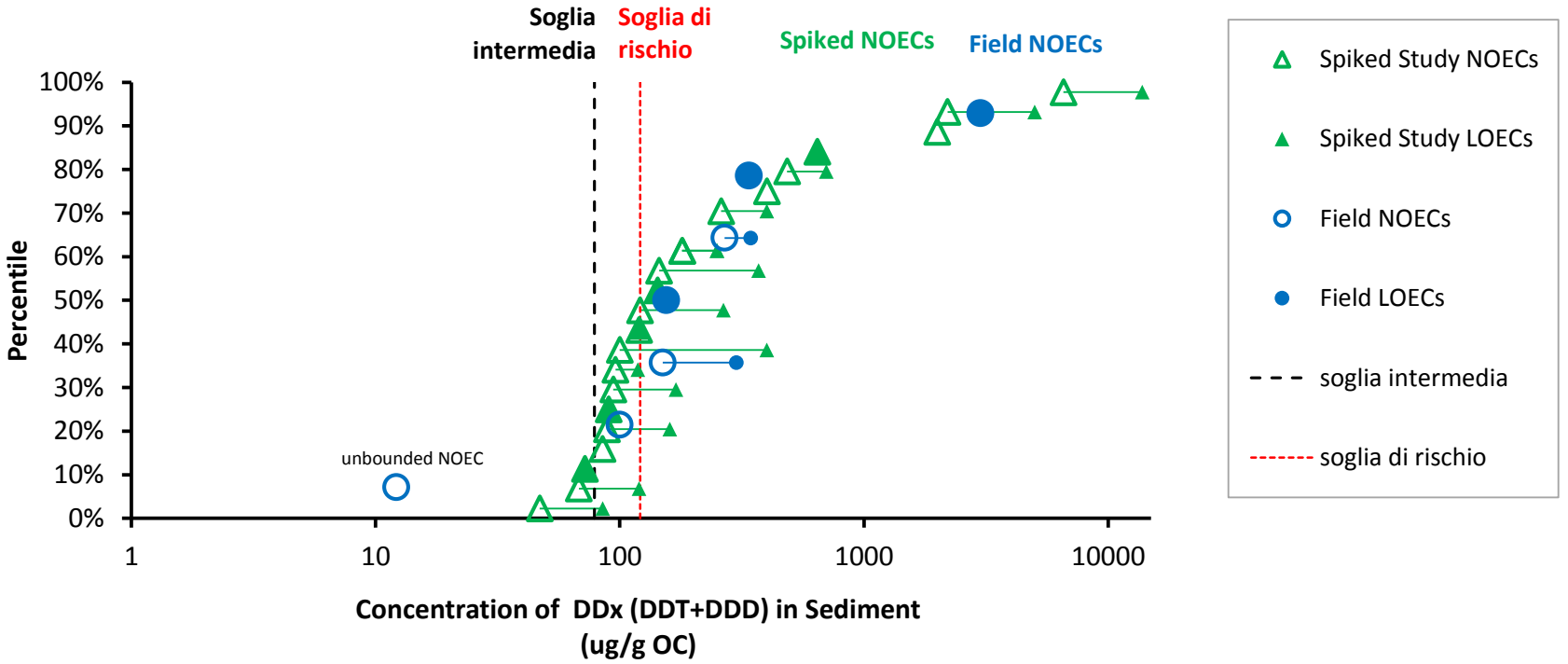
Calculation of risk and attention concentrations for DDx in sediments

Risk benchmark was calculated using:

$\sqrt{(P_{50}\ \text{Effect dataset} \times P_{85}\ \text{No Effect dataset})}$

Attention benchmark was calculated using

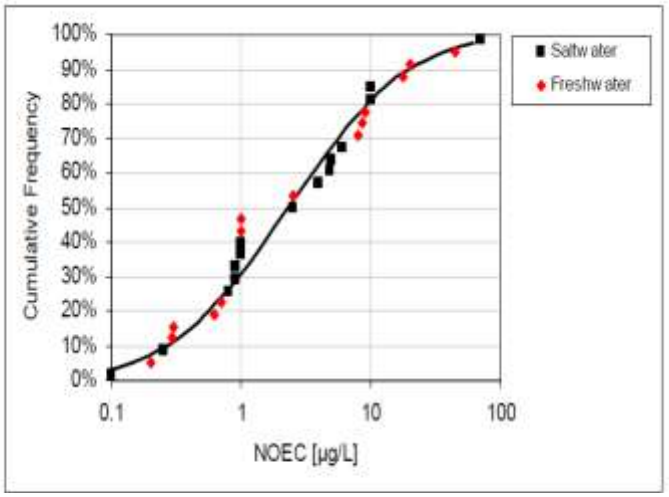
$\sqrt{(P_{15}\ \text{Effect dataset} \times P_{50}\ \text{No Effect dataset})}$

