Application of Particle Transport Modeling and Chemical Forensic Analysis in Sediment Contamination Source Evaluation

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Introduction: The authors have collaborated on multiple projects where the source of sediment contamination was in question. Using a combination of particle transport modeling and forensic chemical analysis, we were able to determine the most likely distribution of sediment contamination from a source area and the most likely area of deposition of ongoing sources.

Methods: To predict particle transport and deposition patterns, the authors used the DELFT 3D modeling suite. Validated hydrodynamic models to capture circulation patterns in the river or estuary in the horizontal and vertical were coupled (offline) with a sediment transport model to simulate the distribution of particles from various sources. These sources were either sediment laden storm water discharges or sources of existing contamination in the sediment bed. A range of particle sizes were represented in order to capture the wide variety of erosion and (initial) deposition patterns that are strongly influenced by the particle size distribution of the contaminated sediment in question and the hydrodynamic forcing scenarios.

Multiple chemical forensic techniques were employed. These included PCB congener comparisons, principal component analysis, and PAH ratios.

Results: The combination of physical and chemical approaches proved more powerful than either technique alone. The analysis of the model results focused on finer particles sizes as contaminants largely adhere to fine sediments. In the case of sediments discharged from outfalls, coarser particles were not transported far from the source, whilst finer particles were often transported and deposited over very large areas. Where existing contaminated sources in the sediment bed were simulated, the degree of resuspension and redistribution of the contaminated sediments depended on both the degree to which the source area was exposed to hydrodynamic stresses and the strength of the sediment bed.

Discussion: As contaminated sediment management becomes more important worldwide, also in relation to beneficial sediment and circular economy considerations, accurate analysis of the source of existing contamination and prediction of where existing sources will have an adverse effect on sediment quality will be increasingly relied upon to settle the questions “who should pay?” for sediment cleanup and “will this source continue to cause unacceptable contamination?”. This will also allow for better risk assessment and possibilities for beneficial sediment use. Numerical models provide useful tools as part of this analysis, particularly to assess what may have happened in the past or what may occur in future scenarios.