Sediment quality assessment criteria: new approaches and views

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Introduction: Environmental Risk Assessment (ERA), including sediment assessments, is a comprehensive approach to support decision making in the regulatory context, and covers a wide spatial set of situations under very different regulatory contexts. This includes analysis for setting ecological quality standards/criteria, the emission-permit authorisations, the assessment of risk associated with contaminated sediments and its management, etc.

In the last decade a giant effort for understanding the contaminants chemical and physical behaviour in the aquatic sediments and their potential single and combined effect on the ecosystem has been done. Recently, the use of multiple lines of evidence consistent with the integrated assessment philosophy is currently considered a comprehensive and modern approach for assessing sediment quality. In particular, lines of evidence include chemistry of sediments, bioaccumulation and ecological assessments and generally combine these and other lines of evidence in Weight-of-Evidence (WoE) framework. However, this assessment relies on professional judgements and the use of tabular decision values remains often the most useful approach for achieving transparency and comprehension by lay personnel.

In environmental assessments of fresh, marine or transitional waters, ERA should be based on holistic approach. This means that it should not be seen as a series of complementary but separate risk assessments for pelagic/benthonic organisms and for the sediment compartment and the protection of communities (rather than individuals) should be considered as a crucial element of risk assessment. Furthermore, the sediment risk assessment should be based on species representative of different trophic levels, feeding strategies, and habitats; in addition, organism life-history and ecology that can modify exposure should be considered. Finally, specific and well-defined protection goals (ecosystem services, wildlife, etc.) need to be identified.

On the chemistry side, the equilibrium partitioning model applied to inorganic and organic contaminants, coupled to the biotic ligand model and different speciation model offers a robust information about the behaviour of pollutants in the sediments and at the aquatic and biotic interfaces. However, mineralogical and physical features (grain size, OC, pore water, burrow water, pH, Eh, Fe and Mn oxyhydroxides, aging of sediments, etc.) create a complex ensemble of variable which make it difficult a clear understanding of the sediments compartment and unpredictable a linear response of the ecotoxicological tests and bioaccumulation through the trophic web. Last but not least, sedimentary systems and their aquatic and biotic interfaces are dynamic systems under changing climate and environmental forcing that reduce our capacity to freeze in a single set of parameters the state of the system. Also differences in these parameters influence the bioavailability of metal contaminants to benthic organisms that are exposed to metal contaminants via both the dissolved phase (i.e. pore water, burrow water, or overlying water) and dietary ingestion of particles (live food, detritus, or sediments). No current SQGs explicitly consider dietary exposure despite biodynamic modelling studies indicating that the dissolved and dietary exposure routes are additive in relation to metal accumulation. However, studies have not yet determined whether the metals that are internalized via these two routes have the same mechanism or similar degrees of toxicity, because of the potentially different internal metal partitioning processes.

A systemic vision: An alternative to a linear and/or combined view of pollutants behaviour, multiple physical parameters of sediments and aquatic/biotic interfaces could be offered by what we call a systemic approach, with its perspective of an emergent property of the whole chemical-physical and ecological system rather than of any or a simple addition of its components. According to the General Systems Theory of von Bertalanffy, a system is ‘a set of elements standing in interrelation among themselves and with [their] environment’. The theory’s principles include a subset that apply to the open, complex, hierarchical and autopoïetic systems that are exemplified by chemical and physical components and the ecosystems. Thus, the concept of sediment quality refers to patterns of the whole system and its components. Specifically, systems can be characterized in two ways: I internal description uses state variables, classically exemplified for biological systems (i.e by the Lotka-Volterra equations. In a simple case, the state variables might be chemical concentration of pollutants, physical parameters of sediments, etc.); . Nevertheless, whether a system is simple or complex, change can be expressed ‘*geometrically ... by the trajectories that the state variables traverse in the state space, that is, the n-dimensional space of possible location of these variables*’. In the case of external description which describes the behaviour of the system in terms of interactions with what is outside the system, often by specifying the relationship between inputs to the system and the resulting outputs. Anthropogenic impact constitutes a pressure, resulting in changes in the (internal) state of the system with consequent impacts on the stability of the system. Resilience is the system property that determines the response of state to a pressure change; it is an emergent property because it cannot be localized in any particular component of the system.