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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

Том II Изучение и мониторинг процессов в почвах и водных объектах

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Главные редакторы: Лотар Мюллер (Лейбниц центр агроландшафтных исследований, Мюнхеберг, Германия) и Виктор Г. Сычёв (Всероссийский научно-исследовательский институт агрохимии им. Д.Н. Прянишникова, Москва, Россия)

Монография содержит информацию о самых современных методологиях и результатах в ландшафтных исследованиях. Она может быть использована в качестве руководства для исследователей, преподавателей, студентов и всех, кого интересует тема ландшафтной науки и смежных дисциплин. Монография является особо ценной информационной базой для лиц, принимающих решения на различных уровнях, от местных до международных органов по принятию решений. Приведенная в монографии информация представляет собой современный уровень ландшафтной науки в очень краткой форме.

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Main editors: Lothar Mueller (Leibniz Centre for Agricultural Landscape Research, Muencheberg, Germany) and Viktor G. Sychev (All-Russian Research Institute of Agrochemistry named after D.N. Pryanishnikov» , Moscow, Russia)

This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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Chapter II/79: MODEL-BASED ANALYSIS OF WATER POLLUTION BY HUMAN PHARMACEUTICALS AT THE LANDSCAPE SCALE
Глава II/79: Анализ загрязнения воды фармацевтическими продуктами в масштабе ландшафта с помощью моделирования

Björn Tetzlaff*[1]; Dieter Steffen[2]
DOI 10.25680/2266.2018.94.61.176
*Email: b.tetzlaff@fz-juelich.de
1.Research Centre Jülich (FZJ), Institute IBG-3: Agrosphere, 52425 Jülich, Germany
2.Formerly: State Agency for Water Management, Coastal and Nature Protection of Lower Saxony (NLWKN), An der Scharlake 39, 31135 Hildesheim, Germany

ABSTRACT. We developed and tested a model for delineating levels of human pharmaceutical pollution of surface waters at the landscape scale. Water quality experts have been suspecting significant concentrations of human pharmaceutical substances in surface waters and harmful effects on the aquatic biocenosis for more than 25 years. Although human pharmaceuticals in the environment belong to the group of emerging substances, reliable data on effects are widely missing due to the system complexity. The same is true for official regulations. Up to now knowledge on pollution levels in Northern Germany as in most of Europe was restricted to point information at few gauging stations. Our model results allow for a state-wide identification of polluted river reaches and pollution sources. About 70 % of the total river length is non-polluted, 16 % has low, 7 % medium and another 7 % high pollution levels. Our research results are being used for planning of ecological investigations and for optimization of cost-efficient monitoring programs.

Резюме. Разработаны и протестированы модели для характеристики уровней фармацевтического загрязнения поверхностных вод в масштабе ландшафта. Более 25 лет специалисты по качеству воды подозревают наличие значительных концентраций фармацевтических веществ в поверхностных водах и отрицательные эффекты на водный биоценоз. Хотя фармацевтические продукты в окружающей среде относятся к группе вновь выявленных загрязнителей, надежные данные об эффектах часто отсутствуют вследствие сложности системы. То же верно для нормативного регулирования. До настоящего времени знания об уровнях загрязнения в северной Германии, как и в большинстве стран Европы, ограничивались точечной информацией для небольшого количества пунктов измерений. Результаты расчетов по разработанной модели дают возможность идентификации загрязненных участков рек и источников загрязнения в масштабе страны. Около 70% общей длины рек не загрязнено, 16% имеют низкий, 7% средний и еще 7% высокий уровень загрязнения. Полученные результаты используются для планирования экологических исследований и для оптимизации экономичных программ мониторинга.

