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Ecological Risk Assessment for Lake Maggiore: Experience Gained from a Participatory Approach

AUTHORS

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INTRODUCTION

Sediments in Lake Maggiore, a subalpine lake in northern Italy, contain DDT and mercury (Hg) from historical industrial contamination. DDT and Hg were discharged for several years into the Toce river, which flows into Lake Maggiore. The area has been declared a National Contaminated Site. The lake and river were extensively studied and most activities were performed in collaboration with public environmental agencies and research institutes.

An ecological risk assessment (ERA) was proposed to support environmental management of the site and a technical board was established made up of experts from academia, public environmental agencies, research institutes and industry, with the final aim of developing a shared approach and evaluating site-specific ecological risks. Methods and criteria used in this case study are described below as this experience may be useful for further development of ERA application in Italy.

METHODOLOGICAL APPROACH FOR THE RISK ASSESSMENT

Methodological design and data intepretation followed a tiered approach, verifying at each step whether further investigations were necessary to understand potential effects and refine uncertainties. The design also took into account the current European legislative framework for protection of surface water bodies.

A conceptual site model was developed to support collection of information relevant for the exposure and effect assessment of selected ecological receptors (Figure 1).

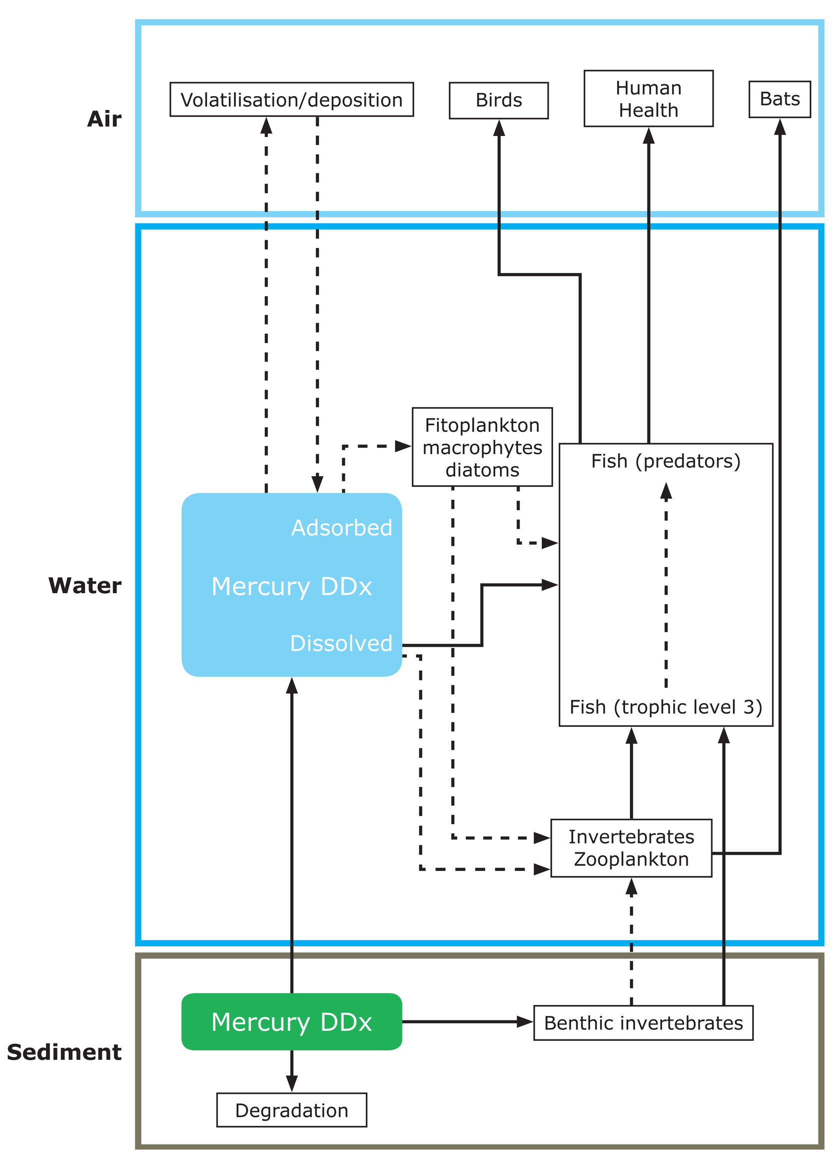

Figure 1: Conceptual site model: ecological receptors and exposure pathways.

As a first step, screening benchmarks were selected from existing environmental quality standards and scientific literature. Data deriving from specific monitoring activities, ie sediment, surface water and tissue concentrations in fish and benthic invertebrates were compared with the selected screening benchmarks. This step emphasised the need for further evaluation for both DDT and Hg, since in most cases concentrations exceeded the benchmarks. For SST and Hg in particular the biota EQS established at national and European level were exceeded and the good chemical status of the WFD cannot be achieved.

