

Pharmaceuticals in the Environment – A first Compilation of German Monitoring Data

During the last years, an increasing number of literature studies showed that pharmaceuticals are continuously present in the environment. In order to get a first overview of the occurrence of active pharmaceutical substances in Germany the Federal Environment Agency (UBA) collected and evaluated available data of pharmaceuticals in the aquatic and terrestrial environment. The results of this study are given in the following and are based on public available literature as well as on monitoring data of the German Federal States.

1. Results of a comprehensive literature review (Bergmann et al., 2011)

In year 2011 UBA funded a literature review on German monitoring data of pharmaceuticals in the environment. The results have recently been published (Bergmann et al. 2011). The study showed that in total 156 pharmaceuticals (of which are 19 metabolites) have been detected in Germany in the matrices surface water, groundwater, drinking water, sewage effluent, sewage sludge, manure, soil and sediment (Fig.1, Fig.2). Most of the pharmaceuticals (n=131) were found in surface waters, mainly in concentration ranges of 0.1-1.0 µg/L (Fig.1). The highest concentrations of human pharmaceuticals were measured near wastewater treatment plant (WWTP) outflow. Besides measurements in surface water pharmaceuticals were also detected in groundwater and sporadically in drinking water. Veterinary pharmaceuticals were mainly detected in livestock manure (dung and slurry) and in soil due to spreading of livestock manure on farmland.

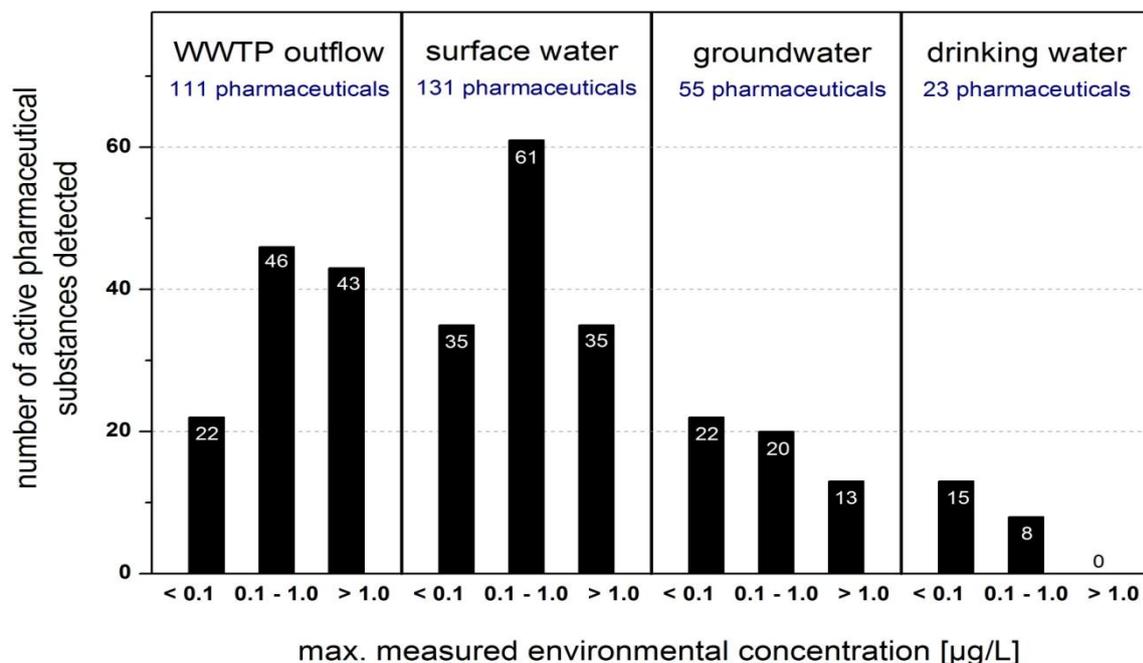


Figure 1: Number of pharmaceuticals detected in WWTP outflow, surface water, groundwater and drinking water in Germany (Bergmann et al. - modified, 2011)