KEYWORDS: Hydrological model, surface waters, micro-pollutants, emerging substances
Ключевые слова: Гидрологическая модель, поверхностные воды, микрозагрязнителей, возникающие вещества

INTRODUCTION

Human pharmaceutical consumption in Germany is high. According to Schwabe and Paffrath [1] more than 3000 substances for human pharmaceutical production are approved in Germany. The situation is enhanced by demographic change as the demand for consuming pharmaceutical substances increases with human age. The substances have in common, that they are mostly polar, non-volatile and persistent although they originate from a diverse range of pharmaceuticals, so as antibiotics, antiepileptics, antiphlogistics, lipid regulators, betablockers, contrast media or hormons. Further characteristics are high resistance against enzymes and low pH as well as stability for long-term storage. High amounts of substances are not retained by the human body (up to 50 %) and are excremented. In waste water treatment plants retardation and decay of human pharmaceuticals are mostly low given their chemical persistence and that the existing purification techniques were installed to eliminate nutrients and organic matter predominantly. Ternes et al. [2] state overall removal rates between 0 and more than 90 %, but for widely used substances like sulfamethoxazole, carbamazepine or diclofenac rates are relatively low with 24, 0 and 33 %. As a consequence, high amounts of substances are discharged into rivers by waste water treatment plant effluents. Partly high concentrations are measured in different landscapes [3], [4], [6], [10], [11].

The processes described are not new but the awareness among experts and in the public has increased in recent years due to improved lab analytics and new discussions, e.g. about the growing number of microbial resistances against antibiotics. This puts pressure on environmental policy, on all EU, national and federal levels to develop strategies for tackling all micro-pollutants. Numerous studies are dealing now with pharmaceuticals as "emerging substances" and "micro-pollutants". But nevertheless knowledge is still restricted to pollution levels at single gauging stations or effects of single substances on very specific aquatic organisms. Studies on ecological risks reveal histopathological changes in the kidney of rainbow trouts, alteration of sex ratios and decreased egg fertilization in fish [5], [8]. With regards to concentrations relevant for risks, river reaches directly downstream of waste water effluent locations appear to be the main target areas.

Widely unknown is how human pharmaceutical pollution differs in the landscape and how a mixture or "cocktail" of substances is effective for the entire biocenosis or even for human exposition via the drinking water pathway, if surface water is being used as a resource [7]. Therefore, the main objective of our research works were the state-wide identification of surface waters with high risk for pollution (hot spot analysis) in Northern Germany (state of Lower Saxony, 48,000 km^2). We determined the waste water load in all rivers and major creeks, i.e. the cumulated share of annual effluent after waste water purification in the average natural discharge in the stream. This waste water load is regarded as a proxy for the contamination of the stream with human pharmaceutical substances as studies show that there is a close dependence [4].

The research results are required by the State Agency for Water Management, Coastal and Nature Protection of Lower Saxony (NLWKN) for planning ecological investigations in the vicinity of treatment plant discharges and for optimization of cost-efficient monitoring programs.

MATERIAL AND METHODS

In a first step a very detailed river network is divided into sub-catchments, whereupon the boundaries coincide with river sub-branches and effluent locations of waste water treatment plants. A distributed hydrologic model is used to supply grid based information on mean runoff and discharge at selected stations. Here, the GROWA model has been used based on climate, land use, artificial drainage, surface geology and relief data as well as soil parameters [9]. Spatial discretization was 100 meters. Model runs have been performed for an average period 2004-2014, a wet year (2008) and a dry year (2014).

The advantage of using a hydrologic model instead of discharge measurements is the availability of data for ungauged catchments, too. GROWA model results have been validated successfully at 192 gauging stations throughout the state. Coefficients of determination range between 0.9 and 0.95 for the model periods.

Furthermore, the annual waste water effluents from 455 sewage treatment plants have been evaluated and effluent locations have been assigned to specific river reaches. In a pollution load analysis the cascading relation between treated waste water and mean discharge has been assessed for each river segment and each effluent location. The general simulation process is shown in figure 1. For validation, simulation results on waste water loads were checked with measured concentrations of three selected substances which are widely used: sulfamethoxazole, carbamazepine or diclofenac [10].

RESULTS AND DISCUSSION

Figure 2 shows simulation results on pharmaceutical pollution levels for all 3000 river branches in the State of Lower Saxony. About 30 percent of all stream lengths are polluted with pharmaceuticals. The substances make their way into the rivers via the waste water discharge of sewage plants after treatment. According to our study, 7 percent of all rivers have a "high" or "very high" level of contamination, 7 percent "medium", and 16 percent "low". A waste water portion of less than 4 % is regarded as "low", a portion between 4 and 7 % is regarded as "medium" and a portion higher than 7 % as "high" polluted. Official classifications are missing.

