Simulation of mercury transport and transformation processes in the Idrijca and Soča Rivers by one-dimensional model MeRiMod

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Abstract: Mercury from the Idrija region, where mining activities ceased about 10 years ago, is still drained from soil, riverbed and floodplains and transported with the Idrijca and the Soča Rivers to the Gulf of Trieste. A part of inorganic mercury is methylated either in the river system, or later in the coastal area, and, due to its bioaccumulativity represents potential danger for human health. A 1-D aquatic model MeRiMod was used to simulate hydrodynamics and sediment transport in the river system from Idrija to the Soča River mouth. Transport of particle bound and dissolved mercury as well as net methylation of mercury in the river system was simulated. Simulation of a Q_{30} flood wave was performed in order to calibrate the model. Methylation at lower discharges was simulated as higher methylation rates occur in such conditions. Compared to measurements, model results for transport of total Hg are within a factor of 3, while results of the methylation were somewhat worse, mostly within an order of magnitude. Additional measurements of hydrological and environmental parameters and mercury concentrations are necessary to improve the accuracy of model results.

Key words: mercury cycling, mathematical modelling, Soča River catchment.

INTRODUCTION

The Soča River catchment is subject to mercury pollution from the region of a former mercury mine in Idrija, Slovenia. About 37.000 tons of mercury has been lost in the environment during 500 years of mining and smelting activity (DIZDAREVIĆ ET AL., 2002). Large quantities of mercury in smelting remains have been deposited along the Idrijca River banks and washed away by flood waves. Mercury accumulated in soil and riverbed sediment is still drained from riverbed and flood area and transported in its dissolved and particle bound form with the Idrijca and the Soča River to the Gulf of Trieste. About 2.500 kg /year of mercury is still released from wider Idrija region. It is also known that about 1.500 kg/year enters the Gulf of Trieste (ŽAGAR & ŠIRCA, 2001), mostly bound to suspended sediment. A part of inorganic mercury is methylated either on the way in the river system and reservoirs of hydroelectric plants, or later in the coastal

area. Due to its bioaccumulativity and biomagnification methylmercury represents an increased risk for human health. HINES ET AL. (2000) have found that about 0.5 % of total Hg is methylated in the river system, reaching maxima of up to 5 % in reservoirs, with concentrations up to 0.6 ng/l near the Idrija, decreasing downstream to less than 0.1 ng/l except for the reservoirs, where concentrations of about 0.2 ng/l were found. To determine hydrodynamics, bank erosion, overbank deposition and transport of suspended sediment and mercury along the river system, a 1-D model MeRiMod was used. The model is a combination of three modified US-EPA models; RIVMOD, WASP5 and MERC4 (CARROLL ET AL., 2000; CARROLL & WARWICK, 2001). The existing model, used for simulations at the Carson River, USA, has been adapted to specific conditions of the Idrijca and Soča river systems. As such, the model was also used to perform simulations of methylation and demethylation in water and riverbed sediment and wet part of the riverbanks.

Figure 1. The River System and The Gulf of Trieste.

RESULTS AND DISCUSSION

To simulate transport of total mercury, the river system between Idrija and the Soča River mouth was divided in 4 parts (between the dams, Fig. 1). Fully unsteady simulations were performed consecutively for all four parts. Rating curve suspended sediment vs. discharge and a rough estimation of bank erosion were estimated from available data. The model was calibrated with measured concentrations of a 1997 flood wave (Q_{30}) at the Soča river mouth (HORVAT ET AL., 1999; ŠIRCA ET AL., 1999). An agreement of simulated and measured concentrations was within a factor of 3. Afterwards, some typical flood events, which statistically occur with high probability in a typical decade, were simulated (Q_{10}, Q_5, Q_2). After an additional calibration and verification of the model, results of 1-D model MeRiMod can be also used as improved input data for 3-D model of marine mercury cycling PCFLOW3D (RAJAR ET AL., 2000; RAJAR ET AL., 2004).

Simulations of net methylation (methylation and demethylation) in summer conditions were performed, as methylation rate was found to be higher with higher temperature and lower discharges (CARROLL ET AL., 2000). As this is the first attempt to simulate mercury transformation processes in the Idrijca and Soča river system, not many measured environmental parameters needed for the model input data were available. Results of simulations were compared to measurements (HINES AT AL., 2000) and the agreement of results was mostly in an order of magnitude. Qualitatively, we achieved a relatively good

agreement (more methylation at lower river-bed-slope and in reservoirs); however, to get a better quantitative agreement, additional measurements (hydrological and water quality parameters as well as different mercury species concentrations in different seasons) are necessary

CONCLUSIONS

An existing 1-D mathematical model has been adapted to specific conditions of the Idrijca and Soča river system. Simulations of suspended sediment and mercury transport as well as simulations of methylation and demethylation in the river system were performed. For transport, agreement of results with measurements within a factor of 3 was achieved, while for transformation processes agreement was somewhat worse but still within an order of magnitude. As this is only the first attempt to simulate mercury transformation processes in the Idrijca and Soča river system not enough input data for additional calibration and verification of the model was available. Further improvement of input data and the model are necessary to achieve better agreement with measurements.

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