SD:SPUR Learning Network

Information on the range of options and techniques available for the management of decommissioning wastes and items

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APPENDICES

1. INTRODUCTION

1.1 Background

Enviros Consulting Limited (Enviros) was commissioned by the SD:SPUR Learning Network to undertake a project to identify and sort information on the range of options and techniques available for the management of decommissioning wastes and items[1].

This report is one of a number of complimentary outputs developed by the SD:SPUR Learning Network (www.sdspur.com). At this stage the report will be limited in its circulation to the Project Steering Group (PSG) members and will be used to inform the future work of the network.

1.2 Overview

The objective of this work is to identify and sort information on the range of options and techniques available to manage decommissioning wastes and items within the SD:SPUR sphere of interest.

The SD:SPUR main guidance (Miller & Tooley, 2005) recommends that options for the management of decommissioning wastes and items be considered broadly and imaginatively to ensure wider sustainability concerns are considered within decision making. In support of this recommendation the guidance provides information on the identification and screening of options for the management of decommissioning wastes and items.

Following the publication of the guidance in October 2005, the SD:SPUR community requested that further information be collected to support the comparison of waste management options and techniques, including:

- Further technical information on the options and techniques available.
- Summary information on options comparison methodologies.
- An understanding of stakeholder concerns & preferences on the use of particular options.
- An understanding of when in the decision-making process wider stakeholder views might most effectively be incorporated.

This report takes the first step towards addressing these needs, by compiling a list of options and techniques available for the management of decommissioning wastes and items, and by establishing references to sources of further information.

For radiologically clean structures or items, the management options considered include refurbishment, deconstruction, sorting and segregation (by material type), reuse, recycling, volume reduction and disposal. For a building where radioactive contamination is suspected, there are additional options which include segregation (by radiological category) and decontamination. Within each of these options (e.g. decontamination) there will be a range of available techniques (e.g. abrasive, chemical) to achieve the desired outcome. The various options categories considered are set out in Table 1.

1 Throughout the paper the term 'items' is used to mean buildings, including their fixtures and fittings, plant and equipment

Table 1 also details the materials, types considered by the report, which for the purposes of this report have been grouped as follows:

A. Items

B. Mixed waste

C. Segregated hard demolition waste

D. Excavation waste & soil

E. Metals

F. Other (plastics, timber etc)

For categories A and C-F it is assumed that appropriate waste treatments will have taken place. Such treatments include size reduction, volume reduction and sorting and segregation. Generally these treatments will involve mechanical practices such as crushing, grinding, shearing, cutting and magnetic separation. Further information on treatment techniques can be found in Appendix A.

In-line with the defined scope of the SD:SPUR Learning Network this report only considers decommissioning wastes and potentially re-useable items that fall into the following radiological categories:

- Radiologically clean wastes that have never been contaminated with artificial radionuclides.
- RSA'93 (Radioactive Substances Act 1993) exempt wastes that contain concentrations of artificial radionuclides that are so low that they are free from specific regulatory control under RSA'93.
- Slightly radioactive wastes, due to contamination or activation, at the lower end of the Low Level Waste (LLW) category.

Table 1: Material types and option categories considered

Material types	**Options categories**							
	Refurbishment	**Deconstruction**	**Demolition (followed by sorting & Segregation)**	**Decontamination**	**Re-use**	**Recycling**	**Volume reduction**	**Disposal**
A. Items								
1. Whole buildings	✓	✓	✓	✓				
2. Foundations			✓					
3. Plant	✓	✓		✓		✓		✓
4. Equipment	✓	✓		✓		✓		✓
5. Assemblies	✓	✓		✓		✓		✓
B. Mixed Demolition Wastes								
6. Hard demolition waste			✓	✓		✓		✓
7. Mixed hard demolition & excavation waste			✓	✓		✓		✓
C. Segregated Hard Demolition Waste								
8. Unbound aggregates				✓	✓	✓		✓
9. Cement bound aggregates			✓	✓		✓		✓
10. Concrete				✓		✓		✓
11. Asphalt				✓		✓		✓
12. Masonry				✓	✓	✓		✓
D. Excavation Waste & Soil								
13. High recovery excavation waste				✓	✓	✓		✓
14. Low recovery excavation waste			✓	✓	✓	✓		✓
15. Soil				✓	✓			✓
E. Metals								
16. Steel				✓		✓	✓	✓
17. Non-ferrous metals				✓		✓	✓	✓
F. *Other (plastics, timber etc)*								
18. Plastics			✓	✓	✓	✓	✓	✓
19. Glass			✓	✓		✓		✓
20. Plasterboard				✓	✓	✓		✓

2. ITEMS

This section covers the techniques available for dealing with waste from whole buildings, foundations, plant items, equipment and assemblies.

Whilst some of the techniques described have only been used to any significant extent to deal with non-radioactive contaminants, all of those included would be equally suitable for radioactive contamination.

2.1 Buildings

In this context, **'Buildings'** is used to describe the basic fabric used in their. They may be comprised of concrete (which may be reinforced) brick or stone and may also have surface claddings of other materials.

General references in this area are

- Strategic National Guidance "The decontamination of buildings and infrastructure exposed to Chemical, Biological, Radiological or Nuclear(CBRN) substances or material" Available at http://www.communities.gov.uk/documents/fire/pdf/143837
- Information on techniques used in site restoration together with an indication of their effectiveness is given in Chapter 19 of the USA Department of Defence Document "Nuclear Weapon Accident Response Procedures (NARP) [DoD 5100.52-M] which can be found on this website : http://www.globalsecurity.org/wmd/library/policy/dod/5100-52m/chap19.pdf
- Further information on general techniques has been developed as part of the European STRATEGY project in document Eged, K. *et al*. 2003. Guidelines for planning interventions against external exposure in industrial areas after a nuclear accident. Part 1. A holistic approach of countermeasure implementation .available on the STRATEGY website at http://www.strategy-ec.org.uk/output/GSF%20report%2001_2003%20Part%20I%20CMS.pdf

<table>
<tr>
<td>Refurbishment</td>
<td>Refurbish for reuse</td>
<td>Building refurbishment involves retaining the integral structure of a building whilst undertaking appropriate modifications and improvements to facilitate its further use. Refurbishment is only likely to be a viable option where no or only very low levels of contamination are or remain present and where a future use has been identified which justifies the cost of the refurbishment. The practicability of refurbishment depends on the age of the building; generally the older the building the harder the refurbishment process will be.

Space management continues to be a pressure on many licensed sites due to the physical constraints placed on their development by site boundaries. In response to this many sites have established track records in the re-use of buildings. This is particularly true for Sellafield and other research sites which have experienced repeated cycles of activity within their lifetimes (e.g. experimental, pilot, production, decommissioning) and changes in the focus of activities (e.g. Magnox, AGR, MOX).

Successful science parks have been established at many licensed sites (including Winfrith, Harwell and Culham) through the refurbishment of redundant office buildings. Many sites are also currently considering future uses of buildings and assets as part of the end state consultation process.

