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Emission via erosion and retention of heavy metals in river basins of Germany

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The input of heavy metals into surface waters is a serious impairment of the aquatic environment. However, measures implemented within the scope of a more rigorous water legislation have decisively contributed to a decline of heavy metal emissions via point sources over the last decades. Today's emissions of heavy metals into river basins of Germany are thus mainly caused by diffuse sources. The objective of this study was to estimate the regionalised input of heavy metals via erosion into the large river basins of Germany and to balance the retention within the river channels. The study was carried out in the framework of a comprehensive survey that estimates the emission of heavy metals from all relevant point and diffuse sources on a yearly basis since 1985. The emissions are quantified for all watersheds of Germany with a mean area of 100 km^2. In addition the foreign areas of the large river basins are considered to allow for the validation of the calculated emissions using data at monitoring stations.

For each watershed the heavy metal input via erosion was quantified by multiplying the sediment input, the average heavy metal concentration in the top soil and the enrichment ratio according to the preferential transport of fine particles. Due to the large spatial scale long term erosion rates were estimated based on the USLE and combined with a sediment delivery approach to account for sediment input at the catchment scale. Heavy metal concentrations were regionalized for the area of Germany using background data in the top soil of arable land for various bedrock types provided by the environment agencies of the Federal States and the geological map of Germany. The measurement values were mainly taken in the 1990s. To account for the accumulation of heavy metals due to atmospheric deposition and agricultural cultivation (fertilisation) a balance was made for the input and output to quantify the accumulation since the 1990s. The enrichment of heavy metals can be calculated from the ratio of heavy metal concentrations in suspended sediments and in the top soil of arable land. We determined the enrichment ratio for 16 medium-sized watersheds located in different regions of Germany. Using the results of these watersheds a power function based on specific sediment input was adapted and applied to all watersheds under consideration to account for the variation of the enrichment ratio.

For the metals Cr and Pb erosion was identified as the most important pathway with a share of 63 % (Cr) and 48 % (Pb) in the total of today's emissions. For Ni the share is 24 % and for the rest of the metals (Cd, Hg, Cu, Zn) about 10 % of the total emissions. The heavy metal emissions were validated on balanced river loads using datasets of a range of monitoring stations. For the comparison of calculated heavy metal emissions with measured heavy metal loads the losses due to retention processes within the river systems have to be considered. The heavy metal retention was estimated using a power function based on specific runoff of the watersheds. High retention rates were calculated for metals which are strongly affected by erosion such as Cr, Pb and Ni. In general, a good correspondence was found between estimated and measured heavy metal loads for the large river basins of Germany. For smaller river basins the deviations between observed and modelled river load are increasing. This could be explained by the lumped model approaches and the input data that is available for the area of Germany which both do not allow an adequate consideration of local catchment characteristics and processes.