A pilot scheme to clean up rivers that have been heavily polluted by abandoned metal mines is delivering "staggering" results

Vertical flow pond removal

'DEAD' RIVERS

Modern Wales has often paid a heavy price for its industrial past, which has left its deep scars scattered across the landscape. Long-abandoned metal mines, which once produced lead, zinc and copper, are now the source of severe pollution whose toxic discharges can have a huge impact on the water quality of the surrounding area.

Metal mining in the UK peaked in the 18th and 19th centuries and, though they have all closed, their effect on the environment is still all too evident. As Peter Stanley, geotechnical engineer in geoscience, Natural Resources Wales (NRW), says: "Wales has the challenging record of being home to nine of the 10 worst metal mine polluted catchments in the UK and overall has more than 1,300 abandoned metal mines, which impact on over 600km of river and 67 water bodies. Nine of the 10 worst affected metal mine catchments in the UK are in Wales.At the Cwm Rheidol mine, near Aberystwyth, in Ceredigion the polluted water discharging there has been directed to filter beds since the 1960s, in an attempt to remove the metals, with little success.

"More recently, treatment trials of a passive system (vertical flow pond, shown above) using a combination of compost, wood chips, cockle shells and digested sewage sludge over a limestone bed (by Dr Adam Jarvis of Newcastle University), have been more effective and subsequently scaled up at Force Crag, Cumbria," he adds.

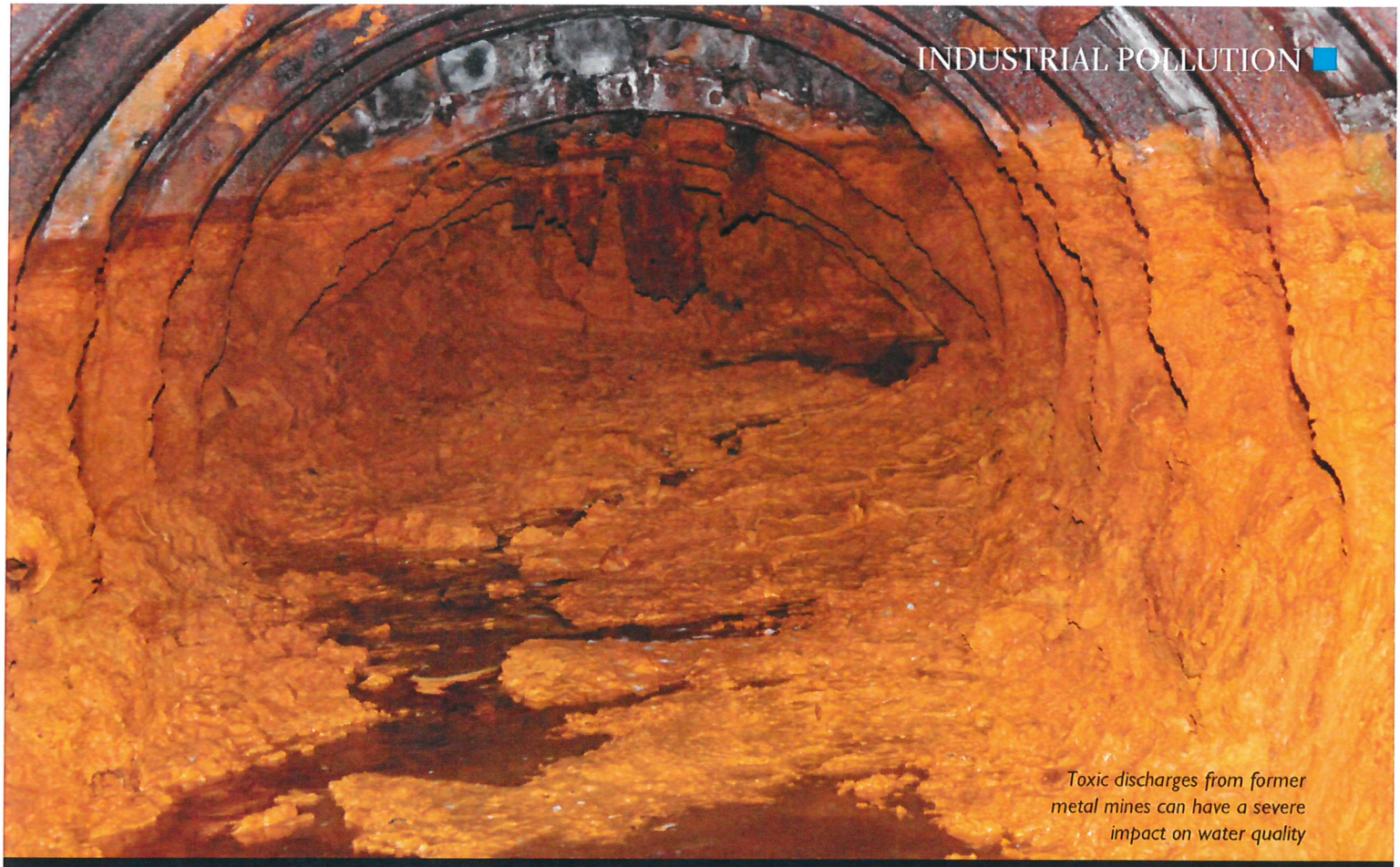
Elentec unit during construction (Photo courtesy of Elentec)

