



Comparison of Dissolution Methods for ICP-OES Analysis of PGMs from Printed Circuit Boards

Dr. Andile Mkhohlakali

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Presentation Outline



- INTRODUCTION AND BACKGROUND
- BIBLIOMETRIC ANALYSIS
- EXPERIMENTAL FRAMEWORK
- STUDY OBJECTIVES
- RESULTS AND DISCUSSION
- CONCLUSION
- ACKNOWLEDGEMENTS

Introduction and Background

Overview

- Growing global e-waste challenge: Generated in large volumes of electronic waste, with growing environmental risks.
- Waste-PCBs are composed of PGMs such as Au, Pd, Pt and base metals (Sn, Pb, Al).
- Recovery of PGMs supports the circular economy and suitability
- Preconcentration of PGMs due to their extremely low natural abundance and complex ore matrices

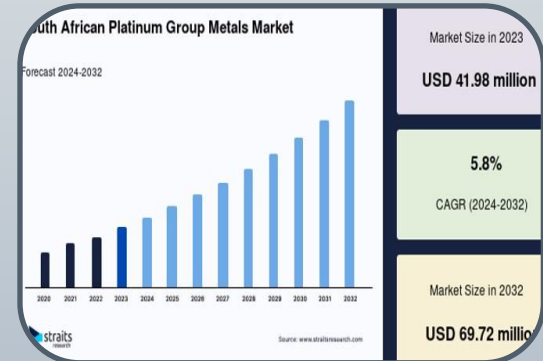
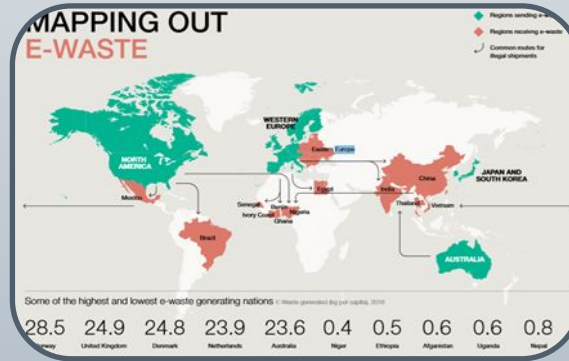


Fig. 1. Global mapping out of e-waste and PGMs market

Bibliometric Analysis

- **Data collection** : Scopus: 2001-2025, past 10years
- **Keywords search**: PGM_S, PCBs, Recycling
- **Outputs**: Keywords visualisation map, word cloud, leading countries
- **Top contributors**: Leading nations
- **Research gap**: Benchmarking

