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Relevance of urban glyphosate use for surface water quality

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ABSTRACT

Relative contributions of agricultural and urban uses to the glyphosate contamination of surface waters were studied in a small catchment (25 km^2) in Switzerland. Monitoring in four sub-catchments with differing land use allowed comparing load and input dynamics from different sources. Agricultural as well as urban use was surveyed in all sub-catchments allowing for a detailed interpretation of the monitoring results. Water samples from the river system and from the urban drainage system (combined sewer overflow, storm sewer and outflow of wastewater treatment plant) were investigated. The concentrations at peak discharge during storm events were elevated throughout the year with maximum concentrations of 4.15 $\mu g\ L^{-1}$. Glyphosate concentrations mostly exceeded those of other commonly used herbicides such as atrazine or mecoprop. Fast runoff from hard surfaces led to a fast increase of the glyphosate concentration shortly after the beginning of rainfall not coinciding with the concentration peak normally observed from agricultural fields. The comparison of the agricultural application and the seasonal concentration and load pattern in the main creek from March to November revealed that the occurrence of glyphosate cannot be explained by agricultural use only. Extrapolations from agricultural loss rates and from concentrations found in the urban drainage system showed that more than half of the load during selected rain events originates from urban areas. The inputs from the effluent of the wastewater treatment plant, the overflow of the combined sewer system and of the separate sewer system summed up to 60% of the total load.

1. Introduction

Glyphosate is one of the most used herbicides worldwide (Baylis, 2000). It has a non-selective mode of action with a broad application spectrum. It is widely applied in agricultural, silvicultural and urban environments. One of the reasons for its success was the development of glyphosate tolerant plants such as soy, maize or canola. Due to its low toxicity and high efficiency it is also a popular herbicide to control weed in urban areas.

Glyphosate sorbs strongly to the soil matrix and is therefore considered relatively immobile in soil. Furthermore, it undergoes microbial degradation in soil. Despite these facts glyphosate occurs in rather high concentrations in surface water (Skark et al., 1998; Köllensperger et al., 2006). In order to explain the widespread occurrence of glyphosate in surface water, urban and agricultural sources have to be identified and investigated. Agricultural sources can be separated into diffuse and point sources. Diffuse losses are a result of applied herbicides being washed out from the field and transported to surface or groundwater by different pathways. Recent studies on the mobility of glyphosate in soil showed that the loss rate from agricultural fields is lower than for other herbicides (Siimes et al., 2006; Shipitalo et al., 2008). Besides these diffuse input pathways, also point pollutions due to improper handling (by farmers due to filling or cleaning of spraying equipment) have to be considered. Gerecke et al. (2002) for example found that 14% of the load of the agricultural herbicide atrazine in Lake Greifen reached the surface water through wastewater treatment plants (WWTP).

Non-agricultural sources are more diverse and thus more difficult to distinguish. Glyphosate is for example used for weed control on railway embankments, along roadsides, by residents in backyards, or by professional gardeners. Depending on the type of urban sewer system, if separate or combined, contaminants can reach surface water directly or through a WWTP. For glyphosate, urban inputs into surface water through WWTPs may be important (Skark et al., 1998; Kolpin et al., 2006; Ghanem et al., 2007). In a recent study, glyphosate transfer from urban sewer systems into surface waters was studied, which showed that besides WWTPs also storm sewers may play an important role (Botta et al., 2009). Applications on hard surfaces for maintenance purposes or in private gardens are important sources as the retention potential of these areas is low. Even though the applied amount on urban areas is usually considerably lower compared to agriculture, the load in surface water may still be significant (Skark et al., 1998; Blanchoud et al., 2007). To assess the relevance of the urban use, the inputs from the various pathways namely the WWTP, sewer overflows and the separate sewer system were quantified. The

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aim of this study was to determine the relative relevance of urban and agricultural sources for glyphosate surface water contamination and to find potential mitigation options. Monitoring glyphosate at different locations in a small catchment (25 km^2) allowed quantifying and characterizing the input as a result of agricultural and urban uses. Therefore, the outlets of different sub-catchments as well as additional sampling sites in the urban drainage system were monitored. This unique design makes this study an important contribution to the ongoing discussion on the sources of glyphosate in surface water.

First of all, the use of glyphosate in urban and agricultural areas was assessed. Second, the concentration pattern of glyphosate throughout the year was studied and the total load was calculated. Third, concentration and load dynamics during a single rain event were examined in detail and compared to herbicides with known uses. The contribution of urban areas to the total load of glyphosate in surface water was determined by extrapolating the urban input from the loads measured at the sampling sites in the urban drainage system (WWTP, combined sewer overflow, separate sewer system). The occurrence of aminomethylphosphonic acid (AMPA), the main metabolite of glyphosate, was studied as well. However, since AMPA is also a transformation product of other compounds, it is difficult to trace its origin (Botta et al., 2009).

