13th International SedNet Conference - 6-8 September 2023, Lisbon, Portugal

Assessing sediment toxicity in reservoirs before flushing: developing a protocol for freshwater in Italy

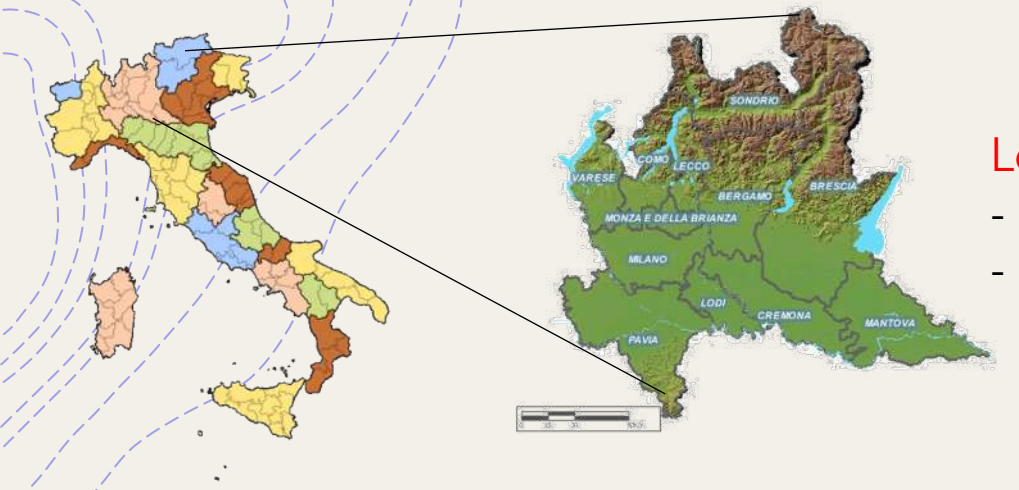
Laura Marziali[1*], Licia Guzzella[1], Lucia Valsecchi[1], Stefano Tasselli[1], Cristina Borlandelli[2], Erika Lorenzi[2], Clara Bravi[3]

[1] Water Research Institute (CNR-IRSA), Via del Mulino, 19, 20861 Brugherio (MB), Italy. *E-mail: laura.marziali@irsa.cnr.it

[2] Lombardy Regional Environmental Protection Agency, Via Rosellini, 17, 20124 Milan, Italy

[3] Lombardy Region, Piazza Città di Lombardia, 1, 20124 Milan, Italy

Reservoirs in Lombardy Region (Italy)



Lombardy Region:
- Large dams: about 80
- Small dams: about 600

Reservoirs accumulate huge quantities of fine sediments: 0.5%-1% annual loss of storage capacity

Sediment flushing: i.e., increasing flow velocities in the reservoir to scour out deposited sediments into the downstream river through the low-level outlets

Effects on the riverine ecosystem downstream the dam:
- **physical-mechanical impact**: acute effects
- **ecotoxicological effects** due to the release of toxic substances from sediments: long-term effects

Water Framework Directive 2000/60/EC

Sediments: a complex matrix … with lacking regulation

- Complex matrix:
  - fine sediments accumulate natural and anthropogenic contaminants
  - toxicity depends on site-specific mixture and bioavailability
  - flushing operations alter solid/liquid ratio, pH, redox conditions, enhancing the release of contaminants from sediments

- Regulation?
  - WFD 2000/60/EC
  - Directive 2013/39/EU

→ **no Sediment Quality Standards** for freshwater sediments

Official protocols for assessing freshwater sediment quality are missing in Italy

A protocol for chemical and ecotoxicological characterization of sediments in reservoirs (PrATo) in Lombardy Region

PrATo was developed and partly included in 2016 in the **Technical guidelines for drafting Reservoir Management Plans** by Lombardy Region and is applied by stakeholders which need to manage sediments in reservoirs

Evaluations with a TRIAD approach based on different lines of evidence:			
chemistry: chemical analysis of sediments and eluates	**ecotoxicology**: test batteries on whole sediments and eluates	**bioaccumulation**: analysis in native benthic organisms	**ecology**: data can be combined with analysis of riverine communities

STEP 1

Aim: planning flushing operations in order with **minimize the risk of detrimental effects in the river**

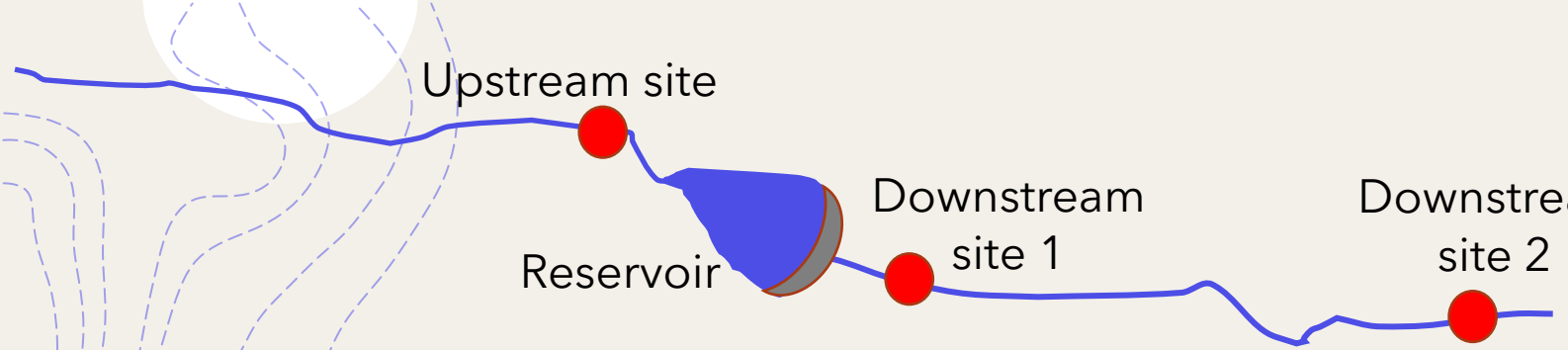
Analyses carried out ***before*** **flushing** on sediments of the reservoir and of the river