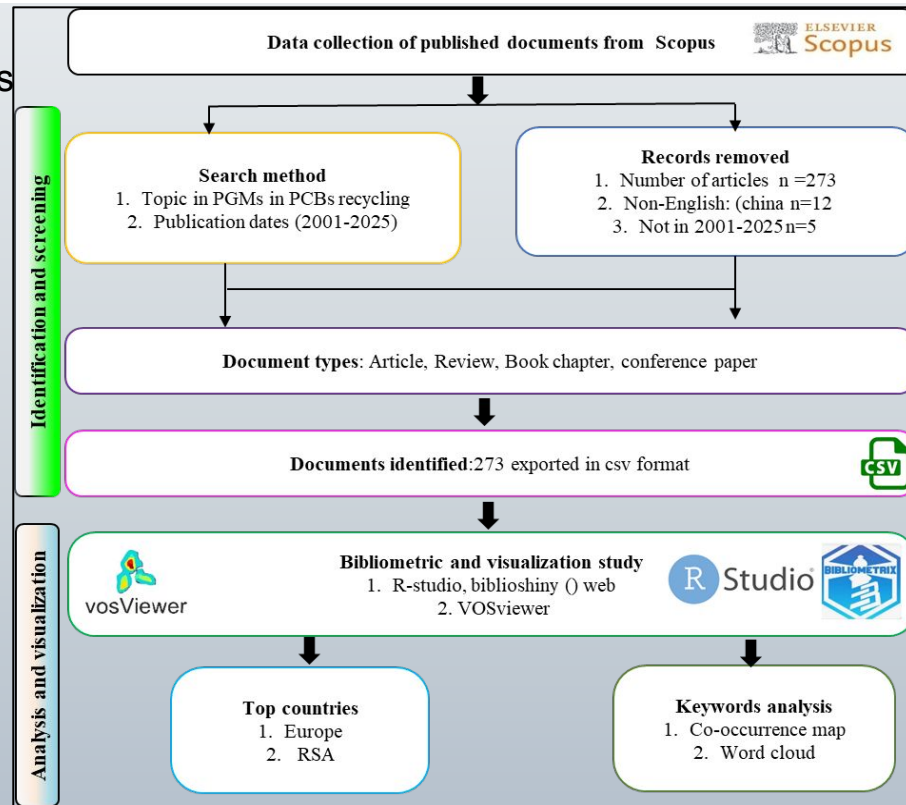


Fig. 2 Methodology Approach for Bibliometric Analysis

- [illegible]



- Explore the bulk PGMs analysis from waste PCBs.
- Compare dissolution efficiency and accuracy between fire assay and microwave-assisted digestion.
- Evaluate how milling or sample preparation affects recovery (i.e. delamination).
- Conduct a bibliometric analysis to map global research trends on PGMs in e-waste from 2001 to 2025.
- Identify research gaps in analytical methodologies (dissolution/preconcentration) for PGMs recovery determination

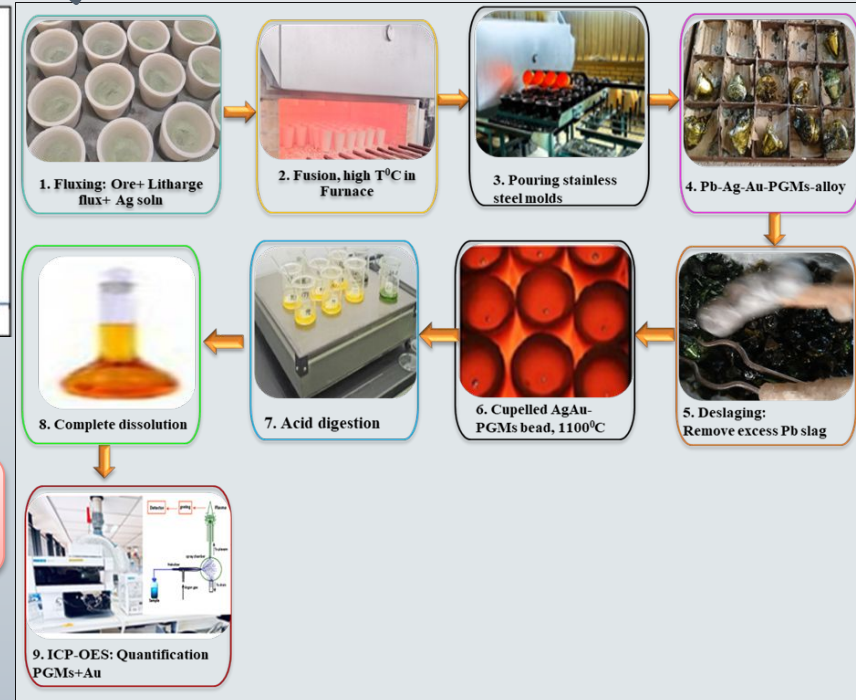
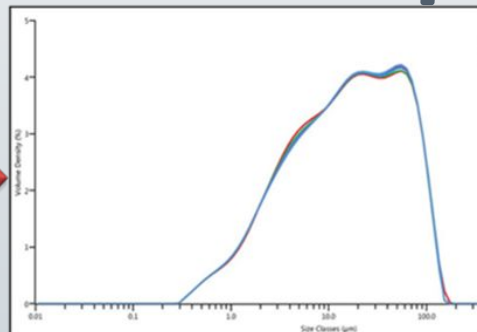
Materials And Reagents

Table 1. Reagents

Materials	Composition
Flux	Litharge, Flour, Silica, Sodium carbonate
Aqua regia	HCl:HNO ₃
Silica	SiO ₂
Silver solution	AgNO ₃
Hydrofluoric acid	HF
Hydrogen peroxide	H ₂ O ₂
Pots and molds	

