

Leaching rare earth elements from phosphors recovered from end-of-life fluorescent lamps



saam vorentoe · masiye phambili · forward together

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Introduction

- Production and usage of fluorescent lamps rapidly increased over the past decades
 - ✓ Consume 75% less energy
 - ✓ Longer life span
- Vast amounts discarded every year. 4 800 million lamps were scraped in 2011 (Zhang, 2012)
- Less than 1% of REE recycling in 2011 despite vast research (Binnemans and Jones, 2014).
- Fluorescent lighting relies mainly on six REEs: Y, La, Eu, Ce, Tb and Gd
- Most preferred method of recovering REEs from powders is hydrometallurgy.

Introduction

Fluorescent powder composition		
Phosphor type	Possible compounds	Typical quantity in tri-band lamps
Red	$\text{Y}_2\text{O}_3:\text{Eu}^{3+}$ (YOX)*	55% (contains mostly yttrium; 4-10% europium)
Blue	$\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$ (BAM) $(\text{Sr,Ca,Ba})_5(\text{PO}_4)_3\text{Cl}:\text{Eu}^{2+}$	10% (contains <5% europium)
Green	$\text{CeMgAl}_{10}\text{O}_{17}:\text{Tb}^{3+}$ $(\text{Ce,Tb})\text{MgAl}_{11}\text{O}_{19}$ (CAT) $(\text{Ce,Gd,Tb})\text{MgB}_5\text{O}_{10}$	35% (contains ~10% terbium)

