CL:AIRE

research bulletin

RB 22
(April 2026)
ISSN 2047-6450 (online)

CL:AIRE research bulletins describe specific, practical aspects of research which have direct application to the characterisation, monitoring or remediation of contaminated soil or groundwater. This bulletin describes the main outputs from the Legacy Wastes in the Coastal Zone project.

Legacy Wastes in the Coastal Zone

1. INTRODUCTION

Legacy Wastes in the Coastal Zone: Environmental Risks and Management Futures was a four-year research project (2020-2024), funded by the Natural Environment Research Council (NERC). The project brought together an interdisciplinary team of researchers (from the universities of Newcastle, Hull, Exeter, Leeds, Liverpool John Moores, Plymouth, Glasgow and the UK Centre for Ecology and Hydrology) and partners (CL:AIRE, Environment Agency, National Trust, Natural Resources Wales, Haskoning, Scottish Environment Protection Agency and Mining Remediation Authority) to undertake a multi-scale assessment of the risks posed by municipal and mineral-rich[1] legacy wastes in the coastal zone and provide a framework for their effective future management. For this project 'legacy wastes' (also referred to as 'historic wastes' in literature) were operationally defined as waste repositories that are no longer operating and for which there is no environmental permit in force (Environment Agency, 2022).

Figure 1: Legacy wastes in the coastal zone: (A) coal mine waste, Lynemouth, Northumberland, (B) municipal solid waste, South Walney, Cumbria, (C) tin mine waste, St Agnes, Cornwall, (D) iron slag waste, Barrow-in-Furness, Cumbria (Photographs: (A) Adam Jarvis, Newcastle University, (B & D) Will Mayes, University of Hull, (C) Rich Crane, University of Exeter).

Historical disposal of wastes from domestic and industrial sources within the coastal zone (where 'coastal' is defined as land within 500 m of the shoreline position in 2021) has left the UK with a considerable environmental pollution legacy. These wastes pose risks to the environment but potentially also to human health and can have significant economic implications. The majority of wastes were deposited before modern environmental regulation existed and as such followed a dilute and disperse model for waste disposal in unlined landfills. Given the UK's rich industrial past, a wide range of legacy wastes were deposited in coastal settings including municipal waste, mine wastes, steel industry by-products, metal-rich wastes from smelting, and chemical process wastes (Figure 1). Contaminants in these wastes may be released to the surrounding environment (Brand and Spencer, 2020).

The motivation for this project was that these releases are predicted to become more frequent as climate change leads to rising sea levels, increased rates of coastal erosion, and increased incidences and severity of tidal flooding (Nicholls et al., 2021). There is already evidence of this at coastal legacy waste sites around the UK (e.g. Brand and Spencer, 2020). However, when this project was conceived by the project team assessments of the nature and severity of these issues were limited to discrete geographical areas of the UK and / or focused on single waste types. In contrast, this project aimed to assess multiple coastal legacy waste types (see Table 1) at a national scale using a unified approach. A key objective of doing so was to inform local authorities, regulatory bodies, and policy-makers of the nature and scale of the issues, and to serve as a basis for developing a strategy to address such pollution issues.

A national-scale screening of legacy wastes within the coastal zone was therefore undertaken, integrating various existing databases into a single geodatabase. Further, region-specific data collection and validation, using a similar method to that previously applied to the national non-coal mine inventory (Mayes et al., 2009), was used to validate findings about priority sites and waste types. A multi-criteria assessment of environmental risks at coastal legacy waste sites was then undertaken to prioritise sites for management. The second component of the project comprised an assessment of the environmental behaviour of different waste types in coastal settings. This included mineralogical and geochemical characterisation of different coastal legacy waste types and controlled experiments to investigate the mobility of pollutants within the wastes under both freshwater and saline water conditions. Analysis of wastes throughout the research project focused on metals and metalloids. This was partly due to logistical and budgetary constraints, but also because metal(loid) contaminants are common to most legacy waste types. Nevertheless, it is recognised that organic contaminants may be significant issues at some sites and therefore screening of such contaminants, potentially followed by more detailed sampling, may be important at sites on a case-by-case basis.

