Bioassays

Sediment Linkages Between the River Catchment and the Sea

Research Article

Application of a New Sediment Contact Test with *Myriophyllum aquaticum* and of the Aquatic *Lemna* Test to Assess the Sediment Quality of Lake Skadar *

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Abstract

Goal, Scope and Background. Situated in the transboundary belt between Montenegro and Albania, Lake Skadar is the largest freshwater reservoir in Southeastern Europe. Because of the wide range of endemic, rare or endangered plant and animal species it supports, Lake Skadar and its extensive adjacent wetlands are internationally recognised as a site of significance and importance (Ramsar site). Within the last 10 to 20 years, Lake Skadar was exposed to intensive pollution. For the assessment of the ecotoxic load of the sediments sampled in Lake Skadar, a triad approach was recently applied. Overall, a complex spectrum of ecotoxic loads was elucidated. The aim of the present study was to use plant-based bioassays for assessing the sediment quality of Lake Skadar in order to facilitate and complement the triad test battery. The newly developed sediment contact test with *Myriophyllum aquaticum* and the aquatic growth inhibition test with *Lemna minor* were applied to native sediments and pore water, respectively, allowing the investigation of different toxicity-effects caused by particle-bound pollutants as well as pollutants in the interstitial water. This investigation is the first application of the novel sediment contact test with *Myriophyllum aquaticum* to lake sediments.

Methods. Sediment samples were taken from nine selected sites at Lake Skadar and investigated by the sediment contact assay with *Myriophyllum aquaticum*. The pore water was extracted from these sediment samples to be analysed in the aquatic growth inhibition test with *Lemna minor*. The results of the sediment contact tests were compared with each other and with those of the aquatic growth inhibition test.

Results and Discussion. Both applied macrophyte biotests revealed distinct changes in the growth behaviour of the two macrophytes subsequent to the exposure to the investigated natural sediments of Lake Skadar. The *Myriophyllum* sediment contact test revealed significant toxicity in the sediment samples from Radus and Kamenik, whereas the aquatic *Lemna* test showed inhibition effects for the samples from Sterboq, Plavnica and Kamnic. Data obtained with the newly developed *Danio rerio* contact test and the *Arthrobacter globiformis* contact test confirmed the *Myriophyllum* results. Analyses of the heavy metal content in the sediments revealed low or moderate contamination levels. Correlation analyses between the content of heavy metals in the sediments and growth inhibition of *Myriophyllum aquaticum* showed a significant correlation between Cr concentrations and growth inhibition. Comparable findings are available for a German river system. In contrast, no significant correlation between inhibition rates and concentration of metals could be observed with *Lemna minor*.

Conclusions. It was shown that the newly developed sediment contact test with *Myriophyllum aquaticum* is applicable to lake sediments. In both the sediment contact test with *Myriophyllum aquaticum* on whole sediments and the aquatic growth inhibition test with *Lemna minor* on pore water, plant growth was influenced by the natural sediments and its components. Therefore, both test systems were found to be suitable for the detection of phytoxic effects upon exposure to sediments. *Myriophyllum aquaticum* as test organism of the contact test grows directly in the sediment without an additional water-layer. Thus, it is able to detect toxicity caused by particle-bound phytotoxic substances as well as pore water-related contamination, while the floating *Lemna minor* can only detect effects emanating from pore water. Significant differences of the results were observed between these two test systems and, accordingly, the two different exposure scenarios. Hence, none of the tests can replace the other one and, as a consequence, both should be included into a test battery for the assessment of sediment toxicity.

Recommendations and Perspectives. Both plant assays were shown to be reliable tools for the evaluation of the eco-toxicological risk potentials of pore water and solid-phase sediment. They should become a complement to the standardised test battery generally used for comprehensive hazard assessment.

Keywords: Bioassays; Lake Skadar; *Lemna minor*; macrophytes; *Myriophyllum aquaticum*; native sediments; pore water; sediment contact test; sediment toxicity

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Introduction

Placed in the transboundary belt between Montenegro and Albania, in a karst terrain on the outer part of the southeastern Dinaric Alps, Lake Skadar is the largest freshwater reservoir in Southeast Europe.

The lake was promoted as a national park in 1983 (Official Gazette SRCG 1991) and, in 1995, as a wetland site of international significance and importance – a so-called Ramsar site (Site 3YU003).