Aim and Objectives

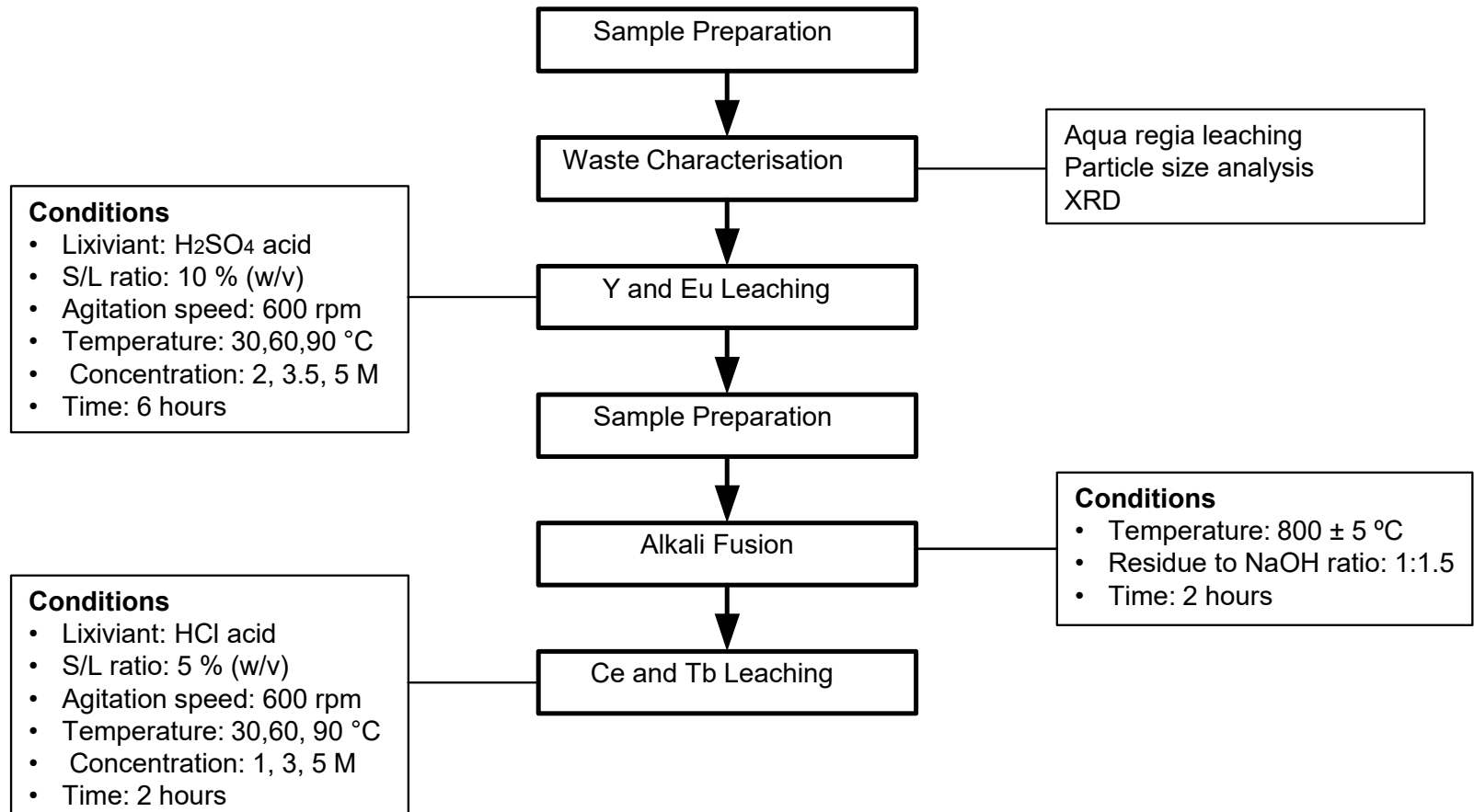
Project Aim

- To evaluate and compare different processes that could be used for REE recovery from phosphor powders in South Africa.

