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In-situ processes in resource recovery from waste repositories

Development of a typology of waste repositories

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Introduction

Waste repositories have many other potential end-uses following the placement of waste including residential and commercial development, agriculture, forestry, amenity, nature conservation and tourism.

This has been achieved through natural regeneration on abandoned sites, or through managed restoration for a specific end use. Many sites are associated with negative impacts; they can cause pollution to water bodies, surrounding ecosystems and populations as well as being unsightly, derelict and hazardous.

However, they often support important habitats and species assemblages as a result of natural regeneration or managed restoration. For example mine sites can be characterised by the presence of rare metal-tolerant plants and lichens, mosaic habitats of grasslands, wildflowers, orchids (Barnatt and Penny, 2004) and important invertebrates, birds and mammals (e.g. lesser horseshoe bats). This has resulted in specific recognition and protection for some waste repositories including Site of Special Scientific Interest (SSSI) status and two priority habitats: *Calaminarian Grasslands* and *Open Mosaic Habitats on Previously Developed Land* (OMH). Many historic mining areas have also been granted conservation status including World Heritage Sites and Scheduled Monuments.

As with many brownfield sites they are under pressure for development, and in the case of metalliferous mine wastes, resource recovery (or decontamination). This research examines the current uses, ecological and historic significance of waste repositories in England and Wales.

This has been achieved through the development of a typology which will contribute to the debate on the ecological and cultural value of restored waste repositories and their management.

Methods

The British Geological Survey BritPits and the Environment Agency Historic Landfill datasets have been used to identify waste repositories in England and Wales. This incudes 128,337 non-active mineral extraction sites in England and 27,124 in Wales and 19,540 landfills in England and 73 in Wales. These data have then been overlain with spatial data on ecological, geological and cultural designations (see *References and data sources*) and Land Cover Map 2007 to examine the frequency and extent of co-location with these designations and land cover.

Results

No pulverised fly ash or furnace bottom ash waste disposal sites were co-located with any cultural or ecological designations and are not discussed further.

The majority of waste repositories are located in areas with no nature conservation status; however there are differences between the types of waste repository. In Wales, only 7.5% of Sand and gravel quarries are co-located with one designation, whereas for Vein minerals (metals) this rises to 27.6% in England. Similarly, while most sites are not co-located with cultural designations, there is variation between the different types of repository, ranging from 5.7% for Coal mines in Wales to 63.9% for Vein minerals in England. Combining all designations, at least 26.6% of all types of waste repository are co-located with some form of designation; up to 84.0% of Vein mineral mines in England.

These data have then been supplemented with information from policy, guidance and academic literature to develop the typology (Table 1).

Land cover data (CEH, 2007) suggests that *Improved Grassland* (IG) is the more common land cover (11.7% to 41.3% of repositories) followed by *Broadleaved Woodland* (BW) (9.2% to 18.8%), *Arable and Horticulture* (AH) (12.3% to 28.4%) in England and *Rough Grassland* (RG) (11.2% to 17.9%) in Wales (Table 1). Others include *Acid Grassland* (AG) and *Suburban* (S).

Cultural designations

Across England and Wales many waste repositories are located in areas with some form of cultural significance (Table 2). Most commonly these are either related to the quality of the landscape (e.g. AONB, NPs) which is not dependent on the mining heritage and may be degraded by such sites (although it may be one component of the landscape) or specifically linked to previous mining activity. Some mining areas are World Heritage Sites, for example, tin-copper mines in the *Cornwall and West Devon Mining Landscape* and coal mines in the *Blaenavon Industrial Landscape* (Table 2).

Table 2. Number of waste sites that are co-located with cultural designations (green=10-20%; orange=20-30%; red>30%).