The lake receives water from several large rivers (e.g. Moraca river, providing the largest (60%) inflow), numerous small streams and several sub-lacustrine springs. The lake's only surface outlet is the Buna river, which flows into the Adriatic sea. The lake is affected by industrial and municipal waste from urban and industrial areas (e.g. Podgorica, Skadar, KAP (a giant aluminium processing plant)), and by an increasing use of artificial fertilizers and pesticides in agriculture (for more details see Rastall et al. 2004 and Mijovic et al. 2006).

According to Filipovic (1983), a decrease in the water quality of the lake was first noticed in the early 1980s for underground waters. The contamination was ascribed to micropollutants and heavy metals. Monitoring of Lake Skadar's water quality, which was conducted in the periods 1987–1994 (Djuraskovic et al. 1997) and 2002–2004 (Mijovic et al. 2006), showed that the changes of physical-chemical characteristics were not significant and that the water quality remained good. This phenomenon may be explained by the fast metabolism of the lake and a well-developed belt of macrophyte vegetation, which trapped the pollutants (Vizi 1995, 1997).

Recent investigations of water quality were carried out within the EULIMNOS project. This project was initiated, with the objective of obtaining a comprehensive insight into the current ecological and ecotoxicological state of Lake Skadar and its tributaries, by application of a collaborative, integrated, multidisciplinary approach. The findings should be used to develop recommendations for the sustainable development and management of the lake ecosystem (Holllert et al. 2004). Results so far point out a betamesoprobic level of saprobity, which corresponds to a moderate pollution with organic compounds (Rakocevic-Nedovic & Hollert 2005) and a clear-cut ecotoxicological hazard potential (e.g. Rastall et al. 2004). Bioassays carried out on samples obtained using Semi Permeable Membrane Devices (SPMD) revealed significant EROD-inducing and estrogenic potential, indicating toxicoologically relevant compounds readily available for uptake by resident aquatic biota (Rastall et al. 2004).

Over the last decades, contamination of river and lake sediments has increased rapidly. Sediments have been recognised not only as a major sink for persistent toxic substances released into the aquatic environment, but also as a potential source (Brils 2002, Förstner 2004, SedNet 2004). Therefore, sediments – being the habitat of an abundant biocenosis and the place for multitude biochemical transformations – play a key role in the assessment of the ecological status of water. Sediment studies are very suitable for highlighting anthropogenic impact on pollution.

At present, the environmental hazard of sediment-bound contaminants is evaluated primarily by chemical analyses. However, according to the concept of the triad approach, i.e. a combination of biology (toxicity tests), chemistry (chemical analysis) and ecology (community structure) of Chapman (2000), chemical data alone are insufficient to assess the potential environmental hazards of chemicals. Bioassays can help to define the ecotoxicological effects of contaminants. Numerous concepts using chemical analyses, bioassays or integrated approaches have been developed for the assessment of sediment quality (Ahlf et al. 2002a,b, Burton 1992, Chapman 2000, Chapman et al. 2002, Heise & Ahlf 2002, Hollert et al. 2003, Feiler et al. 2004, 2006b).

In current biotest approaches, intact organisms or in vitro systems are exposed to sediment samples using different exposure scenarios (Harkey et al. 1994). As a consequence, the question concerning what should be used as the test phase is probably the most important issue in sediment toxicity testing protocols (cf. Hollert et al. 2003, Keiter et al. 2006). Test phases can be categorised as follows: (a) organically extractable phases (in solvents other than water), (b) elutriate phases (water-extractable), (c) interstitial water phases (pore water), (d) whole sediments, and (e) in situ assays (Burton 1992).


As shown previously, sediment contact assays can be used as an additional line of evidence in weight-of-evidence studies to provide insight into the bioavailable toxicant fraction (Chapmann & Hollert 2006).

In order to gain insight into the ecological and ecotoxicological state of sediments in Lake Skadar, a comprehensive triad approach has already been applied to investigate sediment chemistry, sediment toxicity and alterations in the field such as modifications to bacterial and macrozoobenthos community structure. Both acute toxicity, and more specific effects such as mutagenic, genotoxic, teratogenic, dioxin- and estrogen-like responses, were recorded (cf. Hollert et al. 2004, Kostanjsek et al. 2005, Perovic et al. 2007). For an initial screening of the toxic potential of particle-bound contaminants in sediments of Lake Skadar, bioanalytical methods including the sediment contact assay with Arthrobacter globiformis, the Ames test with Salmonella typhimurium TA 98 and TA 100,