Further information:
Refurbishment of office buildings at UKAEA Winfrith and creation of Winfrith Technology Centre.
• Coverage in the SD:SPUR guidance (Miller and Tooley 2005) Available from http://www.sdspur.com/guidance_main.htm
• the WTC Website http://www.winfrithtechnologycentre.co.uk</td>
</tr>
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		Harwell Science and Innovation Centre • http://www.harwell.org.uk/about_us/ Culham Science Centre • http://www.culham.org.uk/about_us/ Potential reuse of buildings on Sellafield for interim waste storage - Integrated Sellafield Site Strategy – Framework document 3: Waste Management (BNG) • http://www.britishnucleargroup.com/UserFiles/File/stakeholder/Framework3.pdf
Deconstruction	Planned deconstruction and segregation of materials	This involves carefully taking apart a building to maximise the sorting and segregation of wastes by type, contamination level and composition. This approach is in line with the ICE Demolition Protocol. The materials arising from planned deconstruction would depend on the nature of the building. Older constructions such as hangars are likely to be brick-based, while newer buildings will generally have a higher steel and concrete content. The SD:SPUR main guidance (Miller and Tooley, 2005) discusses some of the attributes which can be used to judge whether planned deconstruction is a sensible and sustainable practice (e.g. health and safety consideration, concerns related to discharge to water bodies or to the atmosphere, maximising the volumes of materials for reuse or recycling). **Further information:** Planned decommissioning of the Joint European Torus reactor located on the Culham site. • Coverage in SD:SPUR guidance (Miller and Tooley, 2005) available from: http://www.sdspur.com/guidance_main.htm Removal of internals as part of Calder Hall Cooling Tower Demolition • http://www.britishnucleargroup.com/calderhall/index.php • http://www.bre.co.uk/filelibrary/rpts/ConstructionWasteReport240906.pdf
Demolition (followed by Sorting & Segregation)		Demolition involves basic low technology methods to demolish a building to clear a site. It is not always carried out with the intention of sorting and segregating component waste materials. The principal wastes are concrete, brick, rubble and metal. Demolition is generally carried out on buildings that are radiologically clean. Any contaminated buildings would require more careful and planned deconstruction. Unsorted demolition wastes can be used for low-grade applications such as filling for landscaping, or else can be sent to landfill. **Further information** on routine demolition and those circumstances when it is most likely to be used on a nuclear licensed site is provided in the SD:SPUR main guidance (Miller and Tooley, 2005). Available from : • www.sdspur.com/guidance_main.htm More information on how this has been used in the decommissioning of a nuclear site can be found in the case study from a Belgian Site on the website of the EC Co-ordination Network on Decommissioning of Nuclear Installations,(CND) at: • http://ec-cnd.net/eudecom/Belgoprocess-DecommissioningActivities.pdf
Decontamination	Care needs to be taken when applying any decontamination technique that the process itself does not generate a volume of waste lager than	

	the volume of the original material or in a form which is more difficult to dispose of. This is a particular consideration where liquid secondary wastes are created.	
	Vacuuming, Wiping or Swabbing	The physical removal of hazardous dust and particles is undertaken using common cleaning techniques such as vacuuming and wet wiping. Vacuuming is performed using a commercial or industrial vacuum equipped with a HEPA (High Efficiency Particulate in Air) filter. Wiping or swabbing is suitable for small areas of contamination. **Further information** is available in the general references at the beginning of this section
	Gas scouring	The use of a turbulent gas stream (e.g. high pressure steam) to dislodge areas of loose contamination. Steam cleaning physically extracts contaminants from materials and equipment surfaces. The steam is applied by hand-held wands or automated systems, and the condensate is collected for treatment. **Further information** is available in the general references at the beginning of this section
	Peelable/Strippable coatings	Compounds that bind with contaminants are mixed with a polymer and applied to a contaminated surface. After curing, the polymer is removed by cutting with a sharp knife and peeling. Contamination adheres to the polymer that requires disposal as a solid active waste. This technique is useful for removing contaminated particles hidden in the cracks between skirting boards and the floor, since the liquids used are able to penetrate well and dry to an elastic solid. This technique has been well used in the nuclear industry over many years. **Further information** is available in the general references at the beginning of this section
	High pressure hosing/Hydroblasting/Slurry Blasting	A high-pressure (2000 psi) water jet is used to remove contamination from surfaces. All machines have the capability of introducing detergent, other chemicals or grit into hot or cold water. For large areas 5000psi pumped water could be used with equipment mounted on a heavy trolley. The debris and water are then collected and thermally, physically or chemically decontaminated. For large areas with outside access, gulley suckers could be used for collection. **Further information** is available in the general references at the beginning of this section
	Surface removal	Paint or surface layers containing contamination can be removed from surfaces by commercially available paint removers and/or physical means (e.g. scraping, scabbling, scrubbing or abrasive blasting). Scrubbing wood may be inadvisable as contaminated water is forced between the cracks, contaminating the surface below. Abrasive blasting is a surface removal technique in which an abrasive material is used for uniform removal of contaminated surface layers from materials and structures. Sand, alumina, or glass beads may be used as the abrasive. Remote-controlled systems are available. Long reach pneumatic chisels can be used to remove plaster. Scabblers are used to remove cracked or shattered concrete surfaces leaving a textured finish to which the new layer will key satisfactorily. The technique involves several pneumatic hammers shattering the top 6mm of the surface. The surface must be kept wet during the process to prevent re-suspension and recontamination of surfaces. Remote controlled demolition robots (e.g. Brokk machines) can be used prior to the demolition of activated structures to remove areas of higher activity as they are operated by remote control, electrically operated and

		can bee used in areas with limited access whilst allowing the operator stands a safe distance away. These techniques are currently used in the refractory industry. Chemical etching or chemical extraction on surfaces such as concrete, cinder block, brick, and tile , asphalt, wood, cast iron, steel, stainless steel, and other metals, including exotic metals has been carried out in the US using the RadPro® patented method. Dry Ice (or CO_2 Pellet) Blasting is an effective means of removing loose surface and tightly bonded contaminants. The process itself is similar to sandblasting, but provides a non-hazardous, non-conductive, and most importantly, a non-waste generating mechanical cleaning action. The contaminant is removed from the target item as a result of kinetic energy, thermal differentials, and gaseous expansion. Upon impact with a solid surface, the dry ice pellets sublimate to a gas and are evacuated through a high efficiency ventilation system. The process can be gentle enough to clean delicate electrical components or aggressive enough to remove bonded coatings. **Further information:** General information is available in the general references at the beginning of this section. An example of the use of the 'Brokk' machine is given at: • http://www.castle-pryor.co.uk/specialist_services/refractory_kilns.php There are companies offering a range of surface decontamination services for example: • http://www.eai-inc.com/corporate/tech-leadership.asp#1 Evaluation of the RadPro® system • http://www.eai-inc.com/pdf/news/Innovative_Technology_Summary_Report.pdf The use of dry ice is used by several companies an example of which can be found at: • http://www.icesolv.com • http://www.rsg-technologies.com/images/PollutionEngineeringArticle.pdf
	Fixative Coatings	Various reagents can be used as fixative coatings on contaminated residues to fix or stabilise the contaminant in place and decrease or eliminate exposure hazards. Potentially useful stabilising agents include epoxy paint films and polyester resins. The stabilised contaminants can be left in place or removed later by a second treatment. In some cases, the stabiliser/fixative coating is applied in situ to prevent contamination spread during some other phase of the decontamination process (for example, during dismantling or disposal). Again a widely used technique in the nuclear industry. **Further information** is available in the general references at the beginning of this section
	Microbial treatment	INEEL and BNFL have researched the use of a microbial decontamination technology at a nuclear reactor at the Sellafield plant in the United Kingdom. A gel of microbes and sulphur was applied to surface contamination on a concrete wall. As the microbes metabolise they create sulphuric acid which etches the concrete surface and loosens the contaminated layers. **Further information:**

		A brief report of the trials on this technique can be found in a US DoE newsletter 'ESAVE' which can be found on the website at: • http://www.p2pays.org/ref/19/18313.pdf

2.2 Foundations

Foundations are assumed to be the substructure that supports the construction of a building. They may be comprised of concrete (which may be reinforced) or for older buildings of brick or stone.