	Country	Total	NP	CP	AONB	SAM	LHI	WHS	PG
Sand and gravel	England	23675	1490	269	2785	72	N/A	56	358
	Wales	1678	226	8	96	11	301	5	N/A
Igneous rock, sandstone	England	31434	3909	181	5453	139	N/A	483	438
	Wales	8393	903	43	332	26	1191	51	N/A
Chalk, dolomite, limestone	England	35116	4367	98	10507	253	N/A	307	482
	Wales	2317	240	17	375	32	419	30	N/A
Clays	England	23336	1105	89	2596	32	N/A	144	185
	Wales	4935	937	18	116	10	1055	10	N/A
Anhydrite, gypsum, salt	England	285	0	1	9	7	N/A	0	1
	Wales	0							
Coal	England	10247	315	93	163	41	N/A	155	22
	Wales	6429	193	69	12	30	641	91	N/A
Iron ore	England	2832	230	14	311	76	N/A	5	20
	Wales	229	18	0	3	1	95	7	N/A
Vein minerals	England	1885	774	6	432	164	N/A	290	8
	Wales	3107	606	12	470	75	1159	0	N/A
Historic landfill	England	19540	397	240	1277	44	N/A	152	81
	Wales	73	1	0	10	0	15	0	N/A

Ecological and geological designations

Similarly, many waste sites are located in areas with some form of nature conservation status (Table 3). The greatest proportions occur in ancient woodlands, SSSIs, SACs, SPAs, priority habitats (England) and OMHs.

The most significant associations are for Vein minerals: lead mining areas in the Pennines (SAC, SPA, SSSI), North Wales (SAC, SSSI) and the tin-copper mines of Cornwall (SSSI, SAC) (Table 3). There are also significant numbers of Chalk, dolomite, limestone quarries associated with SSSIs.

Many of these sites are protected because of the rare species or habitats specifically associated with mineral extraction, for example metal-tolerant bryophytes. Wastes are also protected for their special geological conditions, which also either exist because of, or have been exposed by, mineral extraction.

Other designations, such as ancient woodlands and priority habitats may be degraded by waste sites.

Table 3. Number of non-active mine sites that are co-located with ecological and geological designations (green=10-20%; orange=20-30%; red>30%).

	Country	AW	SSSI	(p)SAC	(p)SPA	NNR	LNR	PHI	OMH
Sand and gravel	England	533	1784	923	958	102	237	5622	852
	Wales	80	109	62	15	5	5	N/A	11
Igneous rock, sandstone	England	1832	2788	1991	1809	69	230	9901	1572
	Wales	999	310	114	36	15	21	N/A	389
Chalk, dolomite, limestone	England	1420	2448	843	420	166	218	9455	1584
	Wales	220	353	170	6	18	21	N/A	123
Clays	England	615	680	250	306	33	135	4324	784
	Wales	561	337	180	103	19	9	N/A	120
Anhydrite, gypsum, salt	England	3	18	5	5	3	11	80	27
	Wales								
Coal	England	291	217	170	158	10	145	2039	839
	Wales	674	118	40	1	4	47	N/A	728
Iron ore	England	340	114	92	56	2	37	638	138
	Wales	16	15	11	5	0	3	N/A	25
Vein minerals	England	49	390	273	254	8	6	752	199
	Wales	351	674	414	95	31	3	N/A	30
Historic landfill	England	200	297	83	117	22	293	2886	1512
	Wales	4	6	2	0	0	2	N/A	12

Conclusions

The analysis of spatial data suggests that there are significant ecological and cultural resources which need to be considered when planning activities on waste repositories. A review of the planning, guidance and restoration literature suggests that many sites are now providing a range of services including food and timber production, spaces and landscapes for recreation, education, nature and heritage. These need to be balanced against the risk posed by such sites to human health and environmental quality.

