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Original article

The impact of land use on microbial surface water pollution

Christiane Schreiber[a,*,1], Andrea Rechenburg[a], Esther Rind[b], Thomas Kistemann[a]

[a] Institute for Hygiene & Public Health, University of Bonn, Sigmund-Freud-Str. 25, D-53105 Bonn, Germany
[b] Institute of Geography, School of GeoSciences, University of Edinburgh, Drummond Street, EH8 9XP Edinburgh, Scotland, UK

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ABSTRACT

Our knowledge relating to water contamination from point and diffuse sources has increased in recent years and there have been many studies undertaken focusing on effluent from sewage plants or combined sewer overflows. However, there is still only a limited amount of microbial data on non-point sources leading to diffuse pollution of surface waters. In this study, the concentrations of several indicator micro-organisms and pathogens in the upper reaches of a river system were examined over a period of 16 months. In addition to bacteria, diffuse pollution caused by *Giardia lamblia* and *Cryptosporidium* spp. was analysed.

A single land use type predestined to cause high concentrations of all microbial parameters could not be identified. The influence of different land use types varies between microbial species. The microbial concentration in river water cannot be explained by stable non-point effluent concentrations from different land use types. There is variation in the ranking of the potential of different land use types resulting in surface water contamination with regard to minimum, median and maximum effects. These differences between median and maximum impact indicate that small-scale events like spreading manure substantially influence the general contamination potential of a land use type and may cause increasing micro-organism concentrations in the river water by mobilisation during the next rainfall event.

Introduction

During the last three decades, the chemical quality of many watercourses in Germany and Europe as a whole has improved considerably; in particular due to the substantial development and enhancement of sewage treatment systems. In 2000, the EU Water Framework Directive came into force. Its main target is the achievement of a “good ecological condition” in water bodies by 2015 by implementing sustainable management of whole catchment areas. As water courses are increasingly exploited by humans it would be appropriate not only achieving “good ecological conditions” of water bodies but to require watercourses to be healthy for human use as well (Kistemann and Claßen, 2003). In terms of synergies and conflicts, various relationships between health protection and water protection have already been identified (Claßen et al., 2003; Schreiber et al., 2011). Polluted river water can jeopardize human health and in the case of several pathogens, a small number of cells may cause gastrointestinal illness. E.g., the infectious dose of *Campylobacter jejuni* by oral uptake is only 500 cells (Allos and Blaser, 2009). Possible transmission routes include direct usage of the surface water in the case of recreational activities along riversides, swimming and the ingestion of raw fruits irrigated with contaminated water (Donovan et al., 2008; Schönberg-Norio et al., 2004; Yoder et al., 2008). The existing limit values given by the EU Bathing Water Directive are often not verified because many rivers in Germany do not officially count as bathing water although they are used in that way. Beside indicator micro-organisms, there are a lot of other micro-organisms in surface waters that are not routinely investigated, but can cause serious diseases – not only gastrointestinal infections. Another important risk of contaminated surface waters is the threat to drinking water resources, especially reservoirs (Kistemann et al., 2002).

The influence of point sources on the microbiological quality of river water has been quite well investigated (Carraro et al., 2000; Glassmeyer et al., 2005; Kistemann et al., 2008; Rechenburg et al., 2006). There is, however, still a lack of knowledge concerning the sources of non-point surface water pollution even in the absence of sewage and with regard to surrounding land use patterns.

The aim of this study was to determine the influence of different land use types on microbiological quality of surface water by diffuse pollution. The study was conducted in a small river catchment in the

* Corresponding author. Tel.: +49 228 287 16862; fax: +49 228 287 19516.
E-mail addresses: christiane.schreiber@ukb.uni-bonn.de (C. Schreiber), andrea.rechenburg@ukb.uni-bonn.de (A. Rechenburg), e.rind@ed.ac.uk (E. Rind), thomas.kistemann@ukb.uni-bonn.de (T. Kistemann).
[1] www.ihph.de