STEP 2

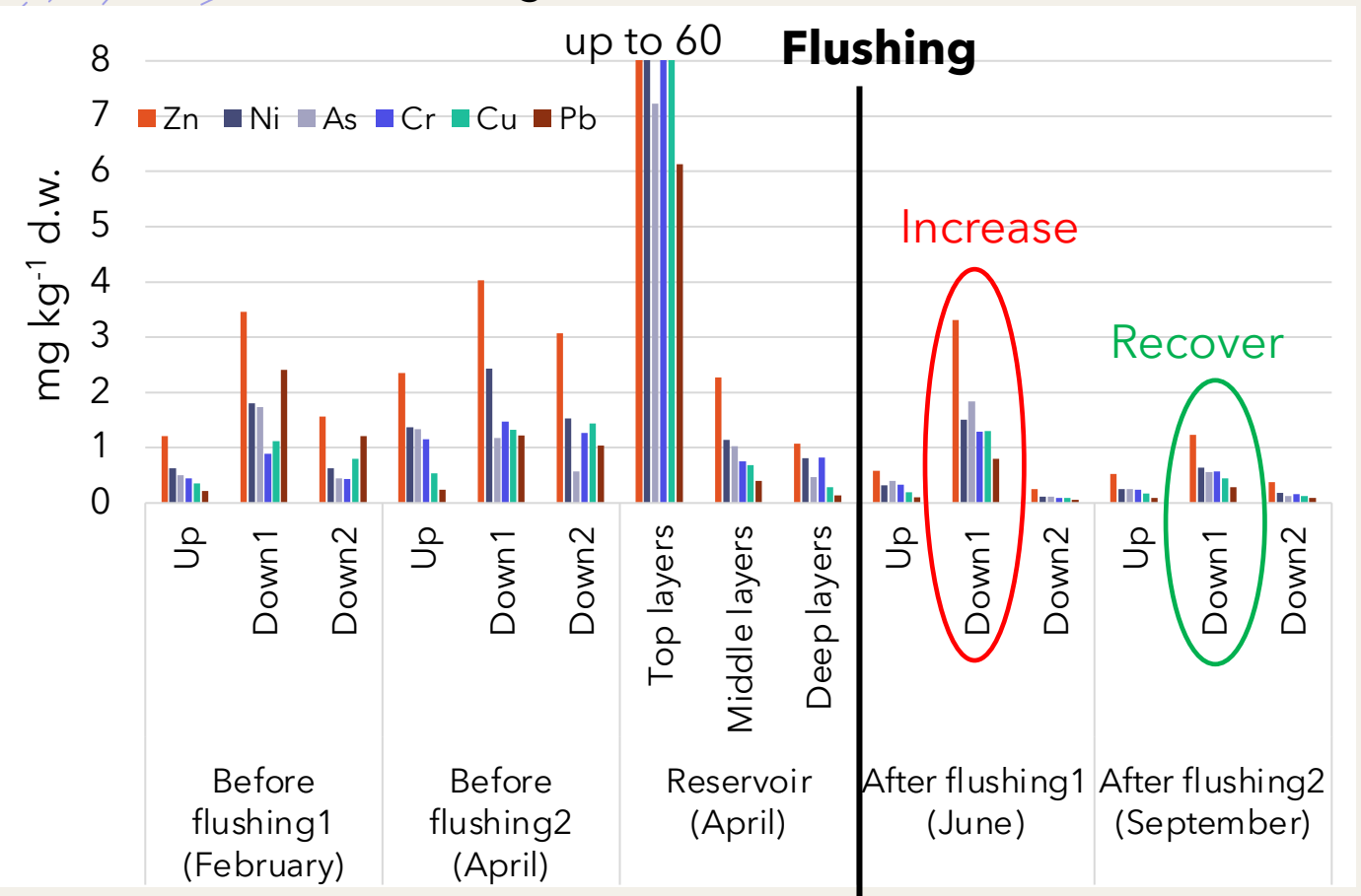
Aim: assessing potential **alterations in the river and time required for recover**

The same characterization is performed ***after*** **flushing** on sediments collected in the downstream river