---

[1] 'Mineral' meaning a naturally-occurring solid compound with a known chemical structure e.g. pyrite (FeS_2).

This bulletin was written by Catherine Gandy, Adam Jarvis, Liz Lewis (now University of Manchester) and Jaime Amezaga, Newcastle University; Will Mayes and Alex Riley, University of Hull; Karen Hudson-Edwards, Rich Crane, Patrizia Onnis (now University of Cagliari, Italy), Elin Jennings (now University of Queensland, Australia) and Violeta Ramos, University of Exeter; Ian Burke, University of Leeds; Patrick Byrne, Liverpool John Moores University; Sean Comber, University of Plymouth; John MacDonald, University of Glasgow; Justyna Olszewska, Malcolm Heath, Stephen Lofts and Bryan Spears, UK Centre for Ecology and Hydrology. For further information please contact Adam Jarvis (adam.jarvis@newcastle.ac.uk) or Catherine Gandy (catherine.gandy@newcastle.ac.uk).

This bulletin summarises the main aspects of the research. Further, more detailed, information is available in the relevant journal publications, listed in the references section, and also on the project website (https://research.ncl.ac.uk/legacywastes/).

2. NATIONAL EXTENT AND PRIORITISATION

A spatial database of legacy waste sites in England and Wales was generated by merging several existing databases containing locations of different waste types, including landfill sites (Historic Landfill Databases of the Environment Agency (2022) and Natural Resources Wales (2021)), areas of coal and metal mine spoil (from Mayes et al., 2009 and Riley et al., 2021) and areas of iron and steel slag deposition (from Riley et al., 2020). A total of 3,219 legacy waste sites were identified in the coastal zone of England and Wales[2] revealing a density of legacy waste sites in coastal areas more than ten times higher than in inland areas (Riley et al., 2022). This high density is likely due to a combination of (1) historically, available low cost land along coastal margins (2) an historic perception that dilute and disperse in the sea was acceptable and (3) proximity to coastal industries generating the wastes.

The overall environmental risk associated with each legacy waste site was assessed by using a conceptual site model (CSM) approach, based on the concept of the pollutant linkage using the source-pathway-receptor model. The use of the CSM is an established approach used for the remediation of land contamination (BSI, 2020; Cooper et al., 2012; Environment Agency, 2025). Risks associated with potential 'sources' of contamination, pollutant transport ('pathway') and environmental receptors of pollution ('receptor') at each waste site were assessed (Riley et al., 2022). The source category was related to waste type and content, including the likely presence of hazardous priority substances and potential leaching products. Each source category (waste type) was assigned a risk weighting as per Table 1 (from highest risk weighting of 1.0 to lowest risk of 0.1), based on literature review and expert judgement of the project team (see Riley et al. (2022) for further details and rationale).

Table 1: Source category (waste type) risk weightings used in the coastal legacy waste prioritisation exercise (modified from Riley et al., 2022).

Waste type	Weight
Radioactive	1.0
Mixed 1960s	0.8
Mixed, Undefined, Household, Commercial, Industrial	0.7
Metal Mine Spoil, Coal Spoil	0.4
Iron and Steelmaking Slags	0.1

The risk of these pollutants being transported was assessed on the basis of current and future coastal erosion rates and tidal flooding (from the Environment Agency/Natural Resources Wales National Coastal Erosion Risk Mapping (NCERM) dataset and Flood Map for Planning datasets; see Riley et al. (2022) and references therein for further details). Environmental receptors were assessed according to the proximity of each waste site to such receptors and the potential for human exposure to the pollution (e.g. Bathing Water Zones). To prioritise coastal legacy waste sites for management, a multi-criteria decision analysis approach was applied, and an overall risk score was generated for each legacy waste site within the database. The method is summarised in Figure 2 (Riley et al., 2022).

