

Enabling the recycling of technology critical elements from e-waste through metrology

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MetroCycleEU



Metrology for the Recycling of Technology Critical Elements
to Support Europe's Circular Economy Agenda

Introduction

- Technology Critical Elements (TCEs) are **essential** for use in smart phones, laptops, energy efficient lighting, electric vehicles (EV) and wind turbines
- These '**unusual**' elements such as **gallium**, **indium** and **neodymium**, along with precious metals such as **gold**, **rhodium** and **platinum**
- They have **unique properties**, making them difficult to replace with alternatives
- Due to their **low natural abundance**, **limitations/interruptions** to supplies and **high demand**, the UK and Europe primarily rely upon imports of TCEs
- In 2022, **5 Mt of e-waste** was scrapped in the **EU** and **62 Mt globally** (~50% estimated to be **metals**)
- Some elements are commonly recovered e.g. copper, but **TCEs are rarely recycled**
- To meet **future energy and technology needs**, a clear mechanism to improve the **recovery of TCEs** from recycling waste electronic goods is required



- This actively supports **resource security** and **sustainability** which is needed to achieve the objectives of the **European Circular Economy Agenda**¹ and the **UN Sustainable Development Goals 7, 11 and 12**



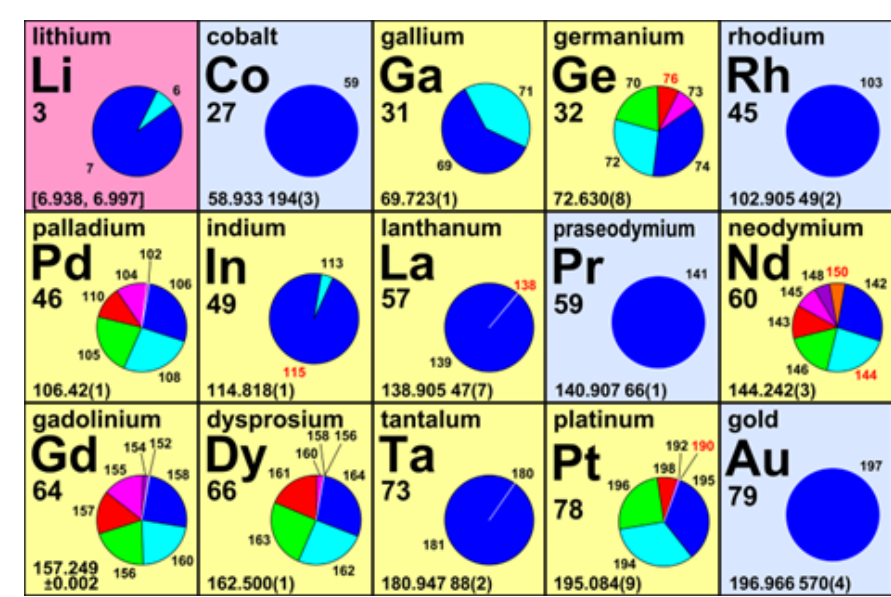
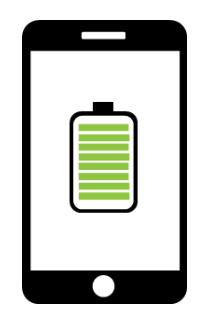
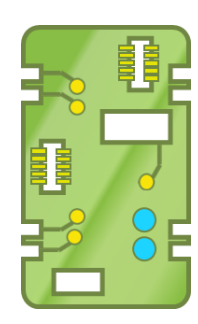
The Challenge

- Electronic waste is **highly complex**, containing metal, glass, plastics, ceramics, etc., and incredibly **heterogeneous across tonnes**
- The recycling industry needs fast, reliable sampling strategies and analytical methods to **develop recycling processes for TCEs** and assess economic value
- However, there is a lack of validated analytical methods and suitable reference materials for TCEs in e-waste. Therefore, a **metrological framework** is required to ensure **SI traceability**, **standardisation** and **validation** of routine techniques.

