

Ecologically engineered solutions to rehabilitate mining waste and mine sites

Short summary of the Impact:

More than 30 million jobs in the EU and many key economic sectors are dependent on a sustainable supply of raw materials, such as aluminium and zinc. However, the extractive operations to process and refine such raw materials generate approximately 300 million tonnes of potentially hazardous waste per annum, representing one of the largest waste streams in the EU-28. In addition, there is an estimated 5.9 billion tonnes of waste in storage across the EU from 'legacy' sites, that is mines or quarries that were operating in the past but which closed leaving limited plans for managing the waste afterwards. This legacy waste was often stored in so-called tailings ponds. Without proper management, these tailings ponds may lead to a host of environmental issues, ranging from acid mine drainage to water contamination, dam bursts and flooding, air pollution, soil erosion and contamination. Over the past decade, Dr Ronan Courtney of the Department of Biological Sciences and Bernal Institute at the University of Limerick has led research projects driven by these industry-environmental needs. This research has created ecologically engineered solutions to help industries both effectively manage the extractive waste they are currently generating and allow the landscape surrounding the site to be reclaimed and reused in the future.

The findings from these research projects are contributing to national and international regulatory standards for the extractive industry for current day compliance. They are also underpinning the drive for ecologically compliant closure plans that foster reclamation and reuse rather than simply storing extractive waste after closing. This research is having a positive impact on problems arising from the past, fulfilling present-day industry needs, and protecting the environment into the future.

Underpinning research:

Extractive wastes vary significantly in their chemical and physical characteristics.

However, common to all the extractive waste residues is need for final rehabilitation, landscaping and safe-closure of the containment facility with effective long-term treatment of drainage waters. To avoid present day extractive waste becoming legacy issues in the future, companies currently working in the raw materials sector are now legally required to develop closure plans. The aim of these 'future-proofing' plans is to ensure that the local environment and landscape can be restored after the company ceases its operations by minimising potential pollution to land and soil.

The research conducted by Dr Courtney has explored two types of ecologically engineered solutions:

1. 'Rehabilitation and restoration strategies' to develop revegetation prescriptions for establishing sustainable vegetation covers on mine wastes. This typically consists of developing a soil-forming layer to promote initial plant growth and establishment, and for the development of self-sustaining ecosystems.
2. 'Passive treatment systems for industrial effluents' to develop constructed

wetlands for the management and treatment of leachate (mine waste derived discharges) by reducing or removing its contaminants. Constructed wetlands can be described as 'nature's technology, nature's kidney'.

These research solutions have been demonstrated in the field, on both live and legacy industrial sites, building upon results from laboratory and greenhouse experimentation. Funding has been provided from Enterprise Ireland, the Irish Research Council and the Environmental Protection Agency (EPA) as well as from industry sources. Over the past decade, Dr Courtney has developed strong links with a range of industrial partners including RUSAL Aughinish, Vedanta, Boliden, Rio Tinto and the International Aluminium Institute (World Aluminium). These links have been instrumental in enabling the research to be carried out on field sites across Ireland and Europe. They also ensure that industry-environmental needs drive the research questions and solutions.

For example, a key research finding arose from greenhouse and field trials at the RUSAL Aughinish Alumina refinery in County Limerick. This was the development of a revegetation prescription for bauxite



This research is supported by

residue; the waste material remaining after alumina has been extracted from bauxite ore. Revegetation in un-amended bauxite residue is limited or fails due to the high alkalinity, low concentration of nutrients and fine texture of the residue that impedes the penetration of plant roots.

Through a series of studies, the research identified novel approaches to physically and chemically modify the residues before additions of organic wastes, which accelerated the transformation of the bauxite residue into a soil-like media. This amended soil displays chemical and biological characteristics typical of Irish soils, hosts populations of soil biological communities and supports the growth of indigenous vegetation species. From an initial seed mixture of six species, after a five-year period in excess of 50 plant species were found to be flourishing on the revegetated area. In addition, the modified residues supported soil microbial communities typically found in Irish soils. Further studies showed that the application of organic wastes can be optimised to provide sufficient nutrient content, support plant performance and facilitate the development of soil faunal communities in the amended soil. Restoration of residue through revegetation avoids the requirement for exhausting soil resources from other sites. (Ref1, 2, 3, 4).