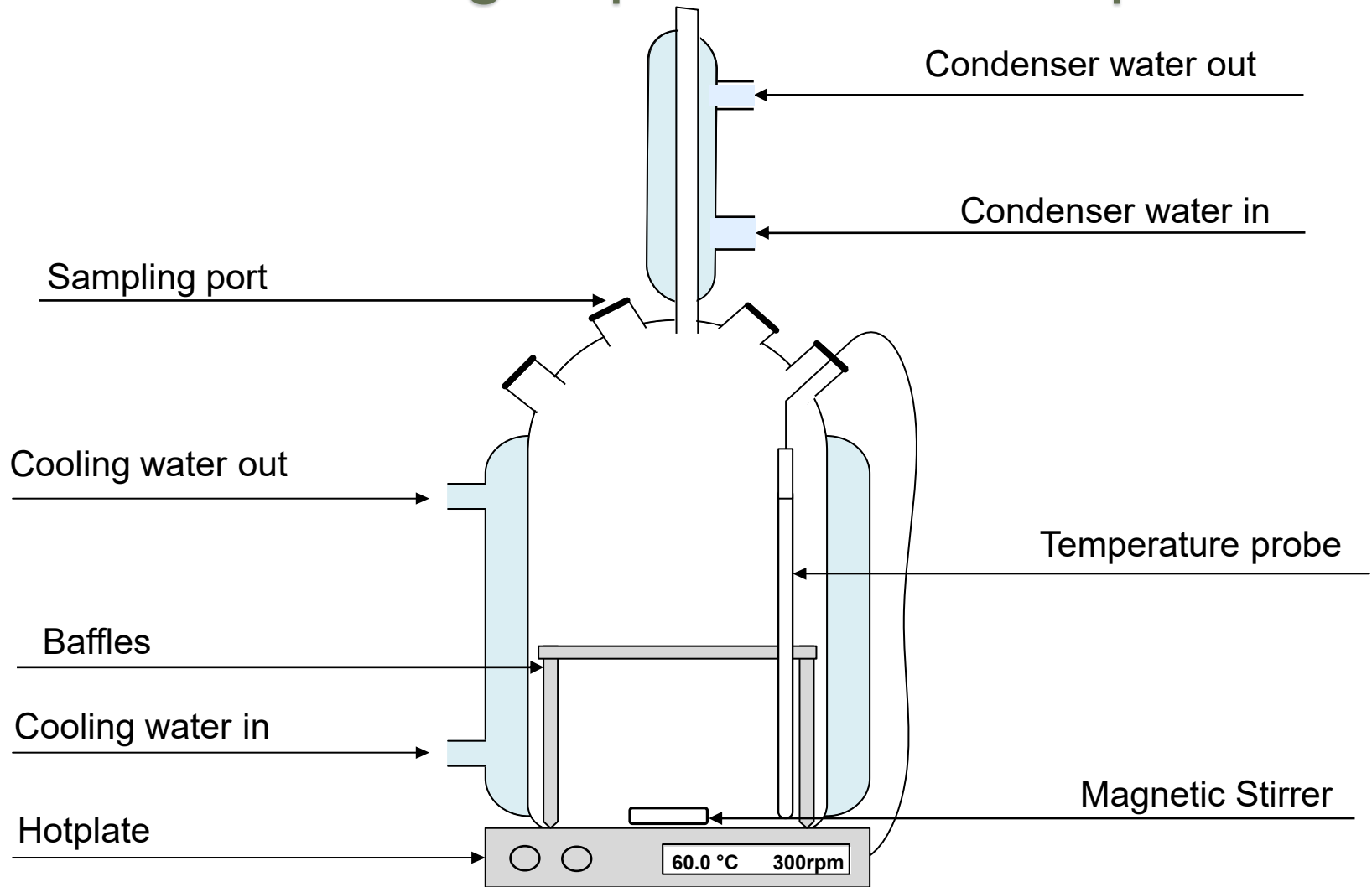
Objectives

- Perform a comprehensive literature review on the current leaching practices.
- Perform experimental work to evaluate the conceptual flow sheet and to identify remaining processing challenges.