"Yet implementing this technique at all major abandoned metal mine sites, in order to have a meaningful impact on the levels of pollution encountered, would require much more land than is available in, for example, this narrow, steep-sided valley," Stanley points out.

INNOVATIVE SOLUTIONS

The upshot is that NRW turned to the technology sector, asking companies if they could come up with an innovative solution. "Natural Resources Wales is responsible for tackling metal mine pollution and, over the years, we have earned the reputation for developing innovative and cost-effective solutions for dealing with such issues," states Stanley. "Two of our most successful innovation projects are at Cwm Rheidol and at Frongoch, and we recently took the opportunity to share our results with our partners in tackling mine water pollution."

That move is now paying dividends, with the fightback against such heavy



Toxic discharges from former metal mines can have a severe impact on water quality

brought back to life

pollution recently taking a major step forward. In fact, according to Stanley, a recent pilot scheme to clean up the rivers that have been so heavily polluted by the abandoned metal mines has delivered "staggering" results.

The treatment plant, which employs a sono-electrochemical technique, has been tested at Cwm Rheidol mine on a stretch of the river Rheidol. The area is popular with tourists for its scenic reservoirs, steam train and red kites, but it was once home to mines producing lead and zinc, which now discharge highly acidic, orange water into the river there.

Approximately eight tonnes of harmful metals, including zinc, cadmium, lead and iron, enter the Rheidol every year, impacting 11 miles (18km) of river, impoverishing its ecology. In extreme circumstances, rivers can be fishless.

Here's how it works. A portable treatment plant – the size of a car – is attached to a small generator. The system treats the polluted water discharged from the mine adits (entrances), using a combination of electrochemistry and 'soneco' ultrasound, correcting its acidity and precipitating metals. NRW reports that the new technology – thought to be a world-first – removed up to 99.5% of metals that impact water quality, with the technique being able to separate the metallic sludge, producing clean water as a result. According to NRW, this marks a potential "step change" in how the problem is handled.