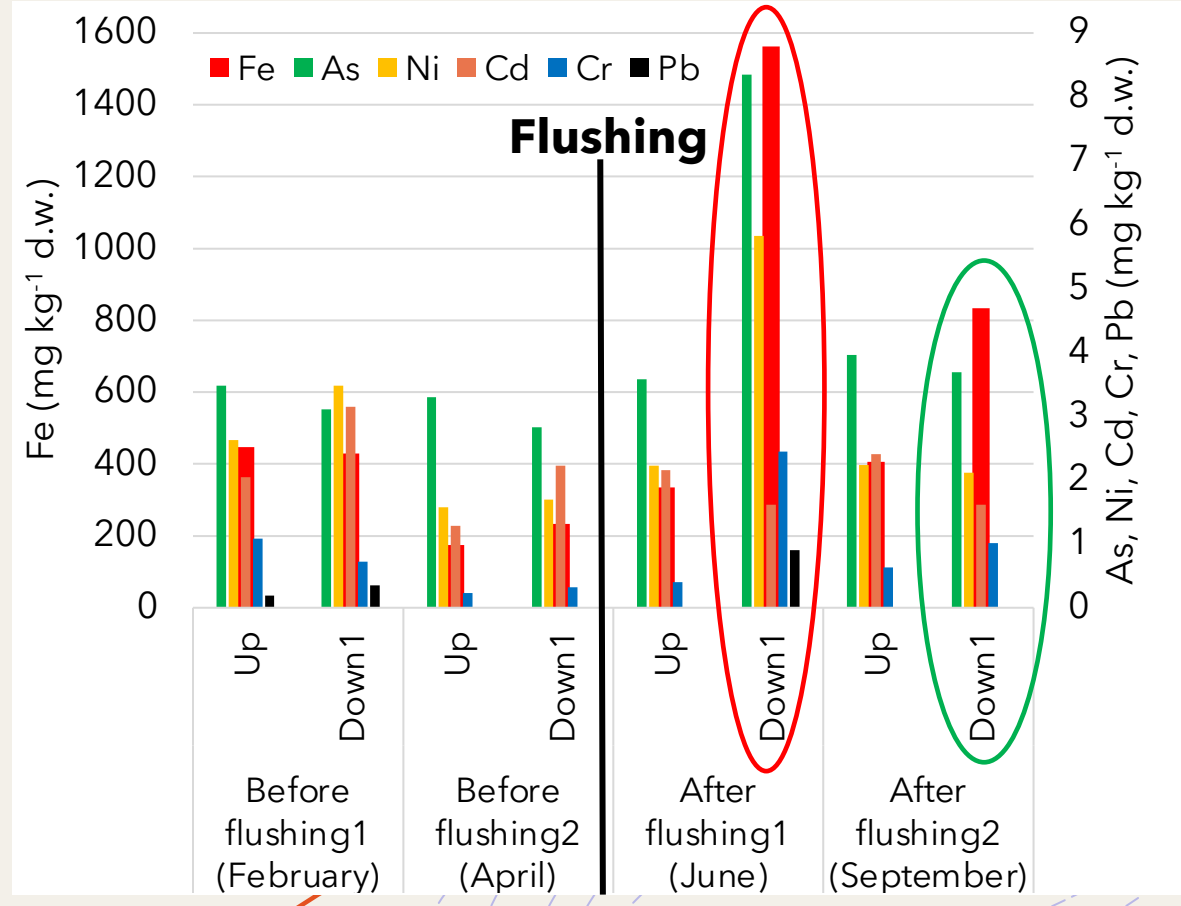
An example



Trace elements in sediments (< 2 mm):
values below SQGs (e.g. MacDonald et al., 2000)