Experimental Overview



Leaching Experimental Setup



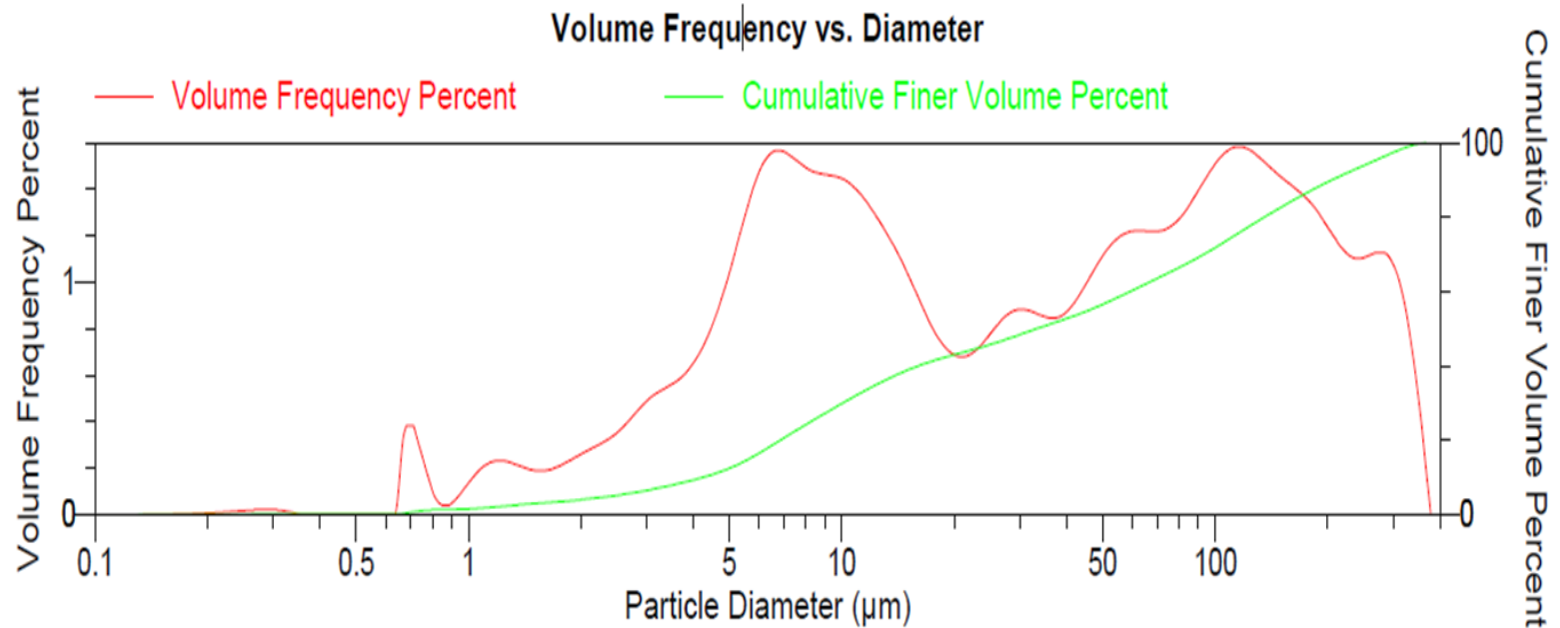
Alkali Fusion Setup



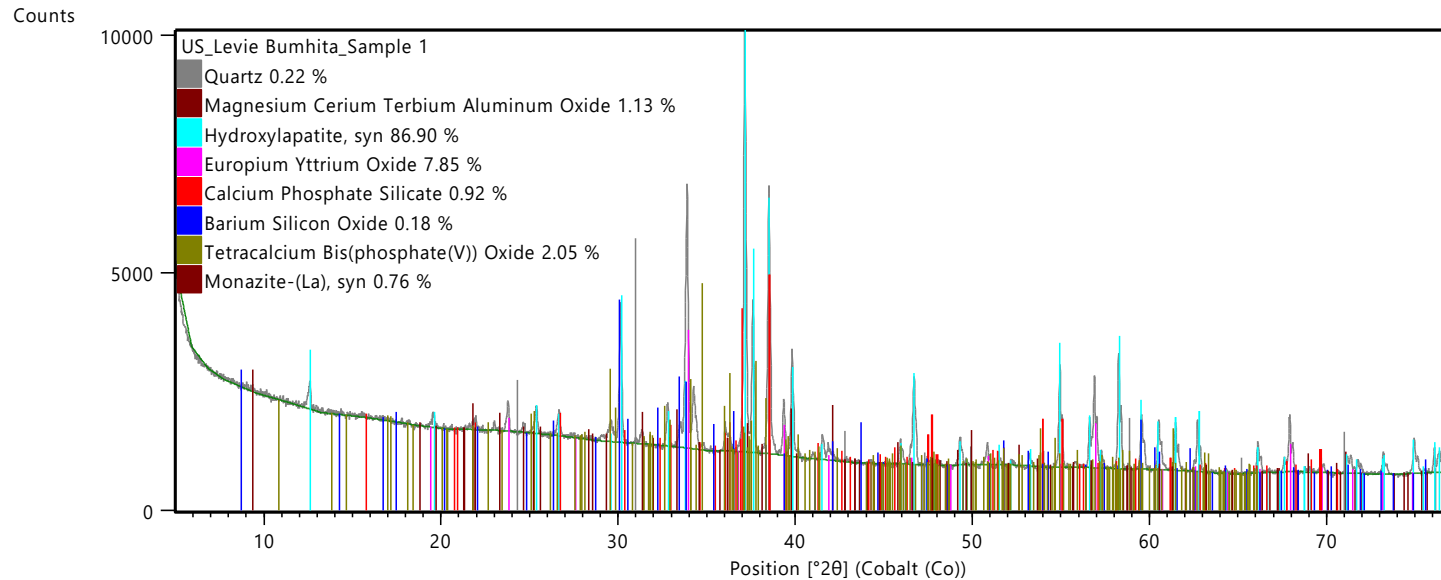
Results - Metal Content

Metal	Average metal content (g/kg)	Metal	Average metal content (g/kg)
Al	7.5 ± 0.09	Fe	5.6 ± 0.2
B	0.55 ± 0.03	Gd	0.8 ± 0.03
Ba	1.2 ± 0.09	La	2.2 ± 1.3
Ca	231 ± 7.1	Mg	2.9 ± 0.04
Ce	2.1 ± 0.5	Tb	1.8 ± 0.2
Cu	0.6 ± 0.03	Y	42.3 ± 0.02
Eu	2.9 ± 0.02	Zn	7.1 ± 3.9

