Developing the case for enhanced landfill mining in the UK

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www.cranfield.ac.uk
Enhanced landfill mining in the UK

• Background- UK landfill legacy and concept of ELFM

• Recent sampling work and experimental data

• Risks associated with landfill mining and remediation

• ELFM in Europe and the UK- the next steps
Landfills in UK

Substantial resource for future exploitation

- Over 20,000 legacy and current landfills in the UK
- Licences required from 1974 under the Control of Pollution Act
- Over 4,000 licensed sites, most of which are now closed
- Currently over 40 million tonnes of waste from all sources is deposited in UK landfills each year
Firstly, what is enhanced landfill mining??

Landfill mining:

'a process for extracting materials or other solid natural resources from waste materials that previously have been disposed of by burying them in the ground'

(Krook at al. 2012)

Enhanced landfill mining [ELFM]:

'the safe conditioning, excavation and integrated valorisation of (historic and/or future) landfilled waste streams as both materials (Waste-to-Material, WtM) and energy (Waste-to-Energy, WtE), using innovative transformation technologies and respecting the most stringent social and ecological criteria.'

(Jones et al. 2013)
'Landfill mining' is limited to:

- Capturing of methane for energy purposes
- Recovery of some materials through physical excavation
- Excavation for reclamation of land (i.e. remediation)

ELFM goes further and aims to elicit higher recovery rates and value:

- In-situ and ex-situ recovery
- Waste to materials and energy using innovative and state-of-the-art technology
- Reclamation of land
Enhanced landfill mining in the circular economy

Need to consider the whole picture

➢ Waste-to-Energy
➢ Waste-to-Material
➢ Chemical feedstock
➢ Land restoration/reclamation

Integration of landfill mining in the circular economy
Modified from Ellen Macarthur Foundation system diagram
Resource or a fuel?

A simplistic overview of ex-situ mining

Materials excavated

- Paper, plastics, textiles etc
- Reprocessing/recycling?
- Waste-derived fuel
- Back into site?
- Value from metals

Soil/fines
Recent Cranfield sampling

Multiple projects and objectives

• 7x sites sampled for composition, metals content of soil/fines, residual biogas testing and leachate characterisation
• 2x site for composition, metals and viability as refuse-derived fuel

For further details on sites 1-7, please see:

• Frank, R.R., Cipullo, S., García, J. Davies, S., Wagland, S.T., Villa, R., Trois, C., Coulon, F. Compositional and physicochemical changes in waste materials and biogas production across 7 landfill sites in UK. Waste Management. 63 (2017), 11-17
Lots of data accumulated

Site 8 - 1x core drill, but split into 22 samples (at 1 metre intervals)
## Results from sites 1-4

<table>
<thead>
<tr>
<th>Metal</th>
<th>Site A</th>
<th>Site B</th>
<th>Site C</th>
<th>Site D</th>
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<tr>
<td>Cu</td>
<td>1,076</td>
<td>1,027</td>
<td>2,595</td>
<td>1,830</td>
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<tr>
<td>Ag</td>
<td>2.26</td>
<td>2.77</td>
<td>3.63</td>
<td>5.02</td>
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<tr>
<td>Au</td>
<td>0.18</td>
<td>0.13</td>
<td>0.16</td>
<td>0.05</td>
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<tr>
<td>Al</td>
<td>17,274</td>
<td>12,357</td>
<td>12,594</td>
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## Sites 8 and 9 (all in ppm)

### HEAVY METALS

<table>
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<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Pb</th>
<th>Zn</th>
<th>Sn</th>
<th>As</th>
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<tbody>
<tr>
<td>Paper</td>
<td>0.51</td>
<td>1,056</td>
<td>94.10</td>
<td>215.55</td>
<td>18.44</td>
<td>2.97</td>
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<td>Wood</td>
<td>0.77</td>
<td>2,435</td>
<td>175.91</td>
<td>325.32</td>
<td>18.88</td>
<td>6.59</td>
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<tr>
<td>Fines</td>
<td>1.11</td>
<td>834</td>
<td>303.73</td>
<td>565.66</td>
<td>30.83</td>
<td>4.81</td>
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<tr>
<td>Film Plastics</td>
<td>1.27</td>
<td>1,187</td>
<td>293.97</td>
<td>519.89</td>
<td>18.98</td>
<td>3.00</td>
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<tr>
<td>Dense Plastics</td>
<td>1.48</td>
<td>59.14</td>
<td>529.09</td>
<td>1,652</td>
<td>104.96</td>
<td>5.13</td>
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<tr>
<td>Textiles</td>
<td>1.69</td>
<td>1,866</td>
<td>567.91</td>
<td>650.75</td>
<td>35.47</td>
<td>6.23</td>
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### Cu, Ag, Li, Sb, Co, Al

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Ag</th>
<th>Li</th>
<th>Sb</th>
<th>Co</th>
<th>Al</th>
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### LREEs