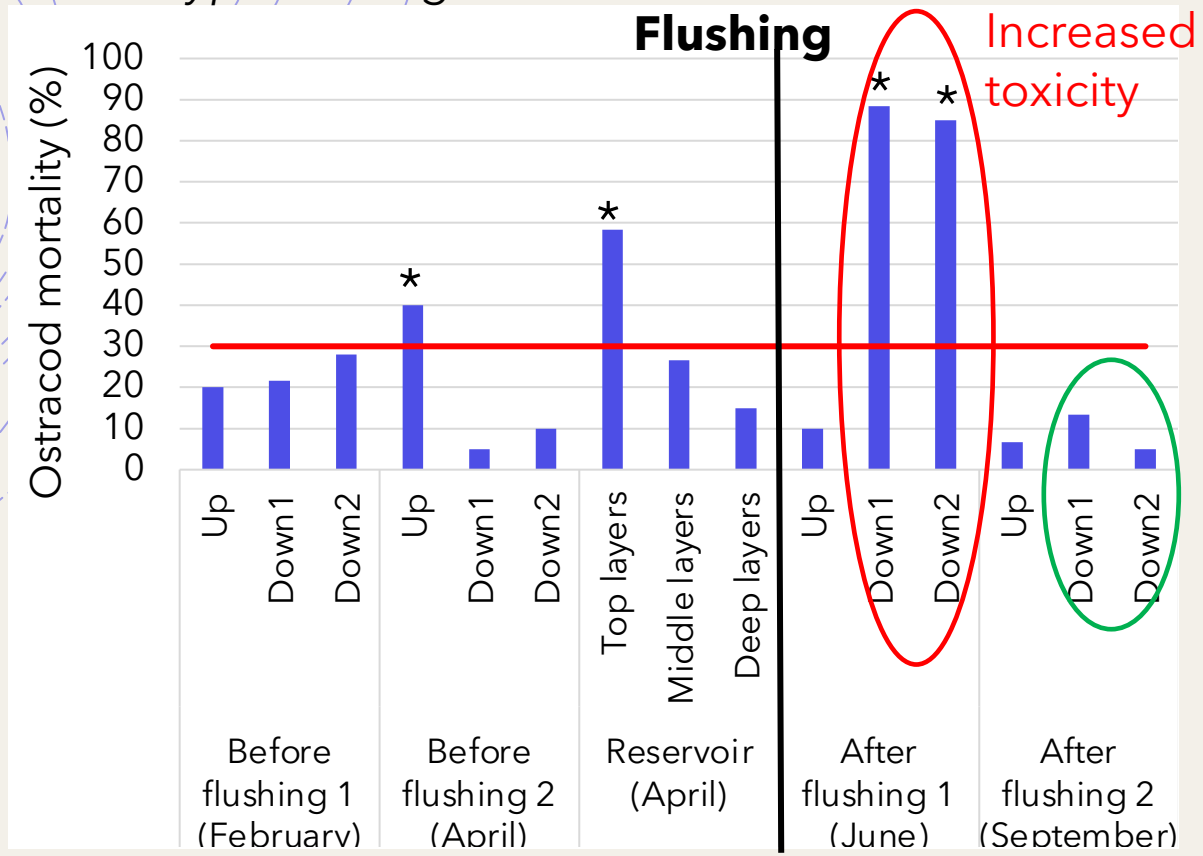


Biaccumulation in benthic invertebrates (*Baetis*):
increased bioavailability after flushing

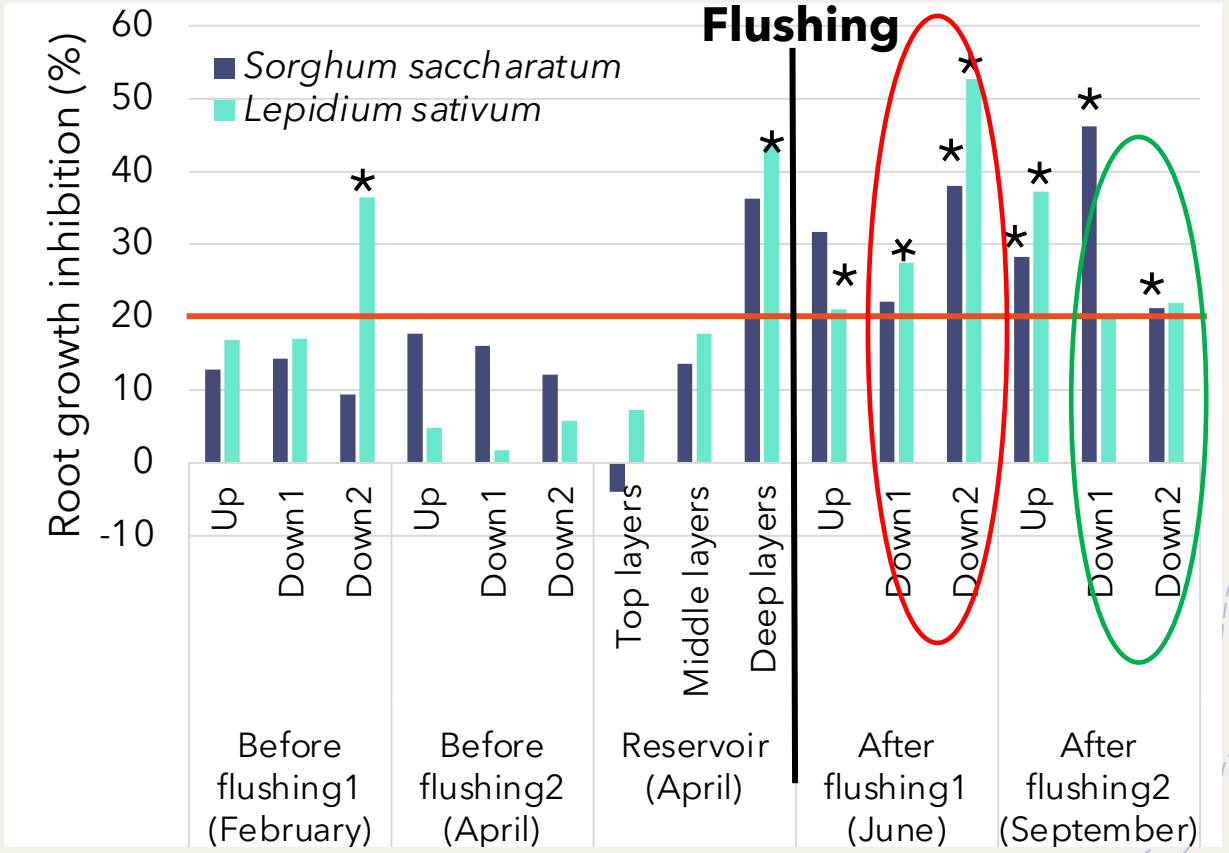


Toxicity tests

6-days whole sediment contact test with the ostracod *Heterocypris incongruens*



3-days whole sediment contact test with higher plants



Evaluations:

1) screening evaluation: comparison with ecotoxicological thresholds (SQGs, toxicity in comparison with control)
2) site-specific evaluation: comparison with upstream site and before-flushing conditions

After flushing required management: washing of the riverbed using high water flow rates

Conclusions: 5 months after flushing, conditions in the river were restored. Confirmed by analysis of macroinvertebrate community

Database on reservoir sediments in Lombardy Region

Results:

- harmonization of sampling design and protocols
- large database on sediments of **56 reservoirs in Lombardy Region**: chemical and ecotoxicological data

