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WORKING FOR A HEALTHIER FUTURE

Department for Environment Food & Rural Affairs

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NANoREG

A common European approach to the regulatory testing of nanomaterials

NANoREG Value Chain Case Study:

Use of carbon-based nanomaterials in electronic goods (with special emphasis on batteries and end-of-life)

Bryony Ross, Araceli Sanchez, Sheona Read, Simon Clavaguera, Cécile Philippot, Veronika Hase & Martie van Tongeren

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Aim & Approach

Aim: *Identify the likelihood of release of carbonaceous MNMs along the life cycle of these materials in batteries, with particular focus on end of life, and identify / collate available information for risk profiling.*

1. • Literature review on MNMs in electronic waste
   • Particular focus (but not exclusively) on batteries containing carbon-based MNMs, and end-of-life processing.
2. • Identified and contacted companies involved in the production of electronics containing MNMs and in the collection and handling of electronic waste (majority UK)
   • Visit companies handling batteries at end-of-life
3. • Identify critical exposure scenarios for human and environmental risk
4. • Undertake series of exposure measurement experiments to investigate shredding, handling and incineration
   • Contribute to exposure scenario development

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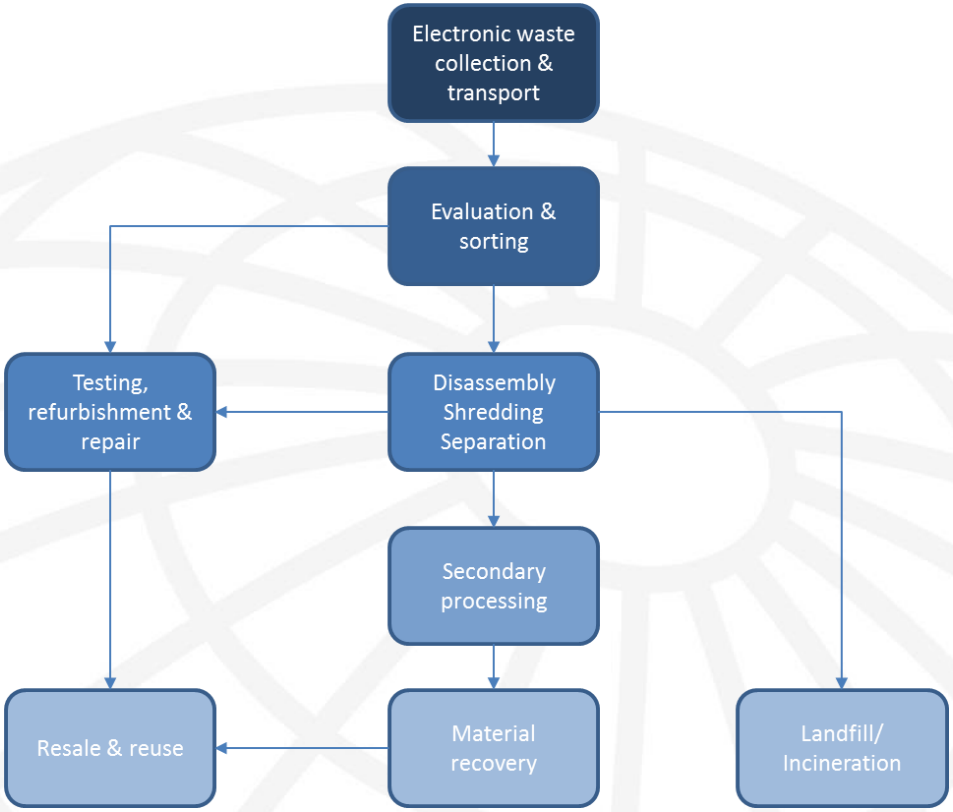
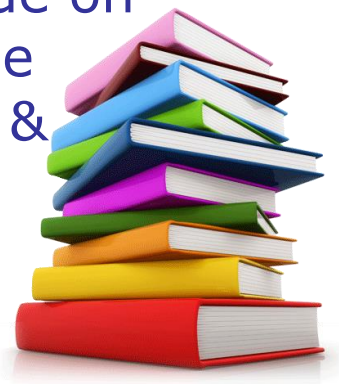
Literature Review