On UK Nuclear Licensed Sites there are occasions when the construction of buildings for certain purposes (e.g. nuclear reactors, nuclear chemical plants) may have necessitated the removal of a substantial amount of subsoil down to rock head and replacement with material of particular geotechnical properties in order to achieve a particular design solution.

Demolition (followed by Sorting & Segregation)		Demolition using basic low technology methods can be used to demolish foundations. This may involve explosive or non explosive techniques such as the use of mechanical breakers or non explosive expansive cracking agents which can be mixed with clean water and poured into pre-drilled holes on rock and concrete. The agent swells and exerts significant expansive thrust on the hole-wall, fracturing the wall and splitting the foundations across the line of the drill holes. **Further information:** Non explosive techniques are marketed for example by a company in the USA called Crackamite and their technique is explained on their website at: • http://www.crackamite.com/ A case study explaining the use of breaking as well as other techniques used in decommissioning on a project in Belguim is given in overview at: • http://ec-cnd.net/eudecom/Belgoprocess-DecommissioningActivities.pdf
Decontamination	Vacuuming, Wiping or Swabbing	See Section 2.1
	High pressure hosing/Hydroblasting/Slurry Blasting	See Section 2.1
	Surface removal	See Section 2.1
	Microbial treatment	See Section 2.1
Recycling	Unbound mixing / general fill	Materials can be mixed together without the use of a binding agent (subject to confirmation of any levels of contamination that may be present). This is commonly employed when materials are used for sub-bases, in-fill, embankments and other low-grade applications. **Further information:** More information on the use of this technique can be obtained from the Quarry Products Association via their website at:

		• http://www.qpa.org/
	Hydraulic binding	Materials from foundation may be stabilised by a hydraulic reaction, normally using cement. Some mixtures may allow the re-use of materials available on site (e.g. soil, demolition wastes) with savings on imported primary material (avoiding the Aggregates Levy). **Further information:** A case study of recycling in BAA maintenance and construction projects including the use of hydraulically bound material is available on the Waste and Resources Action Programme (WRAP) website at: • http://www.aggregain.org.uk/case_studies/recycling_in.html
Disposal		Foundation wastes can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites.

2.3 Plant, Equipment & Assemblies

Plant, Equipment and Assemblies have been treated together due to the similarities in their nature and available management options.

For the purposes of this study **plant** is considered to be large installed items or systems such as ventilation systems, **equipment** is considered to be mobile items such as cranes and **assemblies** are considered to be separable parts of plant or equipment such as drives for pumps.

Refurbishment	Refurbish for reuse	Plant, equipment and assemblies may be refurbished for re-use in a similar way and with similar limitations to whole buildings (See Section 2.1). Opportunities for re-use may be reduced due to the age of the materials and also their compatibility with modern plant, equipment and assemblies. **Further Information:** IAEA TECDOC-1130 Recycle and reuse of materials and components from waste streams of nuclear fuel cycle facilities (IAEA, 2000) includes information on the re-use of Master Slave Manipulators at Sellafield: The document is available at: • www.pub.iaea.org/MTCD/publications/PDF/te_1130_prn.pdf UKAEA have used scrap metal from the decommissioning of the Dounreay Prototype Fast Reactor at the T3uk purpose built trials centre at Janetstown nr Thurso. More information is available from: • http://www.ukaea.org.uk/sites/dounreay_project_updates.htm#Feb0704
Deconstruction	Planned deconstruction and segregation of materials	Planned deconstruction may be considered to be part of post operational clean-out (POCO) which is currently practiced on UK nuclear licensed sites. If this were the case it may be expected that the items under consideration here would be able to be taken out through the existing maintenance routes for the building.
Decontamination	Vapour extraction	See Section 2.1
	Vacuuming, Wiping or Swabbing	See Section 2.1
	Steam cleaning	See Section 2.1
	High pressure hosing/Hydroblasting/Slurry	See Section 2.1

	Blasting	
	Surface removal	Techniques described for the surface removal in buildings (Section 2.1 can also be used on items. Additional techniques may also be applicable depending on the nature of materials under consideration and the degree and location of contamination. For example, various acids (e.g. oxalic, hydrochloric, carboxylic, formic, citric, nitric) may be used to remove radionuclides from the surfaces of a variety of types of steels. Whilst it may be considered relatively easy to remove surface contamination from items such as scaffolding poles it may be expected to be significantly harder to decontaminate areas such as the internal mechanisms of motors. Blasting with crushed walnut shells can be used to remove foreign matter or coatings without etching, scratching or marring the cleaned areas and is useful for cleaning high value or delicate items such as electrical equipment. **Further information:** Decontamination of remote dismantling machine from Niederaichbach nuclear power plant: NEA 2006. Radioactive Waste Management Committee. Management Board of the Co-operative Programme for the Exchange of Scientific and Technical Information concerning Nuclear Installations Decommissioning Projects. A report of the NEA Co-operative programme on decommissioning – Progress during 1995-2005 (NEA/RWM/CPD(2006)3) can be found at:. • http://www.olis.oecd.org/olis/2006doc.nsf/809a2d78518a8277c125685d005300b2/553b9515fe7334f3c1257204003d3f36/$FILE/JT03215575.PDF Two examples of the kind of materials that can be used as blasting media can be found on the following suppliers websites: • http://www.grandnorthern.com/supplies/blasting_media • http://www.kramerindustriesonline.com/blasting-media/walnut-shells.htm
Recycling		Recycling of components could be undertaken if a market can be found that warrants any costs necessary in decontaminating, transporting or further separating the wastes to exploit this option.
Dispose		If no further use can be found the materials may be sentenced as wastes for disposal with the target site(s) being identified on the basis of the levels of radiological contamination and any other chemical or hazardous properties.

Comment [MB1]: Shouldn't this text be used in the disposal sections throughout? Agreed – suggest it is put under 2.3 text.

3. MIXED DEMOLITION WASTES

Mixed demolition wastes are produced by a simplistic demolition programme in which no attempt is made to segregate materials during the demolition processes or to undertake the demolition activities in such a way that similar materials are 'attacked' in campaigns. Given the likelihood that many of the buildings will contain cement bound asbestos cladding such an approach may be unwise.

Two categories of wastes are considered here

- **Hard Demolition Wastes** which contain aggregates, concrete, asphalt and masonry.
- **Mixed Hard Demolition Waste & Excavation Wastes** which contains a mixture of Hard Demolition Wastes as defined above and in addition Excavation Wastes which are softer being comprised of soils and earths.

Datasheets for each of these two mixed wastes are provided overleaf. These techniques are likely only to be applicable where radioactive contamination has been completely removed or where residual levels are sufficiently low as to meet the exemption criteria from the Radioactive Substances Act 1993

Segregated Hard Demolition Wastes are considered in Section 4 and Excavation Waste & Soil is considered in Section 5.

3.1 Hard Demolition Wastes

Hard Demolition Wastes are wastes which contain aggregates, concrete, asphalt and masonry.