Parameter	Unit	Median	Min	Max	SQGs	Samples exceeding SQGs	Total n. data
Altitude	m a.s.l.	1051	237	2987			
Volume	$m^3\ 10^6$	0.35	0.05	63			
Surface	km^2	0.04	0.02	2.2			
Sedimentation rate	$cm\ y^{-1}$	5.6	0.1	74.1			
Fine fraction (< 2 mm)	%	97	6	100			455
Silt fraction (< 63 µm)	% on < 2 mm	43	0.2	99			337
TOC	% d.w.	1.4	0.05	16.2			401
As	$mg\ kg^{-1}$ d.w.	27	0.8	695	33	43 %	384
Cd	$mg\ kg^{-1}$ d.w.	0.29	0.06	10.00	4.98	1 %	287
Cr	$mg\ kg^{-1}$ d.w.	22.0	3.0	146.3	111	1 %	368
Cu	$mg\ kg^{-1}$ d.w.	24.1	1.0	127.8	149	0 %	378
Hg	$mg\ kg^{-1}$ d.w.	0.06	0.01	1.2	1.06	2 %	290
Ni	$mg\ kg^{-1}$ d.w.	21.3	1.5	112.0	48.6	5 %	364
Pb	$mg\ kg^{-1}$ d.w.	18	1	247	128	2 %	369
Zn	$mg\ kg^{-1}$ d.w.	85	12	364	459	0 %	387
PAHs $_{1\%TOC}$	$\mu g\ kg^{-1}$ d.w.	22	0.6	3353	1610	1 %	286
PCBs $_{1\%TOC}$	$\mu g\ kg^{-1}$ d.w.	3.1	0.02	29.9	59.8	0 %	142
Mean PEC-Q		0.3	0.02	4.5			339

Feedback from stakeholders

1. There are no problems with flushing operations, so there's no need to deepen
2. Analyses are too expensive
3. Ecotoxicological tests may give false positives
4. Criteria for interpretation of data should be objective and not just based on expert judgment

MINISTERO DELLE INFRASTRUTTURE E DELLA MOBILITA' SOSTENIBILI

DECRETO 12 ottobre 2022, n. 205

Regolamento recante criteri per la redazione del progetto di gestione degli invasi di cui all'articolo 114, commi 2, 3 e 4 del decreto legislativo 3 aprile 2006, n. 152. (23G00002)

(GU n.7 del 10-1-2023)

Vigente al: 25-1-2023

IL MINISTRO DELLE INFRASTRUTTURE E DELLA MOBILITA' SOSTENIBILI

e

IL MINISTRO DELLA TRANSIZIONE ECOLOGICA

di concerto con

IL MINISTRO DELLO SVILUPPO ECONOMICO

IL MINISTRO DELLE POLITICHE AGRICOLE ALIMENTARI E FORESTALI

Visto il regio-decreto 11 dicembre 1933, n. 1775, recante «Approvazione del Il testo unico delle disposizioni di legge sulle acque e sugli impianti elettrici»;

Visto il decreto del Presidente della Repubblica 1° novembre 1959, n. 1363, recante «Approvazione del regolamento per la compilazione dei progetti, la costruzione e l'esercizio delle dighe di ritenuta»;

VISTA l'articolo 17, comma 3, della legge 23 agosto 1988, n. 400, recante disciplina dell'attività di governo e ordinamento della Presidenza del Consiglio dei ministri;

Visto il decreto legislativo 31 marzo 1998, n. 112, recante «Conferimento di funzioni e compiti amministrativi dello stato alle regioni ed agli enti locali, in attuazione del capo I della legge 15 marzo 1997, n. 59»;

Visto l'articolo 12 del decreto legislativo 16 marzo 1999, n. 79, recante «attuazione della direttiva 96/92/CE recante norme comuni per il mercato interno dell'energia elettrica», relativo alle concessioni idroelettriche;

Vista la direttiva 2000/60/CE del Parlamento europeo e del Consiglio, del 23 ottobre 2000, che istituisce un quadro per l'azione comunitaria in materia di acque;

Visto il decreto del Ministro dell'ambiente e della tutela del territorio 30 giugno 2004, recante «criteri per la redazione del progetto di gestione degli invasi, ai sensi dell'articolo 40, comma 2, del decreto legislativo 11 maggio 1999, n. 152, e

