The RIMAX Joint Research Project HoT

Flood Retention and Drinking Water Supply – Preventing Conflicts of Interest

Matthias Maier[1], Dirk Kühlers[1]*, Heinz-Jürgen Brauch[2], Michael Fleig[2], Dietrich Maier[2], Gerhard H. Jirka[3], Ulf Mohrlok[3], Ekkehart Bethge[3], Hans Helmut Bernhart[4], Boris Lehmann[4], Gudrun Hillebrand[4], Jan Wölz[5] and Henner Hollert[5]

This joint project (http://rimax-hot.ifh.uni-karlsruhe.de) is supported by the German Federal Ministry of Education and Research (BMBF; PT Forschungszentrum Karlsruhe, No. 02WH0690, No. 02WH0691, No. 02WH0692, No. 02WH0693)

[1] Stadtwerke Karlsruhe GmbH, Daxlander Str. 72, 76127 Karlsruhe, Germany
[2] DVGW-Technologiezentrum Wasser (TZW), Karlsruher Straße 84, 76139 Karlsruhe, Germany
[3] Institute for Hydromechanics, Universität Karlsruhe (TH), Kaiserstraße 12, 76128 Karlsruhe, Germany
[4] Institute for Water and River Basin Management, Universität Karlsruhe (TH), Kaiserstraße 12, 76128 Karlsruhe, Germany
[5] Department of Zoology, University of Heidelberg, Im Neuenheimer Feld 230, 69120 Heidelberg, Germany

* **Corresponding author** (dirk.kuehlers@stadtwerke-karlsruhe.de)

DOI: http://dx.doi.org/10.1065/jss2006.05.157

The research project presented investigates the transport paths from flood wave via retention area to groundwater and waterworks. The major objective of the project is the evaluation of the possibility for contaminants and micro-organisms to migrate from the river into a nearby waterworks – under the conditions of extreme floods, on the one hand, and the regular operation of retention basins, on the other hand. Based on the acquired knowledge, strategies are to be developed to prevent mutual impairments of flood retention and drinking water supply.

1 Background

Diverse studies were able to identify a toxicologic risk potential of suspended particles at high water (Brack et al. 2002, Hollert et al. 2000, 2003, Oetken et al. 2005). However, there are significant scientific deficiencies with regard to the influence of extreme floods, in particular on the extraction of drinking water within areas which are inundated at high water.

Numerous studies indeed show high contaminant loads of surface water samples, in part, and deposited and suspended sediments at differing water levels (Breitung 1999, Brauch et. al. 2001, Förstner & Westrich 2005, Hollert et al. 2000, 2005, Kosmehl 2004, Maier et. al. 1997, LfU 1996a). However, there is only one pilot study so far with regard to the toxicologic risk potential of suspended particulate matter during flood events on the production of drinking water. This study indicates that suspended particulate matter during flood events cause an increase of the (eco-)toxicological hazard potential (in several biotests and chemical analyses) of near surface soil samples in a riparian area which is frequently inundated as compared to rarely inundated regions (Ulrich et al. 2002). Present knowledge does not provide an answer to the question of whether either the contaminants which are partially sorbed to the soil are eluted and negatively influence the groundwater and drinking water, respectively, or are reduced or adsorbed along their passage through the unsaturated zone.

Conflicts of interests are to be expected for virtually all major rivers in Germany. On the one hand, retention areas have to be provided to minimize the risks associated with extreme flood events. On the other hand, the groundwater and bank filtrate of many riparian areas are used for the production of drinking water. Along the river Rhine, between the cities of Basel and Duisburg alone, there are 15 sites where projected retention basins and water protection areas overlap (IKSR, IAWR 1998). Water suppliers – who provide drinking water directly or indirectly taken from the Rhine for more than 20 million people – are concerned about the potentially increased risk of pollution of the groundwater resource by the establishment of a retention area in the vicinity of their water extraction facilities: Organic pollutants could be a danger to the extraction of drinking water by means of the retained water and the transported, suspended particulate matter at flood events (LfU 1996b). Besides a general degradation of the quality of the groundwater by nearby flood plains, the actual operation of water collection facilities may be endangered over longer periods, especially during extreme flood events.

2 Aim of the Joint Research Project

Within the project, which is supported by the German Federal Ministry of Education and Research (BMBF), the dominant processes and mechanisms along the transport path from flood wave via retention area and groundwater to the waterworks are investigated. On the one hand, it is aspired to estimate whether contaminants and micro-organisms are able to migrate from the river into the aquifer and a nearby waterworks under the specific conditions of extreme floods. On the other hand, it is investigated whether substances and micro-organisms may reach the nearby waterworks during a regular operation of the retention basin, which is necessary for providing the retention area during extreme flood events.