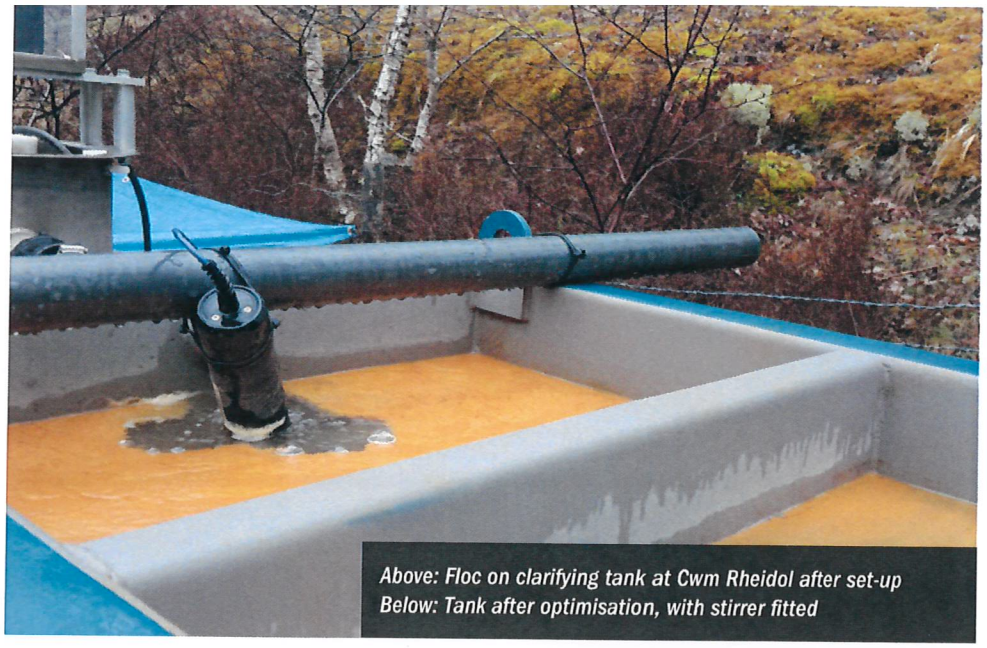
CLEANING UP

Swansea-based Power and Water is the company behind the technology. "What we are able to do is to add a small amount of power onto an anode and cathode, which slowly dissolve into the [contaminated water]. That allows for a chemical reaction where any contaminants are removed and the clean water can safely be discharged," says chief executive Gareth Morgan.

The metallic sludge, which sinks to the bottom of the tank, can then also be removed safely. In future, it is hoped the sludge could potentially be sold and the metals extracted and re-used. The three-month trial – which cost approximately £90,000 – was funded by the Welsh Government's Contaminated Land Fund. Welsh Government has now given a further £3m of Revenue and Capital funding to NRW to tackle metal mine pollution.

Power and Water says it has been granted an international patent for the technology, which it hopes to install at other abandoned mines following the success of this trial. It reports interest from consultants working in Sumatra and Australia, as well as enquiries relating to mines in England and Scotland. "Not only are we looking to try to create a solution that is going to have a beneficial impact on these historical metal mines within Wales itself, but the potential to export outside of the country is exciting," adds Power and Water's Morgan.

So, what is the big advantage of the system trialled? "The mine is situated



Above: Floc on clarifying tank at Cwm Rheidol after set-up
Below: Tank after optimisation, with stirrer fitted

in a narrow, steep -sided valley," says Stanley, "which is unsuitable for traditional treatment processes, which require a considerable area of land." Preliminary laboratory results from tests carried out on the Power and Water system were encouraging, he adds, "and the small footprint of the equipment makes it particularly suitable to rugged upland locations where traditional passive pond systems simply will not fit".

MASSIVE REMOVAL RATE

Also, when NRW filtered the samples, it showed a 99.5% removal rate of metals, "which is quite staggering," adds Stanley. "I don't know how much more excited I could be, in relation to the results that have been shown here – it gives us a new tool in our armour to effect treatment at metal mines, particularly those in steep, challenging environments like this".

These independent laboratory results confirmed the treatment's success with raw samples, showing metal removal of 87%, while filtered samples confirmed 99.5% removal of metals. A full-scale system, benefiting from added filtration to reduce fine particulate matter, might well be expected to achieve 98% or more reduction of metal loading, he concludes.

Lying to the south east of Aberystwyth is Frongoch, another former lead and zinc mine that operated between the mid-18th century and 1905. Frongoch is the larger of the two sites and has already been the subject of extensive remedial

work, including intercepting and diverting streams, capping and landscaping much of the site to limit water entry and thus seepage, minimising the volume of polluted water entering rivers downstream.

