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Geo-referenced modelling of metal concentrations in river basins at the catchment scale

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1. Introduction
The European Water Framework Directive demands the good ecological and chemical state of surface waters [1]. This implies the reduction of unwanted metal concentrations in surface waters. To define reasonable environmental target values and to develop promising mitigation strategies a detailed exposure assessment is required. This includes the identification of emission sources and the evaluation of their effect on local and regional surface water concentrations.
Point source emissions via municipal or industrial wastewater that collect metal loads from a wide variety of applications and products are important anthropogenic pathways into receiving waters. Natural background and historical influences from ore-mining activities may be another important factor. Non-point emissions occur via surface runoff and erosion from drained land area. Besides deposition metals can be deposited by fertilizer application or the use of metal products such as wires or metal fences.
Surface water concentrations vary according to the emission strength of sources located nearby and upstream of the considered location. A direct link between specific emission sources and pathways on the one hand and observed concentrations can hardly be established by monitoring alone. Geo-referenced models such as GREAT-ER (Geo-referenced Regional Exposure Assessment Tool for European Rivers) deliver spatially resolved concentrations in a whole river basin and allow for evaluating the causal relationship between specific emissions and resulting concentrations. This study summarizes the results of investigations for the metals zinc and copper in three German catchments.

2. The model GREAT-ER
The geo-referenced model GREAT-ER has originally been developed to simulate and assess chemical burden of European river systems from multiple emission sources [2]. Emission loads from private households and rainwater runoff are individually estimated based on average consumption figures, runoff rates and the site-specific population and surface area (roof, gutter, street) connected to the local sewer system. For emissions from industry and mine drainage quantitative data on average annual loads are collected. WWTP effluent loads additionally consider average removal during wastewater treatment. Runoff from non-point sources such as agricultural areas and unsealed soils is estimated from average wash-off rates per area multiplied with the total area drained into a specified river reach of the river system. Groundwater infiltration is considered in quantities equal to the base flow in the respective river stretch. The model simulates the steady-state concentration distribution in the whole river basin considering transport and removal processes in the river system. The only major removal process for metals in surface water is sedimentation. Simulations have been carried out exemplary for zinc and copper in the German river basins Main (27,292 km2), Ruhr (4,485 km2) and Sieg (2,832 km2).

3. Results and discussion
Model estimations of effluent loads for selected WWTPs agreed well with available surveillance data so that the emission module outcome can be assumed as appropriate starting point for surface water modeling. A detailed comparison of simulated surface water concentrations with monitoring data was performed for zinc in the Ruhr river basin. Good agreement between monitoring data and model simulations was achieved at 20 monitoring sites in the Ruhr River and its major tributaries. GREAT-ER was able to simulate zinc concentrations in surface waters based on estimation of loads from several emission sources and via different emission pathways. A wide

applicability of the model was corroborated by successful simulations of zinc concentrations in the Main river basin and simulations for copper in both catchments. The functionality of the model allows for running scenarios with different emission assumptions that can be easily compared. Such case studies can be used to demonstrate the effect of specific mitigation strategies such as improved treatment of rainwater, reduction of metal products exposed to rain or reduced input from mine drainage. The model can thus be a valuable tool for setting up management plans as required in the Water Framework Directive with a special emphasis on promising mitigation strategies in case of exceedance of target values.

4. References

[1] Directive 2000/60/EC of the European Parliament and of the Council (EU Water Framework Directive)

[2] Feijtel T.C.J., Boeije G., Matthies M., Young A., Morris G., Gandolfi C., Hansen B., Fox K., Holt M., Koch V., Schröder R., Cassani G., Schowanek D., Rosenblom J. and Niessen H.; Chemosphere 34, 2351-2374, 1997.

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