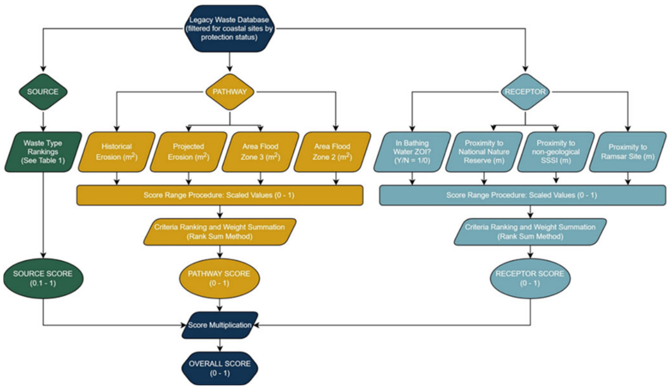

Figure 2: Overview of the multi-criteria decision analysis method used to generate overall risk scores for each legacy waste disposal site (taken from Riley et al., 2022).

The spatial distribution of these coastal legacy waste sites was analysed by River Basin District (RBD) (areas defined by the Water Framework Directive (WFD) for management purposes) and by waste type. In both cases a distinction was made between protected and unprotected sites (Figure 3) (Riley et al., 2022).

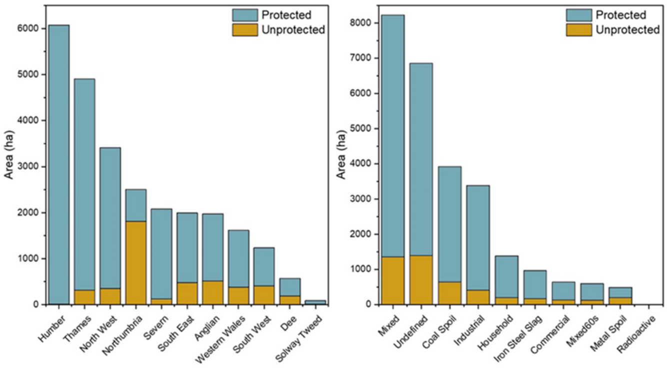

Figure 3: Total area of protected and unprotected coastal legacy wastes in England and Wales per River Basin District (RBD) (left) and per waste type (right) (taken from Riley et al., 2022).

Whilst the Humber and Thames RBDs contain the greatest areas of waste (approximately 6,000 ha (421 sites) and 5,000 ha (701 sites), respectively), most of this waste is protected by defences and is therefore considered to be relatively low risk, assuming that coastal defence and flood protection assets are well maintained. The Northumbrian RBD, on the other hand, contains the highest area of unprotected waste (1,807 ha, 243 sites), which signifies a much greater potential risk, representing around 72% of the coastal waste within this RBD. In terms of waste type, the mixed and undefined categories cover the greatest areas and represent the highest risk given the unknown contents of these wastes. Generally, the spatial distribution of waste type is linked to industrial activity, with

---

[2] National databases equivalent to those for England and Wales were not available for Scotland, which could not therefore be included in the assessment.

approximately 60% of all coastal metal mine waste situated along the coastline of South West England, 56% of all coastal coal mine waste located in North East England, over 55% of coastal iron and steelmaking slags located in North West England, and around 45% of all coastal industrial waste situated within the Humber RBD.

The multi-criteria decision analysis generated an overall risk score for each legacy waste site within the database, which enabled identification of sites which may present a greater risk to the environment (Riley et al., 2022). Many of the highest priority protected sites are located within the Thames RBD and contain undefined or mixed waste types. The highest priority unprotected sites, on the other hand, include a wider variety of waste types and a broader spatial distribution, with many situated along coastlines in former industrial and mining areas such as North West and North East England.

3. MINERALOGICAL AND GEOCHEMICAL CHARACTERISTICS OF LEGACY WASTES

The project team visited nearly 100 individual sites during the course of the research, to validate database outputs (as far as reasonably practicable given >3,000 coastal sites in total), but also to identify a selection of sites from the database, of different waste type, for more detailed analysis. Eighteen sites that were both (1) actively eroding and (2) safely and easily accessible were selected for more detailed waste characterisation (sites included municipal waste, coal mine waste, metal mine waste, non-ferrous (metal) and ferrous (iron and steel) slags and bauxite residues). A total of 83 sets of samples were collected across these 18 sites. Details of the sampling protocols can be found in Gandy et al. (2025) and Burke et al. (2025). In brief, sampling involved collection of three to five composite samples at each site. Each composite sample comprised five or six individual 100 – 150 g sub-samples collected along approximately 10 m of the actively eroding face of the waste. In all cases the upper surface of the waste (30 – 50 mm depth) was collected using a plastic trowel. Acid digestion of the samples determined their total elemental composition, and detailed mineralogical analysis, specifically X-Ray Diffraction (XRD) and QEMSCAN[3], determined their mineralogical composition.