Therefore further investigations and a detailed literature review of ~200 papers was performed to evaluate cause-effect, concentration-response relationships. The technical board agreed on the importance of evaluating reliability and relevance of each paper, adopting a modified Klimisch approach (Klimisch, 1997; Kase *et al*, 2013). This step allowed us to define 'attention' and risk benchmarks for the different environmental compartments, as described herein.

ECOLOGICAL RISK ASSESSMENT FOR DDT AND HG

Benthic invertebrates

To define risk benchmarks for sediments, the literature research focused on:

- Spiked sediment toxicity tests: controlled experiments that can establish concentration-response relationships, provided that chemical bioavailability is sufficiently understood. These tests tend to overestimate chemical bioavailability due to limited chemical-sediment contact time.
- Sediment toxicity and benthic community data for major DDx and Hg-contaminated sediment sites. Case study results could be affected by other stressors but represent bioavailability under field conditions.

On the basis of these studies, a dataset was compiled with NOEC and LOEC data, and two benchmarks were defined to evaluate site specific data without the use of uncertainty factors (according to guidances USEPA 1998 and FCSAP 2012):

Risk threshold = $\sqrt{P_{50}\,\text{LOEC dataset} \times P_{85}\,\text{NOEC dataset}}$ defined to detect significant risks and "Attention" threshold = $\sqrt{P_{15}\,\text{LOEC dataset} \times P_{50}\,\text{NOEC dataset}}$ defined to address monitoring actions and preventive measures.

For DDT, further evaluations were conducted using the equilibrium partitioning (EqP) approach. Sediment pore water concentrations are a reliable measure of the bioavailable fraction of nonpolar organic chemicals and can effectively predict toxicity in whole-sediment exposures. The EqP approach was applied using a final chronic value defined from a species sensitivity distribution that was then extrapolated to sediment. The EqP benchmark was consistent with the risk tresholds calculated using spiked sediment study and case study data (Figures 2 and 3).

Risks to benthic invertebrates were evaluated using the following lines of evidence:

- Comparison of field sediment concentrations with the selected benchmarks for sediments (Figures 4 and 5): both "attention" and risk threshold were exceeded in some cases. For mercury in sediment the attention threshold has been taken into account due to the high uncertainties of the risk threshold.
- Comparison of invertebrate tissue concentrations to tissue-based toxicity reference values for benthic organisms derived from scientific literature, considering the full range of applicable studies, study quality and endpoints, and selecting a concentration in invertebrate tissue expected to be without deleterious effects on relevant species. The risk thresholds were not exceeded.
- Invertebrate community structure assessment: taxonomic surveys were conducted in River Toce and Lake Maggiore. Taxonomic data and environmental parameters were evaluated using multivariate statistical approaches and several indices of ecological status. Results indicated absence of evident stress signals in benthic community status. Monitoring by ARPA for the Water Framework Directive confirmed these results.
- Sediment bioassays: Toxicity studies were performed on field-collected sediment using the midge *Chironomus riparius* (28 d exposure). Additional tests on elutriate used the waterflea *Daphnia magna* (48 h exposure) and the algae *Pseudokirchneriella subcapitata* (72 h exposure). No significant relationships were observed between endpoints and DDx and Hg concentrations but further anaysis should be performed to confirm the data.

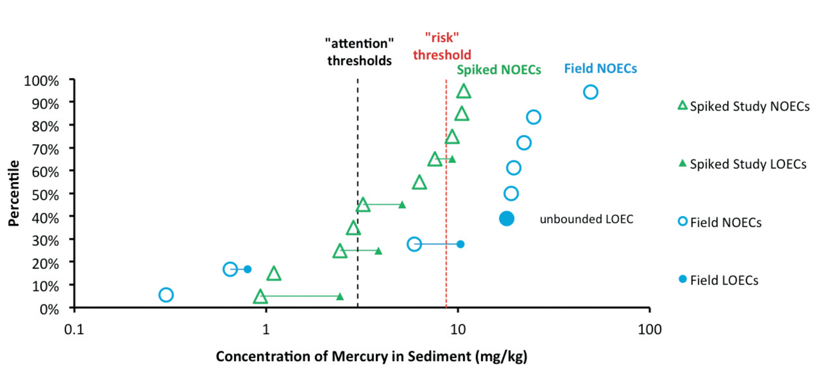

Figure 2: No observed effect concentration and lowest observed effect concentration for mercury, derived from literature review.