Highly contaminated river reaches are typical for the conurbations Osnabrück, Hannover, and Braunschweig. Water bodies at times do not carry enough water into these densely populated areas to dilute the waste water from sewage plants sufficiently. As a result, wide stretches of the rivers Hase, Wietze, Fuhse, and Oker are heavily polluted. Such distribution patterns following densely urbanized areas were confirmed for dryer regions in Spain by Osorio et al. [11].

Furthermore, figure 2 shows very well dilution effects caused by non-polluted tributaries, e.g. east of the city of Bremen. The comparison of simulation results between the average period and the wet and dry year does not show strong variations. In the wet year 2008 the hot spot regions described above are still outlined, even with additional dilution. In the dry year 2014 the strongly polluted area around the city of Hannover is extended downstream towards Bremen.
Model results reveal pollution levels for all 3000 river reaches in Lower Saxony for the first time. Up to now insights on pollution levels were restricted to 80 water quality gauging stations and to the pharmaceuticals Diclofenac, Sulfamethoxazol and Carbamazepin. Checking model results with these measured concentrations show reasonable fit for all substances. But about 50% of the total variance is not explained, meaning that additional factors like waste water „import" from states upstream, heterogenous composition of waste water between plants, demographic reasons etc. play a significant role. Furthermore, the sampling frequency was between 4 and 8 in a two year period (2010-11), leading to increased uncertainty associated with the average concentrations. This is being evaluated currently in greater detail in a follow-up project. Public as well as media interest in this project is high.

CONCLUSIONS

1. Strongly urbanized regions are hot spots of pharmaceutical pollution in rivers, even in temperate zones
2. The contribution of waste water to the discharge in streams does not explain substance concentration satisfactorily. Additional factors like demography, varying waste water contents, number of hospitals etc. need to be included in pharmaceutical load assessments.
3. Great public interest in the project should be used to raise awareness of the problem and for simple countermeasures, like disposal of unused pharmaceuticals not via the toilet, reduction of pharmaceutical usage in favour of household remedies, if possible.