For the first time, a common methodological approach was used for analysis of multiple legacy waste types to provide a comparative assessment of relative environmental risks across the 18 sites. Whilst differences in bulk composition (see below) were not entirely surprising given the greatly varying provenances of different waste types, the collection of both total contaminant content (acid digestion) *and* mineralogical data provides important insights into the potential for contaminant release.

There was considerable variation in major and minor element concentrations between waste types. The non-ferrous (metal) slags had the highest concentrations, and greatest range in concentration, of potentially toxic elements (PTEs) such as chromium (≤154,000 mg/kg), copper (≤97,000 mg/kg), manganese (≤19,000 mg/kg), nickel (≤17,000 mg/kg), lead (≤42,000 mg/kg) and zinc (≤46,000 mg/kg). These samples were dominated by iron (≤50 vol %) and had a high total sulfur content, which was primarily present as sulfide (mean = 4 vol %) (Onnis et al., 2026). The metal mine wastes also had high concentrations of PTEs, including the highest arsenic concentrations recorded in all the wastes (≤8,000 mg/kg). The coal mine wastes, on the other hand, contained lower concentrations of PTEs than the other wastes, albeit arsenic concentrations were still above predicted effect levels (PEL)[4], suggesting they could have an adverse effect on ecosystem health. These wastes were dominated by silicon, iron and aluminium and also had a high sulfur content, which was largely present as sulfide (mean = 13 vol %) (Onnis et al., 2026). Metal concentrations in municipal waste varied greatly between sites, likely due to the different origins of the waste, but samples were mostly enriched in calcium, iron and aluminium and contained high concentrations of manganese, zinc, nickel, and lead. The ferrous (iron and steel) slags also demonstrated considerable variability in major element concentrations, particularly in calcium, iron and aluminium, due to different ore mineralogy, methods of extraction and processing histories (Riley et al., 2024). With the exception of manganese and zinc, concentrations of PTEs were only slightly higher in these wastes than those in the coal mine wastes. The bauxite residues were dominated by calcium, aluminium and iron and had a relatively high chromium concentration.

The mineralogy also varied greatly between waste types but largely reflected the waste composition (Figure 4). The non-ferrous (metal) slags were generally rich in low solubility iron, and other metal oxides (e.g. hematite, goethite, spinel, cassiterite) and silicate minerals whilst the mineralogy of the metal mine wastes, coal mine wastes and municipal wastes was largely dominated by quartz, feldspars and clay minerals. In addition, the coal mine wastes contained redox-sensitive sulfide (e.g. pyrite) and sulfate (e.g. jarosite, gypsum) minerals with some samples of metal mine waste also containing sulfide minerals. The municipal wastes, in contrast,

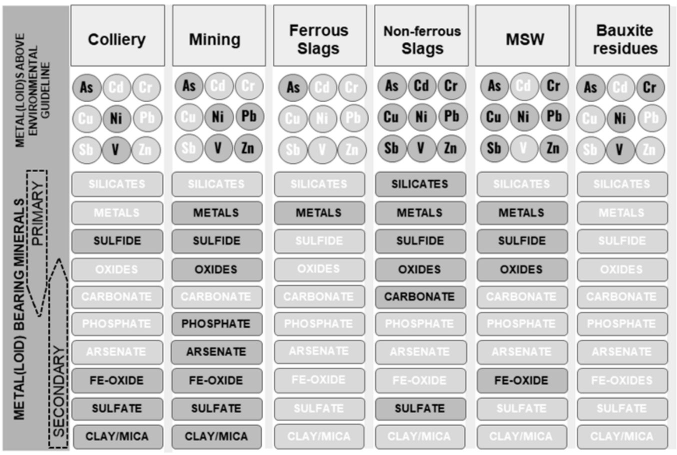

Figure 4: Hazards associated with coastal legacy wastes, showing individual PTEs above environmental guideline values (from acid digestions; bold text in circles) and minerals most likely to be the sources of these PTEs (from XRD/QEMSCAN analysis; bold text in rectangles) (environmental guidelines are Canadian soil guidelines for the protection of the environment and human health (CCME, 2011), since no formal guidelines are available for the UK) (adapted from Onnis et al., 2026).