The Project

- The EMPIR project **MetroCycleEU**³ brought together the metrology community with industry (mining, waste recycling, analytical services, instrument manufacturers), academia and research institutes.
- The aim was to develop **SI traceable measurements of 15 TCEs in real e-waste** materials at mg/kg levels to improve the efficiency and accuracy of TCE recycling

- Printed circuit boards (PCBs)
- Light emitting diodes (LEDs)
- Lithium-ion batteries (LiBs)

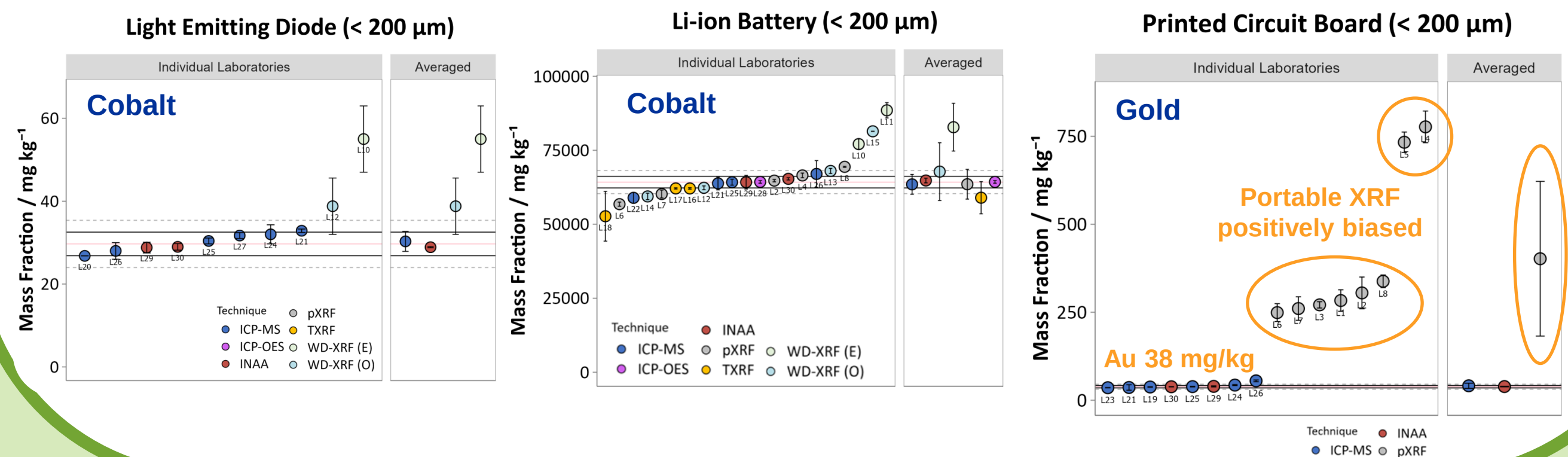


Analytical Method Development

- Sample preparation of these complex materials is challenging
 - Direct analysis, Pelletisation, Ashing, Acid digestion, Alkali fusion
- Lack of appropriate reference materials for validation
- Multiple measurement techniques used by industry including portable devices
 - XRF (portable, WD, ED, T), ICP-MS, ICP-OES, AAS
- TCEs are rarely analysed therefore metrology institutes need to develop SI traceable methods with uncertainty budgets
 - Isotope dilution mass spectrometry, Standard addition calibration, INAA
- A comprehensive evaluation of techniques was performed using PCB, LED and LiB, comparing **30 data sets** with different conditions and methods⁵
- Good results and some challenges were identified!**