While the work has dramatically reduced metals pollution, concentrations in the three discrete discharges from the site are still high. To combat this, trials are now underway with Elentec, a company located at Menai Bridge, which provides research-based water treatment solutions using an innovative approach involving an energy-efficient portable containerised electrochemistry unit. The unit is said to be ideal for upland terrain or adaptable for 'fly in, fly out' mine contracts abroad.

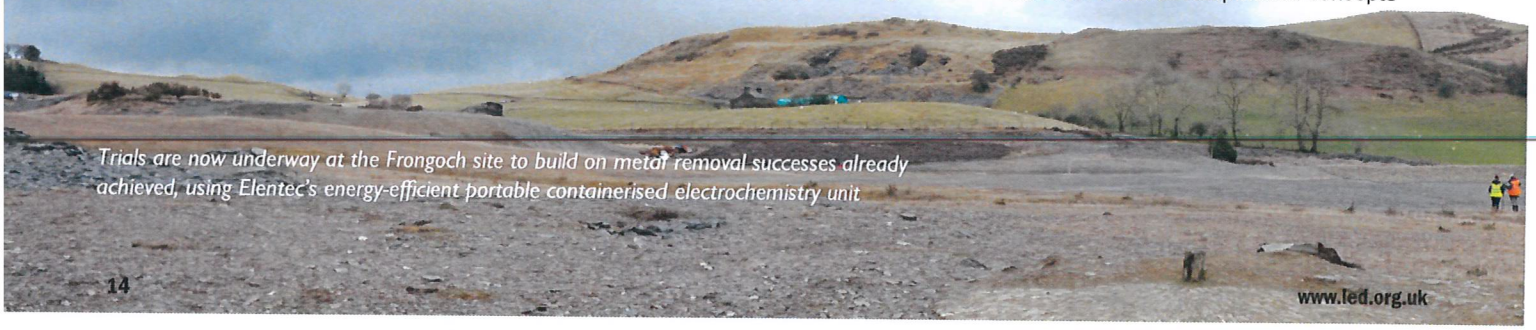
Says Stanley: "Two highly polluted sources which contribute 3.8 tonnes per year of zinc, lead and cadmium to Frongoch stream are collected and fed through the electrode chambers. The polluting metals are then separated from the water through precipitation in a purpose-built clarifying tank, allowing the treated water to be discharged. Preliminary results were encouraging, enabling optimisation of the treatment process to remarkably secure 99.9% removal of lead and 92% of zinc.

And there are spin-off benefits, too. "The success of the Cwm Rheidol and Frongoch trials has the potential to offer NRW and others interested in metal mine water remediation and the clean-up of metal mine process waters new tools for successfully treating harmful discharges. And it's not just the environment which will benefit from this technology; the Welsh economy could also receive a boost, as the companies involved in this work share the technology with overseas markets."

Ultimately, might remediation and/or metal mine water treatment prove to be cost neutral due, to the value of recovered metal? Sadly, not, confirms Stanley. "However, they can be used to offset costs and NRW is researching this with several R&D stakeholders. NRW's Metal Mine Team has used a Small Business Research & Innovation (SBRI) challenge-led competition [funded by Innovate UK and the Welsh Government] to assess varying technologies for metal mine water clean-up in steep upland terrain with a lack of infrastructure, such as transport and power."

Apart from Elentec's preliminary electrochemistry trial referenced above, this has included: use of iron ochre RAPS – Reducing Alkalinity Producing Systems – courtesy of Dr Devin Sapsford, Cardiff University; algae on which to harness metals by sorption (Steve Skill, Swansea University); and Allay (Algae & Clay) beads to use in a bed reactor to recover metals by sorption (Prof Chris Greenwell, Durham University).