Demolition (followed by Sorting & Segregation)	General	The degree of separation of materials prior to crushing has a major impact on the range of applications for which the crushed material can be used. Crushing mixed material reduces the quality of the end product. All sites must be inspected prior to demolition for contaminants such as asbestos which need to be removed prior to any further handling of the waste materials.
	Screening	Conveyor belts using meshes for sorting grains into grades can also be used. The belts vibrate and feed the material along steel meshes graded to capture grains of a specified diameter
	Magnetic separation	Magnets are used to remove ferrous materials from feedstock being fed into a recycling plant. Varieties of magnets include drum magnets, heavy-duty electromagnetic drums (for separation of ferrous materials from non-ferrous materials, permanent magnetic drums (for the separation of fine irons), and conveyor end roller magnets. The purpose of magnets is to avoid damage to the plant, recovery of valuable material and improvement of the quality of end product.
Decontamination	General	Decontamination may take place before or after demolition although it can generally be expected to be carried out before demolition in order to minimise the spread of contamination during demolition and also the practicality of some techniques (e.g. scabbling) which may only lend themselves to application to contamination in situ.
	High pressure hosing/Hydroblasting/Slurry Blasting	See section 2.1
	Surface removal	See section 2.1
	Microbial treatment	see section 2.1
Recycling	Cold bituminous mixtures	Recovered aggregate can be bound using bitumen as the binding agent for the construction of roads and footways. Materials are graded to a prescribed size before being mixed with filler such as pulverised fuel-ash and binding agents such as cement or lime before being mixed with foamed bitumen. **Further information:** The Borough of Merton used cold in situ recycling of 2,500 tonnes of aggregate for road reconstruction is described in a case study on the AGGREGAIN The sustainable aggregates information service from UK Waste & Resource Action Programme (WRAP), website at:

		• http://www.aggregain.org.uk/case_studies/2692_performance.html
	Unbound mixing / general fill	Materials can be mixed together without the use of a binding agent. This is commonly employed for sub-bases, in-fill, embankments and other low-grade applications. Of particular interest may be the possibility of using aggregate as infill or as part of landscaping following decommissioning activities at Nuclear Licensed Sites. Several sites have identified such options during the course of the recent End State Consultation process.
	Hydraulic binding	See section 2.2
Disposal		Hard Demolition Waste can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites.

3.2 Mixed Hard Demolition and Excavation Wastes

Mixed Hard Demolition Waste & Excavation Wastes are wastes which contains a mixture of Hard Demolition together with Excavation Wastes which are softer being comprised of soils and earths.

Demolition (followed by Sorting & Segregation)	General	The degree of separation of materials prior to crushing has a major impact on the range of applications for which crushed material can be used. Crushing mixed material reduces the quality of the end product. All sites must be inspected prior to demolition for contaminants such as asbestos which need to be removed prior to any further handling of the waste materials.
	Washing	Washing may be used to reduce the amounts of clay and fines within materials to improve the efficiency of any subsequent recycling and increase the value of the final recycled product. **Further information:** A case study on the Bowhill Restoration and Recycling facility, Lochgelly, Fife demonstrates the use of washing equipment to support the production of added value aggregated products. This can be found at: • http://www.aggregain.org.uk/case_studies/aggregates.html
	Screening	See section 3.1
	Magnetic separation	See section 3.1
Decontamination		See section 3.1
Recycling	Unbound mixing / general fill	Materials can be mixed together without the use of a binding agent. This is commonly employed for sub-bases, in-fill, embankments and other low-grade applications. **Example:** The use of this technique is also demonstrated on the case study on the Bowhill Restoration and Recycling facility. • http://www.aggregain.org.uk/case_studies/aggregates.html
	Hydraulic binding	See section 3.1
	Blending of fines in the production of soil.	Fines produced in the sorting, segregating and crushing of demolition and excavation wastes are commonly considered to be un-recyclable, though WRAP trials have demonstrated that such fines can be input into mixtures for manufactured soils. **Further information:** "Increasing recycling of quarry, biodegradable, green, construction, demolition and excavation waste stream through the

		manufacture of soils." WRAP. 2005. • http://www.wrap.org.uk/nations_and_english_regions/english_regions/regional_case_studies_and_projects/hampshire_soils.html
Disposal		Mixed Hard Demolition and Excavation Wastes can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites

4. SEGREGATED HARD DEMOLITION WASTE

Segregated Hard Demolition Wastes are produced either by planned demolition activities in which similar materials are 'attacked' in campaigns or the sorting and segregation of mixed Hard Demolition Wastes.

Five categories of wastes are considered here

- **Unbound Aggregates** which include the gravels and sub-base used below foundations, structures and roads.
- **Cement Bound Aggregates** which comprise aggregate materials that contain cement as a binding agent.
- **Concrete** which consists of cement, gravel, sand and admixtures[2]. Both mass concrete and reinforced concrete, which includes steel reinforcing bars, are expected to be encountered.
- **Asphalt** which comprises bituminous materials which may have been removed from roads, hard standing and pavements. Assumed to include both blacktop and macadam
- **Masonry** which may include cement free brick, block-work, tiles and ceramics.

Datasheets for each of these wastes are provided overleaf. Again, these techniques are likely only to be applicable where radioactive contamination has been completely removed or where residual levels are sufficiently low as to meet the exemption criteria from the Radioactive Substances Act 1993.

2 Admixtures are specially formulated products that are added in small amounts to concrete, mortar or grout during the mixing process in order to modify the concrete properties in the plastic and/or hardened state.

4.1 Unbound Aggregates

Decontamination		Decontamination of unbound aggregates may be possible using either a surface washing technique or other techniques applied ex situ such as bio-remediation. The nature of the aggregate will have an important control on the efficacy of techniques (e.g. porous gravels may be not amenable to decontamination). However, as discussed previously most decontamination may be expected to take place prior to demolition. See section 2.1 surface removal techniques. **Further Information:** A description of the use of bio-remediation on wate materials in practice can be found at • http://www.vhe.co.uk/services/bioremediation.htm
Reuse		Unbound aggregates may be readily reused in similar applications.
Recycling	Cold bituminous mixtures	See section 3.1
	Unbound mixing / general fill	See section 3.1
	Hydraulic binding	See section 3.1
	Cement binding	Unbound aggregates can be mixed using cement as the binding media to construct the sub-base beneath roads. **Further information:** Use of recycled aggregates and in-situ stabilisation on the A120 Stansted to Braintree Bypass is described in a case study on the Aggregain website • http://www.aggregain.org.uk/case_studies/use_of_ra_and.html
Disposal		Unbound aggregates can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites.

4.2 Cement Bound Aggregates

Decontamination		See section 4.1
Recycling	Cold bituminous mixtures	See section 3.1.
	Unbound mixing / general fill	See section 3.1
	Hydraulic binding	See section 3.1
	Cement binding	See section 3.1
Disposal		Cement bound aggregates can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites.