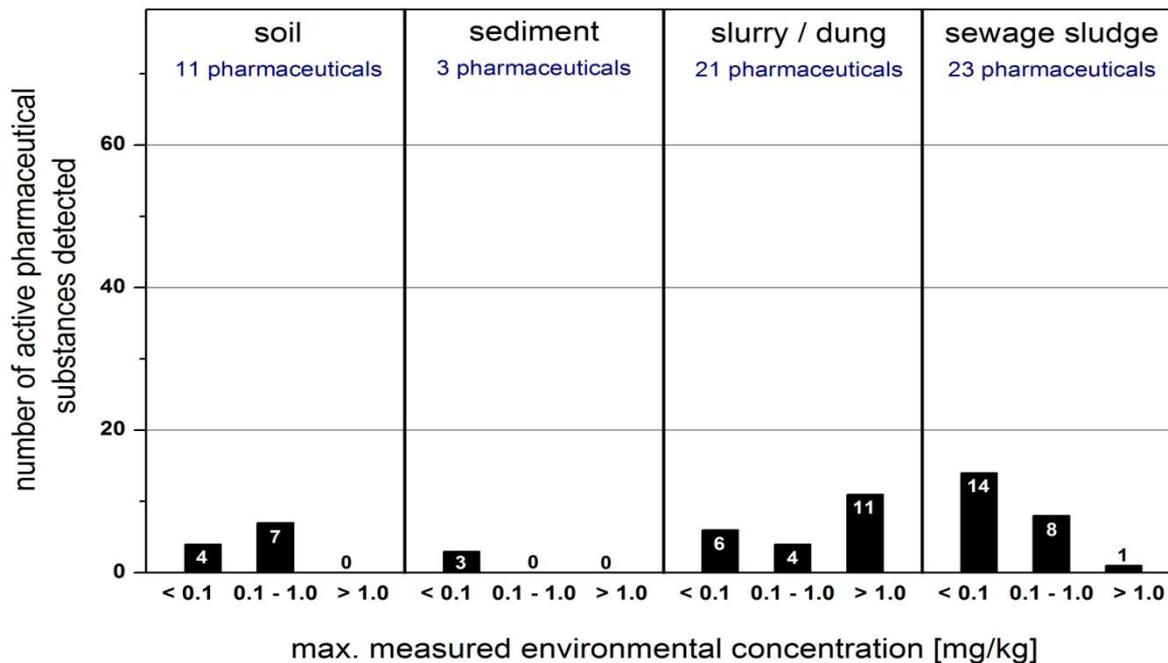


Figure 2: Number of pharmaceuticals detected in soils, sediments, slurry/dung and sewage sludge in Germany (Bergmann et al., 2011 – modified)

2. Monitoring data obtained from screening programs of the German Federal States

In Germany there is no systematic monitoring of the occurrence of active pharmaceutical substances in the environment established. However, several specific field campaigns are carried out by the Federal States for some years. The results of these campaigns provide useful information on the local exposure situation. For instance, active pharmaceutical compounds, such as carbamazepine, diclofenac and sulfamethoxazole have been found to occur nearly ubiquitous in water bodies which are influenced by waste water.

2.1 Concentrations measured in surface water

UBA constantly compiles data on surface water monitoring generated by the Federal States in a Water quality Data Base for Fresh water. These data which are supplied by the Working Group of the Federal States on Water Issues (LAWA) show that until 2011 altogether 27 active pharmaceutical substances were found in mean concentrations > 0.1 µg/L in German surface water. Table 1 shows for these substances the maximum mean concentration in the period 2009 - 2011 as well as the range of all measuring points. These measured values are compared with corresponding sales data for the active compounds.