Subsequent research conducted by Dr Courtney with colleague Dr Teresa Curtin, also on site at RUSAL Aughinish, involved the construction of wetlands. Constructed wetlands are a passive, low cost, natural alternative to energy intensive technical methods of wastewater treatment. They are man-made systems engineered to manipulate the characteristics of naturally occurring wetland ecosystems to improve the treatment capacity of a wide range of pollutants. They have gained popularity worldwide from both regulatory authorities and industries alike.

Constructed wetlands have, mainly been used to treat waste of an acidic rather than alkaline nature. The constructed wetlands in this research are pioneering as they are the first designed to treat alkaline waste from mineral processing industries. The primary objective of the research is to passively reduce the alkalinity of the bauxite leachate

to below regulatory standards so that it can be directly discharged into the surrounding environment. Laboratory and greenhouse trials have identified mechanisms for successfully buffering the alkalinity of the leachate and have demonstrated the potential for wetland plants to establish and grow in soils inundated with residue leachate (Refs 5 and 6). The long-term effectiveness of this wetlands system site continues to be successfully demonstrated in field-based trials. The approach developed through this research is now being implemented at other mine sites both nationally and internationally.

References to the research

Research Publications

1. Courtney, R., Harrington, T. and Byrne, K. (2013) Indicators of soil formation in restored bauxite residues. *Ecological Engineering*, 58, 63–68
2. Schmalenberger, A., O'Sullivan, O., Gahan, J., Cotter, P.D. and Courtney, R. (2013) Bacterial communities established in bauxite residues with different restoration histories. *Environmental Science and Technology*, 47, 7110–7119
3. Callery, S. and Courtney, R. (2015) Assessing metal transfer to vegetation and grazers on reclaimed pyritic Zn and Pb tailings, *Environmental Science and Pollution Research*, 22, 19764–19772
4. Smart, D., Callery, S., and Courtney, R. (2016) The Potential for Waste Derived Materials to Form Soil Covers for the Restoration of Mine Tailings in Ireland, *Land Degradation & Development*, 27, 542–549
5. Higgins, D., Curtin, T., Pawlett, Courtney, R. (2016) The potential for constructed wetlands to treat alkaline bauxite residue leachate: *Phragmites australis* growth *Environmental Science and Pollution Research*, 23, 24305–24315
6. Buckley, R., Curtin, T., Courtney, R. (2016) The potential for constructed wetlands to treat alkaline bauxite residue leachate: laboratory investigations. *Environmental Science and Pollution Research*, 23, 14115–14122.



Grants

Grants awarded total over €1.6 million and cover a wide range of topics related to the environmental management of mine waste and processing residues. Research funders include International Aluminium Institute (World Aluminium), Rio Tinto, Boliden, Irish Research Council, Environmental Protection Agency, Enterprise Ireland and Rusal Aughinish.

Recent research grants

Rio Tinto/ International Aluminium Institute, 2016–2019, Bioassays for assessing mine tailings rehabilitation strategies, €220,000

Boliden Tara Mines, 2016 – 2018, The development and demonstration of closure techniques for a mine tailings facility, €45,000

Irish Research Council, 2013 – 2016, The use of ecosystem function analysis to determine restoration success of industrial waste sites, €72,000

International Aluminium Institute/Rusal Aughinish, 2012–2016, Constructed wetlands for treatment of alkaline leachate from bauxite residue disposal areas, €422,000

Details of the Impact

This research has had significant impacts on the environment, environmental standards and industry practice and sustainability. By helping industry leaders working in different raw material sectors to operate their facilities in a sustainable manner and to make effective, compliant closure plans, this research enables the surrounding landscape to be restored. It is also contributing to national and European environmental



standards for the management of extractive waste.