"Being mindful of resource recovery as a means to offset remedial costs and by using interest expressed in the SBRI challenge, we developed a platform called the mineXchange for institutions, innovators, consultants and other interested parties to come together to learn of our programme and exchange innovative and developmental concepts



Trials are now underway at the Frongoch site to build on metal removal successes already achieved, using Elentec's energy-efficient portable containerised electrochemistry unit

in metal mine clean-up," adds Stanley. "The platform has been very successful in enabling R&D interests to be explored and tested for commercial applications."

MINDS ON MINES

The 'meeting of minds' has enabled the Metal Mine Team to collaborate, support and occasionally fund R&D research or developmental work. "We have supported the Cardiff University INSPIRE research project in the Resource Recovery from Waste (@RRfW6) programme." According to INSPIRE: "Societies have historically disposed of vast quantities of industrial, municipal, metallurgical and mining waste in the ground. Generally considered as a legacy waste issue, this research project seeks to reconsider waste repositories as 'resource hubs' for future recovery of valuable metals and energy."

Stanley adds: "Our objective is to explore whether energy and valuable metals can be recovered from landfills and mine sites in situ, thus avoiding the need to actively mine the material and thereby minimise ecological and environmental impacts." Precipitates from the Power & Water trial have also been supplied to Aberystwyth University, Cardiff University and Sheffield University for detailed chemical analysis, increase solid content of precipitates and assessment of resource recovery. The precipitate from the Elentec process has been supplied to SPECIFIC Innovation & Knowledge Centre at the College of Engineering at Swansea University, whom we have supported in Dr Darren Oatley-Radcliffe's successful bid with University of Vic (Catalunya) in their LIFE Demine project (http://mon.uvic.cat/life-demine/partners).

"They will assess particle size distribution, detailed chemical analysis, in order to understand improved harvesting of nanoparticulates, reduction of water content and resource recovery.

"Samples will be shared with Aberystwyth, Cardiff and Sheffield also, as the two discharges have significantly different characteristics, Cwm Rheidol being highly acidic pH ~3.0 and includes ~4T/yr Fe and combined concentration of Zn at ~17mg/l, whereas at Frongoch the discharge is circumneutral, includes very little Fe and combined concentrations of Zn at two groundwater discharges of 80-100mg/l," he explains.

Peter Stanley, of Natural Resources Wales: the Power & Water system showed a 99.5% removal rate of all metals, which is exceptional, offering new treatment opportunities

Stanley also reveals how Prof Barrie Johnson of Bangor University has considered biomining and sequential electrowinning for Parys Mountain, a huge open cast copper mine on Anglesey, which is unique to the UK in scale and metal loading discharge.

Both Johnson and Devin Sapsford (Cardiff University) have outlined opportunities to recover metals at Parys Mountain, in order to offset remedial costs and provide small-scale employment from artisanal creation of jewellery and cookery products.

At the same time, NRW remains interested in applications to recover enhanced products and is seeking to fund what it describes as encouraging work by Dr Sudhagar Pitchaimuthu (SPECIFIC IKC Swansea University). "This is novel to the UK, in developing organic waste-derived nanocomposite adsorbents to recover high value cadmium ions to produce nanoparticulate cadmium sulphide for use in thin film technology and photoelectrocatalysis, in treating metal mine water and breaking water, to produce H^+ energy."

NRW is also looking at aspects other than metal mine water treatment, such as: use of renewables; studies on bioaccumulation around Frongoch with Nottingham University; use of biochar and seed mixes at Frongoch and also Nant y Mwyn (varied R&D & commercial interests); synoptic sampling of small river catchments, by Dr Patrick Byrne, Liverpool John Moores University; and cultivating Canary Reed Grass and Miscanthus, with Dr Elaine Jensen and Dr Kerrie Farrar of IBERS, Aberystwyth University, to limit infiltration and erosion.

Clearly, NRW's vision when it comes to a cleaner, healthier environment, is a broad one. "As our programme develops, we also wish to trial and adopt IoT applications to measure performance of discharges, water quality and remedial systems, and help provide real-time data to colleges, schools and visitor centres," Stanley concludes.