Quantifying heavy metal pollution along river profiles using conservative mixing models

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Jonas Eschenfelder, Alex Lipp, Gareth Roberts

Department of Earth Science & Engineering, Imperial College London

Email: jonas.eschenfelder18@imperial.ac.uk
Twitter: @JonasEsch

1. Introduction

Increased heavy metal concentrations in river sediments can have **adverse effects on its ecosystem**, making it vital to understand their distribution for accurate hazard assesments [1].

Hazard assesment is often limited by sparse sampling and poorly constrained natural baselines.

We use novel modelling techniques to calculate excess heavy metal levels continuously across drainage basins. This is demonstrated using data gathered by the BGS from the upper Clyde, Scotland [2].

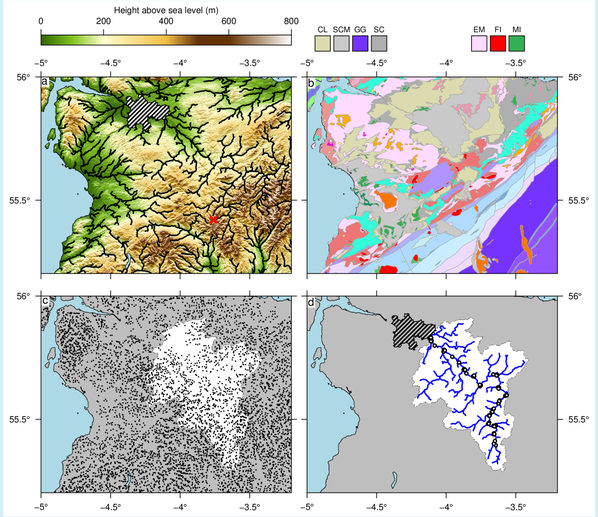

Fig. 1 Study Area: a) Topography and drainage network. Hashed polygon: Glasgow. Red cross: Lowther Hills. b) Geologic map. c) G-BASE first-order stream samples. d) Upper Clyde drainage basin. Circles: Downstream sediment samples.

2. Generating a baseline

The **source region geochemistry** is **estimated by interpolating first-order stream sediment** sample data from the Geochemical Baseline Survey of the Environment (G-BASE) by the British Geological Survey (Fig. 1c & 2a).

Using a **conservative mixing model** [3]**, continuous downstream** river sediment **geochemistry** is predicted (Fig. 2b & 3d).

These predictions are **used as 'natural'** (i.e. without human influence) **environmental baseline** for the 16 studied elements.

3. Predicted baseline & observations

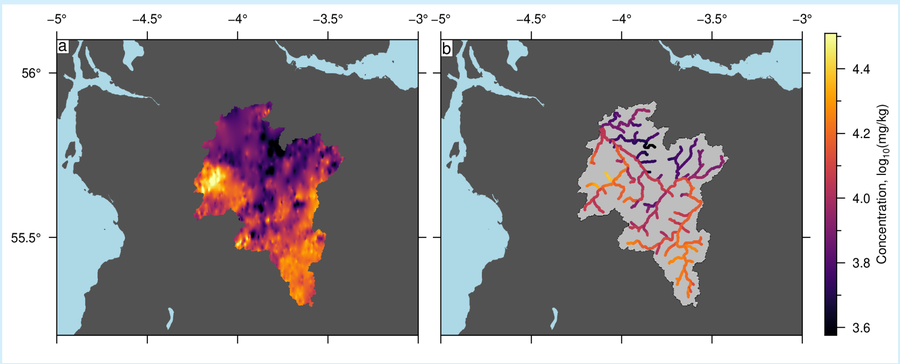

Fig. 2 Source region and predicted baseline of Mg: a) Source region geochemistry found by interpolating G-BASE first-order stream sediment samples. b) Continuous downstream river sediment geochemistry, the natural baseline, predicted by conservative mixing [3].