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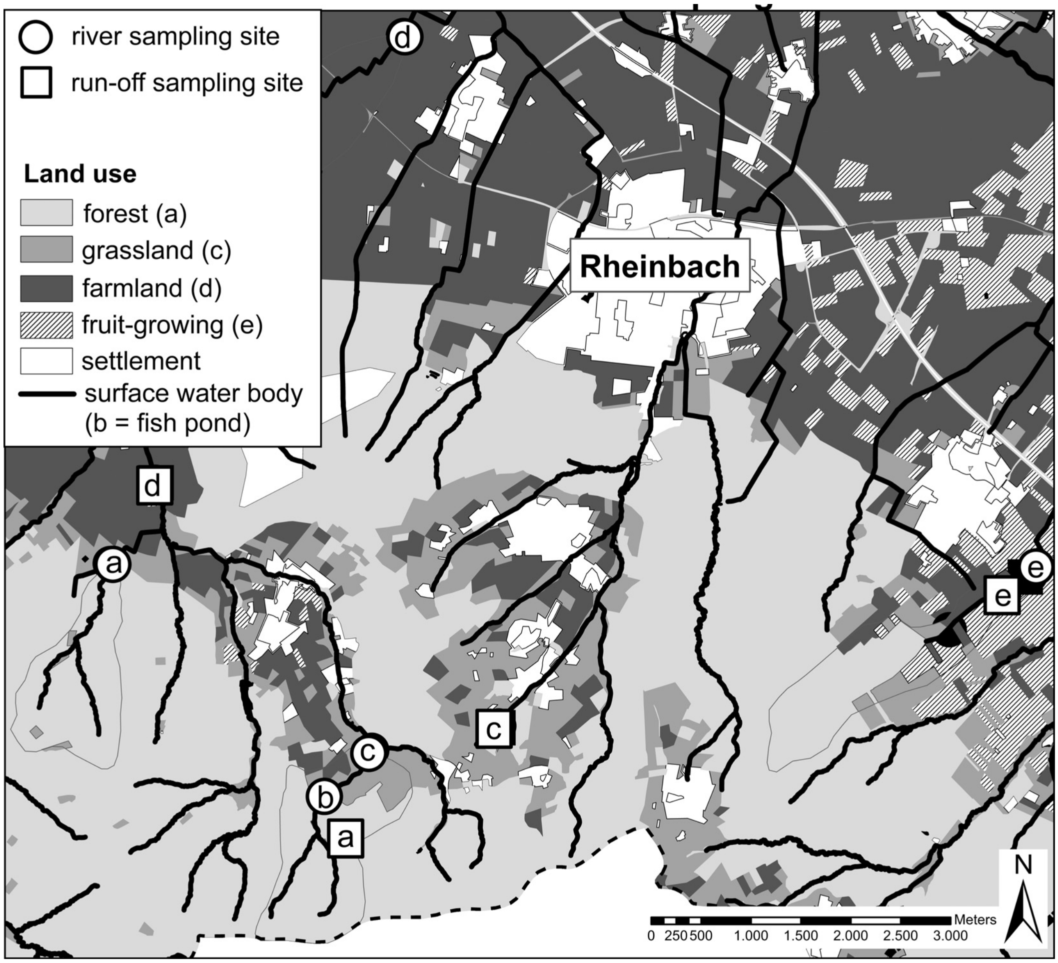

Fig. 1. Land use in the catchment area of the river Swist and location of sampling sites.

south–west of Germany. It focused on the microbiological concentrations of river water in the upper reaches of the Swist river system that are not influenced by any point sources. The concentrations of several bacteria and parasites in river water were investigated over a period of 16 months. In addition, the emission potential of surface and subsurface run-off from areas of different land use types on the receiving watercourses was studied.

Material and methods

Study area

The study area is located in the federal state of North-Rhine Westphalia (NRW), Germany, south–west of Cologne (Fig. 1). It comprises the catchment area of the small river Swist (289 km^2). The study was performed in the upper reaches of the Swist, where the small tributaries are not influenced by any settlements or wastewater. Climatically, the area is characterized by an average annual precipitation of about 650–700 mm, with small maxima in summer and winter and an average annual temperature of 9–10 °C, resulting in mild, dry winters and relatively cool summers. In combination with productive soils, this provides favourable conditions for intensive farming: the most common land use in this region is agronomic cultivation. A smaller area, mainly located in the south and north, is covered by forests. Grassland predominates in the upper regions. Another typical land use in the catchment area is fruit growing, e.g. orchards or strawberry cultivation. Water from the river Swist is taken for irrigation purposes or for cattle watering tanks. Due to the short distance to the urban area of the cities Cologne and Bonn, local recreation including water-related activities is also popular.

Sampling strategy

The sampling of river water was carried out on a regular basis at five locations, each lying in a sub-catchment comprised of different but uniform land uses (forest, fish pond, pasture, farmland, fruit growing). The slope of all sampling sites was less than 15°. Subsequent to rainfall events, additional samples of the surface and subsurface run-off were taken in these areas (except for the fish pond). A sampling device (Fig. 2) with two separate tanks inside was embedded in the ground and facilitated the separate sampling of actual surface run-off and subsurface run-off. This ensured that the original use of each sampling site up to the site of the device remained undisturbed. The sampling device allowed the collection of both surface run-off and subsurface run-off up to one meter below ground, separated from each other. Surface run-off was collected by infiltration through the perforated cover plate into the upper tank. Subsurface run-off up to a depth of one metre was collected separately through a perforated front plate in a lower tank. The tank had a volume of 50 litres for each type of run-off. Two angles (near the surface and at a depth of one metre) ensured that only subsurface run-off passed into the lower tank. The device's measurements were: length 2 m, width 0.3 m and depth 1 m (Franke et al., 2009). This approach differs significantly from commonly applied extended rainfall simulations