Metal induced succession in benthic diatom consortia

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Citation for published version (APA):
SUMMARY

The ubiquitous occurrence of diatoms and their taxonomic diversity has led to these algae being used widely for monitoring the environmental conditions in rivers and lakes. Widespread metal contamination affects water quality and may lead to changes in the relative abundance of diatom species in communities. Metals may cause a replacement of sensitive diatom species or clones by more tolerant ones. It was hypothesised here, however, that not only metals but also other factors, such as nutrient concentrations, affect the algal succession in communities. Hence, metal and nutrients may interact in modulating algal density and diatom species composition. Algal growth form and biofilm characteristics were put forward as factors modifying the response of individual algal cells to environmental stressors.

In the present study the characteristics of microphytic river biofilms in situ and under experimental conditions were analysed. Factors interacting and determining the physiognomy and response of microphytic biofilms in the field were identified. The ecological role of species and structural characteristics of biofilms determining the response to external factors was here experimentally investigated.

This study departed (in chapter II) from an in situ evaluation and characterisation of the biotic and abiotic components and of the physiology of microphytic biofilms in the River Dommel. The River Dommel has been exposed to enhanced Zn and Cd concentrations for more than a century due to the activities of a former Zn foundry located in its catchment. Colonised glass discs and samples of natural assemblages on coarse sand were used to test if prolonged exposure to metals in the field had led to Zn tolerance in algal communities. Tolerance was characterised by measuring inhibition of $^{14}$C-incorporation in microalgae and $^3$H-thymidine incorporation in bacteria. Bacterial assemblages on both glass and sand from the extremely metal polluted site were resistant to Zn when compared to populations from the cleaner upstream site. Algae from the extremely polluted site were only slightly affected by the highest Zn
concentration tested but bacteria were one order of magnitude more sensitive. Biofilm thickness and metal deposition were pointed out as being responsible for the low sensitivity of algae to Zn.

In chapter III, diatom species composition was experimentally related to water quality by transferring racks with colonised glass discs from a metal polluted stream to a reference stream and *vice versa* in spring, autumn and winter. Metal concentrations and dry weight in translocated biofilms tended to conform with those in local biofilms within an incubation time of 14 to 18 days. Bray-Curtis similarity values from the different communities indicated that diatom communities responded more completely to the metal polluted conditions than to the reference water quality providing a first indication of an active metal selection force on the algal consortia of the streams. However, the distribution and changing abundance of taxa indicated that metal exposure was not the only selective factor, and that other ecological variables may influence the composition of microphytobenthic communities.

In chapter IV, the roles of enhanced phosphate and metal concentrations for diatom succession were investigated and the interaction of both factors was analysed. Microalgal biofilms from a reference stream were exposed in the laboratory to concentrations of Zn, Cd and P as found at a polluted stream in the same catchment. Zn alone was found to cause a severe decrease in growth of the biofilm algae, but phosphate totally compensated for this Zn effect. However, P could not fully compensate for the combined effects of Zn and Cd. The succession of diatom species in experiments matched in general the observed difference in microphyte communities at the reference and polluted river stations, but a simple interaction scheme of the three main factors (Zn, Cd and P) was insufficient to explain the species' role in detail. Also the combinations of the three factors had an impact on diatom ranking scores that were in contradiction to the basic assumptions in these ranking systems (TDI and %PTV). The roles of adherent, erect and motile species and their variable abundance during different stages of biofilm maturation was put forward as a major cause of complex, non-linear responses of multispecies biofilms even to simple factor combinations.
In chapter V, it was hypothesised that mature biofilm structure acts as a barrier against deleterious effects of metals on microphytobenthos. To validate this, micro-algae were allowed to settle for 2 and 6 weeks at a reference and a metal polluted stream. These “young” and old biofilms were subsequently exposed in the laboratory to Zn and Cd concentrations, mimicking the polluted stream, for a period of two weeks. Observations on diatom species composition, chlorophyll, carbohydrates, Zn and Cd concentrations, minimal chlorophyll fluorescence ($F_0$) and photon yield ($\phi_p$) showed that biofilms in an early colonisation stage are more vulnerable to metal exposure than mature biofilms.

In chapter VI, it was investigated whether an increased tolerance to Zn of the diatom *Gomphonema parvulum* could explain its abundance at both metal polluted and reference sites. Diatom strains from a reference and a metal polluted stream were cultured as mono-specific biofilms thus maintaining their benthic mode of growth. Short-term (5 h) toxicity experiments with Zn and Cu were performed with the strains using pulse amplitude modulated (PAM) fluorometry. The Zn concentrations that caused a 50% reduction ($EC_{50}$'s) of the $\phi_p$ of the strain from the metal polluted stream were significantly higher than those of the isolate from the reference stream. Such a differentiation of clones was absent for Cu. The genetical nature of increased Zn-tolerance in *G. parvulum* was confirmed by the persistance of the Zn tolerance of the polluted strain two years after isolation. Zn-induced tolerance of *G. parvulum* was confirmed in intact biofilms from the polluted stream.

In the concluding remarks (chapter VII) three questions were put forward and tentatively answered as follows:

*Is metal contamination steering algal succession towards more tolerant forms?*
Consistent with general ecological theory the answer to this question was positive. Within the taxon *G. parvulum* adaptation to Zn was observed. However, the indirect effect of toxic metal levels were shown to retard biofilm maturation and this effect was shown to affect species succession as well. The packing of algal cells in maturing
biofilms was indicated to disqualify current procedures to measure pollution induced community tolerance (PICT) with intact biofilms.

*How do nutrients modulate metal-steered diatom succession in biofilms?*

The resilience of biofilms to change under disturbing external factors is tightly bound to their degree of succession and maturity, and thus their spatial organisation. Both nutrient and metals affect the vertical micro-distribution of diatom species in biofilms. Stimulation of succession and algal density by nutrients is counteracting the inhibitory effects of metals that delay growth. The resulting succession in response to interacting metal-nutrient mixtures rely on the competitive abilities of diatom species as determined by their autoecological traits and growth-form and fit in with general growth-disturbance concepts on microphytobenthos.

*Are experiments needed to support the use of benthic diatoms for water quality assessment?*

Diatom monitoring has been established almost exclusively empirical and has been based on accepted sensitivity of taxa to varying selected factors. The multiplicity of factors in natural environments, some of them analysed in this thesis, demand for a re-examination of the current use of consortia of diatoms and their species composition for monitoring. Even the value of indicator species, as currently established, is put under question, because the risk of co-varying variables may lead to false interpretations. Diatom research needs the support of a general ecological context.