2. Experimental section

2.1. Study catchment

The study catchment is located in the North-East of Switzerland and part of the Lake Greifen catchment where pesticide behavior has been studied in the past (Leu et al., 2004; Freitas et al., 2008). In 2007, the significance of agriculture and urban uses of biocides and pesticides was studied in a small part of the catchment (Wittmer et al., 2010a,b). Based on this study, the behavior of the herbicide glyphosate was examined.

The study catchment (Fig. 1) covers 25 km^2, of which 75% is used for agriculture, whereas 470 ha of the agricultural area are used for arable farming. Climate, soil, and land use are representative for the Swiss Plateau. There are two villages with 10 000 and 2000 inhabitants respectively. The urban sewer system is a mixture of a combined and a separate system (Fig. 1c). In the combined sewer system, wastewater from households and the urban storm water are collected in the same sewer and discharged to the WWTP. In case of intense rainfall these combined sewer systems route excess water via overflows to surface waters. In the separate sewer systems the urban storm water is collected separately and discharged directly to surface waters. The municipal waste water system lies completely within the hydrological boundaries. To differentiate the sources, the catchment was divided into four hydrological sub-catchments with different land use. The river water at each catchment outlet was sampled separately. The sub-catchments were characterized as follows (Fig. 1b):

Sub-catchment URB_{north} is highly influenced by water from urban origin since the larger city is situated in this area (site 2). There are two combined sewer overflows (CSO) active during heavy rain events and several storm sewers (StS) discharging into the small creek. The total catchment size of the CSOs is 120 ha, whereas the one of the StSs sums up to 46 ha. The wastewater treatment plant (WWTP), which collects wastewater from the whole catchment, is a conventional treatment plant and discharges into this creek as well. Additionally to the river water the effluents of the WWTP (site 5) and of one StS with a catchment of 5.7 ha were monitored (site 6).

Sub-catchment AGR is dominated by agricultural uses (site 3). There are no CSO or StS discharging into this creek.

In sub-catchment URB_{south}, the smaller village is located. The creek is mainly influenced by agricultural inputs (site 4). Only during rain events part of the discharge is composed of urban originated water from a CSO and several StS. The CSO, with a retention basin of 300 m^3 and a catchment size of 41 ha, was sampled at the outflow (site 7).

The land use in sub-catchment DRAI is dominated by agriculture. There is also one CSO with a catchment size of 28 ha discharging storm water into the creek; however, this CSO is hardly ever active. At the sampling site at the outlet of this sub-catchment, water from the entire catchment was collected (site 1).

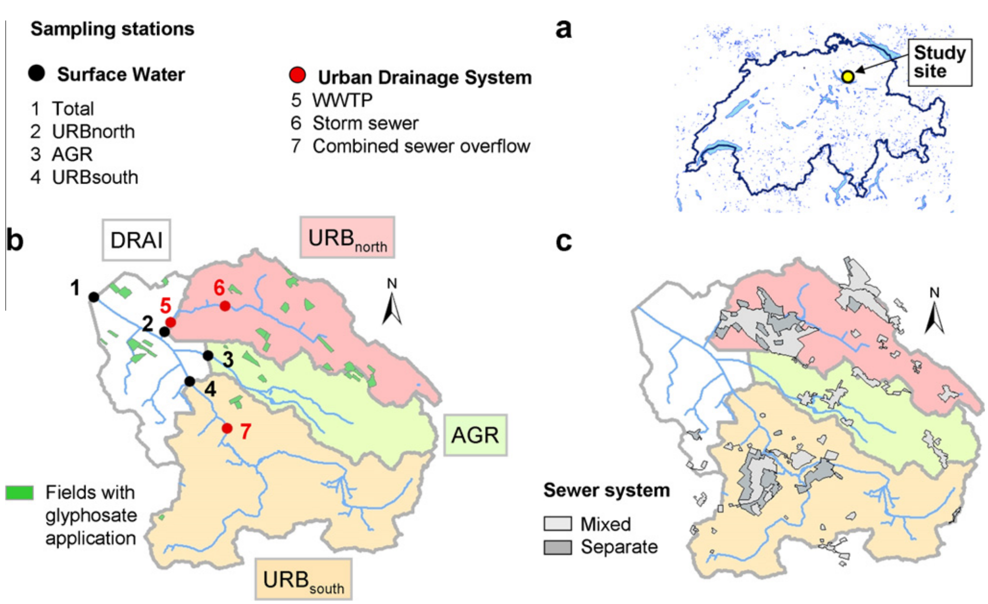

Fig. 1. (a) Location of the study catchment in Switzerland. (b) Study catchment separated into the four sub-catchments (DRAI, URB_{north}, AGR, and URB_{south}) with sampling sites in the river (black, 1–4) and in the urban drainage system (red, 5–7). Furthermore, agricultural fields which were treated with glyphosate in 2007 are shown in green. (1c) Urban areas with mixed or separate sewer system. (Swisstopo JA082266, AWEL). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)