4.3 Concrete

Decontamination		See section 2.1
Recycling (processing)	Unbound mixing / general fill	See section 3.1 **Also:** Sustainable decommissioning of Windscale Pile 2 chimney in described in a case study on this project is available on the Aggregain website: • http://www.aggregain.org.uk/case_studies/sustainable.html
	Hydraulic binding	See section 3.1
	Cement binding	See section 4.1
	Dynamic Compaction	Dynamic compaction is a ground improvement process for compacting and strengthening loose or soft soils to support buildings, roadways, and other heavy construction. The method involves the systematic dropping of heavy weights, 100 to 400kN, from a height of 5 to 30m, in a pattern designed to remedy poor soil conditions at the proposed building site. In soft ground areas, dynamic compaction has proved to be an effective and economical alternative to traditional piling and vibro-stone column techniques especially where hi-frequency vibrations may lead to potential damage to vibration sensitive sites such as embankments and nearby buildings. **Further Information:** Dynamic Compaction using Recycled Concrete Aggregate was used at Voyager Park, Industrial Estate Portsmouth and a case study on this project is available on the Aggregain website: • http://www.aggregain.org.uk/case_studies/dynamic.html
Disposal		*Concrete* can be disposed of to inert landfills (subject to confirmation of any levels of contamination that may be present) paying the lower level of landfill tax for such sites.

4.4 Asphalt

Decontamination		Shotblasting of asphalt using steel balls has been trialled as an alternative to washing techniques which have been shown only to be effective soon after deposition of contamination. A report on this work can be found at: • http://rpd.oxfordjournals.org/cgi/content/abstract/21/1-3/141 Vitrification using a mobile vitrification plant has been used in the US to treat mixed wastes including asphalt but it is expensive. A report is available at: • http://www.wmsym.org/abstracts/2003/pdfs/112.pdf • http://www.globalsecurity.org/wmd/library/policy/dod/5100-52m/chap19.pdf
Recycling (processing)	Cold bituminous mixtures.	The base, binder and surface courses of asphalt surfaces can be fully recycled (up to 10% by mass recycled asphalt may be used in surface layers and up to 50% in all other layers). Asphalt can be recycled back into hot asphalt, a process which gains the benefit from the original bitumen and high quality aggregate; or into cold lay foamed bitumen. Methods and equipment for recycling bituminous pavements are well developed and established; this can be done in situ or ex situ. **Further information:** The performance of cold recycled bitumen bound material was used in highway construction within Dudley Metropolitan Borough and a case study on this project is available on the Aggregain website: • http://www.aggregain.org.uk/case_studies/2694_the_perform.html General information from the North American information network, who publish the “Basic Asphalt Recycling Manual” is also available from the Asphalt Recycling and Reclaiming Association (North America) at: • www.arra.org/
	Hot In-place Recycling	Hot In-Place Recycling (RHIR) is a method of recovering and regenerating deteriorated asphalt surfaces to a typical depth of between 20 to 60 mm by applying heat to soften the surface layer. The softened asphalt material, having been loosened and removed by milling devices, is mixed together, with or without the addition of a recycling agent. The resultant mixture is then re-laid and compacted to complete the recycling process. New hot-mix asphalt or aggregate materials are added for structural correction and upgrading. **Further information:** Associated Recycling Solutions Ltd, is one example of a Hot In-place Recycling machinery manufacturer in the UK. Information about Associated Recycling can be found at: • www.rslplant.com The highways agency uses these techniques and examples of their use can be found on their website at • http://www.highwaysmaintenance.com/bitcyctxt.htm
	Cold In-place Recycling	Cold In-place Recycling (CIR) is an on-site process of reprocessing asphalt pavements to a typical depth of between 50 to 100 mm without the application of heat. Depths of 125 to 150 mm are possible with the addition of chemicals. It is a method in which old asphalt cement is pulverized to a precise depth, mixed with a liquid binder and repaved to an accurate grade and profile. In most cases CIR requires that a new wearing course be applied over the recycled material. **Further information** on this technique can be found at

		• http://www.millergroup.ca/pavement/cir.html
	Full-depth Reclamation	Full Depth Reclamation (FDR) is a recycling method in which the full thickness of the asphalt pavement and a predetermined portion of the underlying materials (base, sub-base and/or sub-grade) is uniformly ground and blended to provide an upgraded, homogeneous base material. FDR is performed on the roadway without the addition of heat, similar to CIR. Treatment depths vary depending on the thickness of the existing pavement structure, but generally range between 100 and 300 mm. Comparisons of this and other techniques are given at • http://www.cement.org/pavements/pv_sc_fdr.asp
	Recycling asphalt to concrete	Concrete can contain up to 5% asphalt as a foreign material although Recycled asphalt is generally not viewed as a concreting aggregate.
	Hydraulically bound mixtures (HBM)	Up to 100% of a road sub-base and base can be constructed from hydraulically bound mixtures of recycled asphalt.
	Unbound mixing.	50% of a road sub-base can be constructed from unbound mixtures of recycled asphalt, 100% recycled asphalt may be used if approved. **Further information:** This technique was used in the A34 Chieveley/M4 J13 Improvement - case study published by AggRegain at:. • http://www.aggregain.org.uk/case_studies/use_of_1.html
	Dynamic Compaction.	See section 4.3
Disposal		See section 4.1

4.5 Masonry

Masonry is commonly used for the walls of buildings and other structures and includes brick, concrete block masonry and stone. In some cases some or all of the cores of blocks are filled with concrete or concrete with steel reinforcement (rebar).

Decontamination		See Section 2.1
Reuse		Masonry offers more scope for material reuse than other hard demolition wastes. “Second brick” (reused bricks) are valuable resources on a deconstruction/demolition site. Cement and filler can be removed from the bricks manually or mechanically and then the bricks can be used again. The same principle can apply to stone work, breeze blocks and other component masonry. **Further information:** Central Procurement Directorate – Northern Ireland, Sustainable Construction Group – Guidance notes. Available at: http://www.cpdni.gov.uk/index/guidance-for-purchasers/sustainable-construction.htm give the approach to the re-use of masonry being applied in Northern Ireland.
Segregation		Separation techniques including vibrating screen, magnetic and mechanical removal of separate materials such as metals can be employed to achieve the highest recovery rates of the various materials occurring in the masonry waste material.
Recycling (processing)	Reclamation and reuse of bricks	This method involves removing old mortar from the bricks by hand. A small hand tool is used to remove old mortar from the bricks, stone, breeze blocks etc. At present this is the only technique commercially employed to enable used bricks to be made suitable for reuse in their original form.
	Masonry to sub-base material	Masonry, including bricks and mortar, can be pulverised and screened to produce a product that can be used in the production of sub-base road construction material. Similarly, such pulverised materials can be used in a number of base course and binder course mixtures.
	Unbound mixtures	Unbound mixtures of suitably sized, crushed and screened masonry materials can be used as a sub-base construction material.
	Coarse Aggregate in concrete	Suitably sized and screened masonry materials can be recycled as the coarse aggregate in concrete production. Certain conditions must be met when using recycled materials in concrete. **Further information:** Further information on the conditions that must be met when using recycled materials in concrete can be found in the WRAP publication “Quality protocols for the production of aggregates from inert waste” • http://www.wrap.org.uk/downloads/0083_Quality_Protocol_A4.fa264e8d.pdf *Recycling of Demolished Masonry Rubble as Coarse Aggregate in Concrete: Review*. Journal of Materials in Civil Engineering. Volume 16, Issue 4, pp. 331-340 (July/August 2004). provides a review of previous work covering the use of demolished waste, especially crushed brick, as the coarse aggregate in new concrete