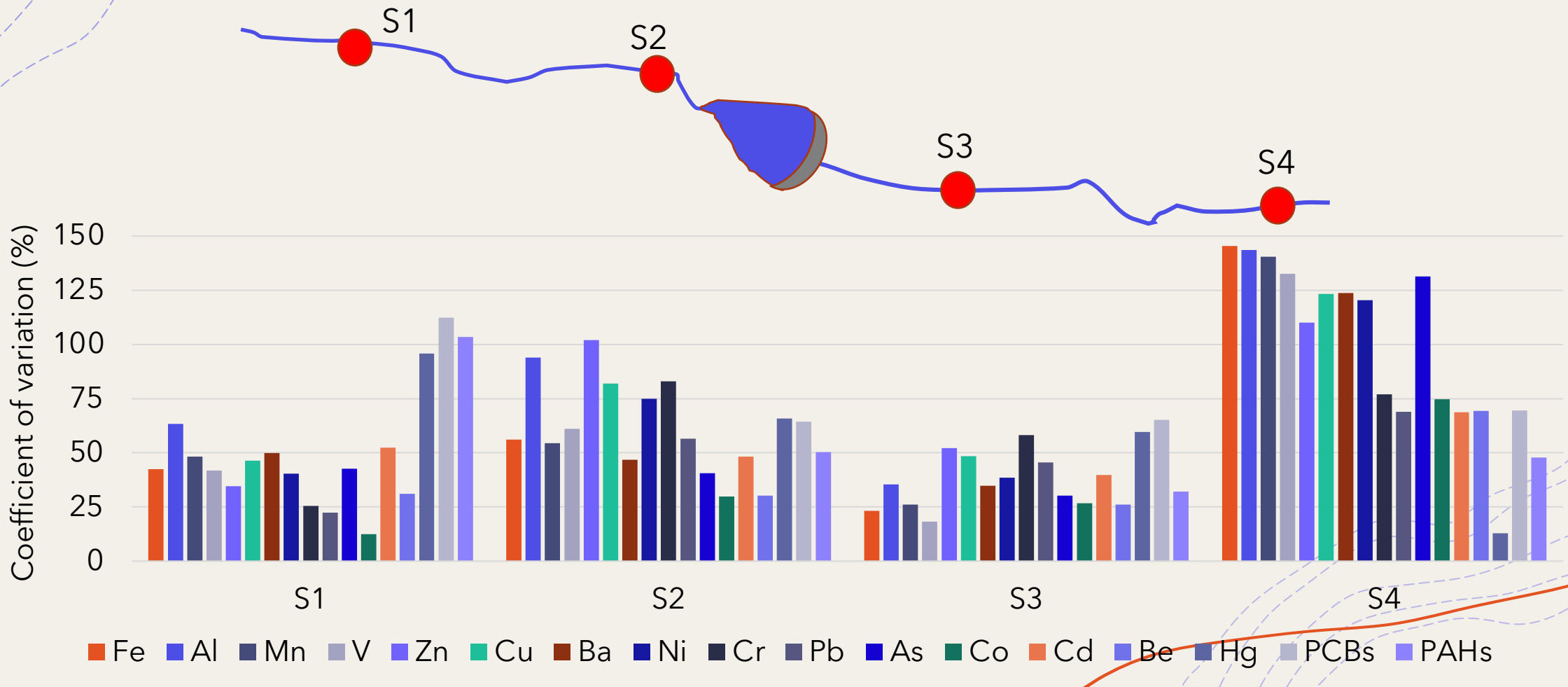
Ministerial Decree n. 205, published on 12 October 2022
Regulation containing criteria for the drafting of the Reservoir Management Project

- Chemical and ecotoxicological characterization of sediments of all reservoirs in Italy is requested (with some exceptions)
- Sampling design and approaches are similar to those of PrATo: analysis of sediments of the reservoir and of the downstream river
- Each Italian Region is called upon to develop protocols and evaluation criteria

Background levels of toxicants in the river basins are not known

Analysis of annual variations of concentrations in the river may help defining risk thresholds for a specific river.

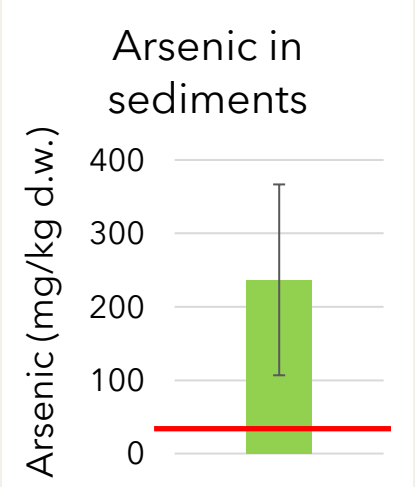
Example: 5 samplings of sediments in one year (before flushing): coefficients of variation showed «natural» variations up to 100-150% (granulometry is a confounding factor)



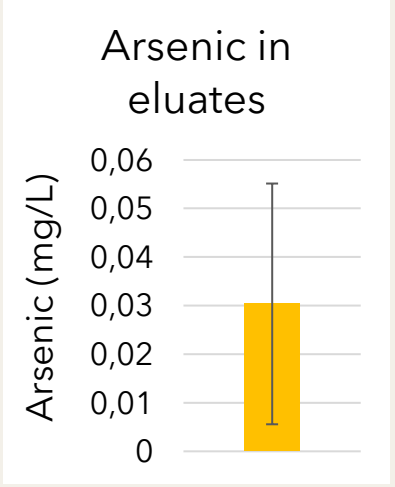
Toxicity depends on bioavailability

- Ecotoxicological tests may give an answer!