- Information in general is still scarce
- Based on available resources, key areas of end-of-life management were identified:



- For each of these, general scenarios where there may be potential for release of nano-objects was outlined and supporting evidence to date referenced
- Formed a guide on which to shape scoping visits & interviews



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Company Inventory and Questionnaire

- A number of companies were contacted:
  - 81 manufacturers of electronic components/devices,
  - 81 WEEE management/processing companies,
  - 15 key contacts in the area of NM manufacture (sourced from the NANoREG consortium)

Key findings:

- Limited responses mean outcomes can not be considered representative of the industry as a whole.
- A range of MNMs are being used in production of electronic components & devices
  - *Electronics manufacturers seem to be aware of the need for health and safety measures where NMs are used*
- In contrast, awareness of potential presence of MNMs in waste electronic components/devices handled by WEEE organisations is lacking
  - *Notable that one WEEE company requested further assistance and information on how to identify whether there were MNMs present in products they receive to process.*

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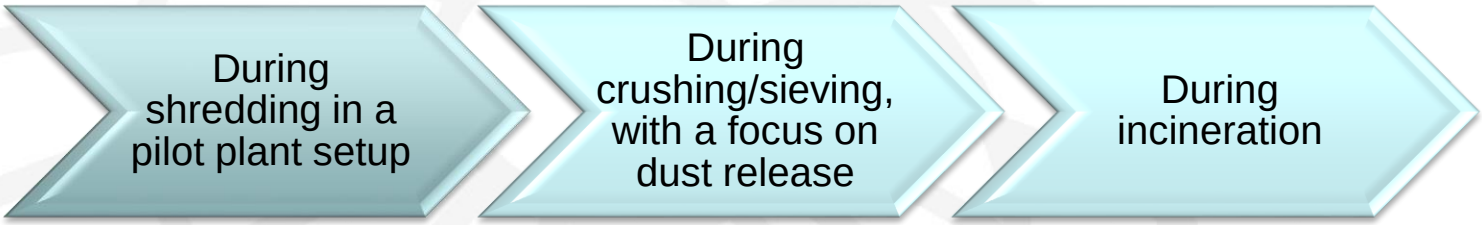
Site visits & development of exposure experiments

- Liaison undertaken with 5 industrial partners
- Crushed battery electrode material with and without MNM sourced for analysis from French industrial contacts.
  - MNM- Traditional Graphite coated on Copper
  - MNM+ Super P (CB) and VGCF (MWCNT) coated on Aluminium
- A series of experiments were designed to investigate release of MNM:

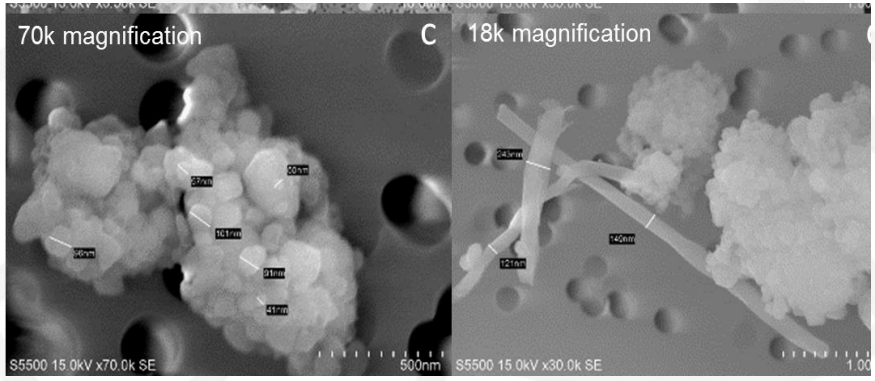


- The three experimental setups contributed to development of a comprehensive Value Chain for MNM in batteries, with a detailed focus on end-of-life

