20 years of long-term atrazine monitoring in a shallow aquifer in western Germany

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Introduction

Atrazine application was banned in Germany since 1991. In this study, we present results of a monitoring study of atrazine concentrations in the Zwischenscholle aquifer. This aquifer is a phreatic aquifer exposed to intensive agricultural land use and susceptible to contamination due to a shallow water table.

Materials and Methods

In total 60 observation wells in an area of 60 km² were monitored since 1991, of which 15 are sampled monthly today (see figure 1a). The filter depths vary between 0 m to 14.2 m (mean: 4.7 m) below the groundwater table and the filter screen lengths vary between 1 m and 10 m (mean: 3.1 m). In the samples, the pesticides atrazine and simazine and the metabolites deethylatrazine (DEA), desisopropylatrazine (DIA) were measured together with other groundwater quality parameters like DOC and nitrate concentrations. The ‘regression on order statistics’ (ROS) was used to represent non-detects in the statistical analysis of the data. The deethylatrazine-to-atrazine ratio (DAR) was used to distinguish between diffuse – and point-source contamination by atrazine (Thurman et al., 1998). To detect relations between different groundwater parameters, we used a principal component analysis (PCA).

Figure 1: a) Location of sampled groundwater wells. The colour coding represents the mean atrazine concentration in the samples from the well and the arrow indicates trend of the concentrations in the well over time. b) box plots of concentration distributions in the groundwater samples collected during different years.
Results:
The monitoring data show that even 20 years after the ban of atrazine, the groundwater concentrations in sampled observation wells remain on a level close to the threshold value of 0.1 µg l$^{-1}$ without any considerable decrease (Figure 1b). The spatial distribution of atrazine concentrations is highly heterogeneous with observation wells exhibiting permanently concentrations above the regulatory threshold on one hand and observation wells where concentrations are mostly below the limit of quantification (LOQ) on the other hand (Figure 1a). No relation between the depth of the well filter below the groundwater table, which varied between 0 and 14.2 m, was observed (Figure 2a). But analytical data of monthly sampled single observation wells showed a seasonal variability which was related to the variations of the groundwater table depth with lower concentrations when the groundwater level was higher. This indicates that pesticide concentrations were diluted by groundwater recharge. With a global mean value of 0.84, the DAR indicates that atrazine concentrations mainly resulted from diffuse contamination. The diffuse nature of atrazine sources is also confirmed by the PCA (Figure 2b) which shows similar loadings for atrazine, DEA and nitrate. The PCA further indicates that DIA is closely related to simazine and is therefore rather a metabolite of simazine than from atrazine.

Conclusions
Atrazine concentrations were found to vary considerably in space in the aquifer but the spatial pattern of the concentration distribution was relatively stable over the 20 year period of monitoring. This variation might be related to aquifer heterogeneity and spatial variation of source zones. These findings point at the general challenge to estimate mean concentrations for entire aquifers. The high persistence of atrazine concentrations in a number of observation wells over a long time after its presumed stop of application also raises questions about the use of groundwater monitoring studies as a strategy to evaluate the safe use of pesticides.

References