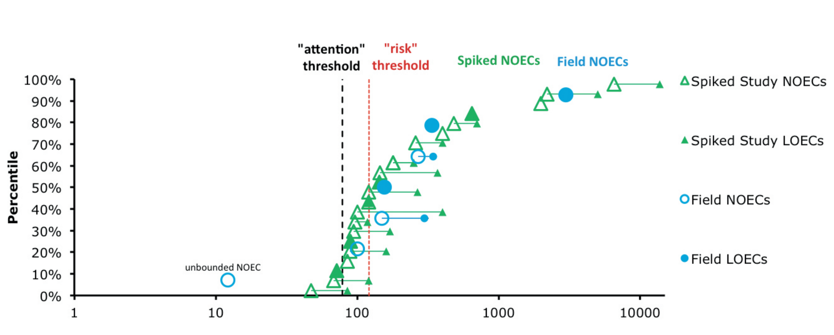

Figure 3: No observed effect concentration and lowest observed effect concentration for DDT, derived from literature review.

Lake Maggiore.

Fish and wildlife

Risks to fish were evaluated using the following lines of evidence:

- Comparison of fish tissue concentrations to effects thresholds: fish tissue benchmarks were derived considering the full range of applicable studies, study quality and endpoints, and selecting a concentration in fish tissue expected to be without deleterious effects on relevant species (Beckvar *et al*, 2005, Dillon *et al*, 2010). The risk benchmarks were not exceeded (Figure 6).
- Comparison of water concentrations to benchmarks: derived from species sensitiviy distributions based on toxicity data for fish and pelagic invertebrates.

Risks to mammals and piscivorus birds were evaluated considering:

- Comparison of dietary exposure to effects thresholds derived from scientific literature. The risk benchmarks were not exceeded.
- Evaluation of site-specific data on grebe eggshell thickness.

Human health risk

Human health risks were assessed considering exposure from fish tissue concentrations detected in the period 2010-2012. In fishes, mercury concentrations were lower than food regulatory limits for human consumption (Commission Regulation 1881/2006/EC). DDx values exceeded limits from current Italian legislation, especially in shads (*Alosa fallax*) and fishing has been forbidden. The exposure scenarios calculated are lower than the tolerable daily intake (EFSA 2006) for the period studied; edible fish tissue will be monitored to verify the trend decline of DDx concentrations and the levels of mercury.

CONCLUSION

Comparison of site-specific chemical data versus risk thresholds indicate that, in a few sites, sediment concentrations were above risk thresholds and in some matrices the concentrations exceed the 'attention' thresholds and the good chemical status was not achieved (Figures 4, 5 and 6). However ecological and ecotoxicological data showed that benthic communities, fish and wildlife are not significantly affected by DDx or mercury under current conditions.

On this basis, the technical board recommended that policymakers implement a long-term monitoring plan to verify environmental conditions, in order to confirm the absence of significant ecological risks and verify that conditions in Pallanza Bay are improving due to the natural deposition of relatively clean sediments. Furthermore the board has recommended to continue the activities of the remediation of the industrial site of Pieve Vergonte.

Scientific evaluations and decision making were conducted through a participatory approach, involving environmental and health authorities (ARPA Piemonte, ISS and ISPRA), public and private research institutes (CNR-IRSA and Ramboll Environ) and industrial managers (Syndial). This approach was fundamental to facilitating scientific discussion, communication and decision making, bridging gaps between stakeholders. We believe the participatory experiences gained in this case-study provide an example for other contaminated sites in Italy.

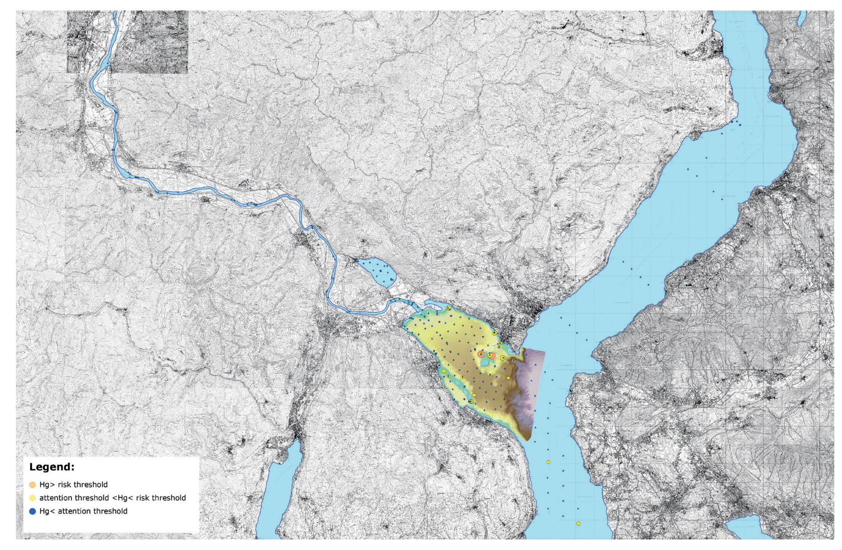

Figure 4: Sediment concentration vs thresholds (mercury).

