The combination of chemical contamination, toxicity and in situ sediment structure is responsible for the low biodiversity of Lake Rummelsburg (Berlin)

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Introduction: The sediments of the Rummelsburger See, a lake-like, partly separated expansion of the river Spree located in the metropolitan area of Berlin have been contaminated due to the discharge of mainly industrial waste water in the course of about one century. Meanwhile the territories around the lake are progressively reclassified as residential area. It has been suggested that the contamination of the lake with a number of chemicals is the main reason for significant abnormalities of the biological diversity in the lake sediments. Restorative remediation measures between 1999 and 2001 were primarily focused on sediment conditioning in order to decrease the nutrient load and digested sludge and to increase the visibility depth.
In the present study the sediment conditions were comprehensively analyzed by chemical, biological and ecotoxicological analyses. A sediment quality guideline approach was used to assess the data of the chemical analysis. The main goal of this project was to determine the extent and the nature of ecological stressors such as chemical contamination and missing structural habitat diversity in order to recommend possible future measures for a natural repopulation of the aquatic environment with benthic organisms.

Methods: Representative sediment samples of the lake were taken from the sediment surface in June 2012. One sediment core and one reference sample from the river Spree were taken additionally. Chemical and biological analyses as well as ecotoxicological tests were performed with the same material. Chemical analysis included: SVOCs, mineral oil hydrocarbons, 7 PCBs, 16 EPA-PAHs, organotin compounds, dioxins, alkyl phenols, and heavy metals. A bioassay battery consisting of tests with luminescent bacteria, freshwater algae, daphnids (*Daphnia magna*), nematodes (*Caenorhabditis elegans*), and higher plants (*Lemna minor, Myriophyllum aquaticum*) was used for measuring the toxicity of sediment, pore water and elutriates. If possible, test systems were performed as sediment contact tests. Additionally, *in vitro* tests on mutagenicity (Ames fluctuation test) and endocrine disruption (YES-test) were conducted. Macrozoobenthos was identified, if possible, to the species level and abundances (ind./m^2) were recorded. Settlement homogeneity was analysed by cluster analysis. Species diversity was calculated using the Berger-Parker-Index. Additionally, the toxic potential of the sediment samples and the incidence of toxicity were calculated based on probable effect concentrations (PECs) of two different sediment quality guideline data sets.

Results and Discussion: Chemical analyses (normalized to the <63 µm fraction) of freshly deposited sediments revealed concentrations of 400 – 1400 µg/kg (Sum of 7 PCB), 90-700 µg/kg p,p'-DDD, 2500-6500 µg/kg mineral oil hydrocarbons, 55-370 mg/kg (sum of 16 EPA-PAHs), 1100-2400 µg/kg tributyltin and 9,7-76 ng I-TE/kg dioxin like activity. Metals, measured in the fine grained fraction < 63µm showed concentrations of 80-440 mg/kg Cr, 9-46 mg/kg Cd, 2,2-4,1 mg/kg Hg, 1000-6400 mg/kg Cu, 64-98 mg/kg Ni, 1600-2700 mg/kg Zn, 340-830 mg/kg Pb, and 20-51 mg/kg As. Whereas sediment pore waters and elutriates showed no toxic effects to freshwater algae and daphnia and a moderate toxicity to luminescent bacteria, the samples were moderately to highly toxic to *L. minor*. Growth of *C. elegans* was moderately inhibited but the reproduction of the nematodes was severely disturbed in most cases. Estrogenicity ranged from 5 to 25 ng/l EEQ and was (with the exception of one sample) highly correlated to the concentrations of iso-Nonylphenols (normalized to TOC). Pore waters were not mutagenic but particle bound mutagenicity was detectable. Mutagenicity increased with the metabolic competence in the test condition. PAHs, nitroarenes and aromatic amines supposed to be responsible for the mutagenic effects. Surprisingly, the reference sample also showed a considerable chemical contamination and toxicity towards *L. minor* and *C. elegans*.
The analysis of macrozoobenthos showed that species diversity was low. Especially those species were found that have low demands on their habitat. Cluster analysis revealed two distinct series depending on the sand / silt ratio of the substrate. SPEAR species were almost absent. Analysis of PEC-quotients revealed a high probability of toxicity for benthic organisms.

Conclusions: The combination of high chemical contamination with persistent organic and inorganic chemicals, toxicity and specific substrate composition makes a natural repopulation scenario for the improvement of the biological diversity extremely improbable. The study suggests that either removal of the sediments or capping with appropriate substrate or a combination of both can improve the situation significantly.