In this project, the transport paths from the flood wave to the nearby waterworks are regarded as a multi-barrier system. The first barrier is the transport of contaminants and micro-organisms into the retention area. The second barrier is the unsaturated zone with its transport and retardation mechanisms. The third barrier is the flow and transport behavior within the saturated zone.

On the basis of the achieved knowledge, strategies are to be established in order to minimize mutual impairments of flood retention and drinking water supply. These strategies will be summarized to a guideline, which highlights and helps to prevent or minimize the predominant majority of present and future conflicts between flood management and drinking water supply by providing a corresponding package of measures.

3 Framework of Investigation

The following studies are carried out within the joint research project:

- Analysis of chemical and toxicological characteristics of the water quality data and studies on suspended and deposited sediments depending on the spatiotemporal development and the discharge situation. The results of this work package will be published as a literature review in JSS.
- Chemical and toxicological testing of sediment and water samples taken from the River Rhine at diverse water levels and depending on the method used for collecting the suspended particulate matter using chemical and bioanalytical methods (eg., Gustavson et al. 2004, Klee et al. 2004, Reifferscheid et al. 2005, Seiler et al. 2006)
- Identification of unknown contaminants with biological impact by means of effect-directed analyses (cooperation with the Centre for Environmental Research Leipzig, Dr. Werner Brack; cf. Brack et al. 2005).
- Estimation of particle retention in retention areas by hydrodynamic modeling and approaches of the pelit research.
- Chemical and toxicological field investigations for different soil horizons at the project study area Bellenkopf/Rappenwört (projected retention area at the upper Rhine, river kilometer 354.5 to 359.5) on the differing loads at frequently inundated and not inundated regions.
- Laboratory studies to achieve parameters of several characteristic compounds on their behavior during elution and microbial decomposition.
- Determination of hydraulic soil characteristics in retention areas and modeling of the transport processes in the unsaturated zone.
- Chemical and toxicologic investigations at several groundwater observation wells for documenting the spatio-temporal change of the contaminant load.
- Numerical groundwater modeling for the determination of conditions on which contaminants transported into the retention area may reach a nearby waterworks.

The projected retention area Bellenkopf/Rappenwört (retention volume of 14 Mio. m^3) near Karlsruhe is used for the field studies. A major part of this area is situated within a drinking water protection area, which has been created for a projected waterworks. At the model site, there are regions which are already irregularly inundated at present and are therefore suited for the investigations in the unsaturated zone.

As there are partly sparse investigations (known to us) carried out or published concerning the topic of the project, the project collaborators are grateful for references to publications and also gray literature on chemical and toxicologic loads of suspended and deposited sediments in the context of the literature study (fleig@tzw.de, Henner.Hollert@urz.uni-heidelberg.de).

4 Structure of the Joint Research Project

The joint research project is a cooperation of five partners from four organizations.

The **Stadtwerke Karlsruhe GmbH** is the project coordinator and operating company of the projected waterworks within the investigation area. It is responsible for the numerical modeling of the groundwater flow.

The **DVGW-Technologiezentrum Wasser (TZW) Karlsruhe** carries out the chemical analyses of the soil and suspended sediment samples gathered in the field and, furthermore, investigates the behavior of the contaminants in the retention area by comprehensive laboratory studies.

The **Institute for Water and River Basin Management, Universität Karlsruhe (TH)** is responsible for simulations as well as field and laboratory studies on the suspended load transported into the retention basin.

The **Institute for Hydromechanics, Universität Karlsruhe (TH)** carries out laboratory studies and field investigations to determine the hydraulic characteristics of the unsaturated zone in the study area and numerical modeling of transport and transformation of characteristic compounds.

At the **Heidelberg Institute of Zoology,** toxicological studies and effect-directed analyses are used to determine the biological hazard potential of suspended particles from the flood wave up to within the unsaturated zone and to identify unknown groups of contaminants.

References

Brack W, Altenburger R, Dorusch F, Hubert A, Möder M, Morgenstern P, Moschütz S, Mothes S, Schirmer K, Wennrich R, Wenzel K-D, Schürmann G (2002): Hochwasser 2002 – Chemische und toxische Belastung überschwemmter Gemeinden im Raum Bitterfeld. UWSF – Z Umweltchem Ökotox 14, 213–220

Brack W, Erdinger L, Schirmer K, Hollert H (2005): Identification of mutagenicity and EROD-inducing potency in aquatic sediments. Environ Toxicol Chem 24 (10) 2445–2458

Brauch H-J, Lucas M, Sacher F (2001): Untersuchungen zum Vorkommen von Xenobiotika in Schwebstoffen und Sedimenten Baden-Württembergs. Series 'Oberirdische Gewässer, Gewässerökologie', Landesanstalt für Umweltschutz Baden-Württemberg, Volume 67