Impacts on industry

Four closure areas involving ecologically engineered approaches have been implemented at mine waste facilities across Ireland. RUSAL, a leading global aluminium producer with operations in 19 countries has adopted the closure techniques derived from these projects at their facility in county Limerick as best practice. "RUSAL Aughinish is very conscious of its moral, ethical, and environmental obligations in operating the largest alumina refinery in Europe. The environmental research projects conducted at UL are critical to the continued operation of the Aughinish refinery. Further, the innovative research at UL is creating constant improvements to the environmental management approaches on the Aughinish residue storage facility and is viewed as best practice within the global alumina industry." (Source 1)

In 2015, the Alumina Quality Workshop (AQW) invited Dr Courtney to present the findings of the constructed wetlands project at its annual conference, which is the prime international conference for the industry. The industry and the International Aluminium Institute recognise the importance of the research undertaken at UL 'The volume of bauxite residue generated annually is growing, as demand for aluminium products increases. The International Aluminium Institute, together with its industry members and civil society, is proactive in developing best practice guidelines for the management and environmental closure of residue storage areas. The Institute has a long and ongoing fruitful relationship with UL and builds on its global reputation and innovative research conducted in residue revegetation,

rehabilitation and remediation'. (Source 2) In addition, a number of international industry representatives have visited the constructed wetlands project with a view to implementing similar projects in their sites. The research is also being taken up by other sectors of the extractive industry to develop ecologically engineered solutions for waste facilities and closure plans. Boliden Tara Mines, in County Meath, is currently implementing mine tailings rehabilitation, soil cover options and constructed wetlands for drainage water treatment "Boliden Tara Mines, the largest zinc mine in Europe, is acutely aware of the potential environmental impacts of its operations. The company has always been proactive in its approach to managing its environmental footprint and has employed best available technologies and techniques where possible. The company has recently engaged the University of Limerick to facilitate research that will inform important environmental strategies post operation at Tara Mines." (Source 3). This research is also informing the closure plan at the lead and zinc mine at Lisheen, Co. Tipperary, while ongoing research projects are contributing to closure strategies for a range of facilities in Europe and Australia.

Impacts on national and international environmental standards

Regular assessment and reporting on the ecologically engineered solutions at RUSAL Aughinish's facility is a condition of compliance with the Integrated Pollution Control Licences (IPC) issued by the Environmental Protection Agency (EPA) to the company. The research findings are reported periodically in RUSAL's reporting to the EPA (Source 4) and verified through site audits. The revised licence granted to RUSAL by the EPA in 2012 states that the final 1 metre of exposed mud deposited at the Bauxite Residue Disposal Area at the Aughinish facility must comprise "amended mud" as developed through the University of Limerick research (Source 5).

The proactive dissemination and collaboration with international academic partners (e.g. University of Hull; University of Leeds; University of Queensland; and University of Western Australia) has also led to significant impact on standards nationally and internationally, and in different areas

across the extractive industry sector. The European Commission is currently reviewing its Best Available Techniques Reference Document for the Management of Waste from Extractive Industries, in accordance with Directive 2006/21/EC. The 2016 draft review references the outputs of the restoration projects conducted by Dr Courtney (Source 6). Taking the findings of the research, this document indicates how residues can be transformed to effective plant growth media displaying the necessary physical, chemical and biological characteristics of soils. It highlights that this approach negates the need for the expensive and resource-depleting exercise of topsoil stripping and transportation.

Sources to corroborate the impact

1. Quote from Damien Clancy, Chairman RUSAL
2. Quote from Katy Tsismelis, Manager - Mining & Refining, International Aluminium Institute (World Aluminium)
3. Quote from Oliver Fitzsimmons, Senior Environmental Engineer, Boliden Tara Mines
4. RUSAL Aughinish Alumina Annual Environmental Report 2009 available via the Environmental Protection Agency at http://www.epa.ie/licences/lic_eDMS/090151b280355c49.pdf
5. Licence number P0035-05 available via the Environmental Protection Agency database <http://www.epa.ie/terminalfour/ippc/>
6. Best Available Techniques Reference Document for the Management of Waste from Extractive Industries, June 2016 draft available to download http://susproc.jrc.ec.europa.eu/activities/waste/documents/MWEI_BREF_Draft.pdf

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