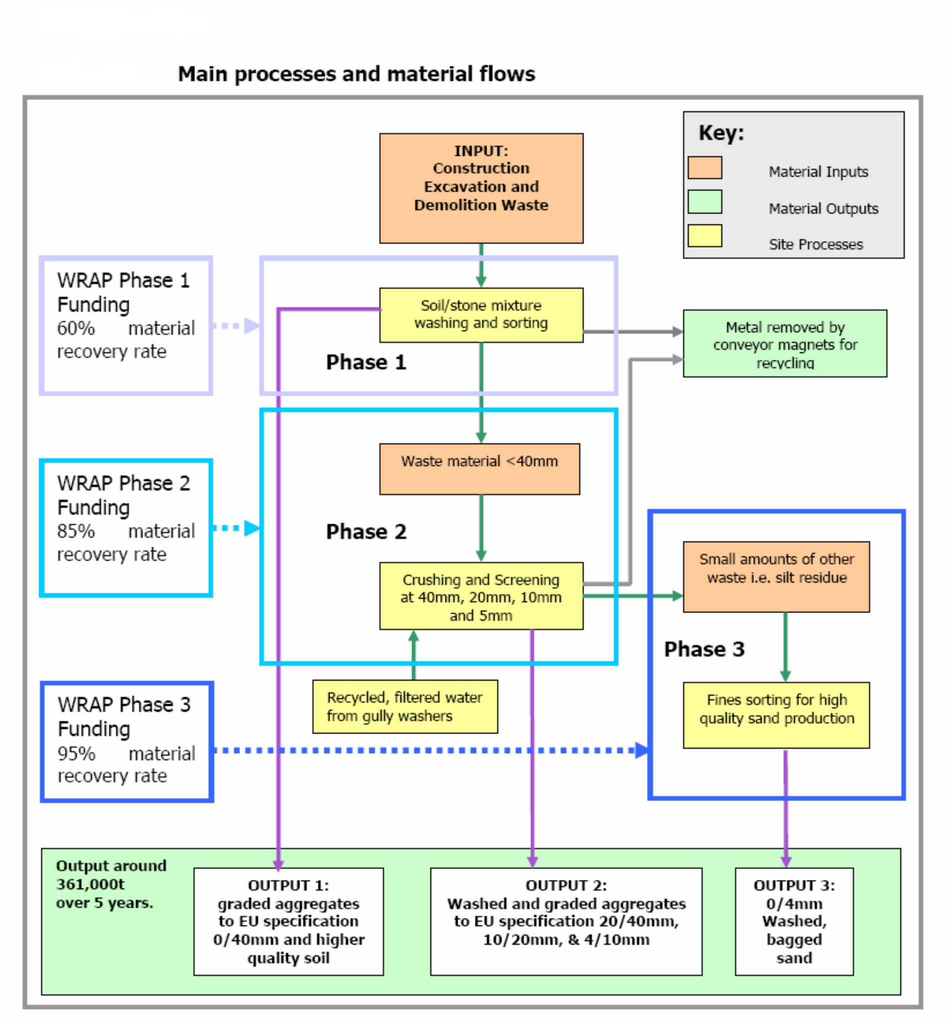
	Hydraulic binding	Crushed and screened masonry materials can be suitable for use in HBMs as base and sub-base application.
Disposal		See section 4.1

5. EXCAVATION WASTE AND SOIL

Waste and soil from excavation on a site can be dealt with in a number of ways as illustrated in this figure taken from a case study in Scotland where a three phase project was undertaken at a former Colliery. Each phase took the process further increasing the amount of material diverted from landfill.

(http://www.wrap.org.uk/downloads/Realm_Construction_case_study.3f4c699f.PDF)

Figure 1 Processing for soil manufacture using reclaimed aggregates[3]



3 WRAP creating markets for recycled resources
Aggregates case study Aggregates Programme for Scotland –Production of high value aggregates from construction, demolition and excavation waste

5.1 Excavation waste (high recovery)

Excavation waste with a low soil content is defined as high recovery. The utility of excavation waste and soil is dependent upon the degree to which it is sorted prior to recovery. More intense grading, crushing, sorting and segregation gives rise to more recycling opportunities. Again reuse and recycling options will only be applicable where radioactive contamination has been completely removed or where residual levels are sufficiently low as to meet the exemption criteria from the Radioactive Substances Act 1993

Decontamination		Studies have been carried out into remediation of soil following a Chemical, Biological, Radiological or Nuclear (CBRN) incident and the techniques are likely to be transferable. **Further information** can be found at: • http://www.globalsecurity.org/wmd/library/policy/dod/5100-52m/chap19.pdf
Reuse		See section 4.1
Recycling (processing)		See section 4.1
Disposal		See section 4.1

5.2 Excavation waste (low recovery)

Excavation waste with a high soil content is defined as low recovery. The utility of excavation waste and soil is dependent upon the degree to which it is sorted prior to recovery. More intense grading, crushing, sorting and segregation gives rise to more recycling opportunities. Again reuse and recycling options will only be applicable where radioactive contamination has been completely removed or where residual levels are sufficiently low as to meet the exemption criteria from the Radioactive Substances Act 1993

Decontamination		See section 5.1
Reuse	Separation.	Soils can be manufactured by the recycling of quarry, biodegradable, green, construction, demolition and excavation waste streams. **Further information** can be found in the WRAP document "Increased recycling of quarry, biodegradable, green, construction, demolition and excavation waste streams through the manufacture of soils. Project code: RMD3-047" available at: • http://www.wrap.org.uk/downloads/RMD3-047_Final_Report.ac4a0bd2.pdf
Recycling (processing)	Crushing and screening:	Crushing and screening can be used to separate soil like material from bricks and concrete in excavation wastes.
	Unbound mixing.	See section 4.1
Disposal		See section 4.1

5.3 Soil

Decontamination		See section 5.1
Reuse	Separation.	In civil engineering activities, soils can be re-used in cut and fill construction. They can also be re-used in reinforced earth embankments. Central Procurement Directorate – Northern Ireland, Sustainable Construction Group – Guidance notes. Available at: • http://www.cpdni.gov.uk/index/guidance-for-purchasers/sustainable-construction.htm
Recycling (processing)	Crushing and screening	Crushing and screen soil like material along with bricks and concrete excavation wastes.
Disposal		See section 4.1

6. METALS

Decontamination of metals, contaminated with radioactive materials, for re-use or recycling is being increasingly used in the nuclear sector using techniques developed in a wider industrial context.