Active compound	Pharmaceutical group	Max. mean conc. ⁽¹⁾ [µg/L] 2009-2011	Concentration range [µg/L]	Sales in Germany 2012 ⁽²⁾ [t/year]
lomeprol	Iodinated contrast media	13.7	< 0.01 - 20	254.7
lopamidol	Iodinated contrast media	7.58	< 0.005 - 10	27.8
Amidotrizoic acid	Iodinated contrast media	3.98	< 0.01 - 7.1	*
lopromid	Iodinated contrast media	3.10	< 0.005 - 5.3	55.8
Gabapentin	Antiepileptic drug	1.97	< 0.100 - 3.1	83.6
Metoprolol	Beta-blocker	1.59	< 0.005 - 2.9	157.0
Diclofenac	Analgesic	1.47	< 0.005 - 9.3	84.4
Carbamazepine	Antiepileptic drug	0.726	< 0.001 - 1.6	52.3
Sotalol	Beta-blocker	0.718	< 0.005 - 1.3	4.8
Beta-Sitosterol	Lipid-lowering agent	0.568	< 0.03 - 4.8	< 0.1
Bezafibrate	Lipid-lowering agent	0.493	< 0.001 - 0.66	12.2
Atenolol	Beta-blocker	0.475	< 0.005 - 0.71	5.7
Ibuprofen	Analgesic	0.448	< 0.003 - 1.2	975.5
Sulfamethoxazole	Antibiotic	0.423	0.007 - 1.2	26.1
Metformin	Antidiabetic	0.340	Single value	1,602.9
Clarithromycin	Antibiotic	0.313	0.003 - 0.43	13.3
Roxythromycin	Antibiotic	0.296	0.002 - 0.52	4.3
Iohexol	Iodinated contrast media	0.279	0.017 - 0.82	19.9
Oxazepam	Psychotropic drug	0.268	< 0.025 - 0.53	1.2
Bisoprolol	Beta-blocker	0.250	< 0.003 - 0.36	9.0
Naproxen	Analgesic	0.235	< 0.01 - 0.32	16.5
Sulfadimidin/ Sulfamethazine	Antibiotic	0.213	0.003 - 0.74	*
Erythromycin	Antibiotic	0.213	< 0.005 - 0.24	7.8
Trimethoprim	Antibiotic	0.210	< 0.005 - 0.3	5.7
Fenofibric acid	Metabolite of fenofibrate (Lipid-lowering agent)	0.146	< 0.025 - 0.29	8.3 (Fenofibrate)
Codein	Analgesic	0.144	< 0.002 - 0.35	3.6
Ioxitalamine acid	Iodinated contrast media	0.136	< 0.01 - 0.25	6.6

*No sales data available, ⁽¹⁾ Compiled by the Federal Environment Agency from data supplied by Working Group of the Federal States on Water Issues (LAWA), ⁽²⁾ Sales data from IMS Health AG. 2012. MIDAS Database. Frankfurt/Main, Germany

Table 1: Active pharmaceutical substances detected in arithmetic mean concentrations > 0.1 µg/L in surface waters in Germany (max. mean concentration = highest average value of all measuring points in the period in 2009 - 2011)

In Fig. 3 the monitoring data of the 27 active pharmaceutical substances are given in Table 1 classified according to 8 substance classes. It is obvious that active substances from nearly all pharmaceutical classes are found in surface water. The variations in measured concentrations seem to reflect the different substance specific characteristics (e.g. persistence, mobility) as well as the different sales data.