Results - Particle Size Analysis

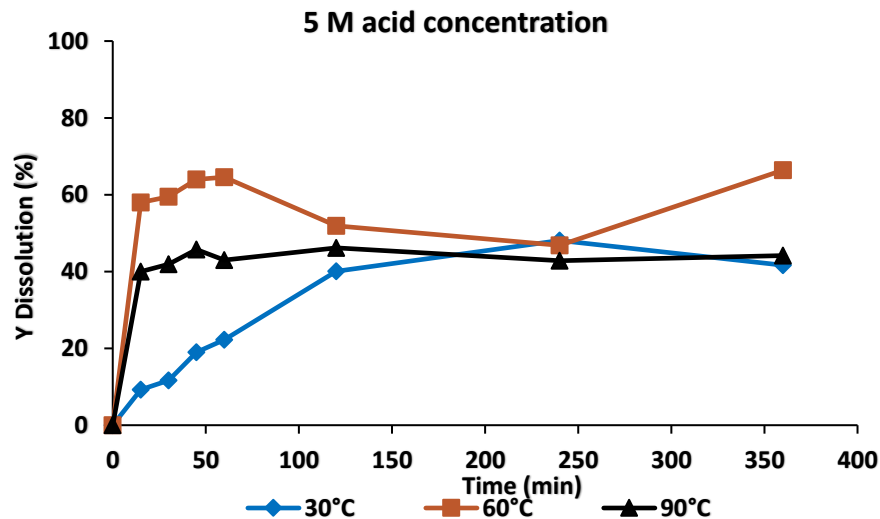
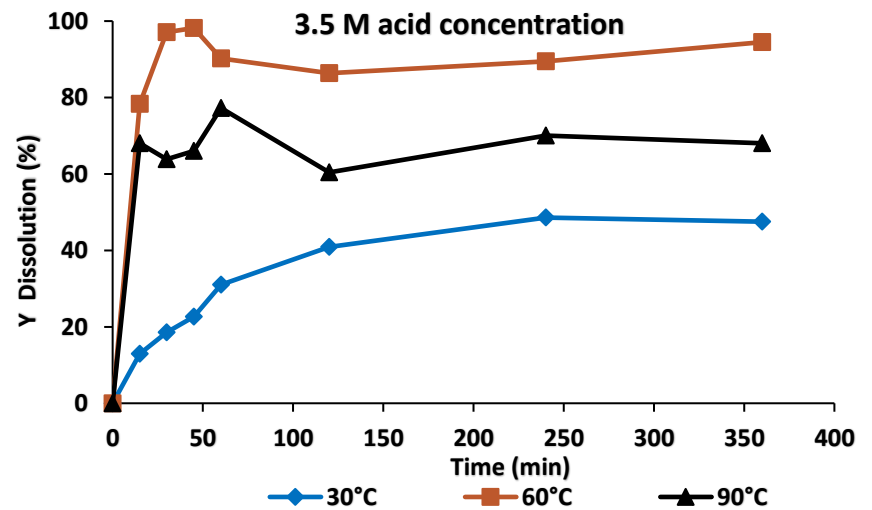
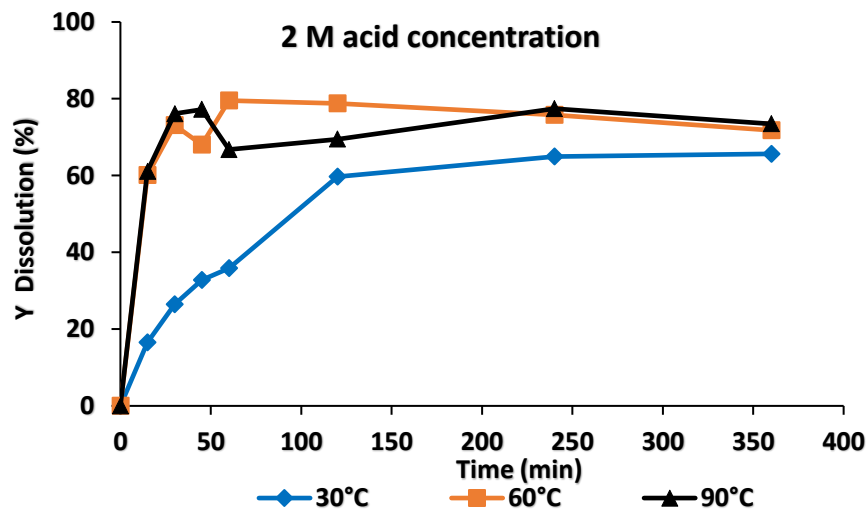