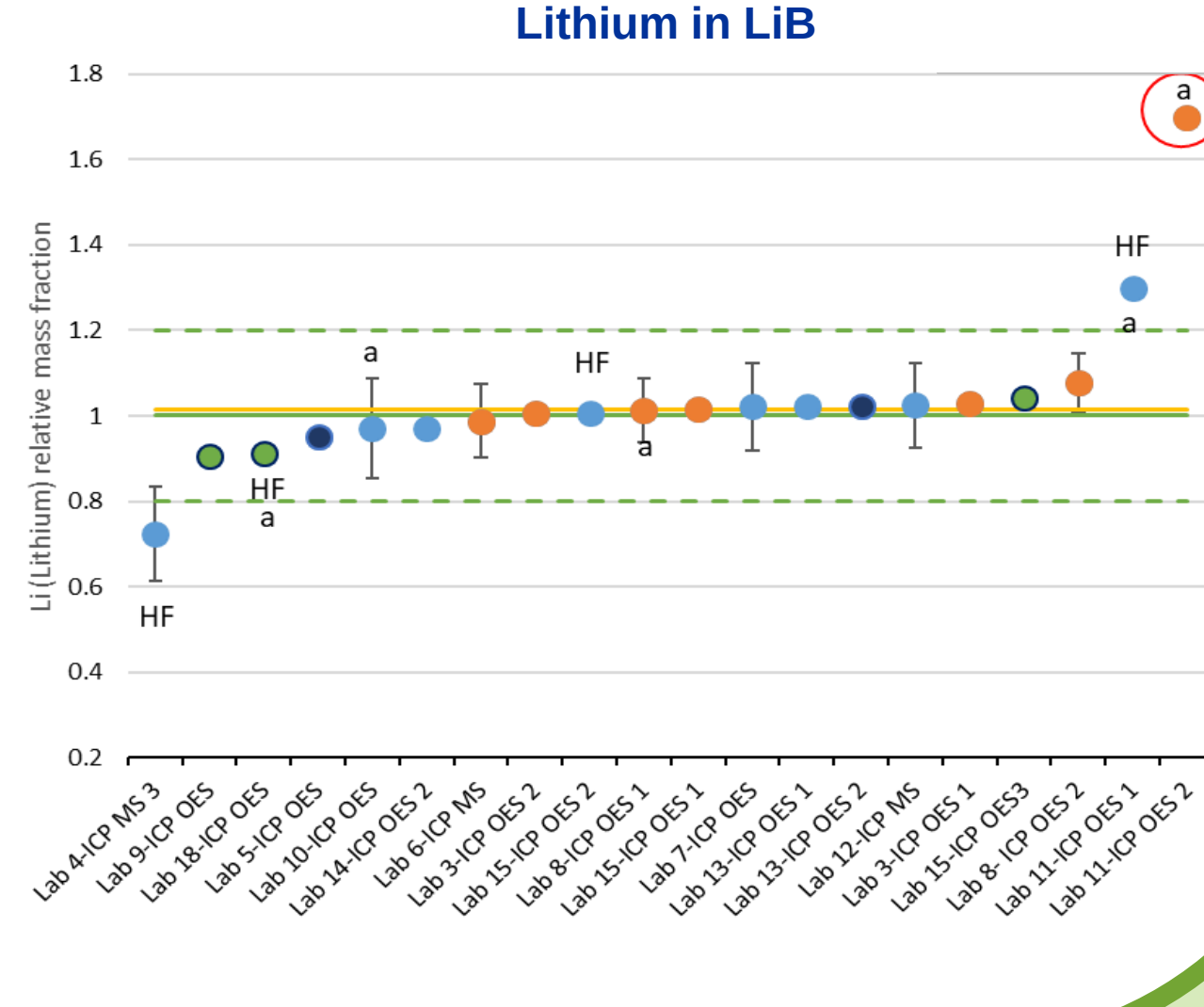
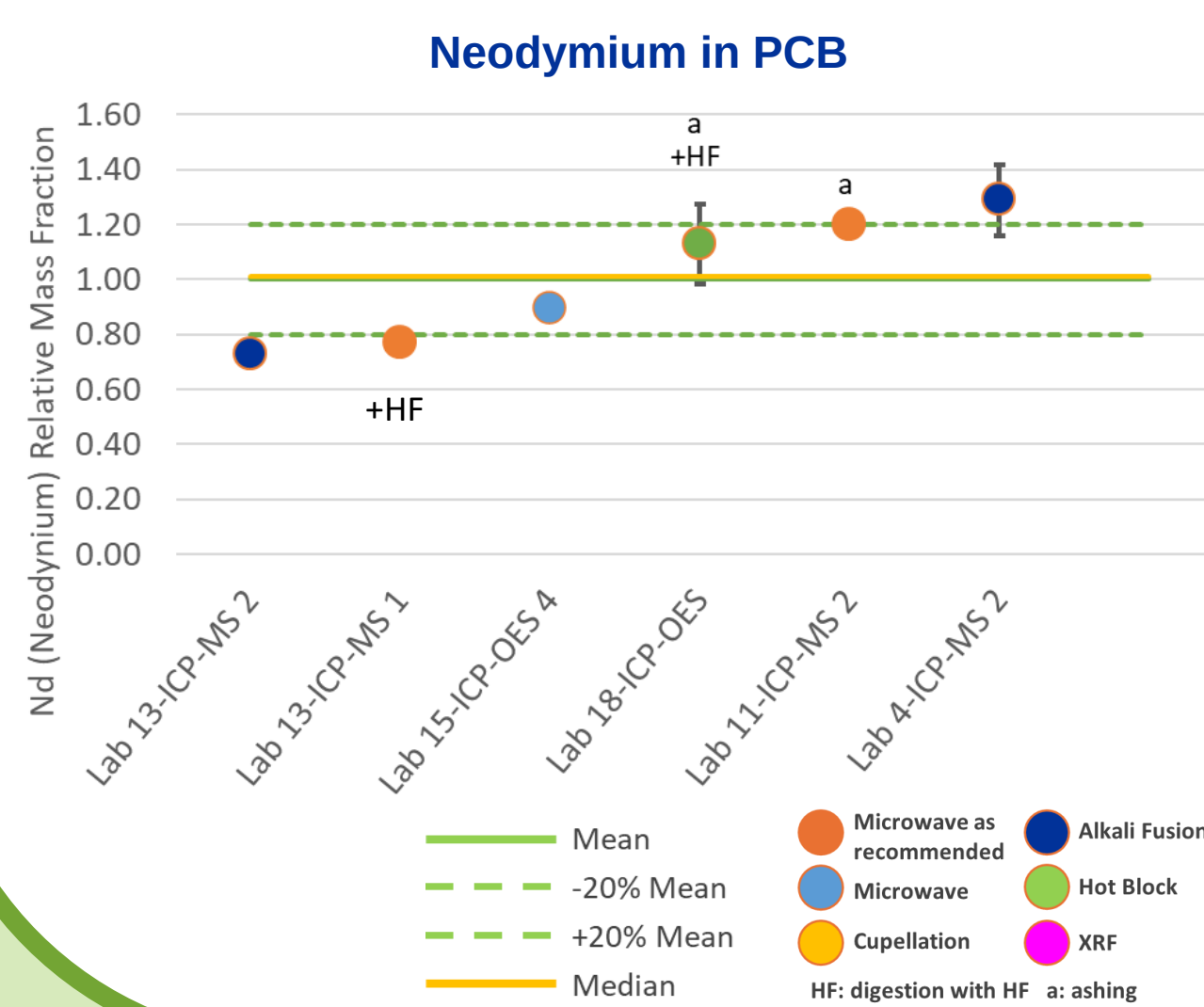
Cobalt in LED and LiB showed good agreement between various techniques over 3 orders of magnitude