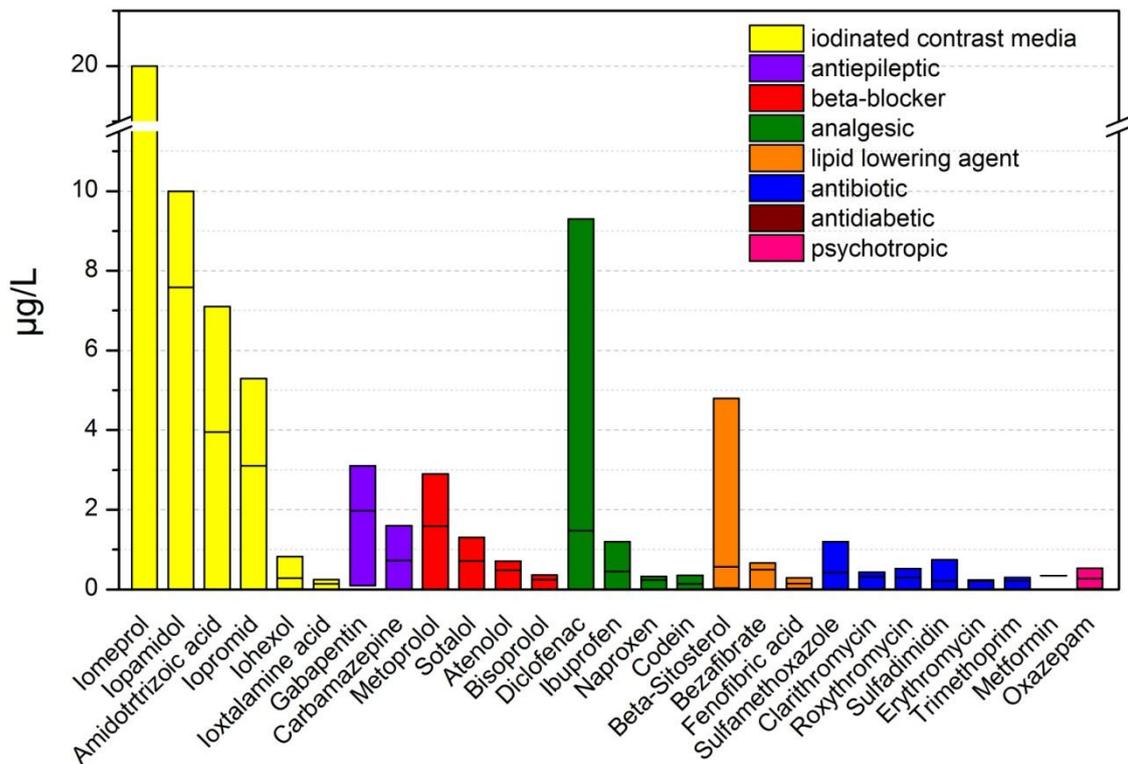


Figure 3: Active pharmaceutical substances detected in arithmetic mean concentrations > 0.1 µg/L in surface water classified according to pharmaceutical groups, compiled by the Federal Environment Agency from data supplied by Working Group of the Federal States on Water Issues (LAWA); (Box plots: max. and min. of range; line: max. mean; exception metformin: line for single value)

2.2 Concentrations measured in groundwater

Studies have shown that a variety of active pharmaceutical substances are present in groundwater. Some antibiotic substances and a few other active pharmaceutical substances, including the analgesic diclofenac, have been detected in German groundwater in concentrations > 1 µg/L. Table 2 shows maximum concentrations for different substances and the respective groundwater origin found in the public available literature within the last 12 years.

Active compound	Pharmaceutical group	Conc. [$\mu\text{g/L}$]	Groundwater origin	Source
Sulfadimidin/Sulfamethazine	Antibiotic	4.0	irrigation of slurry	Weiss (2008)
Tylosin	Antibiotic	1.0	irrigation of slurry	Weiss (2008)
Diclofenac	Analgesic	3.4	irrigation	Lilienblum et al. (2000)
Carbamazepine	Antiepileptic drug	1.1	bank filtration	Ternes (2001)
Iopamidol	Iodinated contrast media	0.88	exposed groundwater	BLAC (2003)
Sulfamethoxazole	Antibiotic	0.41	bank filtration	Sacher et al. (2001)
		0.47	irrigation	Hirsch et al. (1999)
Ibuprofen	Analgesic	0.51	irrigation	Lilienblum et al. (2000)
Metoprolol	Beta-blocker	0.03	representative groundwater	BLAC (2003)
		0.14	exposed groundwater	
Amoxicillin	Antibiotic	0.1	representative groundwater	BLAC (2003)
Clarithromycin	Antibiotic	0.043	exposed groundwater	BLAC (2003)
Trimethoprim	Antibiotic	0.04	bank filtration	Bayerisches Landesamt für Wasserwirtschaft (2004)

Table 2: Active pharmaceutical substances measured in groundwater in Germany

2.3 Concentrations measured in drinking water

Some pharmaceutical substances like the very mobile and quite persistent iodinated contrast media have already been detected in drinking water. Table 3 exemplarily shows the results of investigations of drinking water performed by agencies of the Federal State Bavaria.

Active compound	Pharmaceutical group	Concentration [$\mu\text{g/L}$]	Source
Amidotrizoic acid	Iodinated contrast media	0.200	LfU and LGL 2010)
Iopamidol	Iodinated contrast media	0.120	LfU and LGL 2010)
Carbamazepine	Antiepileptic drug	0.077	LfU and LGL 2010)
Sulfamethoxazole	Antibiotic	0.023	LfU and LGL 2010)
Primidone	Antiepileptic drug	0.019	LfU and LGL 2010)

Table 3: Active pharmaceutical substances measured in drinking water in Germany

2.4 Comparison of concentrations of active substances of pharmaceuticals and of plant protection products in surface water

In the context of a regular monitoring of active substances of plant protection products in surface water bodies of the Federal State Rheinland-Pfalz in 2011 several active pharmaceutical substances were investigated as well. It is notable that some pharmaceutical substances were detected at any time of the year. Figure 4 shows exemplarily the seasonal course of concentrations of active substances of plant protection products and pharmaceutical substances in the stream Pfrimm throughout the year 2011. Unlike the seasonal variable concentrations of plant protection products surface water concentrations of pharmaceutical substances turned out to be steady over the year. In spring and autumn/winter the concentrations of pharmaceutical substances exceed the concentrations of plant protection products. Considering that the number of pharmaceutical substances was small compared to the high number of different plant protection products that were investigated in that monitoring, the total concentration of all pharmaceutical substances in these water bodies might be much higher.

