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Risk assessing heavy metals in the groundwater-surface water interface at a contaminated site (Rådvad, Denmark)

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Abstract

Increasing anthropogenic pressure on water resources is causing serious problems, especially in industrialised countries such as Denmark. The Water Framework Directive sets criteria and new objectives to reach good water quality status through integrated assessments on different compartments such as surface water and groundwater (EC, 2017). The current study quantified and assessed the contamination of As, Cd, Cr, Cu, Ni, Pb and Zn in the shallow aquifer, hyporheic zone, stream water and streambed sediments at Rådvad site, a former metal manufacturing industrial area located in Denmark, investigating sources, pathways and final targets of contamination. Previous studies showed the presence of contact zones in the northern part of the area between the unconfined aquifer and the stream passing through the site, besides revealing a heterogeneous contamination (CAH, BTEX in the water and heavy metals in the soil). Stream water was sampled in 12 points, while groundwater was sampled in 4 wells close to the stream where the interaction was suspected. Sediments and hyporheic zone were sampled in pair, where upward hydraulic heads have been detected. A drain discharging in the river was also sampled. Sediments were divided in different layers and both heavy metal total concentration and chemical partitioning were analysed. Redox species and dissolved organic matter were also analysed in the water samples, while fraction of organic carbon was investigated in the extracted sediments. Results showed a high degree of heavy metal contamination in all the investigated resources. Groundwater was found under reduced conditions and polluted by Pb, Ni and Zn, exceeding the quality criteria by a factor of 2,7, 4,2 and 9 respectively. No clear correlation between groundwater and hyporheic zone was detected. Consequently, it was not possible to deduce where the polluted groundwater was flowing. Once entered in the contaminated site, the stream was also found polluted by Zn and Cu, confirming the anthropogenic role to the environmental pollution of the area. Sediments' total concentration analysis revealed high pollution of all the investigated heavy metals especially in the top sediments (0-10 cm), suggesting run-off contribution. However, the high concentrations cannot be explained just from the soil contamination found in the previous studies. Thus, past disposal of metal or construction/demolition waste could be another source of contamination. Chemical fractionation showed that Zn and Cd were the most easily available heavy metals, since a high portion of them was bound to acid soluble/exchangeable fraction, which can explain the high stream water Zn concentrations. Cr, Ni and As were mostly bounded to the residual fraction, while Cu and Pb were mainly associated with the oxidizable and reducible fractions respectively. Finally, the classification of the compartments ordered according to the risk they pose was defined as: 1) soil contamination, evaluated as the major concern at Rådvad site since the risk of exposure to heavy metals is very high in the northern and southern part of the area, where a Naturskole and residential houses have been built to reclaim the area; 2) sediment contamination, due to Zn and Cd high portion in the acid soluble/exchangeable fraction that pose high ecological risk; 3) stream water contamination, as Zn and Cu were exceeding the maximum allowable concentration in many investigated points; 4) shallow aquifer contamination, evaluated as the least risky since the detected upward flow from the deeper aquifer to the shallow contaminated aquifer would probably avoid downward migration of the leachate to the deeper aquifer, which is used for drinking water purposes. The current method used to evaluate the contamination and assess the risk, highlighted the importance of studying contaminated sites at a broader scale. Integrated approaches could help determining the fate and distribution of pollutants, building classification risks to prioritize and optimize the management of contaminated sites.

References

EC, European Commission, Environment 2017: http://ec.europa.eu/environment/water/water-framework/index_en.html