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BIOFILMS IN FRESHWATER ECOSYSTEMS AND THEIR USE AS A POLLUTANT MONITOR

S. Fuchs, T. Haritopoulou and M. Wilhelmi

Institute for Aquatic Environmental Engineering of the University of Karlsruhe, Am Fasanengarten, D-76128 Karlsruhe, Germany

ABSTRACT

A simple biofilm sampling device is used to collect representative microcoenoses from the River Alb in Germany. The samples are analyzed for their copper, cadmium and lead contents and the results are shown to be comparable to those from the techniques. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Receiving water quality; heavy metals; biofilm; monitoring method.

INTRODUCTION

The pollution of urban stormwater runoff has been intensively surveyed in a great number of research projects. It is not a point of discussion that according to the extension of human activities the concentrations of priority pollutants (US EPA) rise. Especially in highly urbanised areas the contaminant loads which are discharged into receiving waters from diffuse sources, like stormwater runoff, are high. In spite of various research activities in this area including field and laboratory experiments the question of the ecological relevance of such pollutant loads in freshwater ecosystems still remains unanswered. In some studies the correlation between detected pollutant concentrations and uptake or mortality of organisms was investigated (Seager & Abrahams, 190; Bascombe *et al.* 1990) in order to demonstrate the impact of discharges but the results were rather poor. Considering the transport dynamics in freshwater systems and the mobility of the indicator organisms this fact is not surprising.

A method used for the identification of pollutant sources in sewer systems (sewer slime: Sielhaut Gutekunst, 1988) by accumulation in the sewer slime initiated the idea to apply this experience to freshwater systems. For this reason we developed a measurement method based on aquatic biofilms/microcoenoses to prevent the difficulties described above. The main characteristic of biofilms is their ability to adsorb and incorporate material. Biofilms can be found at almost any surface exposed to water and they represent a microbial community with various inhabitants such as sessile bacteria, protozoa, fungi and algae. The microbial cells as well as abiotic materials are embedded in an organic polymer matrix of microbial origin, the EPS (ExoPolySaccharides). According to their structure biofilms are able to incorporate contaminants, to grow rapidly and they offer an easy sampling possibility. Thus these aquatic microbial communities can be used as a pollutant-indicator-system.

METHODOLOGY

In order to prove the applicability of the indicator property of biofilms some measurements in the river Alb near Karlsruhe were carried out. Biofilms at different locations were analyzed with regard to their heavy metal pollution (copper, cadmium, lead). The results were compared with the results of other investigators, who monitored the heavy metal pollution of sediments and suspended solids in the same river system (Schäfer, 1995).

For the collection of representative (and following comparable) microcoenoses a biofilm sampling device was designed (Figure 1). A PVC-pipe (diameter 20cm, length 60cm) and 6 sheets of glass with an entire surface of $0.48m^2$ were combined to an artificial substratum sampler. Before exposition the sheets were coated with a thin layer of stearic acid to enhance the microbial growth at the beginning of the exposure.

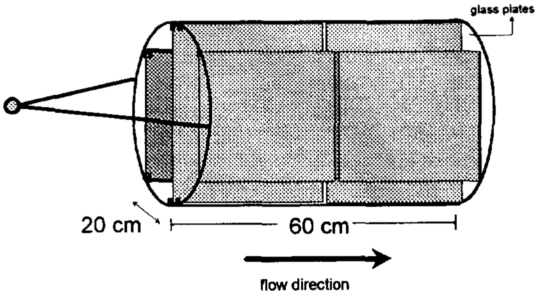

Figure 1. Biofilm sampler.

The biofilm was allowed to grow for 14 days. After this period the samplers were collected and transported in water prior to the analysis in the laboratory. In the laboratory the biofilm was scraped from the plates and characterized by organic content, water content, proteins and carbohydrates.

Finally the biofilms were freeze dried and analyzed for their heavy metal content. All samples were digested with HNO_3/HC1 (1:3) for 2h at 180°C, filtered and measured for cadmium, lead and copper with the AAS graphite furnace method. In this way 16 biofilm samples were treated in the period from January to December 1995. The sediments (upper layers 2-3cm) in lenitic zones were collected using a small shovel and were preserved in water. In the laboratory the sediments were fractionated by sieving into 4 grain classes (>250μm, 125μm, 63μm and <63μm) and the fractions <63μm wer freeze-dried. The suspended solids were collected under both dry and wet weather conditions - 2-5L of river water were filtered through glass fibre filters (Schäfer, 1995). All samples were treated in the same way as described above to quantify their heavy metal content.

CASE STUDY: ALB

The measurements relating to the heavy metal loading of the biofilms were carried out at three sites in the river Alb (Figure 2). The river Alb's origin is in the northern Black Forest at a height of 750m, it flows 55km up to its discharge into the river Rhine. The mean flow velocity ranges from >0.5m/s in the upper water course to 0.3m/s in the urbanised area. The average discharge volume (MQ) is in the order of 3.4 m^3/s (LFU, 1970). The sampling sites were chosen to be in different river reaches, which are characterized by various human activities. The upper reaches of river Alb (site 1) are only influenced by extensive agricultural activities. The first minor effects of urbanisation are evident downstream the city of Ettlingen (38,000 inhabitants) although up to the boundary of Karlsruhe (shaded area, site 2) the river maintains its seminatural characteristics. Significant changes in morphology and pollution are the results of increasing human activities in the catchment of Karlsruhe (ca. 300,000 inhabitants). At site 3 the river is highly degraded.