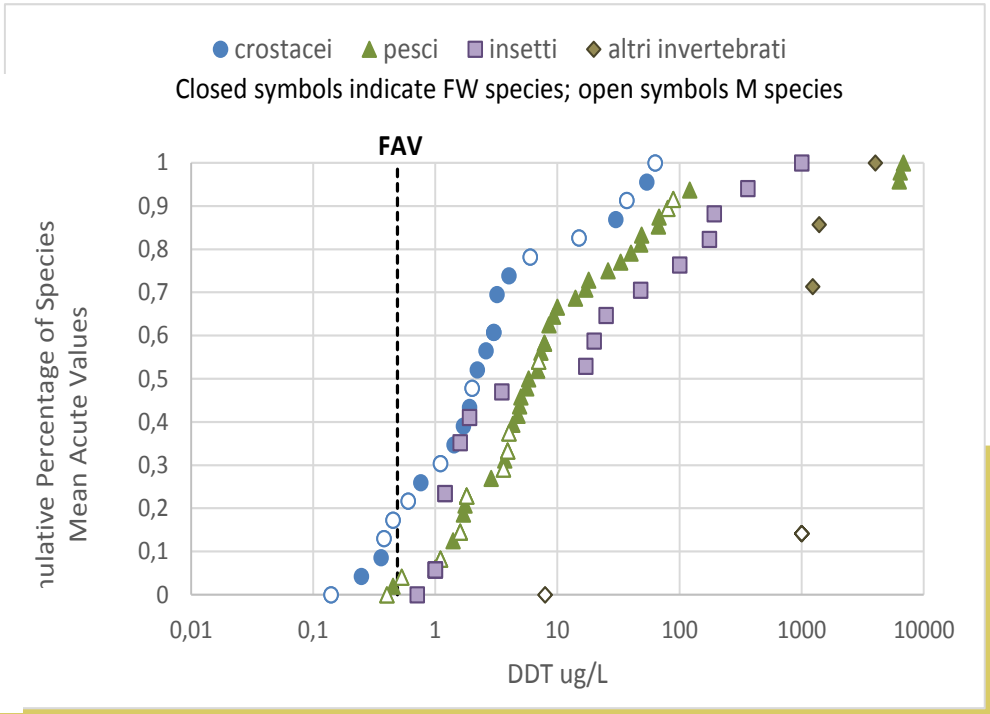


Fish and aquatic organisms – waters

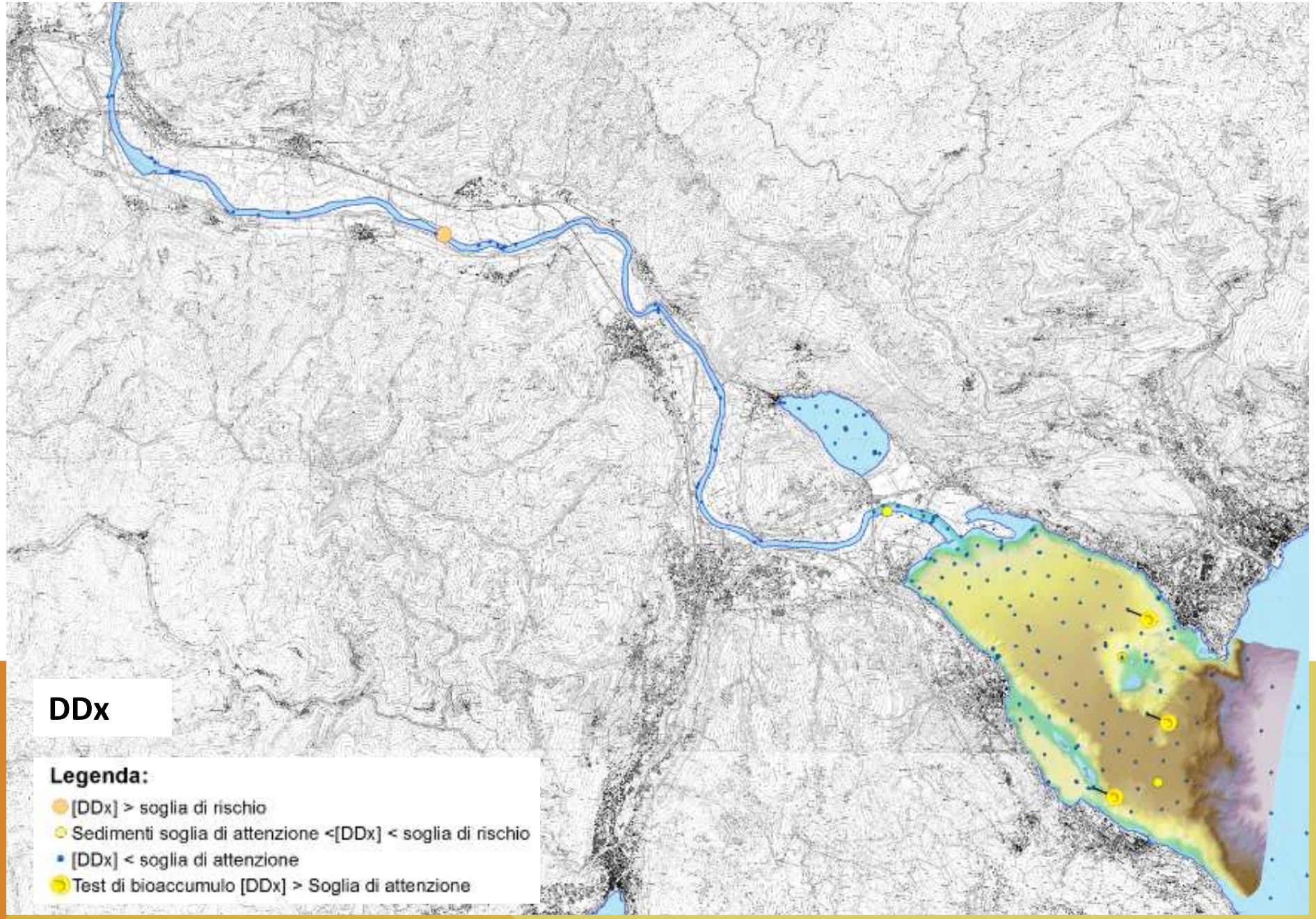
Risk benchmark was calculated through a *Species Sensitivity Distribution* (SSD)

- **Mercury**: the European datasheet on freshwater organims was used for SSD (5% cut-off value of 0,16 µg/L)
- **DDx**: no European datasheet are available, so paper review and SSD approach was used, considering aquatic organisms sensitive to DDT. So on the basis of acute toxicity values (FAV) divided for a acute/chronic cautelative value (10) Final Chronic Value (FCV) for waters (0,049 µg/L) was calculated .





