Zinc is a widespread problem for water quality in areas of abandoned metal mining; although an essential trace element for all life, an excess in the aquatic environment is highly toxic to fish. **Barbara Palumbo-Roe's** team trace the journey of zinc from mine to river.

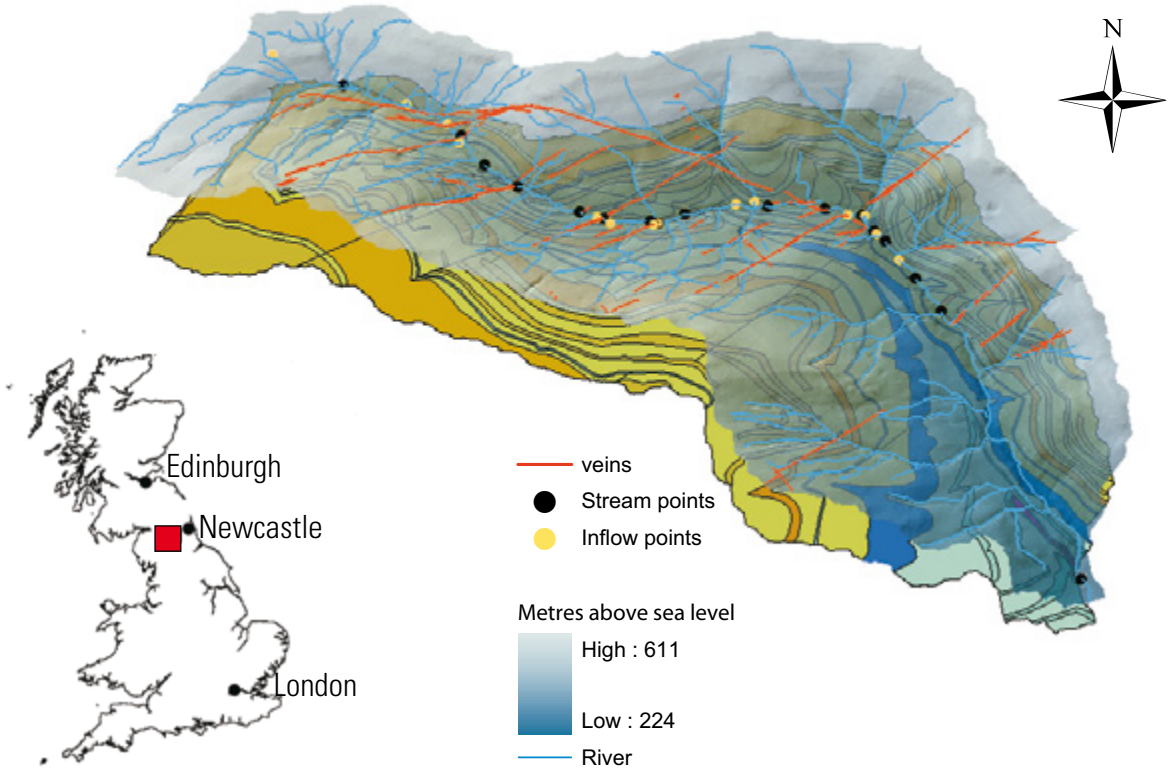
Zinc: the invisible threat

Between 2007 and 2009 a BGS team undertook a comprehensive monitoring programme — using flow measurements, synoptic sampling, and zinc isotopes — of the Rookhope Burn catchment in the Weardale valley, North Pennines. This area has been subject to historical mining of lead and zinc for over two centuries. Zinc is the major contaminant; exceeding the environmental quality standards (EQS) value for salmonid fish where three adits discharge significant quantities of mine water with a Ca-HCO_3-SO_4 composition enriched with calcium sulphate and bicarbonate to the Rookhope Burn. Areas of contaminated land, spoil heaps, tailings dams and stream sediments also act as potential sources of contamination. Distinctive increases in zinc load in the Rookhope Burn occur as a result of major visible point sources of mining-related contamination (mine adits) and subsurface diffuse contributions of mine water through the river bed.

The total flux (volume of flow over time) of zinc (195 tonnes/yr), arsenic (5.1 tonnes/yr), lead (18.5 tonnes/yr) and cadmium (630kg/yr) arising from unregulated metalliferous mining discharges is of a similar magnitude to that discharged from all licensed discharges across England and Wales. These polluting sources pose considerable barriers to compliance with the demands of the EU Water Framework Directive (WFD) in many parts of the UK.

To date, in the Rookhope catchment mitigation efforts have focused on 'pollution source' regulation based on the occurrence of known mine waste deposits and the outflow from the mine adits and shafts, which were considered the dominant source of water pollution. More recently, the importance of diffuse pollution sources and their potential to affect water quality and ecology at the catchment scale has been recognised. These secondary inputs arise from seepage and run-off from mine waste, contaminated groundwater inputs through the hyporheic zone (the zone of groundwater–surface water interaction) and remobilisation of previously deposited metal-rich material in stream and floodplain sediments. Cost-effective remediation of the effects of metals from mining in the catchment requires knowledge of the most significant sources of metals.

There has been lead and zinc mining activity in the Rookhope area since the eighteenth century. The Groverake mine, pictured here, is located near the convergence of three major lead-bearing veins. Zinc and lead often occur together but have been mined at different points in history according to the demand dictated by industry.



A 2D view of the Rookhope Burn catchment digital terrain model underlain by the geology (catchment area 37 square kilometres). blue = limestone, green and orange = sandstones, red = Great Whin Sill.

Metals can be transported from a mine-water source and slowly accumulate in downstream sediments. A study of the shallow hyporheic zone has indicated that zinc and manganese are co-attenuated in this zone, probably during oxide precipitation.

Laboratory-based inundation studies (simulating events in which sediment is covered with standing or slow-moving water) have been carried out to investigate the impact of short-lived flood events on the release of zinc and other potential harmful elements (PHE) from mine-contaminated sediments into the water column. In the case of zinc, during the approximately 90-day inundation period the sediment becomes a contaminant source releasing zinc into the flood water to differing degrees depending on the initial sediment location and concentration.

Mine-water outburst at Wolfcleugh, December 2006. With zinc concentrations of 1.45–2.42 milligrams per litre it represents the principal point source for the stream waters.

The hydrological understanding was also applied to subsequent baseline monitoring of the stream ecology. Our baseline monitoring of the stream ecology has assessed the macroinvertebrate community using a range of biotic indices. The results demonstrate an ecological response to mine-water inputs. This research included the quantification of metal concentrations in macroinvertebrates. When compared with the control sites, elevated zinc and arsenic concentrations were determined in Leuctridae (stonefly) and cadmium in Limnephilidae (caddisflies) at the mine-affected locations.

Current work is focused on testing the potential of zinc isotopes to fingerprint sources and pathways of zinc in the aquatic system. The catchment surface water shows a large range in zinc isotope values, warranting further investigation. The relative abundances of zinc isotopes in natural waters may be used to fingerprint sources of this metal and to probe important biogeochemical reactions. Our ability to interpret these measurements is limited by the paucity of published studies that explore the mechanisms of zinc isotope fractionation, and poor understanding of how these elements fractionate during weathering reactions. More work is needed to gain further insight on the fractionation behaviours of zinc isotopes and other transition element isotopes to make them valuable geochemical probes in biogeoscience.

For further information, contact:

Barbara Palumbo-Roe, BGS Keyworth
Tel: +44(0)115 936 3003
e-mail: bpal@bgs.ac.uk