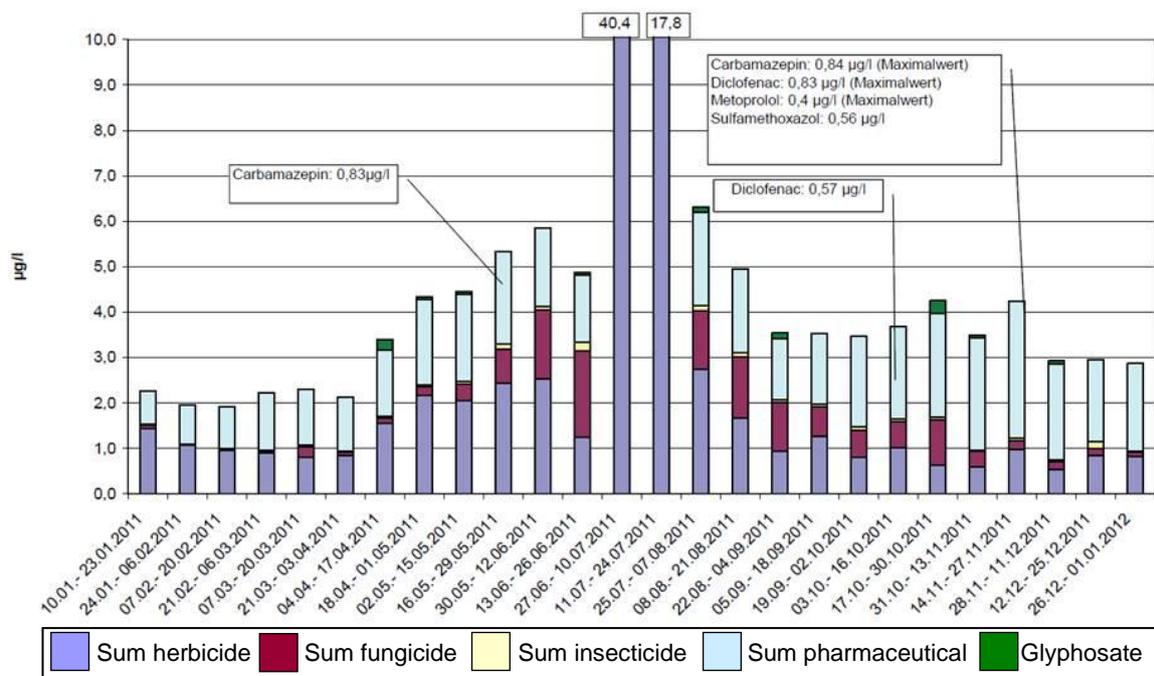


Figure 4: Seasonal variation of concentrations of active substances of plant protection products and pharmaceuticals in the stream Pfrimm throughout 2011 (taken from Sälzer and Ittel, 2012)

Conclusion

Pharmaceuticals are biologically highly active substances. They have continuously and repeatedly been detected in the environment during the last years. Data available from literature and field campaigns of the Federal States of Germany demonstrate that more than 150 different pharmaceuticals and metabolites have been detected in Germany in various

environmental compartments until now. Surface water concentrations of active pharmaceutical substances have been found mainly in the concentration range of 0.1 - 1.0 µg/L. Those concentrations detected are comparable with concentrations of substances used in plant protection products. For various pharmaceutical substances laboratory experiments and field studies indicate a potential for adverse environmental effects on aquatic and terrestrial organisms, even at population level (e.g. Brodin et al. 2013, Foster et al. 2010, Kidd et al. 2007). Thus, there is a strong need to evaluate potential effects of pharmaceuticals present in the environment in more detail. As a first step, a systematic monitoring approach could help to identify substances of concern and need for action.

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