Breitung V (1999): Organische Schadstoffbelastung in Schwebstoffen des Rheins während Hochwasserwellen. Hydrologie und Wasserwirtschaft 43 (1) 17–21

Förstner U, Westrich B (2005): BMBF coordinated research project SEDYMO (2002–2006): Sediment dynamics and pollutant mobility in river basins. JSS – J Soils & Sediments 5, 134–138

Grunewald K, Unger C, Brauch HJ, Schmidt W (2004): Elbehochwasser 2002 – Ein Rückblick – Schadstoffbelastung von Schlamm- und Sedimentproben im Raum Dresden (Sachsen). UWSF – Z Umweltchem Ökotox 16, 7–14

Gustavsson L, Klee N, Olsmann H, Hollert H, Engwall M (2004): Fate of Ah receptor agonists during biological treatment of an industrial sludge containing explosives and pharmaceutical residues. ESPR – Environ Sci & Pollut Res 11, 379–387

Hollert H, Dürr M, Erdinger L, Braunbeck T (2000): Cytotoxicity of settling par–ticulate matter (SPM) and sediments of the Neckar River (Germany) during a winter flood. Environ Toxicol Chem 19, 528–534

Hollert H, Haag I, Dürr M, Wetterauer B, Holtey-Weber R, Kern U, Westrich B, Färber H, Erdinger L, Braunbeck T (2003): Untersuchungen zum ökotoxikologischen Schädigungspotenzial und Erosionsrisiko von kontaminierten Sedimenten in staugeregelten Flüssen. UWSF – Z Umweltchem Ökotox 15, 5–12

Hollert H, Dürr M, Holtey-Weber R, Islinger M, Brack W, Färber H, Erdinger L, Braunbeck T (2005): Endocrine disruption of water and sediment extracts in a non-radioactive Dot Blot/RNAse protection-assay using isolated hepatocytes of rainbow trout – Deficiencies between bioanalytical effectiveness and chemically determined concentrations and how to explain them. ESPR – Environ Sci & Pollut Res 12, 347–360

Klee N, Gustavsson L, Kosmehl T, Engwall M, Erdinger L, Braunbeck T, Hollert H (2004): Toxicity and genotoxicity in an industrial sewage sludge containing nitro- and amino-aromatic compounds during treatment in bioreactors under different oxygen regimes. ESPR – Environ Sci & Pollut Res 11, 313–320

Kosmehl T, Krebs F, Manz W, Erdinger L, Braunbeck T, Hollert H (2004): Comparative genotoxicity testing of Rhine river sediment extracts using the permanent cell lines RTG-2 and RTL-W1 in the comet assay and Ames assay. JSS – J Soils & Sediments 4, 84–94

Maier D, Maier M, Fleig M (1996a): Schwebstoffuntersuchungen im Rhein. 29. AWBR-Jahresbericht 1997

Landesanstalt für Umweltschutz Baden-Württemberg: Schadstofftransport bei Hochwasser – Neckar, Rhein und Donau im Januar 1995. Handbuch Wasser 2, Volume 23

Landesanstalt für Umweltschutz Baden-Württemberg (1996a): Auswirkungen von Überflutungen auf flussnahe Wasserwerke – Auswertung von Literatur und Betriebserfahrungen von Wasserwerken. Materialien zum Integrierten Rheinprogramm, Volume 6

Oetken M, Stachel B, Pfenninger M, Oehlmann J (2005): Impact of a flood disaster on sediment toxicity in a major river system – The Elbe flood 2002 as a case study. Environ Pollut 134, 87–95

Reifferscheid G, Arndt C, Schmid C (2005): Further development of the beta-lactamase MutaGen assay and evaluation by comparison with Ames fluctuation tests and the umu test. Environ Mol Mutagen 46, 126–39

Seiler TB, Rastall AC, Leist E, Erdinger L, Braunbeck T, Hollert H (2006): Membrane Dialysis Extraction (MDE): A novel approach for extracting toxicologically relevant hydrophobic organic compounds from soils and sediments for assessment in biotests. JSS – J Soils & Sediments 6, 20–29

Ulrich M, Schulze T, Leist E, Glaß B, Maier M, Maier D, Braunbeck T, Hollert H (2002): Ökotoxikologische Untersuchung von Sedimenten und Schwebstoffen: Abschätzung des Gefährdungspotenzials für Trinkwasser und Korrelation verschiedener Expositionspfade (Acetonischer Extrakt, Natives Sediment) im Bakterienkontakttest und Fischeitest. UWSF – Z Umweltchem Ökotox 14, 132–137