Table 1. Typology of waste repositories in England and Wales

	Type of mine	Type and impact of waste	Restoration and use	Statutory designations	Dominant land cover
Sand and gravel (E=WM, EM, EE, SE, N&E; W)	Open cast (E=99.9%; W=99.8%). Shallow working. Landfill: E=1968 (8.3%).	Overburden and fines. Often used in restoration. Droughty, stony, low pH, N, P deficient. Non-hazardous; visual impact prior to restoration.	Generally restored to some productive use. Progressive restoration common. **Wet pits** allowed to flood to become artificial lakes for **amenity** or **nature conservation**. **Dry pits** can have rapid colonisation to heathland or restoration to **agriculture**, **amenity** or **forestry**.	SSSIs, SACs, SPAs, PHs incl. OMHs, NPs, AONBs.	BW (16%; 10%), AH (27%; 10%), IG (24%; 41%).
Igneous rock, sandstone (E=N&W, NE; W=N&W)	Open cast (E=99.3%; W=99.8%). Landfill: E=1243 (4.0%).	Variable amount of waste, often very little waste overburden. Oversize blocks and very fine particles. Low pH, P deficient. Non-hazardous; visual impact prior to restoration.	Progressive restoration difficult, little waste means restoration often restricted to quarry floor. **Wet pits** allowed to flood to become artificial lakes for **amenity** or **nature conservation**. **Dry pits** restored to **amenity** or **nature conservation**.	AWs, SSSIs, SACs, SPAs, PHs incl. OMHs, NPs, AONBs.	BW (19%; 16%), AH (15%; 6%), IG (27%; 33%).
Chalk, dolomite, limestone (E=EM, NE, NW, S&E, N&W; W=N&W)	Open cast (E=98.8%; W=99.7%). Deep excavation. Landfill: E=1402 (4.0%); W=7 (0.3%).	Variable amount of waste, often very little waste overburden. Used in restoration. High pH, stony, droughty, N (chalk: P, K) deficient, heavy textures, waterlogging, compaction. Non-hazardous; visual impact prior to restoration	Smaller, older quarries colonised, but can take 50 years. Important for **nature conservation** (e.g. gentians, orchids). Progressive restoration difficult, restoration often restricted to quarry floor. **Wet pits** allowed to flood to become artificial lakes for **amenity** or **nature**. **Dry pits** difficult to restore to **agriculture**. Restored to **amenity** or **nature conservation**.	AWs, SSSIs, SACs, PHs incl. OMHs, NPs, AONBs.	BW (17%; 20%), AH (34%; 13%), IG (27%; 27%).
Clays (E=SW, SE NW, NE, M; W=SW, M, NW)	Open cast (E=98.2%; W=92.6%); underground (E=1.6%; W=6.6%). Landfill: E=1301 (5.6%); W=1 (0.0%).	**China clay**: Coarse sand and rock waste; fine slurry. **Slate**: Large fragments, fines washed down. **Clay**: Overburden, clay and sand; relatively little waste. Low pH, droughty, nutrient deficient. **Clay** also heavy textures, waterlogging and compaction. Non-hazardous, visual impact of conical tips of china clay waste, slate waste tips.	**China clay**: Colonisation can take up to 100 years: sparse vegetation builds to full cover of grasses and shrubs; then heathland in exposed areas, acid oak woodland in less exposed areas. **Slate**: Some colonisation of moss and birch, more on quarry floors (e.g. scrub, acid grassland, acid oak woodland. Restored to **amenity**, **woodland** or for **nature conservation**.	AWs, PHs incl. OMHs, NPs, AONBs.	BW (14%; 17%), AH (33%; 6%), IG (23%; 32%).
Anhydrite, gypsum, salt (E=M, NW, SE)	Open cast (E=50.2%); underground (E=46.3%). Landfill: E=31 (10.9%).	**Open cast**: Temporary waste used in restoration. **Underground**: Very little waste. Non-hazardous.	Progressive restoration common and often effectively blended into surrounding landscape. Restored to **agriculture** and **forestry**.	PHs.	BW (22%), AH (28%), IG (21%).
Coal (E=NE, NW, M; W=S)	Underground (E=79.0%; W=94.8%); open cast (E=20.9%; W=5.1%). Landfill: E=398 (3.9); W=1 (0.0%).	**Underground**: very large tips, especially post-1950s. Shale material, heavy textures. **Open cast**: 90% used in restoration. Sandy, pebbly to dense clays, fine to coarse texture. Low pH, droughty, stony, waterlogging, compaction, N, P deficient, salinity. Mainly inert, some with acid mine drainage, visual impact.	**Underground**: Most abandoned waste tips restored in 1980s and 1990s. Natural colonisation possible on wastes with higher pH. Often situated near people; restored for **development** and **amenity**. **Open cast**: Progressive restoration common and often effectively blended into surrounding landscape. Restored to **agriculture** and **forestry**, often to original quality.	PHs incl. OMHs, WHS, LHI.	BW (9%; 19%), AH (19%; 7%), IG (24%; 23%), S (19%; 11%).
Iron ore (E=NW, NE, EM, SE; W=S)	Underground (E=39.4%; W=72.6%); open cast (E=60.0%; W=27.5%). Landfill: E=105 (3.7%).	Mainly 18th and 19th century, waste often removed for construction (e.g. where limestone) or used in restoration but substantial areas abandoned. Waste often left underground. Heavy clay, limestone lumps. High pH, P, K deficient.	Colonisation of flora able to tolerate extreme conditions. Pre-20th century, restored to **agriculture**, 1920s to 1950s restored to **woodland**, most abandoned sites restored in 1950s and 1960s. Some **development** (e.g. industrial estates), but mainly restored to **agriculture**.	PHs incl. OMHs, AONBs.	BW (18%; 13%), AH (26%; 4%), IG (28%; 19%).
Vein minerals (E=SW, NE, NW; M; W=M)	Underground (E=87.6%; W=98.1%); open cast (E=11.6%). Landfill: E=34 (1.8%).	Mainly 18th and 19th century; abandoned wastes, or removed for construction. Change over time; larger pieces to smaller particles (more likely to retain water, oxidise pyrite, support plant growth, lower metal concentration). Droughty, N, P deficient. Acid mine drainage, elevated metal concentrations, impacting on soil and water, radon in SW.	Important for **nature conservation**: colonisation of mosses, liverworts and lichens with evolved tolerance; bats, newts and toads. Many tips restored in 1980s and 1990s but substantial number still unrestored, often important for **historical landscape**. Restored to **amenity**, **woodland** or for **nature conservation**.	AWs, SSSIs, SACs, SPAs, PHs incl. OMHs, NPs, AONBs, LHIs, WHS.	BW (12%; 12%), IG (28%; 21%), AG (10%. 15%).
Landfill (Ubiquitous)	Former mine: E=5048 (25.8%); W=8 (11.0%).	Municipal solid waste, inert, industrial, commercial. Problems with gas migration, leachate production on older landfills.	Colonisation of fungi, mosses, liverworts, legumes and grasses directly on to waste. Restoration for **development**, **agriculture** and **amenity**.	PHs incl. OMHs, AONBs.	BW (13%; 11%), AH (22%, 10%), IG (22%; 12%), S (16%. 19%).