Table 2. ICP-OES Operating Conditions

Parameters	Conditions
RF generator	1.20 kW
Plasma gas flow rate	Argon. 15 Lmin ⁻¹
Auxiliary gas flow rate	1.50 Lmin ⁻¹
Pump rate	15 rpm
Nebuliser flow rate	0.75 Lmin ⁻¹
Rinse time	120 s
Sample uptake rate	0.8 mLmin ⁻¹
Replicate measurement	3



Equation 1-2 Oxidation of Pb During Copulation and Removal of Ag (i.e. Parting)

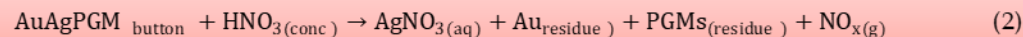
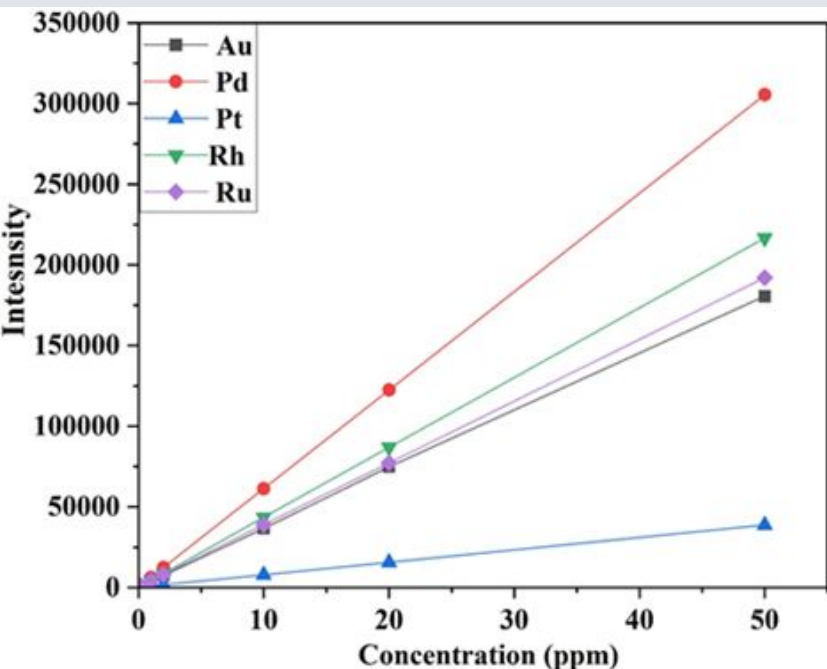


Fig.4. Preparation Method and Detailed Steps Involved in the Determination of PGMs by Fire Assay.

Table 3. Comparative Results Of MW Digestion And Fire Assay Process



	Fire assay method		
Sample ID	Au (ppm)	Pd (ppm)	Pt (ppm)
PCB-1	134.43	74.78	0.264
PCB-1	127.08	68.83	0.246
RSD%	4	6	5
PCB-2	169.19	2.75	0.182
PCB-2	135.81	1.41	0.176
RSD%	15	46	2
	Microwave-assisted digestion		
PCB-1	117	59.5	0.233
PCB-1	132	75	0.609
RSD%	9	17	63
PCB-2	69.0	0.446	0.155
PCB-2	26.8	0.506	0.505
RSD%			

Fig. 5. Linear Curve Indicating Of Selected Pge+au (Pd 340.458nm And Pt 299.296 Nm +Au) Calibration.

Table 5. XRD Analysis and Elemental Composition of PCB Metallic Phase

2 θ (°)	Mineral phase	Assignment and Relative composition
40, 50, 74	Cu metallic of crystalline structure	Major :39%
30-35	Sn, Sn-Cu	Intermediate:27% 13%
15-25	Silica, epoxy resin	Amorphous
-	Pb and Al	Traces