6.1 Steel

Decontamination	Chemical removal	Steel surfaces may be decontaminated using a range of chemical treatments including water, mineral acids (e.g. nitric, sulphuric, and phosphatic), acid, alkaline or organic salts and organic solvents. This is one of the issues addressed in the EC CND programme as can be seen on their website at: • http://ec-cnd.net/eudecom/ecdecomprojects_1979-1983.php?Sid=fcd280cc454d52aaccc167cc43648c3d • http://ec-cnd.net/eudecom/Belgoprocess-DecommissioningActivities.pdf
	Surface removal	Surface layers containing contamination can be removed from surfaces by commercially available paint removers and/or physical means (e.g. scraping, scabbling, scrubbing or abrasive blasting). Soft Blasting is similar to other abrasive blasting equipment as the media is propelled at the surface to be cleaned. The media used can be synthetic open-cell polymer sponge which absorbs and traps contaminants and removes them from the substrate. **Further information** on the use of these techniques for radioactive and non-radioactive facilities can be found at: Wheelabrator at Sellafield. • http://www.wmsym.org/abstracts/2006/pdfs/6430.pdf Dry abrasive blasting: • http://ec-cnd.net/eudecom/Belgoprocess-DecommissioningActivities.pdf Grit blasting and other techniques: • http://www.race-services.com/index.php?p=services&lang=en Soft blast • http://www.icesolv.com
	Peelable/strippable coatings	See section 2.1
Recycling	Melting	A limited number of commercial facilities exist that will accept radiologically contaminated steel for melting with the subsequent recycling of decontaminated product. This process in itself gives a degree of decontamination as the contaminants tend to be separated out in the process allowing a small volume to be treated as radioactive waste with the bulk then available for recycling. This technique has been successfully used in the USA and Sweden. **Further information** on melting being used in the nuclear sector is available from the USA and Sweden: EnergySolutions, USA

		• http://www.energysolutions.com/?id=OTc3 Studsvik, Sweden • http://vp048.alertir.com/index.php?p=services&s=waste_treatment&lang=en
Volume reduction	Melting	Melting will also reduce the volume of metal waste and even if it is not decontaminated to the extent that recycling is possible, the volume reduction in melting items into ingots will reduce the disposal costs.
Disposal	Landfill	Steel can be disposed of to non-hazardous landfills (subject to confirmation of any levels of contamination that may be present).

6.2 Non-Ferrous Metals

Decontamination		See section 6.1
Recycling	Melting	As for steel, melting can be used for other metals and this is carried out again in Sweden and USA for metals with radioactive contamination. Recycling aluminium scrap containing thermal barrier material [United States Patent 4394166] can be achieved by using a rotary kiln to reduce the thermal barrier material in the scrap to combustible gas and cinder and produce a satisfactory aluminium melt furnace feed product. **Further information:** A company has registered a patent on this process as can be seen at: • http://www.freepatentsonline.com/4394166.html
Disposal	Landfill.	Cannot be disposed of to inert landfills

7. OTHERS

7.1 Plastics

The use of plastics within the building construction sector is on the increase and in general, the newer the building, the higher the percentage of plastics contained within the structure. Common applications and plastic types arising in buildings wastes include window frames and flooring (PVC), piping (PVC, PP and PE, especially HDPE), insulation and other foams (PS and Polyurethane) insulated electrical wiring (PS and PVC). This general trend will also have been reflected in more modern buildings within the nuclear sector. To date little plastic material has been recycled in the nuclear industry but again techniques developed in other sectors could be applied.

Sorting and segregation		The recycling of plastics is complex since there are many different types of plastic each of which has to be treated differently. The first stage of any process then is to sort and segregate the different types. This is still mostly carried out manually although there are now a few examples in Europe of automated processes. A number of techniques can be used including • Flotation or particle density sorting relies on different densities of various plastics to sort and segregate different types within a mixed plastic waste stream. • Electrostatic sorting which separates using electrostatic sources • Mechanical sorting which can be achieved by the use of sloped sieves which rely on the different levels of bounciness of plastics Centrifugal sorting which used different centrifugal forces to separate plastics with different specific gravitates against a bowl shaped wall **Further information**: Plastics Europe, an association of European plastics manufacturers publish a good practice guide on waste plastics recycling which includes information on these techniques in practice. This can be found at : • http://www.plasticseurope.org/Content/Default.asp?
Decontamination		See Section 6
Reuse		The reuse of plastics in construction is generally confined to like-for-like applications, e.g. the reuse of old window-frames, piping, etc. Reprocessing of plastics is considered in the recycling section.
Recycling (processing)	Mechanical recycling	Mechanical recycling, also referred to as conventional or melt recycling, is the most developed and widely practiced plastics material recycling technique. This involves a process whereby thermoplastics are reclaimed from the waste stream, washed and contaminants removed, flaked or granulated into small pieces (regrind) which can then be reprocessed directly as polymer feed or made into pellets for sale to plastic product manufacturers. **Further information:** CK Polymers. Information on polymer recycling. CK Polymers Ltd, available at:

		• http://www.ckpolymers.co.uk RECOUP, Fact sheet on Feedstock recycling of mixed polymers. Available at: • http://www.recoup.org/shop/product_documents/26.pdf PlasticsEurope homepage • http://www.plasticseurope.org/Content/Default.asp Schut, J. H. (2001). *Commingled plastic waste: New gold mine for automotive processors*, Plastics Technology, Feature Article. May 2001. Gardner Publications, Inc. The APPRICOD project aimed at "Assessing the Potential of Plastic Recycling in the Construction and Demolition Activities" information available at: • http://www.appricod.org/spip/article.php3?id_article=16
	Feedstock, Chemical or Advanced recycling	Advanced recovery options, including feedstock and chemical recycling, which use thermal or chemical processes to depolymerise plastics to their original constituent substances are increasingly being established throughout Europe. Examples include: **Polyamid 2000:** German company that chemically recycles engineering plastics utilised in carpets through a depolymerisation process. **SVZ Gasification plant**: The SVZ gasification plant in Germany converts various waste materials including mixed plastics waste, Refuse Derived Fuel (RDF), wood, sewerage sludge and waste oils into syngas and methanol by gasification. **Further information:** • Valenti, M., (2000). Trash and Burn: Synthetic gases derived from industrial and municipal wastes fuel cogeneration plants in Europe. Mechanical Engineering, November 2000. The American Society of Mechanical Engineers. • Jones, R. F., (2004). The Impact of Globalisation on Recycling, GPEC 2004 Paper No. 23. Presented by R. Jones of Franklin International, LLC.
	Blast furnace	Plastics are used in pig iron production acting as a carbon source replacing coal and heavy fuel oil as a reducing agent in the blast furnace. Plastic chips are fed into the blast furnace where the plastics gasify with the resultant synthesis gas reacting with, and removing oxygen from the iron ore (the reduction process) which is necessary in the manufacturing of pig iron. **Further information:** ◆ Tukker, A., De Groot, H., Simons, L., Wiegersma, S., (1999). Chemical Recycling of Plastics Waste (PVC and other resins). Netherlands Organisation for Applied scientific Research, TNO-report STB-99-55 final. Commissioned by the European Commission DG III. • Deutsche Gesellschaft für Kunststoff-Recycling GmbH (DKR) Home page, available at: http://www.dkr.de/en/technik/234_589.htm

	Thermafuel system	A pyrolysis system for the conversion of post consumer plastics waste into a synthetic fuel exhibiting diesel fuel properties complying with EU fuel standard EN590. The Thermafuel synthetic diesel pyrolysis system has been developed by Ozmotech Pty Ltd and is being established in the UK and Ireland by Cynar Plc. **Further information:** ◆ Ozmotech Thermofuel homepage available at: http://www.ozmotech.com.au/ ◆ Cynar Plc, UK and Republic of Ireland agent for thereafter system, homepage available at: http://www.cynarplc.com/