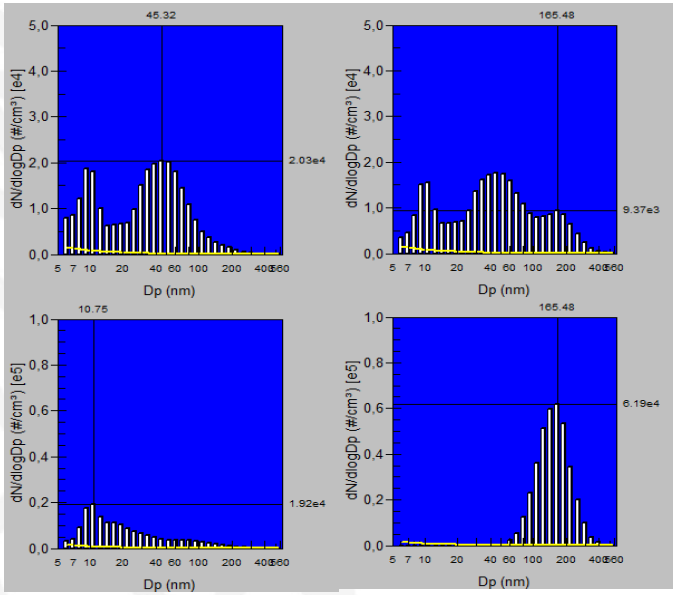
Shredding Experiment

- Airborne measurements during shredding of battery electrodes in a pilot plant

	MNM-	MNM+
CPC	No significant rise from background	Significant rise during shredding and pouring
FMPS	PSD mean 165nm	PSD = 143-165nm
SEM: conclusions on composition	Sub-micron and micron particles	Micron and nanoparticles, inc. sub-micronic fibres



- No major change in PSD or total NP concentration
- Main difference is presence of fibres (unquantified)

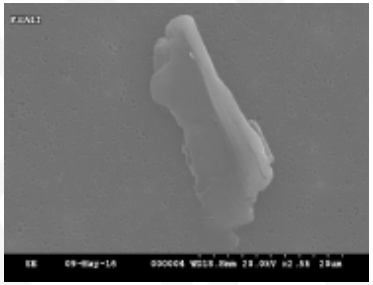


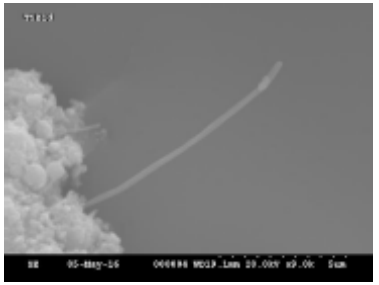
Dustiness Testing

- Commercial aerosoliser from Naneum used to aerosolise respirable fraction for analysis.
- Range of instruments used to characterise (inc. FMPS, Dust Trak, APS, CPC), followed by SEM to examine constitution.

	MNM-	MNM+
Mass Analysis	80% of sample <2800µm	58.1% of sample <2800µm
Laser Analysis	Bi-modal peaks @ 300 & 30µm	Bi-modal peaks @ 300 & 2000µm
SWeRF (by number)	6.9% in sub-2800µm fraction	12.2% in sub-2800µm fraction
SEM: conclusions on composition	Carbon flakes, particles and platelets, 5-30µm	Agglomerates of electrode coating and CNTs Free CNTs ~10µm

- MNM- has higher proportion or particle mass sub-2800µm
- MNM+ has higher respirable fraction value based on analysis from number-rated distribution (consistent with APS & Dust-Trak characterisation.)





Incineration Experiment

- Examined release of MNM during incineration via NanoScan SMPS, and analysed the composition of the released material via SEM.

	MNM-	MNM+
Temperature range for release	200℃+ (highest @ 250-900℃)	200℃+ (highest @ 650-990℃)
Predominant size (SMPS)	11-50nm	11-30nm
SEM: notes on composition	Almost complete combustion of C in electrode	Al NPs and MWCNT released

- Higher concentration of NP with small diameter released from MNM+ samples
- Implications for thermal processing of electronic goods
- Potential accumulation in fly or bottom ash of incinerators, and subsequent handling or transport.

Conclusions & Future Directions

- Release of free and bound CNT shown for three key points of end-of-life processing: shredding, dustiness and incineration.
- CNT carries known hazard
- Data collected contributes to developing a risk profile for waste electrical handling

- Next Steps:
  - How to identify electronic goods containing MNM? Major IP issues
  - Repeat experiments at plant scale using Batteries rather than electrodes for clearer picture
  - Consider raising awareness and effective exposure management for those working in close proximity to these activities