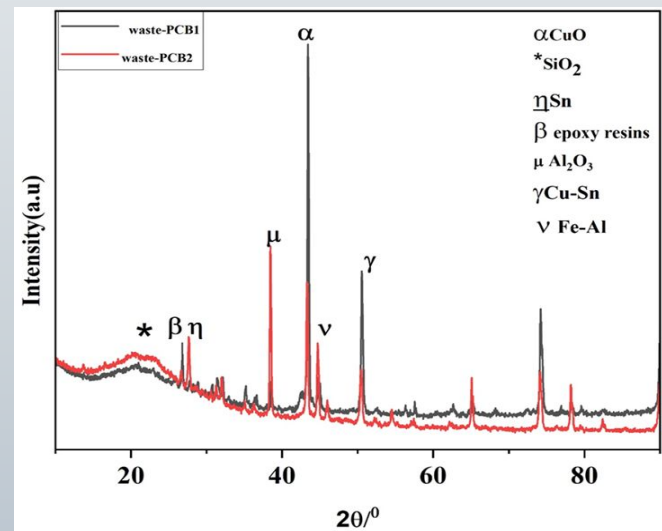
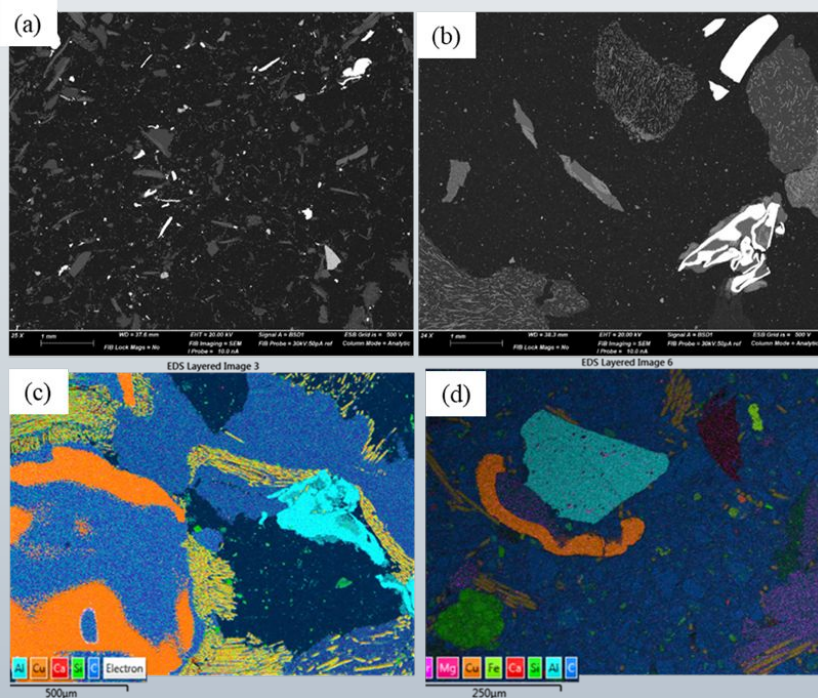


Fig. 6. XRD pattern of PCB1 and PCB2



- In Fig. 7, both SEM images display glassy fibre materials due to the substrate, delaminated Cu, Si, Sn, Al traces, and clearly visible fractured epoxy resins
- The microstructure, with disjointed morphology, indicates recycling challenges as it appears that different fractures are bonded tightly.
- However, SEM characterisation and the presence of Cu, Si, Sn, confirmed by EDX mapping (Fig. 7 (c-d), suggest an opportunity for recycling
- The elemental distribution of Cu, Al, Fe, alongside Si and calcium, confirms the coexistence of glass fibre-reinforced epoxy resins and metallic traces.
- Fig. 7(d) exhibits the complexity of metrics where Cu is embedded with areas that are rich in Al, Mg, which is the nature of PCB's composition.

Fig. 7. SEM Micrographs Of Waste-printed Circuit Board (A) Crushed And Milled And (B) Crushed Only, And (C-d) Their Corresponding EDX Results.

Conclusion and Recommendation

- Fire assay exhibited higher PGMs recovery
- Microwave illustrated faster and greener digestion, although it requires optimisation
- Milling and pulverisation improved the reproducibility
- The heterogeneous nature of waste PCBs is confirmed by SEM-ED, XRD and ICP-OES
- Bibliometric analysis confirms the lack of analytical Benchmarking
- The study supports the circular economy objectives

Recommendation

- Develop and validate the method for PGM analysis from PCBs
- RM production and certification for waste PCBs metrics

- ❑ Mintek
 - Analytical Chemistry Division leadership

- ❑ Southern African Institute of Mining And Metallurgy (SAIMM)



200 Malibongwe Drive
Randburg
South Africa

Tel: +27 11 709 4111

www.mintek.co.za



MINTEK

Private Bag X3015
Randburg
2125
South Africa



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