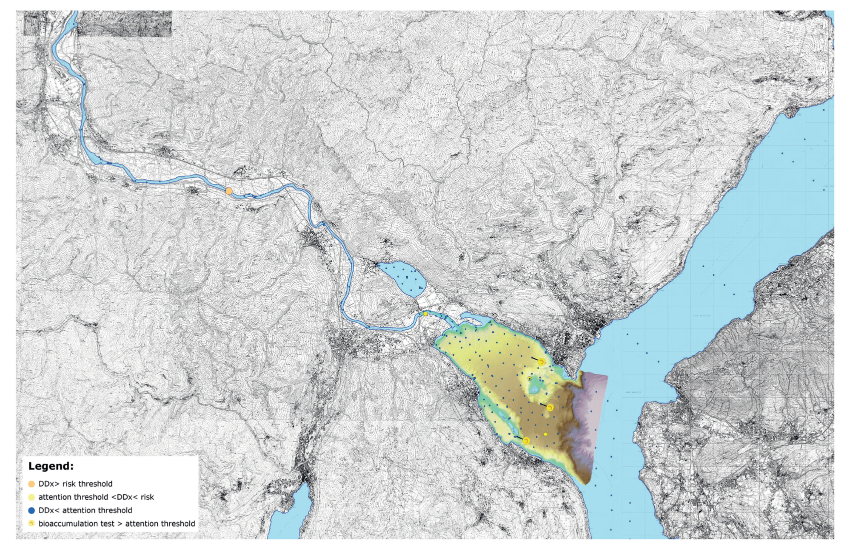

Figure 5: Sediment concentration vs thresholds (DDx).

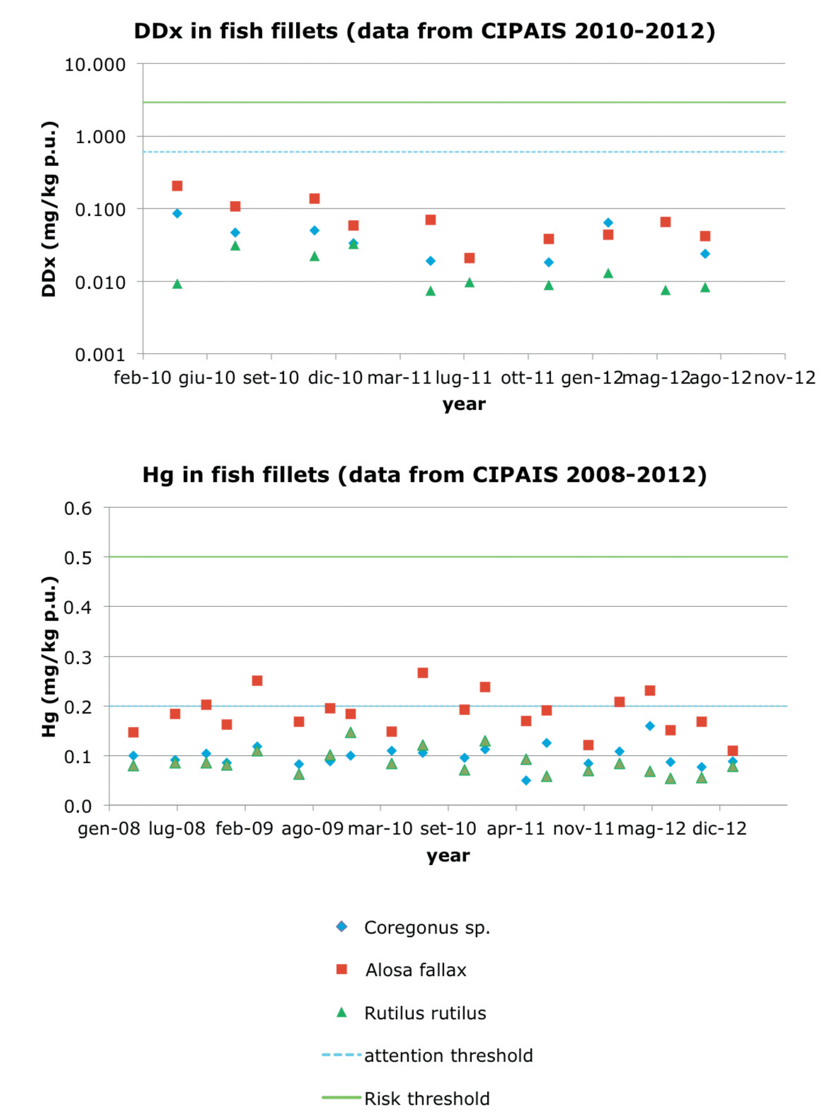

Figure 6: Fish tissue concentrations vs ERA thresholds.

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