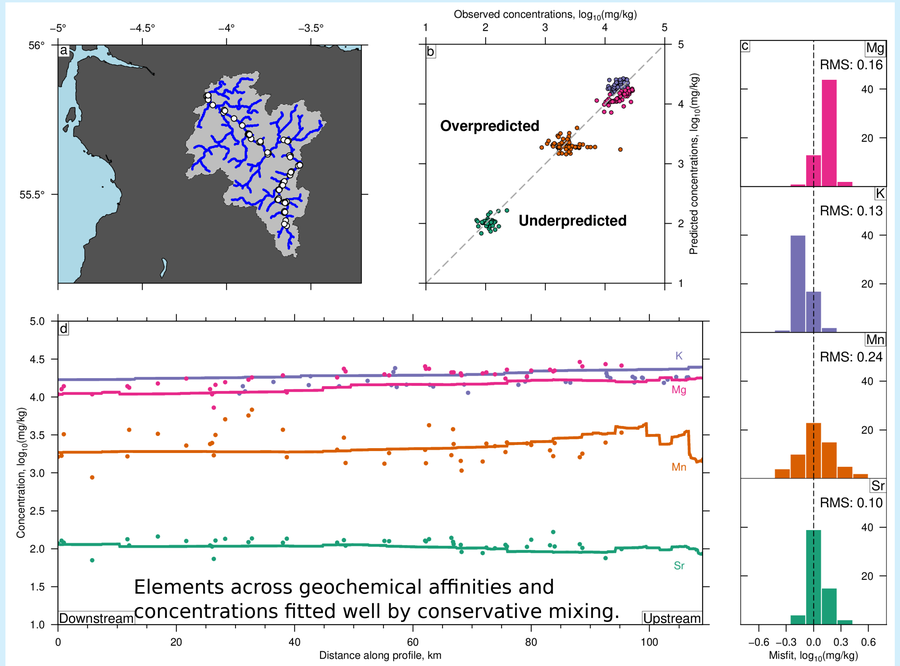

Fig. 3 Predicted baseline compared to observations: a) Map of upper Clyde drainage basin. White circles: Loci of downstream observations. b) Cross-plot of baseline results and observed concentrations. Dashed line: 1:1 relationship. c) Histograms of misfit between baseline and observations. Note the Root-mean square error (R) in top right. d) Concentrations along main chanel profile. Lines: Natural baseline concentration. Circles: Observed concentrations of downstream samples.

Most elements follow the natural baseline well with only minor local variation.

Only the **heavy metals** Pb, Cu and Zn are **continuously underpredicted** (Fig. 4).

References:

[1] Hudson-Edwards K. A. et al. (2008) Environment Agency; [2] Smedley et al. (2017) BGS;
[3] Lipp et al. (2020) JGR Earth Surface; [4] Lipp et al. (2021) Geochem Geophys;
[5] Rowan et al. (1995) J. Geochem. Explor.

4. Quantifying excess Pb

Using an inverse model to **unmix downstream sediment** [4] creates **well-fitting continuous** river sediment **geochemical profiles**.

The **inverse model** predicts **Pb concentrations exceeding** the natural **baselines.**

Tributary sampling the **Lowther Hills** (red cross in Fig. 1a), a **historic Pb mining region** [5], causes **largest increase in concentration at 83 km**.

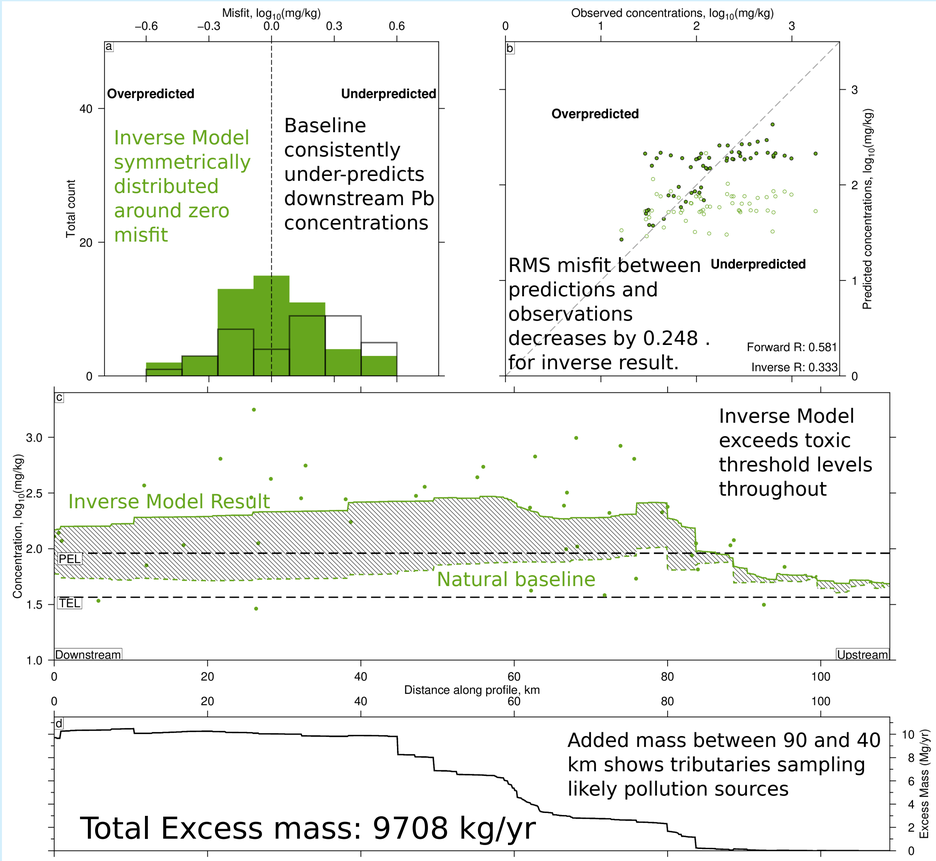

Fig. 4 Predicted excess Pb along the upper Clyde: a) Histogram of misfit between predictions and observations. Green/black: inverse predictions/baseline. b) Cross-plot between predictions and observations. Solid/open: results from inverse model/baseline. c) Concentration of Pb and excess Mass along the upper Clyde. Circles: Measured Pb concentrations of main river. TEL/PEL: Threshold and Predicted effective level for toxicity in river sediments [1].

5. Conclusions

Conservative mixing reliably predicts the concentrations of **many elements** that occur **in nature along rivers.**

The **largest discpreancies** are for **heavy metals** (e.g. Zn, Cu, Pb). The excess masses in source regions required to account for the observed compositions along rivers are Pb: 9.7 Mg/yr, Cu: 1.5 Mg/yr, Zn: 5.7 Mg/yr.