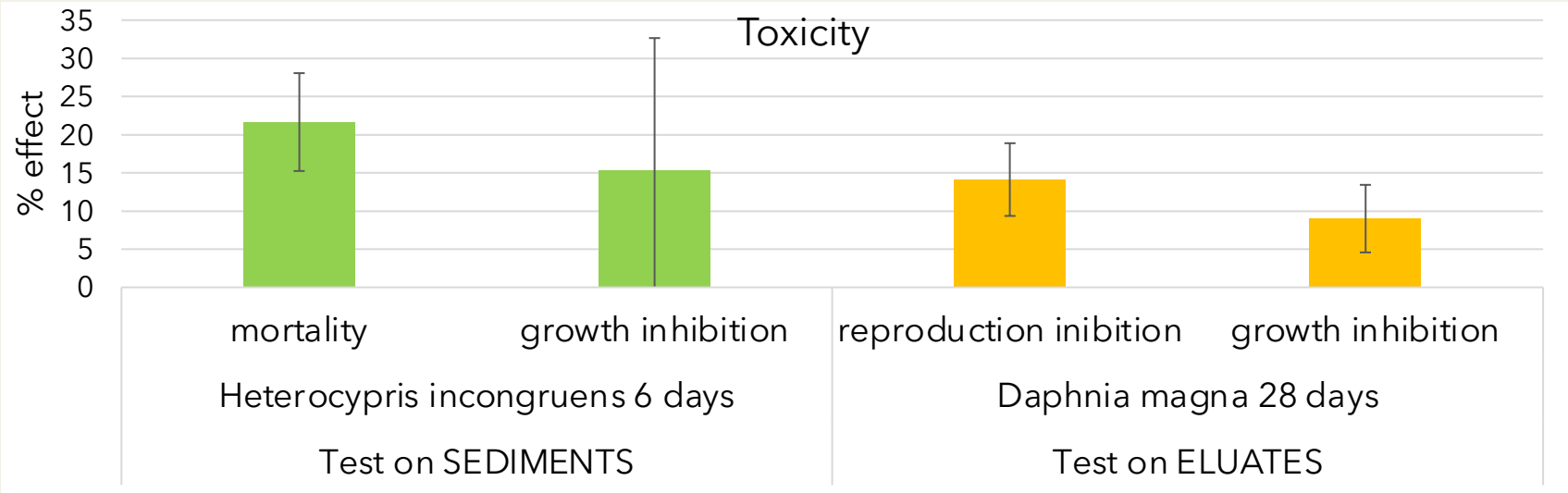
Example: high concentrations of Arsenic in sediments, but no toxicity



PEC=
33 mg/kg d.w.

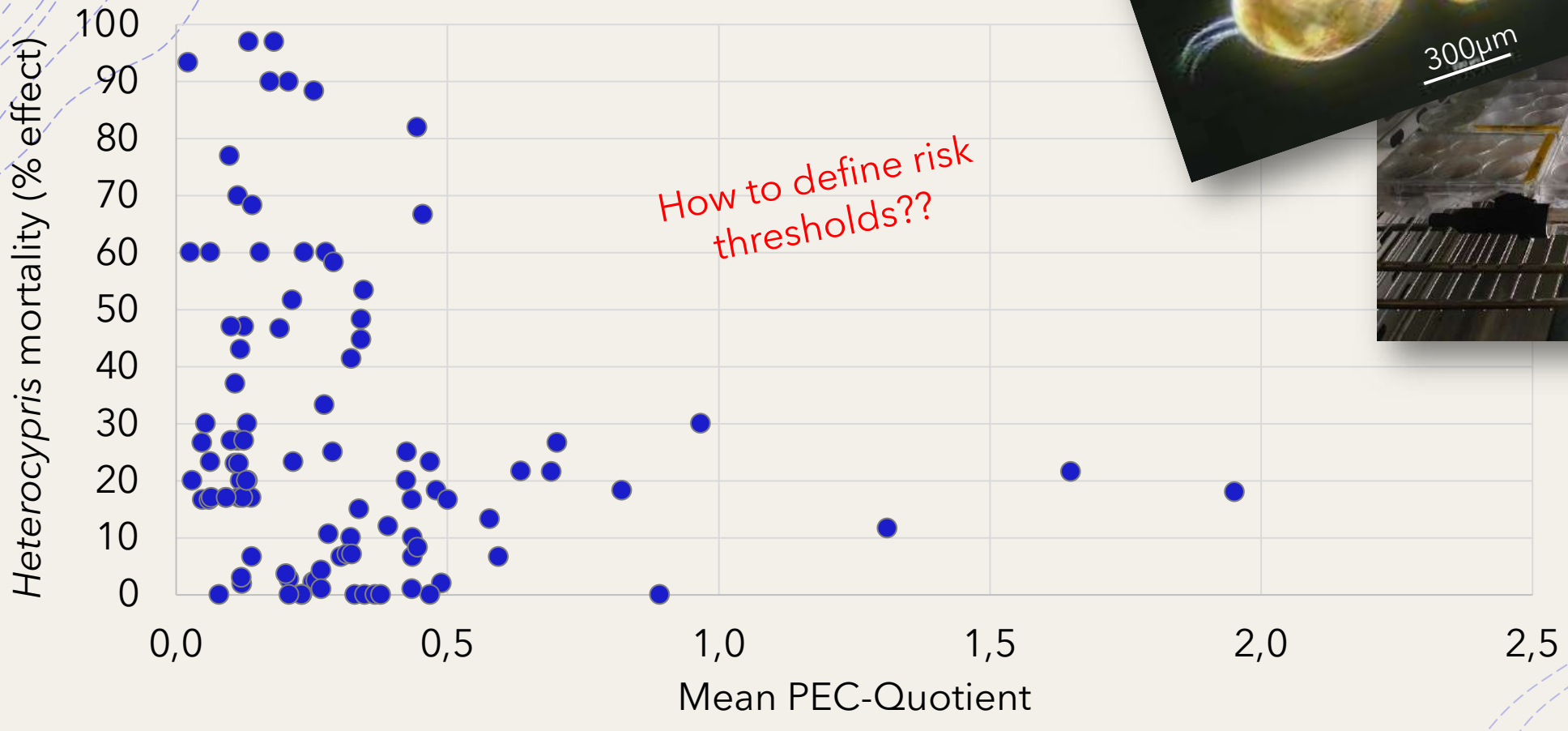


48h LC_{50} *Daphnia* =
5.2 mg/L



Chemical analysis can hardly predict mixture toxicity

Test batteries on sediments are needed!