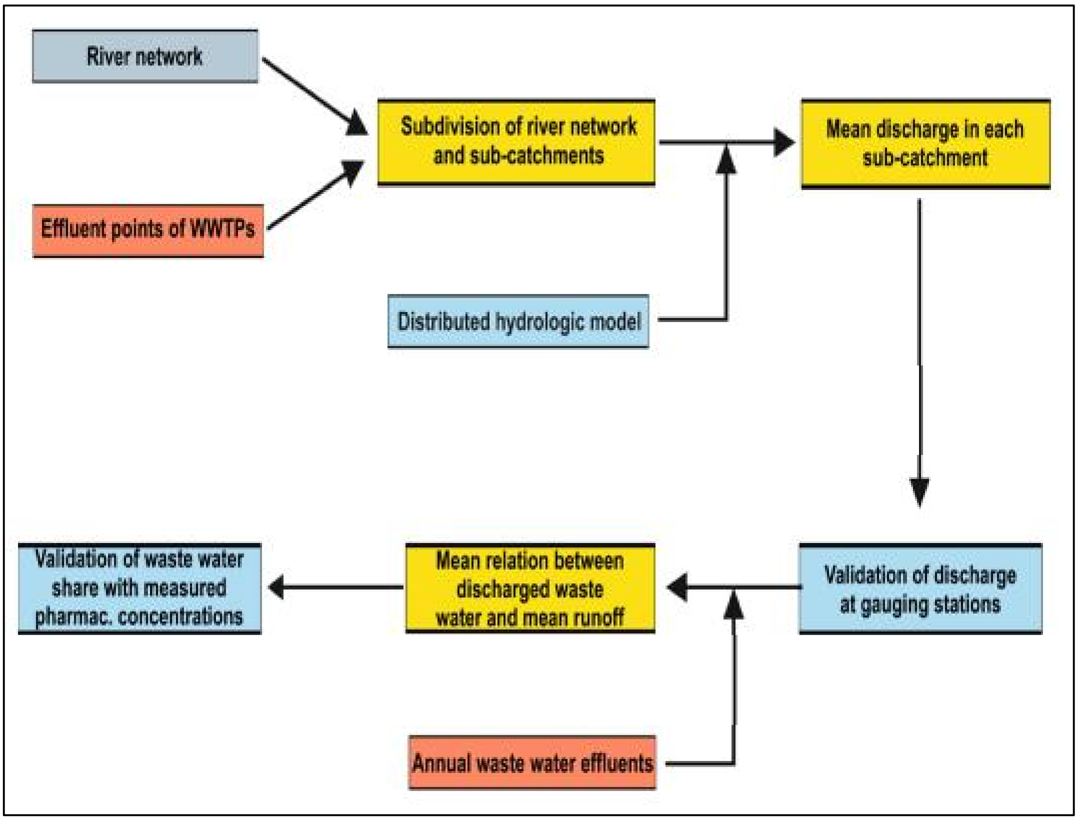

Figure 1 – General overview in simulation process

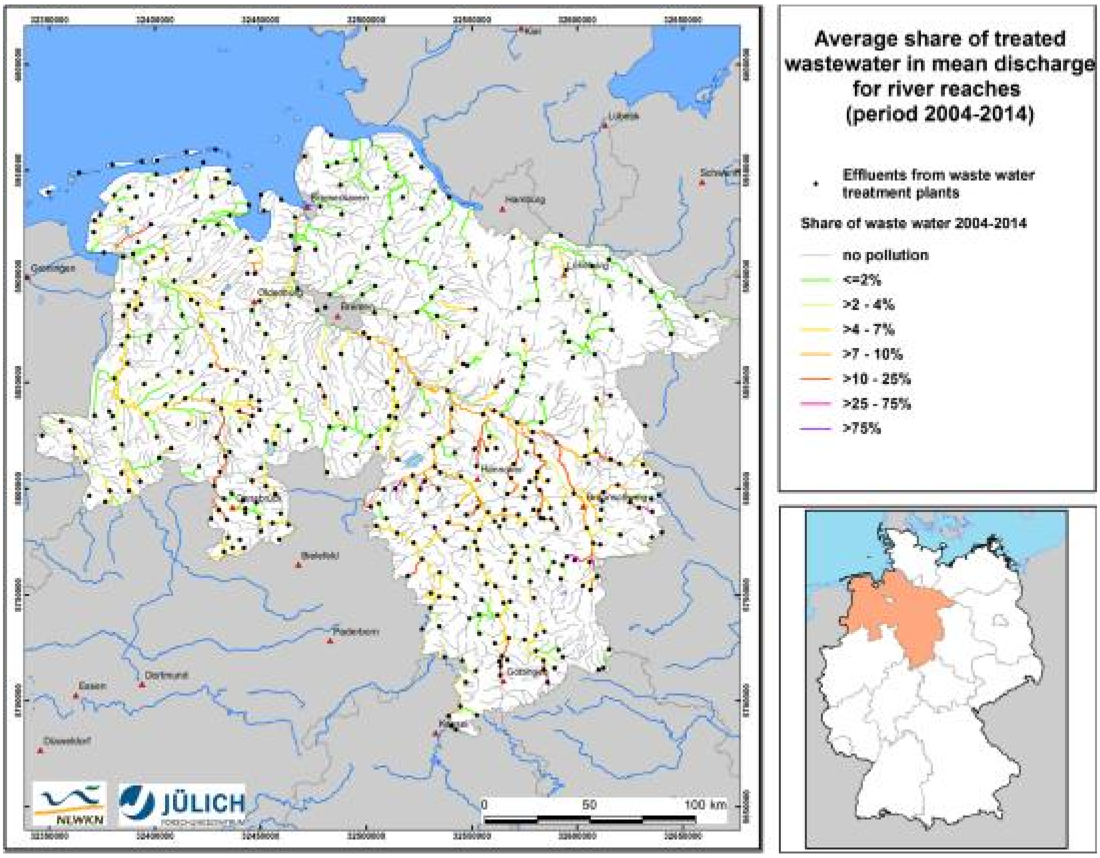

Figure 2 – Simulation results on pharmaceutical pollution levels in river reaches in the State of Lower Saxony (Northern Germany) and location of Lower Saxony in Germany (small map)

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