Modelling mercury transport in legacy mining catchments in Victoria, Australia

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Abstract: Mercury (Hg) contamination from historical gold mining remains a persistent threat to environmental and public health. In Victoria, the extensive gold mining in the 19th and early 20th centuries has left a legacy of mercury pollution in waterways. This study investigates mercury transport, transformation, and fate in the Upper Goulburn catchment, a Victorian river system with a well-documented history of legacy gold mining and mercury contamination, using a coupled hydrological and water quality modelling framework. This study is guided by three core research questions:

- What is the spatial distribution and variability of mercury in legacy gold mining catchments?
- How can a coupled hydrological−hydraulic−biogeochemical model improve our understanding of mercury transport and transformation?
- How do seasonal variability and extreme hydrological events influence mercury mobilisation and fate?

To address these research questions, the study combines detailed field data analysis with both event-based and long-term hydrological simulations. Water, sediment, and soil samples were collected along the Upper Goulburn River during multiple trips to capture spatial variability in mercury contamination, including both upstream reference sites and downstream impact zones. In situ measurements included pH, turbidity, temperature, dissolved oxygen, and conductivity. Laboratory analysis of total mercury (THg) concentrations in water and sediment was conducted using a Direct Mercury Analyzer (DMA-80) following US EPA Method 7473. Rigorous quality control procedures were implemented, including the use of blanks, certified reference materials, and duplicates. These field data informed model calibration and validation, and were used to identify contamination hotspots, supporting the simulation of mercury dynamics under varying hydrological conditions.

The modelling approach links three process-based models, i.e., HEC-HMS for rainfall-runoff processes, HEC-RAS for hydraulic and sediment transport dynamics, and the Water Quality Analysis Simulation Program (WASP 8.4) Advanced Toxicant Module for mercury transport and transformation. This integrated framework enables simulation of mercury behaviour under varying flow regimes, including extreme hydrological events and long-term seasonal patterns. Preliminary results highlight spatial heterogeneity in mercury concentrations along rivers and show that legacy mining significantly influences contamination profiles downstream of historical mine sites, with several locations exceeding national sediment quality guidelines. Model sensitivity analysis reveals that hydrological variability and sediment dynamics are key drivers of mercury mobility and bioavailability.

This research addresses critical knowledge gaps related to the spatio-temporal variability of mercury in legacy mining landscapes and demonstrates the need for integrated modelling for understanding complex contaminant behaviour. Notably, this study represents the first attempt to develop a comprehensive mercury transport and transformation model in an Australian context, advancing the understanding of mercury dynamics in mining-impacted catchments nationwide. The framework developed is transferable to other mining-impacted catchments and provides practical decision-support tools for environmental managers aiming to assess risk, guide remediation, and protect downstream ecosystems.

REFERENCES

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