References and data sources

References: Barnatt, J., Penny, R. 2004. The lead legacy. The Prospects for the Peak District's Lead Mining Heritage. English Heritage, Peak District National Park Authority, Natural England. CEH. 2007. Countryside Survey: Land Cover Map 2007 Dataset Documentation. CEH Wallingfrord. Palumbo-Roe, B., Colman, T., Cameron, D.G., Linley, K., Gunn, A.G. 2010. The nature of waste associated with closed mines in England and Wales. British Geological Survey Open Report, OR/10/14. Available from: http://nora.nerc.ac.uk/10083/. Data sources: mine data from BRITPITS Licence No. 2014/098BP ED British Geological Survey © NERC. All rights reserved. Historic Landfill data © Environment Agency copyright. Contains Ordnance Survey data © Crown copyright and database right 2016. Local Nature Reserve (LNR), National Nature Reserve (NNR), Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC), Special Protection Area (SPA), Ancient Woodland (AW), Priority Habitat (PH), Open Mosaic Habitat on Previously Developed Land (OMH), Area of Outstanding Natural Beauty (AONB), Country Park (CP), National Park (NP), Parks and Gardens (PG) data for England © Natural England copyright. Contains Ordnance Survey data © Crown copyright and database right 2016. Scheduled Monument and World Heritage Site data for England © Historic England 2016. Contains Ordnance Survey data © Crown copyright and database right 2016. The Historic England GIS Data contained in this material was obtained on 29th June 2015. The most publicly available up to date Historic England GIS Data can be obtained from HistoricEngland.org.uk. Land Cover Map 2007: Great Britain 25m [TIFF geospatial data], Scale 1:250000, Tiles: GB, Updated: 18 July 2008, CEH, Using: EDINA Environment Digimap Service, <http://digimap.edina.ac.uk>, Downloaded: 2015-08-17 12:14:09.596. All other data © Natural Resources Wales copyright. Contains Ordnance Survey data © Crown copyright and database right 2016.

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