---

[3] QEMSCAN is Quantitative Evaluation of Minerals by Scanning Electron Microscopy, and is used to identify mineral types and abundance within a sample.

[4] Predicted Effect Level (PEL) is a Canadian soil quality guideline (CCME, 2011) which has been adopted by the Environment Agency in England. A concentration equal to or greater than the PEL for a given contaminant may have adverse impacts on ecosystem health.

contained iron oxides and carbonate minerals. Whilst highly variable between samples, the mineralogy of the ferrous slags consisted largely of silicate minerals with some additional carbonates and iron, tin and calcium oxides. The mineralogy of the bauxite residues comprised silicates, calcite and metal oxides, including iron, tin, and aluminium oxides.

4. LEGACY WASTE CONTAMINANT MOBILITY IN COASTAL SETTINGS

To investigate pollutant release from these varied legacy wastes, standard laboratory leaching tests were conducted, under both freshwater (deionised water) and seawater conditions (actual seawater from the North Sea in all cases, filtered to remove sand prior to use in tests). The degree of metal leached from the wastes varied considerably, both within and between waste types (Figure 5). For the majority of metals, the mass leached was substantially higher for the coal mine wastes than the other wastes, despite this waste containing lower concentrations of metals. Copper and lead were an exception, with up to 240 mg/kg of lead and 300 mg/kg of copper leached from the non-ferrous (metal) slags under freshwater conditions. These variations in leaching behaviour can be attributed to the different waste compositions. The weathering of sulfide minerals, such as pyrite, present within the coal mine waste, generated acidic conditions and led to the dissolution of secondary minerals and any metals associated with them (Gandy et al., 2025). In contrast, metals within the other wastes were present in a more stable form and leaching of these wastes generated neutral to alkaline leachates with less risk of metals being released (Riley et al., 2024; Burke et al., 2025). Leaching from coal mine wastes also showed the greatest variation between samples, including within a single site, due to the heterogenous nature of this waste. Generally, leaching was greater under freshwater conditions than saline conditions for all waste types, albeit there were some exceptions such as zinc and manganese which were leached more by seawater in certain waste types. The full results of the leaching tests are available in Jarvis et al. (2026).

Given the relatively modest leaching potential of most waste types, physical erosion and transport of contaminants as particulates likely poses the greater environmental risk to coastal water bodies. It has, for example, already been demonstrated in North East England that waste erosion rates as high as 5 – 10 m/year are evident at some locations, and that these eroded wastes are being transported to, and deposited on, neighbouring beaches due to processes such as longshore drift (Pitman et al., 2024). For coal mine wastes, there is the added risk of mobilisation of considerable quantities of PTEs to coastal waters. Whilst dilution by seawater will reduce concentrations of these PTEs, it is nevertheless the case that impacts on near-shore marine ecosystems remain uncertain.

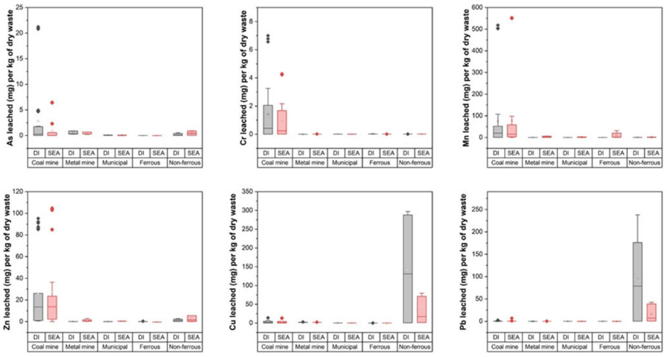

Figure 5: Mass of selected metals leached per kg of dry waste during leaching tests on legacy coastal wastes (DI = deionised water; SEA = sea water; in the box and whisker plot: lower line of box = first quartile, line within box = median, upper line of box = third quartile; open circle within box = mean, top and bottom of whiskers are maximum and minimum, respectively, and closed diamonds are outliers (calculated using inter-quartile range method)).