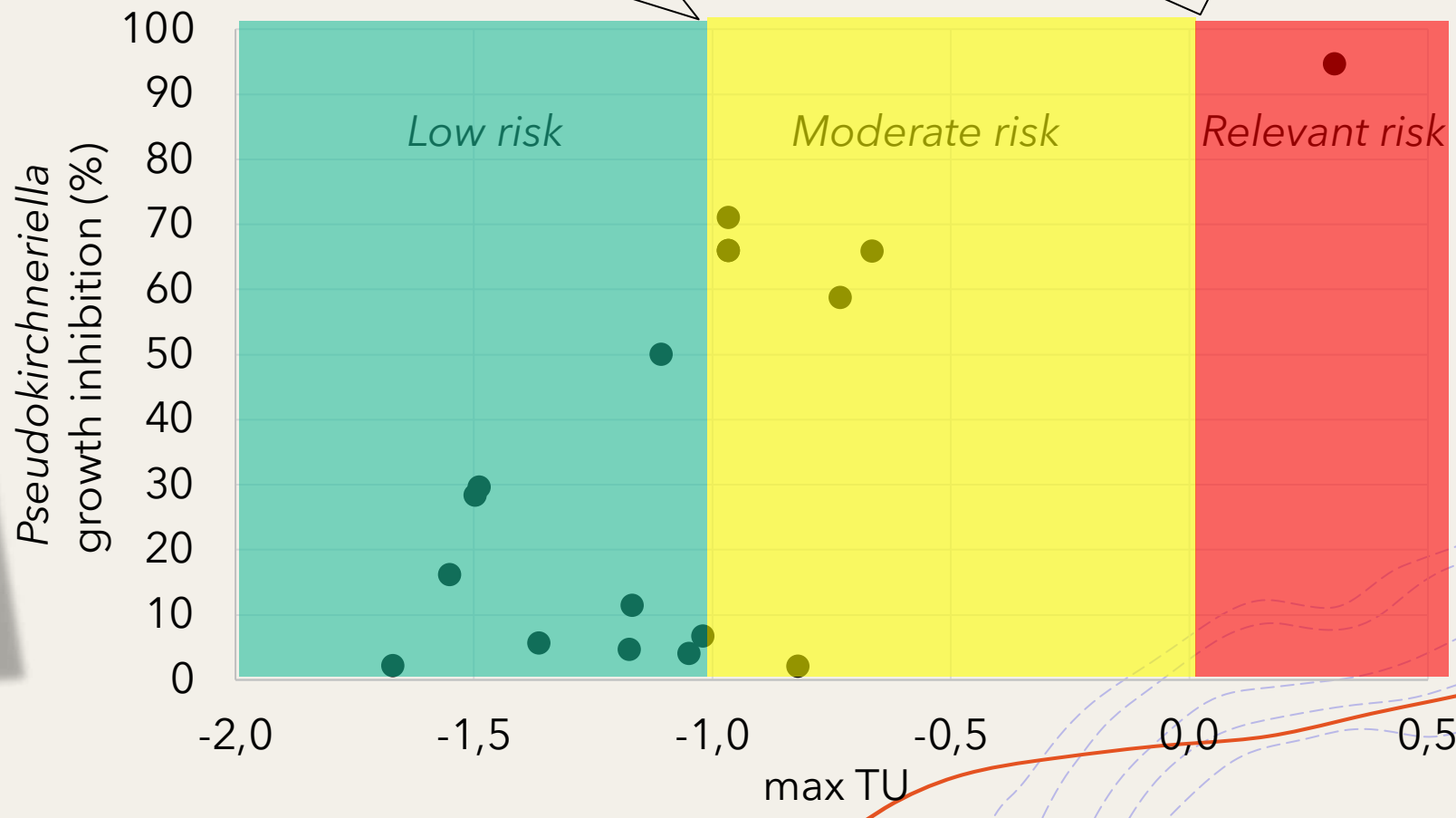


Relation between **concentrations in eluates and toxicity** may help deriving risk thresholds

Example: Toxic Unit approach: $$Toxic\ Unit\ (TU) = log_{10}\left(\frac{measured\ concentration}{48h\ LC_{50}\ Daphnia\ magna}\right)$$

Lower risk threshold:
concentrations 10 times lower than LC_{50} for *Daphnia*

Higher risk threshold:
at least one concentration reaches the LC_{50} for *Daphnia*



Management of flushing operations

Results of sediment characterization will be translated into operational guidelines for reservoir managers

- characterization ***before flushing***:
  - to calculate a sediment:water dilution factor to be applied during flushing to prevent the exceedance of toxicity thresholds
  - if needed, to limit the quantity of sediments to be flushed
  - to program washing operations after flushing to restore the downstream river

- characterization ***after flushing***:
  - to perform additional washing, if necessary
  - to remodulate future operations, e.g., by limiting the quantity of flushed sediments and/or the frequency of flushing operations

Conclusions

Reservoirs: more and more strategical for energy production and freshwater storage.

Climate change: declining storage volumes and streamflow droughts.

Italian Decree Law “Drought” (n. 39/2023, law n. 68/2023: requires to urgently recover storage volumes in reservoirs to allow water storage.

Sediment management in reservoirs is needed, but regulation and protocols are still lacking.

PrATo protocol is a basis to collect data with harmonized procedures and for risk evaluations based on site-specific data.

The ultimate goal is to develop sediment management strategies central to the sustainable management of dams and reservoirs.

Thanks for your attention