Comparison between on-site data and benchmarks: DDx



Conclusion and management directions: DDx

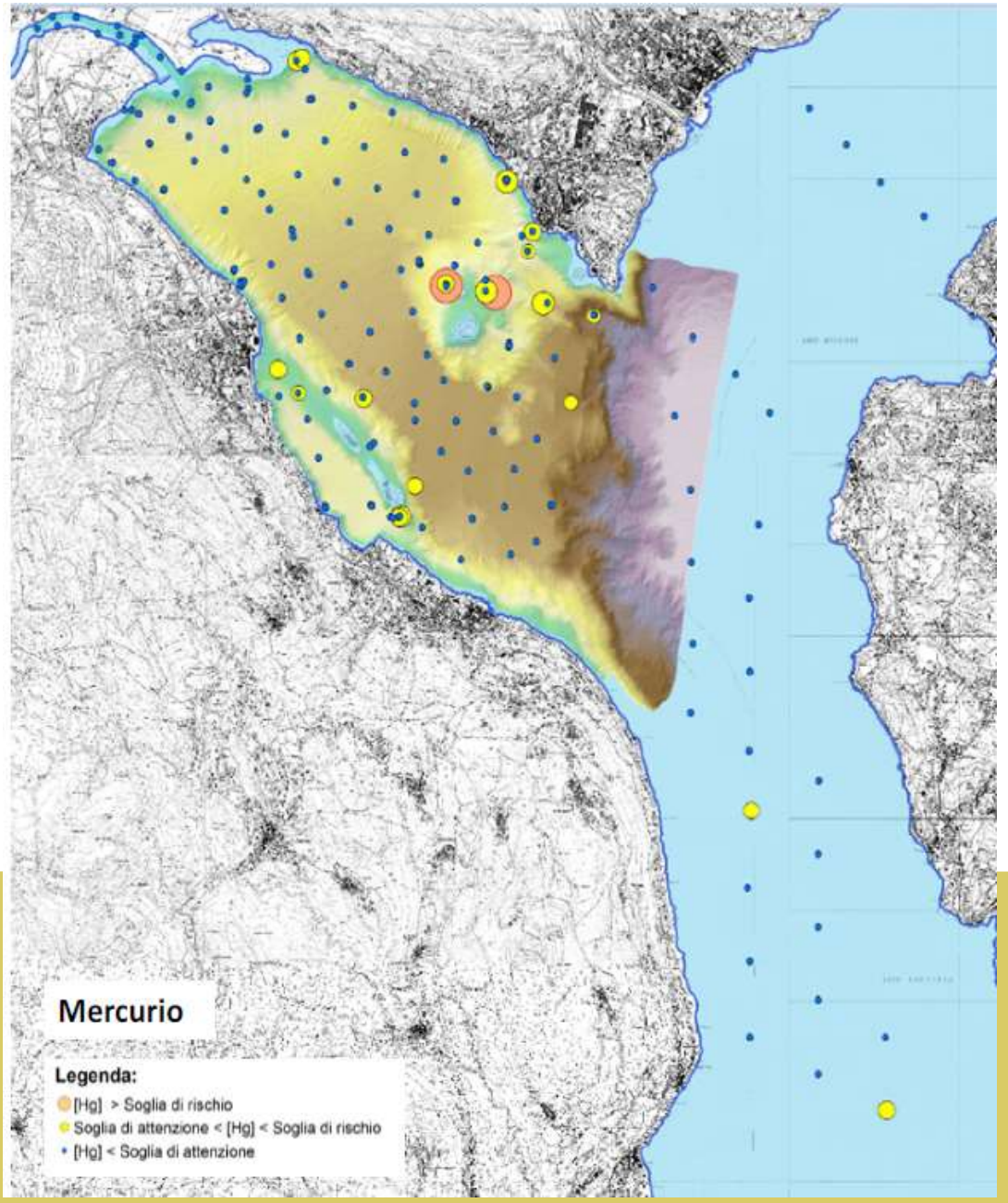
Sediment Quality Triad for DDx							
	Benthos				Fish or other aquatic organisms		*Secondary poisoning*
	Sediments	Benthos Tissues	Toxicity tests	Ecologiical status	Waters	Fish tissues	Fishing birds or bats
Lake Maggiore	Exceedance of attention benchmark	Exceedance of attention benchmark	No toxic effetcs	Good Ecological status	No Exceedance of risk benchmark	**No Exceedance**	No Exceedance of risk benchmark
Toce River	**One Exceedance of risk benchmark in 2009 and of attention benchmark**	No Exceedance	Some toxic effects on *C. riparius and* on algae test upstream and downstream the industrial site	Good Ecological status	No Exceedance of risk benchmark	**No** Exceedance	

Exceedance of risk benchmark or toxicity

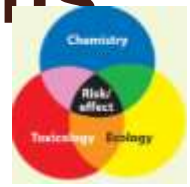
Exceedance of attention benchmark or toxicity not correlate with DDx and Hg levels

No Exceedance

Comparison between on-site data and benchmarks: Hg



Conclusion and management directions: mercury



Sediment Quality Triad for mercury							
	Benthos				Fish or other aquatic organisms		*Secondary poisoning*
	Sediments	Benthos Tissues	Toxicity tests	Ecologiical status	Waters	Fish tissues	Fishing birds or bats
Lake Maggiore	**Two v alues exceeded the risk benchmark and others the attention benchmark** .	**No exceedance**	No toxic effetcs	Good Ecological status	No exceedance of risk benchmark	Exceedance of attention benchmark	No exceedance of risk benchmark
Toce River	No exceedance	**No exceedance**	Some toxic effects on *C. riparius and* on algae test upstream and downstream the industrial site	Good Ecological status	**two values exceeding the risk benchmark in 2010 No exceedance in 2013-2014**	No exceedance	

Exceedance of risk benchmark or toxicity

Exceedance of attention benchmark or toxicity not correlate with DDx and Hg levels

No exceedance

Conclusion and management directions

All on-site values are lower than risk benchmark with some limited exceptions : one station for DDx in sediments of the Toce River and two stations for Hg in sediments of the Lake Maggiore

A general exceedance of attention benchmark in sediments and benthic invertebrates for DDx and in fish tissues for mercury was observed

No evidence of significant ecological risk for the community, but WFD good chemical status still not was achieved (exceedances of EQS).

Advice for managing: dredging of Pallanza Baia sediment is not necessary , while implementation of **monitoring programm** in a long term approach **to follow DDx and Hg trends is recommended**

The remediation of the Pieve Vergonte national site (to avoid and prevent further contamination of the bay) remains necessary

This advice was agreed by the TECHNICAL BOARD on the CONTAMINATED SITE (SIN) ESTABLISHED BY the ENVIROMENTAL MINISTRY