Gold in PCB Portable XRF: Au too low to detect and potential interferences from Zn & Br in the matrix causing spectral overlap



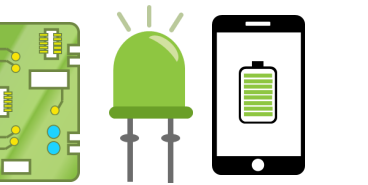
Industry

- An **Industry survey** performed to understand current issues and instrumentation
- A **Best Practice Guide**³ was produced for TCE analysis and uncertainty calculations for e-waste using knowledge gained from the development activities
- A free **Toolbox App** was created in Excel to assist labs with **measurement uncertainty calculations** (available online⁶)
- An **interlaboratory comparison** was organised with PCB and LiB for experienced industry services labs, instrument manufacturers, academic and research institutes
 - Excellent agreement ($\pm 20\%$ of consensus mean) was found for majority of elements. Although potential outliers may be present, in general no major trends were identified



Impact

- The project overcame many challenges related to the material preparation, sample preparation and analysis to further knowledge in this important field
- Successfully produced **three real e-waste reference materials**
- Provided support and knowledge transfer through:
 - stakeholder **workshops**
 - online **training modules**
 - international **presentations**
 - **guidance documents**
 - peer reviewed **publications**³
 - **calculation tools**
- The **interlaboratory comparison** demonstrated impact of the advice and guidance for TCE analysis in real e-waste materials
- Together, this project provided **valuable data** and **resources** to support the recycling industry to **improve data reliability** ensuring optimal recycling methods are selected for **maximum recovery of TCEs from e-waste**



Future Directions

- Much more work is needed, particularly in the clean energy area e.g.
 - New battery material development, life cycle considerations
 - End of life e-vehicles, solar panels, wind turbines
 - Environmental contamination and bioavailability



[1] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en [2] <https://sdgs.un.org/goals> [3] <https://www.metrocycle.eu/>
[4] MetroCycleEU Sampling Strategy Calculation Tool [5] <https://doi.org/10.1016/j.wasman.2024.10.015> [6] MetroCycleEU Toolbox App