Coastal legacy wastes are not the only contributor to the PTE burden of estuarine and marine waters. Leaching and associated processes from inland legacy mine waste may also lead to estuarine and marine contamination. The Carnon River system in Cornwall, UK, is a good example. Despite mining ending over 30 years ago the major outlet from the Wheal Jane tin mine, the County Adit, remains the dominant source of arsenic, copper, iron and zinc load to the Carnon River (Jennings et al., 2025). However, a newly identified metal-rich (ochre) floodplain, formed by deposition of metal(loid)-bearing iron oxides, extending towards the estuary acts as a significant secondary contamination source through erosion and reductive dissolution. Elevated concentrations of arsenic, copper, and zinc were found in estuarine sediments, linked to fine particle accumulation, remobilisation, and tidal reworking (Jennings et al., 2025). These findings highlight how inland legacy mine discharges and waste sources continue to contaminate estuarine environments via ongoing leaching, sorption and desorption, and redox-driven remobilisation processes. The Carnon River illustrates the persistent and complex nature of legacy mine pollution and underscores the need for long-term remediation strategies targeting both source discharges and sediment-bound contaminants in river systems (Jennings et al., 2025). More widely, management of contaminant burden to estuarine and near-shore marine environments should consider not only erosion and leaching of coastal legacy wastes but also, potentially, fluvial delivery of contaminants from inland wastes.

5. RECOMMENDATIONS AND FURTHER RESEARCH

The research has (1) highlighted the national extent of legacy waste sites in the coastal zone of England and Wales, (2) prioritised sites within a source-pathway-receptor framework, taking account of critical influences on environmental risk, and (3) evaluated the likelihood of, and mineralogical and geochemical reasons for, pollutants being released from these coastal legacy wastes (see Burke et al. (2025) and Gandy et al. (2025) for further details). These outputs should be a useful resource for coastal managers seeking to mitigate the risks of coastal legacy wastes.

Nevertheless, addressing the problems of coastal legacy wastes will require ongoing efforts, both through updating and refinement of the approach developed during this project, and through further research into the character and impacts of these wastes. The national scale screening of legacy wastes in the coastal zone was based on information available at the time (for Scotland, availability of such information was limited, which is why the project necessarily focused on England and Wales). It is recommended that the legacy wastes database (available in Riley et al. (2026)), and the prioritisation system created from it, are refined as additional information becomes available on waste composition e.g. updates to the National Coastal

Erosion Risk Mapping (NCERM) dataset. Efforts to collate and harmonise databases of waste location are essential here, given some of the large volume waste deposits associated with past mining are not effectively captured by existing national landfill databases (Environment Agency, 2022; Mayes et al., 2009; Natural Resources Wales, 2021; Riley et al., 2020, 2021). The considerable variability in waste composition, both within and between waste types, has also been highlighted by the research described here. This presents a particular challenge with respect to quantifying environmental risk and developing mitigation measures. For example, with respect to risk, composition alone does not provide sufficient information to determine the potential mobilisation of pollutants from these wastes. In terms of mitigation, the spatial heterogeneity of contaminant concentrations and mobility, even within individual sites, makes targeting interventions, and evaluating costs and benefits of such interventions, very challenging, albeit there is a growing body of effective site interventions developing (Cooper et al., 2012). Finally, this research has focused on the geochemical mobilisation of metal and metalloid contaminants from wastes. Physical mobilisation and transport of waste materials is also substantial at many sites. The impacts of physically mobilised waste sediments on the marine environment remain unclear and should be the subject of further research. Also, it is recognised that at some sites organic contaminants (e.g. PCBs, PFAS) may be an environmental risk. Analysis of these organic constituents was outside the scope of this research project, but it is certainly the case that they may be important at some legacy waste sites on a case-by-case basis.