7.2 Glass

Sorting & Segregation		Clean separation of glass from frames to avoid contamination from stone, dust and other rubble is time consuming and therefore expensive although it can be automated.
Decontamination		As for unbound aggregates.
Recycling	General	There is no mature infrastructure for collection of flat glass and the two companies are actively involved in the recycling of flat glass (window and door glass) only collect flat glass from manufacturers rather than demolition sites. Other difficulties include the fact that flat glass is often tempered and returning flat glass back to the original melters is problematic. Some preliminary trials are being undertaken using bus shelter toughened glass and investigations are underway on use of demolition flat glass from the London 2012 Olympic site. **Further information:** Research into waste glass window and door frames from the demolition and replacement window industries', WRAP Research report GLA2-022, James Hurley, BRE, June 2003 at • http://www.wrap.org.uk/downloads/ResearchIntoWasteGlassWindowAndDoorFrames.03922f51.pdf More information from British Glass about glass recycling in the UK is available in their research Report " A Mass Balance Study" • http://www.britglass.org.uk/Files/UKGlassManufactureAMassBalance.pdf
	Unbound mixing / general fill	As for unbound aggregates. Increasingly the practice when demolishing a large building is to crush the concrete and masonry to produce a secondary aggregate for use in roads and other construction projects or landscaping. Glass may contribute to this market. More information from British Glass about glass recycling in the UK is available in their research Report " A Mass Balance Study" available at: ◆ http://www.britglass.org.uk/Files/UKGlassManufactureAMassBalance.pdf

	Building products	Various building and architectural products such as paving stones have been developed using recycled glass.
	Fibre glass manufacture	Fibre glass can be manufactured using a number of methods to produce either continuous or short fibres. Short fibres may be used in the production of blanket fibre material such as that used for insulation and this is a significant use of recycled glass. Further information on the recycling of glass can be found on the waste-online website • http://www.wasteonline.org.uk/resources/InformationSheets/Glass.htm and on the Aggregain website at • http://www.aggregain.org.uk/applications/wrap_pdf/aggregain/pdf_material.cfm?id=2922 and in the WRAP Glass Market Survey at • http://www.wrap.org.uk/downloads/GlassMrktSitRpt_final.015df503.pdf
	Container and flat glass manufacture	A major use of waste flat glass is as a feedstock for the manufacture of glass containers or flat glass. As can be seen from the WRAP Glass Market Survey at: • http://www.wrap.org.uk/downloads/GlassMrktSitRpt_final.015df503.pdf
	Reflective paint manufacture	A minor use of recycled glass is the manufacture of glass beads for reflective paints and shot peening. As can be seen from the WRAP Glass Market Survey at: • http://www.wrap.org.uk/downloads/GlassMrktSitRpt_final.015df503.pdf
Disposal	Landfill	Post-consumer flat glass is regularly sent to inert landfill. As reported in the WRAP document "Research into waste glass, window and door frames from the demolition and replacement window industries" which can be found at: • http://www.wrap.org.uk/downloads/ResearchIntoWasteGlassWindowAndDoorFrames.3a633860.pdf

7.3 Plasterboard

Decontamination		Plasterboard is very difficult to decontaminate except by removal of the outer paper layer
Recycling	General	'Recycle Now' publishes advice on recycling of plasterboard on their website at • :http://www.recyclenow.com/what_more_can_i_do/can_it_be_recycled/plasterboard_6.html **Further information:** At present there is no definitive UK guidance for fully developed techniques for recycling of plasterboard. However there are recycling research and trials being carried out for products for the use of gypsum in construction agriculture and other industries and further information can be found at: • http://www.wrap.org.uk/construction/plasterboard/plasterboard_1.html
	As road bases	Research is currently being carried out to use recycled plasterboard in road bases, sub-bases and stabilised sub-grades by developing novel cementitious mixes using plasterboard and gypsum waste **Further information:** • http://www.coventry.ac.uk/researchnet/d/304/a/1221 • www.skanska.co.uk
	As a soil stabiliser or soil conditioner	Research is currently being carried out to use recycled plasterboard as a soil stabiliser for the construction and maintenance of slopes by the Sports Turf Research institute as reported on their website at: • http://www.stri.co.uk/23.asp Research is currently being carried out to use recycled plasterboard as a soil conditioner on commercial arable farms to improve soil structure. This is the Waste and Resources Action Plan (WRAP) *Project ORG0033-017* at: • http://www.velcourt.co.uk/research_dev/arable/environmental_project2.html
	In blocks and bricks	Research is currently being carried out to use recycled plasterboard in the manufacture of blocks and bricks to prove if recycled plasterboard can be used as part of a commercially and technically viable building product **Further information:** Use of recycled material is described by a supply company 'Akritos on their website at • www.akristos.com Recycling of Plasterboard in Scotland • http://www.royhatfield.com/recycling/news-article.asp?link=98

	Mould manufacture	Research is currently being carried out to use recycled plasterboard as mould material for ceramics and metal casting.
	Reprocessing into gypsum	New West Gypsum Recycling in Canada have developed and patented a process which accepts both wet and dry plasterboard waste from a range of different sources and recovers the gypsum core. There is a case study on this on the WRAP website at: • http://www.wrap.org.uk/downloads/Case_study_-_Plasterboard_recycling_in_Canada.b85d8d55.pdf
Disposal	Landfill	'Recycle Now', a website report that almost all of this waste goes to landfill. • http://www.recyclenow.com/what_more_can_i_do/can_it_be_recycled/plasterboard_6.html The Environment Agency guidance (Guidance for waste destined for disposal in landfills Version 2 June 2006)states that wastes with up to 10% sulphate content can be co-disposed with other biodegradable municipal wastes. This has hindered the development of recovery techniques and markets as it effectively permits continued mixed landfill disposal of the majority of plasterboard wastes. The EA guidance can be found at : • http://www.environment-agency.gov.uk/commondata/acrobat/wacv2_1006008.pdf

APPENDIX A. PRE-TREATMENT OPTIONS

Table 1 Mixed wastes (including segregated hard demolition wastes, excavation wastes and soils)

Washing.	Aggregates may need to be washed to rid them of clay and fines to improve the efficiency of any subsequent recycling.
Crushing.	Crushing can be carried out using mobile or fixed plant, both techniques involves a stationary steel jaw and a moving jaw which is used to crush and pulverise material. Cone crushers may also be used which use the same principle of a stationary and moving parts, but using cones rather than jaws as the pulverising implement
Screening.	Conveyor belts using meshes for sorting grains into grades can also be used. The belts vibrate and feed the material along steel meshes graded to capture grains of a specified diameter
Magnetic separation.	Magnets are used to remove ferrous materials from feedstock being fed into a recycling plant. Varieties of magnets include drum magnets, heavy-duty electromagnetic drums (for separation of ferrous materials from non-ferrous materials, permanent magnetic drums (for the separation of fine irons), and conveyor end roller magnets. The purpose of magnets is to avoid damage to the plant, recovery of valuable material and improvement of the quality of end product.
Separation.	Separation of materials prior to crushing is crucial to the range of applications for which material can be used. Crushing mixed material reduces the quality of the end product. All sites must be inspected prior to demolition for contaminants such as asbestos. Certain wastes such as asbestos must be removed to authorised sites for appropriate disposal.

Table 2 Metal

Cutting/ Shearing	Equipment such as hydraulic shears, hydraulic cleavers, shear/baling presses and gas and plasma cutters are commonly used
Separation	Techniques such as magnetic and cyclone systems and eddy current separation (ECS) are commonly used
Shredding	Equipment such as shredders and fragmentisers are commonly used
Baling	Equipment such as baling presses and hydraulic balers are commonly used

Table 3 Glass

Sorting, washing and crushing	Cullet reprocessors sort recovered glass:- i.e. colour separation for glass destined for remelting at container plants, wash glass to remove unwanted materials and crush glass to the desired size

APPENDIX B. BIBLOGRAPHY

General references are listed here. Further detailed references are set out at the end of each Section

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