Analysis of sources and sinks of mercury in the urban water cycle of Frankfurt am Main

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Mercury (Hg) is a global pollutant that can cause negative effects on humans and the environment due to its toxicity and ability to bioaccumulate throught the food chain. Especially, waters in urban areas are subject to increased loads of Hg. This may be caused by point sources such as effluents of industrial and municipal wastewater treatment plants (WWTPs), but also by diffuse inputs such as direct atmospheric deposition and stormwater runoff. Hg inputs via municipal and industrial wastewater decreased significantly during the last two decades due to technical improvements, laws, regulations and use restrictions. Nevertheless, Hg is still in focus of environmental research, since its levels in fish still frequently exceed the Environmental Quality Standard (EQS) under the Water Framework Directive of 20 µg/kg biota (Directive 2008/105/EC). Current Hg levels in bream from German rivers are in the range of 100 – 300 µg/kg biota (2013) and exceed the EQS by a factor of 5 – 15 [1]. Therefore, it is important to identify the sources of Hg pollution in the aquatic environment and to develop effective strategies for reducing the concentrations in fish.
The aim of this study was to analyze Hg in different parts of the urban water cycle of the city of Frankfurt am Main. Samples were taken from the river Main and its tributaries, rain, stormwater runoff, effluents of two municipal WWTPs, stormwater management structures such as combined sewage overflows and stormwater retention tanks. Loads of Hg have been determined based on the measured concentrations and a Hg mass balance for the aquatic system was created. A total of 160 water samples were analyzed by cold vapor atomic fluorescence spectroscopy (CVAFS) according to US EPA Method 1631. The Hg mass balance showed that 5 kg Hg/a enter and 15 kg Hg/a leave the model region 'Frankfurt am Main' via the river Main. It was determined that the combined sewage overflows during heavy rain events supply the greatest contribution to the load increase of Hg in the river Main with a value of 0.59 – 1.18 kg/a. Much less contribution has been calculated for the rainwater from stormwater sewers with a load of 0.13 kg/a – 0.60 kg/a. The lowest loads were determined for the direct atmospheric deposition on the river surface (0.07 kg/a – 0.10 kg/a) and the effluents of the two municipal WWTPs in Frankfurt a. M. (0.07 kg/a). Furthermore, the largest amount of Hg (35.07 kg/a) throughout the urban water cycle of Frankfurt am Main is transported via wastewater. The two WWTPs in Frankfurt am Main have been identified as the largest Hg sink, since 99.8% (35 kg/a) of the Hg is shifted from the wastewater and stormwater during treatment into the sewage sludge. Thus, it was shown that the discharge of Hg by effluents of WWTPs into the river Main was significantly overestimated in earlier models [2], [3].
However, a total of 8.05 – 9.14 kg Hg of the annual inputs into the river Main could not be explained so far. Further possible sources should be investigated such as the direct discharges of 3 industrial WWTPs in Frankfurt am Main, which could not be analysed yet.

References:
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