ACKNOWLEDGEMENTS

The Legacy Wastes in the Coastal Zone: Environmental Risks and Management Futures project was funded by the Natural Environment Research Council (NERC) under grants NE/T003286/1, NE/T002824/1, NE/ T003022/1, NE/T003200/1. We would like to thank our Project Partners for their insights and contributions: CL:AIRE, Environment Agency, National Trust, Natural Resources Wales, Haskoning, Scottish Environment Protection Agency and Mining Remediation Authority. The views expressed in this Research Bulletin are those of the research team and do not necessarily represent those of the Project Partners.

REFERENCES

- Brand, J.H., Spencer, K.L. 2020. Will flooding or erosion of historic landfills result in a significant release of soluble contaminants to the coastal zone? Science of the Total Environment, 724, 138150. https://doi.org/10.1016/j.scitotenv.2020.138150
- British Standards Institution (BSI). 2020. BS EN ISO 21365:2020 Soil quality. Conceptual site models for potentially contaminated sites. British Standards Institution, London.
- Burke, I.T., Onnis, P., Riley, A.L., Gandy, C.J., Ramos, V., Rollinson, G.K., Byrne, P., Crane, R.A., Hudson-Edwards, K.A., Jennings, E., Mayes, W.M., Mosselmans, J.F.W., Jarvis, A.P. 2025. Speciation and leaching behaviour of inorganic contaminants in actively eroding historical coastal municipal solid waste landfills. Marine Pollution Bulletin, 219, 118341. https://doi.org/10.1016/j.marpolbul.2025.118341
- CCME, Canadian Council of Ministers of the Environment. 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Excerpt from Publication No. 1299; ISBN 1-896997-34-1.
- Cooper, N.J., Bower, G., Tyson, R., Flikweert, J.J., Rayner, S., Hallas, A. 2012. Guidance on the management of landfill sites and land contamination on eroding or low-lying coastlines (C718). Construction Industry Research and Information Association (CIRIA).
- Environment Agency. 2022. Historic landfill sites. Available at: https://data.gov.uk/dataset/17edf94f-6de3-4034-b66b-004ebd0dd010/historic-landfill-sites (Accessed June 4, 2022).
- Environment Agency. 2025. Land contamination risk management (LCRM). Available at: https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm (Accessed January 5, 2026).
- Gandy, C.J., Burke, I.T., Byrne, P., Cooper, N., Crane, R.A., Hudson-Edwards, K.A., Mayes, W.M., Onnis, P., Riley, A.L., Jarvis, A.P. 2025. Spatial variability of metal(loid) leaching from coastal colliery wastes under freshwater and saline water conditions. Journal of Environmental Management, 376, 124489. https://doi.org/10.1016/j.jenvman.2025.124489
- Jarvis, A., Gandy, C., Mayes, W., Riley, A., Burke, I., Hudson-Edwards, K., Crane, R., Onnis, P., Jennings, E., Byrne, P., MacDonald, J., Amezaga, J., Lewis, E., Spears, B., Olszewska, J., Malcolm, H., Comber, S., Lofts, S. 2026. Constituent concentrations of leachates from standardised leaching tests using deionised water and seawater in contact with legacy waste materials collected from coastal areas of the UK between 2020 and 2024. NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/843ebced-e75c-4963-9d0a-363c9d20ee15
- Jennings E., Onnis, P., Crane, R., Comber, S.D.W., Byrne, P., Mayes, W.M., Jarvis, A.P., Hudson-Edwards, K.A. 2025. Spatial and temporal (annual and decadal) trends of metal (loid) concentrations and loads in an acid mine drainage-affected river. Science of the Total Environment, 964, 178496. https://doi.org/10.1016/j.scitotenv.2025.178496
- Mayes, W.M., Johnston, D., Potter, H.A.B., Jarvis, A.P. 2009. A national strategy for identification, prioritisation and management of pollution from abandoned non-coal mine sites in England and Wales. I: Methodology development and initial results. Science of the Total Environment, 407(21), 5435-5447. https://doi.org/10.1016/j.scitotenv.2009.06.019
