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Example Paper up to 4 pages maximum: Challenges in urban hydrogeology

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Abstract Urban areas are a focus of increasing conflict with regard to water use and water protection. Half of the world's population and about 73 % of Europeans live in cities. Currently, about 82 % of the total population growth of the world occurs in the cities of the developing countries. As a direct and/or indirect consequence of human activity, urban water systems are frequently polluted with organic contaminants. Many of these contaminants are related to human behaviour and activity, such as pharmaceuticals, personal care products (collectively PPCPs) and endocrine-active substances which are increasingly being found in urban water systems. However, the behaviour and the effects of these contaminants in the environment have been widely unknown until now.

Key words urban groundwater; PPCP; contamination; investigation techniques; modelling; pharmaceuticals

INTRODUCTION

The availability of high quality water plays a crucial role in the protection of ecosystems and the quality of human life. To maintain this water quality, tremendous societal efforts have been directed toward a reduction of toxic industrial effluent releases into lakes and rivers and toward efficient waste water treatment. Yet, despite these efforts over the past several decades, pressure on water as an essential resource continues to rise. Urban areas are one focal point of controversy over water use and protection because of their growing population.

QUANTIFICATION OF ACIDIFICATION RATES

Two separate modelling studies were undertaken. The first was a simple set of calculations based on gross estimates of oxygen fluxes to the tailings residues, aimed at determining the relative importance of vertical and lateral pathways. The second used information from the first study to define a simplified spatial model within which more sophisticated reactive transport processes were addressed.

Oxygen ingress estimation

Oxygen diffusion in the soil gas phase in a partially water-saturated soil may be modelled by:

$$R\frac{\partial C_g}{\partial t}+D_{eff}\nabla\cdot\left(\nabla C_g\right)=-S_g^{org} \tag{1}$$

where R [-] is the retardation factor, including air-water partitioning, but in this case with zero sorption:

$$R=\theta_g+K_H\,\theta_w \tag{2}$$

written in terms of a depth-independent tortuosity model.

Indicator substances

From a variety of parameters which are related to anthropogenically induced activities, we have selected suitable indicators for studying the sources, transport and distribution, and the transfer processes of water-bound micropollutants in urban surface and groundwater. The selected indicators are evaluated for their applicability to reflect the various impacts on the urban water cycle under the given hydrogeological conditions and urban structures. The criteria for the chosen indicators are the following:

- They should be typical for special kinds of anthropogenic emissions, *e.g.* from hospitals or residential areas.
- For investigating their spread in the environment, they should be persistent. For investigating their biodegradation, non-persistent indicators have to be considered.

In view of these selection criteria, the selected indicators and important parameters are shown in Table 1 including their original usage. In the following, the indicators are characterised with regard to their sources and crucial known environmental properties.

INVESTIGATION AND MONITORING IN URBAN AREAS

Contaminant transport in urban areas can be extremely variable, both temporally and spatially. This requires new, more efficient investigation and monitoring strategies. Point measurements at discrete times in selected monitoring wells do not usually allow drawing conclusions concerning contaminant fluxes in urban areas. These flux calculations are necessary, however, to perform a meaningful risk analysis and to select remediation strategies (Schirmer & Bopp, 2007).

Investigation of the influence of urban waste water has to include the respective temporal scales (Fig. 1). The scale has to account for the acute and cumulative nature of the effects; the spatial scale has to account for the extent of the effects on the water bodies (Reinstorf *et al.*, 2007). Acute effects act fast, within minutes for example, during waste water discharge. Cumulative effects result from gradual changes in the water bodies or after a threshold value is reached. Typical examples of cumulative effects are the release of nutrients and toxins from sediments (Harremoes, 1988).

Table 1 Selected indicators in the urban water cycle, their occurrence, use and analytical detection limits.

Reactant / indicator	Application / occurrence / effect	Physico-chemical properties	log K_{OW}	Detection limit / variation
Bisphenol A (BPA)	Component in plastics (resins, poly-carbonate); endocrine disruptor (estrogene)	Aerobe degradable	2.2–3.8	1 ng/L [(1)]
Carbamacepine (CA)	Antiepileptic drug	Persistent, high mobility	1.58	2 ng/L [(1)]
Oxygen isotopes $^{18}O/^{16}O$	Water, air, rocks/sediments; origin, transport, mixing processes	Isotope fractionation at transfer processes	not relevant	$\delta^{18}O$ ±0.1‰ –55 to >+35 ‰
Sulphur isotopes $^{34}S/^{32}S$	Minerals, S-bearing compounds: origin, degradation, acidification	Isotope fractionation at transfer processes	not relevant	$\delta^{34}S$ ±0.2‰ –50 to +40 ‰
Boron isotopes $^{11}B/^{10}B$	Borates, detergents; origin, transport	Isotope fractionation at transfer processes	not relevant	$\delta^{11}B$ ±0.8‰[(4)] –30 to +40 ‰

[(1)] Data refer to the analytical methods used at the UFZ: GC-MS (Dr. M. Möder, pers. comm. to BPA, CA, HHCB, AHTN), Ion chromatography (sulphate, nitrate), ICP-AES (boron), Isotope ratio MS (isotopes); [(2)] Braun *et al.* (2003); [(3)] Hennebrüder *et al.* (2004); [(4)] Teichert *et al.* (2005)

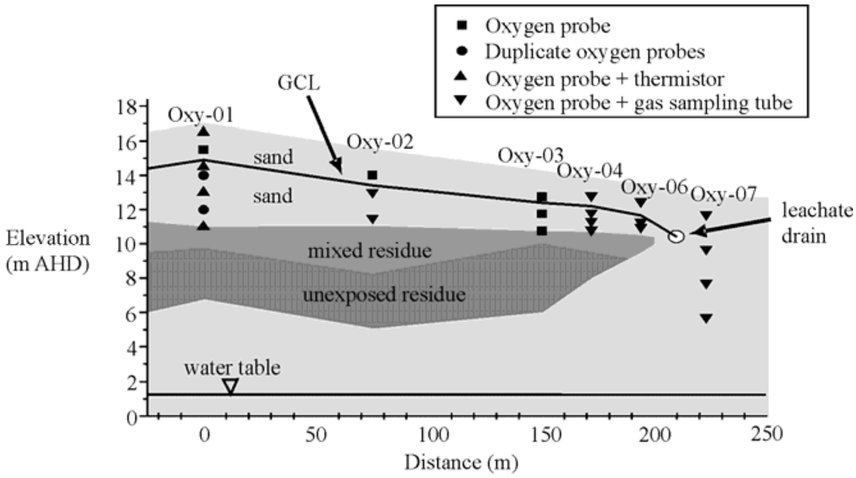

Fig. 1 A schematic cross-section of the tailings facility from the centre to the northern edge, showing monitoring locations.

To start investigating the problems associated with urban water flow, as well as contaminants and their interrelations as mentioned above, a number of research projects have been initiated over the last years. Both qualitative and quantitative methods were applied. The qualitative methods were mainly used to investigate the contaminant concentration patterns to detect the urban influence.

FUTURE PROSPECTS

The challenge to objectively and thoroughly estimate contaminant concentrations and their effects in urban aquifers requires understanding the input, transport and degradation processes at the local scale with a simultaneous perspective on the catchment scale. Due to aquifer heterogeneity combined with extended subsurface infrastructure and a wide contaminant spectrum in urban areas, new efficient investigation, monitoring and evaluation strategies are needed.

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