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Monitoring urban impact on groundwater quality - statistical analyses in Darmstadt, Germany

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The EU Water Framework Directive Environmental demands that a "good status" of surface water and groundwater is achieved by 2015. This necessitates documentation, monitoring and if necessary, reduction of the urban impact on groundwater quality. However, permanent, city-wide monitoring is complicated by the usually dense setup of buildings, roads, pipelines etc., which makes it almost impossible to install a (good practice) sampling well network. Also, depending on the local conditions, the same anthropogenic influence does not always cause the same effects of the same magnitude. Absence of specific synthetic indicator substances for urban influences, e.g. for exfiltration of sewage, does not guarantee for an absence of this influence. Moreover, analysis of these indicators is often expensive and thus not suited for routine monitoring. When using naturally occurring substances, naturally high concentrations and/or natural change of groundwater quality on the flowpath under the city have to be taken into account. In the city of Darmstadt (Germany, highly industrialized, 140.000 inhabitants), extensive groundwater quality analyses were carried out, covering up to 68 groundwater measuring wells and springs in the city area and field parameters, standard cations and anions, NH4, PO4, NO2, B, F, B as well as synthetic indicators for anthropogenic impact (e.g. PAH, EDTA, clofibric acid, pesticides). Statistical analysis was used to differentiate between geologic background effects and anthropogenic impact and to assign concentration levels to land use types. The groundwater concentrations in Darmstadt are temporally stable, but spatially heterogeneous due to natural differences between the aquifers (crystalline rocks, Permian sediments and vulcanites, Quarternary unconsolidated sediments) and the pollution caused by different land

use types. By analysis of the correlation coefficients and a factor analysis, groups of parameters which originate from common sources were derived. The carbonatic parameters are mobilized from the aquifer matrix, but also influenced by anthropogenic factors (construction wastes, redox processes). Input of salt can occur isolated as road salt or in combination with sewer exfiltration. Parameters which are increased due to the influence of sewage are linked with indicators for reducing conditions. NO3 occurs separately in combination with oxidized conditions. Statistical analysis of the samples grouped by land use and geological formation allowed assignment of the parameters to distinct influences. Kruskal-Wallis tests showed that the anthropogenic impact on groundwater quality is stronger, i.e. affects more parameters than background geological processes. The concentrations are usually highest for urban land use and the Quaternary aquifer and lowest for forestry and the Crystalline aquifer. From cluster analyses, different urban pollution types were derived, which occur in distinct degrees, as well as background types subdivided by geological formation. In Darmstadt, suitable indicators for routine monitoring of groundwater quality for urban impacts are: Temperature ($> 14°C$), electrical conductivity ($> 1000\ \mu S/cm$), pH (< 7), Cl ($>$ 100 mg/l), SO4 (> 150 mg/l), NO3 (> 50 mg/l), Ca (> 150 mg/l), K (> 5 mg/l), PO4 ($> 0{,}5$ mg/l) and B ($> 0{,}05$ mg/l).