RESULTS

The main task of this study was to validate the biofilm method by comparing the measured pollution with the results of long term monitoring programs based on sediment and suspended solids (SS) samples. The evaluation of the heavy metal pollution and its ecological relevance in different rivers or even river reaches based on sediment or SS investigations requires more detailed information (e.g. flow condition, substrate composition) as well as further analytical procedure (e.g. sieving, filtration).

Figure 2 shows a comparison of the average heavy metal pollution in the selected river reaches as detected in different measurement campaigns.

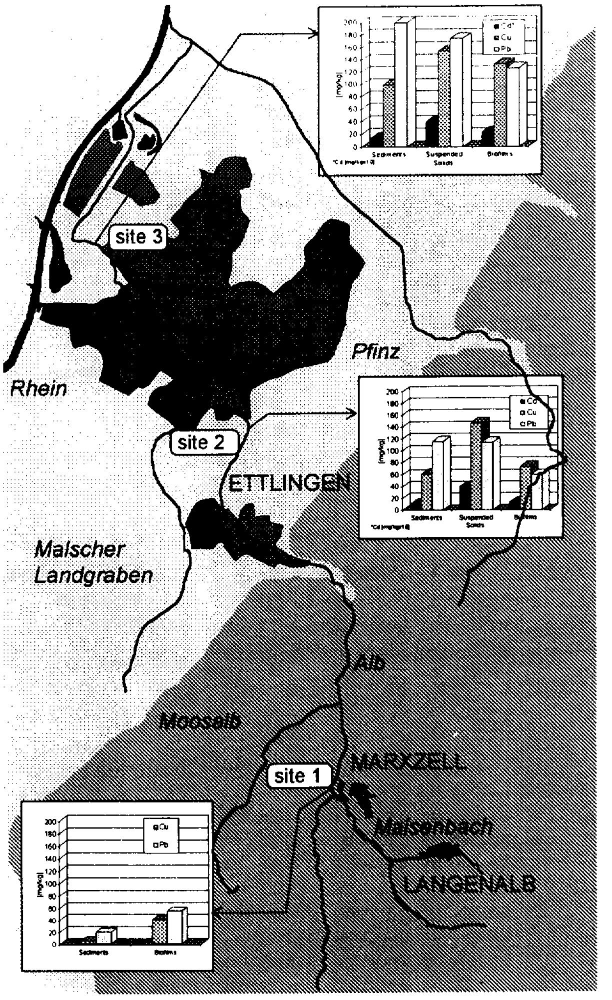

Figure 2. The investigation area (river Alb) with the sampling sites and the detected heavy metal concentrations in the biofilms and sediments.

Starting from the upstream sampling site we found increasing heavy metal concentrations towards the highly urbanised area. This well known phenomenon was registered in all compartments of the surveyed system (biofilms, SS, sediments). Thus the biofilms distinguish themselves as an equivalent tool for the monitoring of river pollution.

The reported high variability of heavy metal concentrations in different samples (e.g. Schäfer, 1995) was not applicable for the biofilm samples. We calculated coefficients of variation for our database between 20-30%. With regard to the well known enormous variability in sediments and especially SS samples the minor range in the detected data emphasizes the suitability of the biofilm method for heavy metal monitoring in river systems.

Beyond the proven applicability of biofilms as an indicator method the main advantage of this instrument should be pinpointed. The required properties can be summarized as follows:

1. The method does not require complex technical equipment and is applicable under the different specific conditions of river systems (e.g. flow dynamics, substrate types).

2. The results of monitoring are reproducible for an appropriate number of samples.

3. The measured concentrations should be ecologically relevant.

All these expectations are fulfilled by the biofilm method.

Summarizing the above mentioned advantages we can conclude that the biofilm method is suitable for a heavy metal pollution monitoring, Because: a) it shows low variability in the detected values. For a mjor group of aquatic invertebrates (primary consumers) the community of microorganisms is an essential food resource and pollutants are likely to enter the food chains by this way. Thus b) the ecological relevance is given.

CONCLUSIONS AND ONGOING WORK

The results show clear the differences in the heavy metal pollution as a function of urbanisation for the river Alb. The presented biofilm method recommends itself as a practicable instrument for assessing the pollution of river ecosystems. This monitoring system (biofilm) will be applied in other rivers in order to validate the presented results and to prove its wider applicability.

Until now the biofilm was regarded as a "black box" consisting of inorganic matter, EPS, bacteria and other organisms. Further investigations will focus on a separation of the biofilm constituents to identify the binding sites for the heavy metals. The purpose of these experiments will be to get additional information concerning the bioavailability of the pollutants and the sublethal effects on microorganism communities.

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