- Natural Resources Wales. 2021. Historic landfill sites. Available at: https://lle.gov.wales/catalogue/item/HistoricLandfillSites/?lang=en (Accessed June 4, 2022).
- Nicholls, R.J., Beaven, R.P., Stringfellow, A., Monfort, D., Le Cozannet, G., Wahl, T., Gebert, J., Wadey, M., Arns, A., Spencer, K.L., Reinhart, D., Heimovaara, T., Santos, V.M., Enriquez, A.R., Cope, S. 2021. Coastal landfills and rising sea levels: a challenge for the 21st Century. Frontiers in Marine Science, 8, 710342. https://doi.org/10.3389/fmars.2021.710342
- Onnis, P, Jennings, E., Ramos, V., Riley, A., Gandy, C., Crane, R., Burke, I., Rollyson, G.K., Byrne, P., Spears, B., Olszewska, J., Mayes, W., Jarvis, A., Hudson-Edwards, K. 2026. Uncovering coastal legacy wastes and their environmental risks through mineralogy and geochemistry. Journal of Hazardous Materials 504, 141180. https://doi.org/10.1016/j.jhazmat.2026.141180
- Onnis, P., Riley, A.L., Gandy, C.J., Jennings, E., Crane, R.A., Byrne, P., Rollinson, G., Jarvis, A.P., Mayes, W.M., Hudson-Edwards, K.A. 2022. Coastal wastes geochemistry and mineralogy as a tool to identify potential metal(loid) sources. 12th International Conference on Acid Rock Drainage, 18th to 24th September 2022.
- Pitman, S.J., Burke, I.T., Jay, H., Cooper, N., Mayes, W.M., Jarvis, A.P. 2024. Long-term coastal dynamics: the evolution of a mixed sediment mega-nourishment consisting of colliery spoil. Journal of Environmental Management, 371, 123106. https://doi.org/10.1016/j.jenvman.2024.123106
- Riley, A.L., Amezaga, J., Burke, I.T., Cooper, N., Crane, R.A., Comber, S.D.W., Gandy, C.J., Hudson-Edwards, K.A., Jennings, E., Lewis, E., Lofts, S., MacDonald, J.M., Malcolm, H., Mayes, W.M., Onnis, P., Olszewska, J., Spears, B., Jarvis, A.P. 2022. Incorporating conceptual site models into national-scale environmental risk assessments for legacy waste in the coastal zone. Frontiers in Environmental Science, 10, 1045482. https://doi.org/10.3389/fenvs.2022.1045482
- Riley, A.L., Cameron, J., Burke, I.T., Onnis, P., MacDonald, J.M., Gandy, C.J., Crane, R.A., Byrne, P., Comber, S., Jarvis, A.P., Hudson-Edwards, K.A., Mayes, W.M. 2024. Environmental behaviour of iron and steel slags in coastal settings. Environmental Science and Pollution Research, 31, 42428-42444. https://doi.org/10.1007/s11356-024-33897-4
- Riley, A.L., MacDonald, J.M., Burke, I.T., Renforth, P., Jarvis, A.P., Hudson-Edwards, K.A., McKie, J., Mayes, W.M 2020 Legacy iron and steel wastes in the UK: Extent, resource potential, and management futures. Journal of Geochemical Exploration, 219, 106630. https://doi:10.1016/j.gexplo.2020.106630
- Riley, A.L., Mayes, W.M., Jarvis, A.P., Amezaga, J.M., Burke, I.T., Byrne, P., Crane, R.A., Comber, S.D.W., Gandy, C.J., Hudson-Edwards, K.A., Jennings, E., Lewis, E., Lofts, S., MacDonald, J.M., Malcolm, H., Onnis, P., Olszewska, J., Spears, B. 2026. List of legacy waste deposits (including historical landfill sites) across England and Wales, ranked by environmental risk to the coastal environment under future climate scenarios. NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/2501589d-1a13-4e6e-a25b-b74993c5b758
- Riley, A.L., Onnis, P., Jennings, E., Crane, R.A., Hudson -Edwards, K.A., Comber, S.D.W., Burke, I.T., Byrne, P., Gandy, C.J., Jarvis, A.P., Mayes, W.M. 2021. A GIS-based prioritisation of coastal legacy mine spoil deposits in England and Wales for effective future management. Newport, Wales: International Mine Water Association Conference 2021.