<table>
<thead>
<tr>
<th></th>
<th>La</th>
<th>Ce</th>
<th>Pr</th>
<th>Nd</th>
<th>Sm</th>
</tr>
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<tbody>
<tr>
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<td>8.84</td>
<td>1.00</td>
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<tr>
<td>Wood</td>
<td>3.97</td>
<td>9.00</td>
<td>0.99</td>
<td>3.76</td>
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<tr>
<td>Fines</td>
<td>10.07</td>
<td>21.25</td>
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<td>9.22</td>
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<td>4.09</td>
<td>9.08</td>
<td>1.00</td>
<td>4.07</td>
<td>0.72</td>
</tr>
<tr>
<td>Dense Plastics</td>
<td>7.15</td>
<td>15.92</td>
<td>1.78</td>
<td>6.75</td>
<td>1.24</td>
</tr>
<tr>
<td>Textiles</td>
<td>8.78</td>
<td>20.52</td>
<td>2.26</td>
<td>8.64</td>
<td>1.69</td>
</tr>
</tbody>
</table>

All elevated, Pb and Cr are a concern

Al and Cu suggest recovery opportunities

Too low to justify focused recovery
Combustible fraction as a fuel (site 8)

Average moisture content of combustibles: **29.3 %** (12.7-38.5)
Average Gross Calorific Value: **12.9 MJ/kg** (ar)
Average Net Calorific Value: **11.0 MJ/kg** (ar)
Plastics

- Plastics represent around 20-30% by weight of excavated landfill material

- Understanding degradation and contamination

Fresh PP

5 m

6-8 m

39 m
Degradation of excavated polyethylene and polypropylene waste from landfill

Luisa Canopoli, Frédéric Coulon, Stuart T. Wagland *

School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK

HIGHLIGHTS

- CI excavated PP samples >10 years was almost 2 times higher than newer PP.
- CH₂ and CH₃ of samples >10 years were statistically lower than the newer samples.
- Crystallinity of PP and PE >10 years was 1.3 times higher than fresh materials.
- Production of chemical base compounds through excavated plastics pyrolysis
- Chemical base compounds potential revenue is $402–805 million.

GRAPHICAL ABSTRACT

- Closing the loop
- Recycle
- Use
- Make
- Enhanced Landfill Mining
- Excavated Plastic

SMART GROUND example outputs

SMART GROUND aimed to foster resource recovery in landfills by improving the availability and accessibility of data and information on Secondary Raw Materials (SRM) in the EU.

This research has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No 641988.
Processing of excavated materials
Processing of excavated materials

Image courtesy of Vertase FLI
Major risks involved at every step

The site

- Poses a long-term risk to the environment and water sources
- In many cases, records are limited

Abandoned landfills polluting UK rivers, research finds

More than 27 tonnes of ammonium leaches from an Oxford wetland into the River Thames every year, reports the Natural Environment Research Council

Researchers take a sample of water from River Thames at Oxford for analysis. Photograph: Dr Daren Goody/NERC

Abandoned landfill sites throughout the UK routinely leach polluting chemicals into rivers, say scientists.

At Port Meadow, on the outskirts of Oxford, about 27.5 tonnes of ammonium a year find way from landfill into the River Thames. The researchers say it could be happening at thousands of sites around the UK.
Major risks involved at every step

The site

In-situ recovery

- Gas extraction and combustion
- Treatment of leachate
- Potential for metal recovery
Major risks involved at every step

The site

In-situ recovery

Excavation

- Exposure to air
- Release of gases and airborne compounds
- Risk of asbestos fibres
- Exposure to site workers and those in the vicinity

Processing of excavated material

Remediation of site

Exposure to air

Release of gases and airborne compounds

Risk of asbestos fibres

Exposure to site workers and those in the vicinity
Major risks involved at every step

**The site**

- In-situ recovery
- Excavation
- Processing of excavated material
- Remediation of site

*Risks over and above standard waste processing:*
- Soil is a significant component and contains heavy metals
- Potential for asbestos fibres
- Plastics, metals, wood etc are heavily soiled
Major risks involved at every step

The site
- In-situ recovery
- Excavation
- Remediation of site
  - Restoration of land for development

Excavated material

*Image credit: Vertase FLI*
Rising interest in enhanced landfill mining [ELFM]

EU-wide agenda

- European Enhanced Landfill Mining Consortium [EURELCO] established (~60 members);

- Recent EU projects funded in recognition of the importance of this topic:
  - SMART GROUND
  - NEW MINE
  - COCOON
  - RAW FILL

Demonstrable growth in ELFM activity at EU-level

- **EURELCO** formed 2014
- **NEW-MINE** 2016-20 €3.8 million
- **RAWFILL** 2017-20 €2.3 million
- **COCOON** 2017-21 €1.4 million
- **SMART GROUND** 2015-18 €2.5 million
- **REGENERATIS** 2019-23 €4.3 million

Over €14 m funding secured
Interest is growing in the UK too

Europe’s half a million landfill sites potentially worth a fortune

Waste can now be mined for metals and to create fuel
Developing the UK framework

Launch of a new UK ELFM network earlier this year

UK Enhanced Landfill Mining Network

https://elfm-network.co.uk/

Bringing together sector experts to develop an active and engaged community through which a multidisciplinary vision and research agenda associated with enhanced landfill mining will be developed.

The UK ELFM network will lead the UK’s innovation and accelerate knowledge transfer across the sector.
Summary

- Landfill remediation is vital for pollution prevention and for redevelopment of sites for housing
- ELFM provides a mode of recovering valuable resources and will make a significant contribution to the UK circular economy and resource management needs
- Significant challenges to overcome - technology, regulation, H&S, financial

Contact

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Interested in joining?
contact@elfm-network.co.uk