Results - XRD

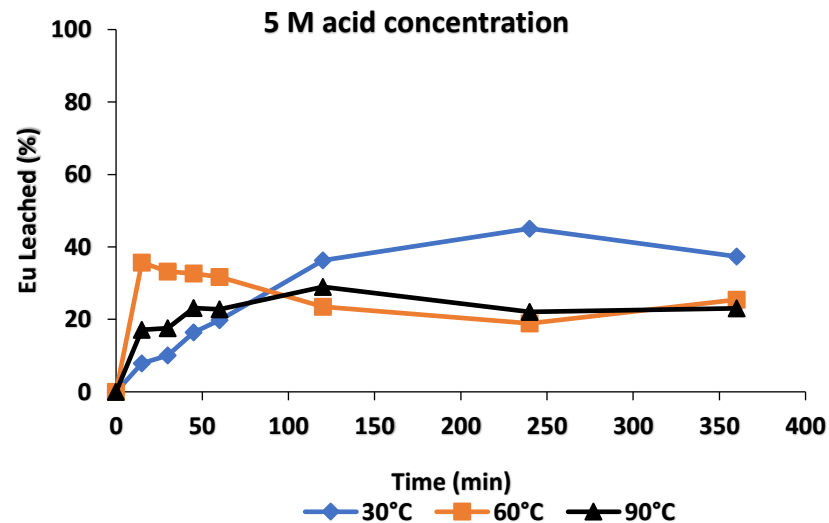
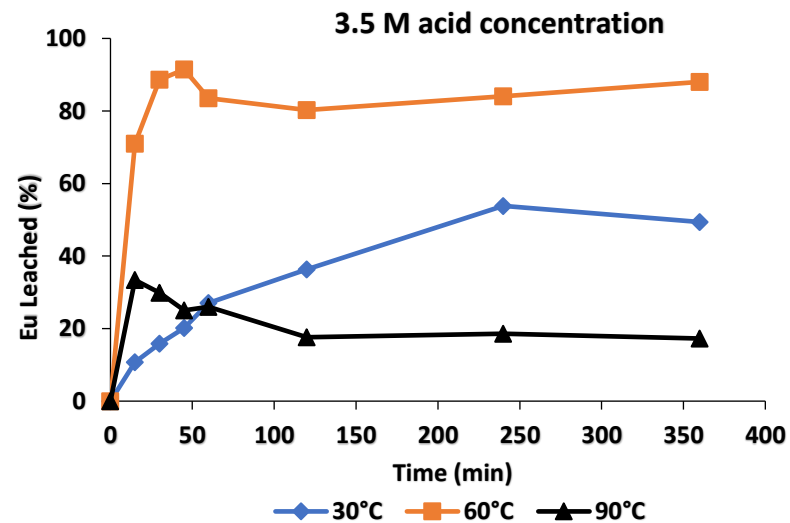
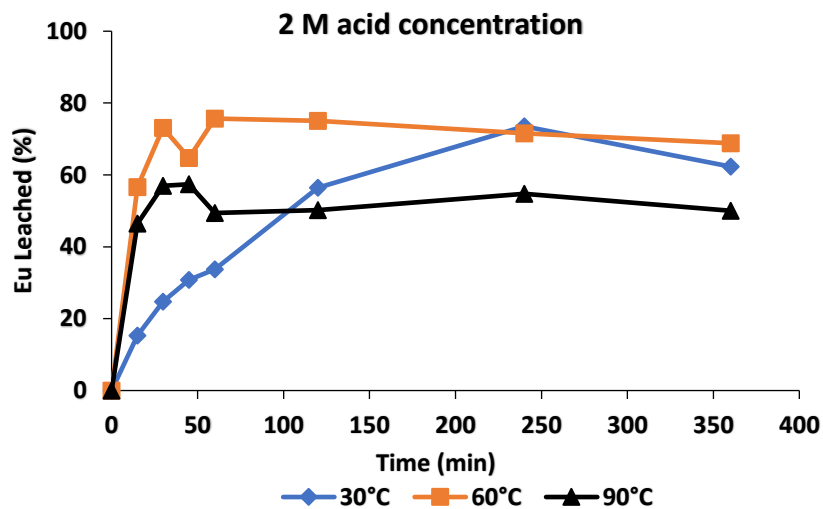


Phase	Formula	Phase	Formula
Quartz	SiO_2	Barium Silicon Oxide	BaSiO_3
Magnesium Cerium Terbium Aluminum Oxide	$(\text{Ce}, \text{Tb})\text{MgAl}_{11}\text{O}_{19}$	Tetracalcium Bis(phosphate(V)) Oxide	$\text{Ca}_4(\text{PO}_4)_2\text{O}$
Hydroxylapatite	$\text{Ca}_5(\text{PO}_4)_3(\text{OH})$	Monazite-(La)	$(\text{La}, \text{Ce}, \text{Nd})\text{PO}_4$
Europium Yttrium Oxide	$\text{Y}_2\text{O}_3:\text{Eu}^{3+}$		

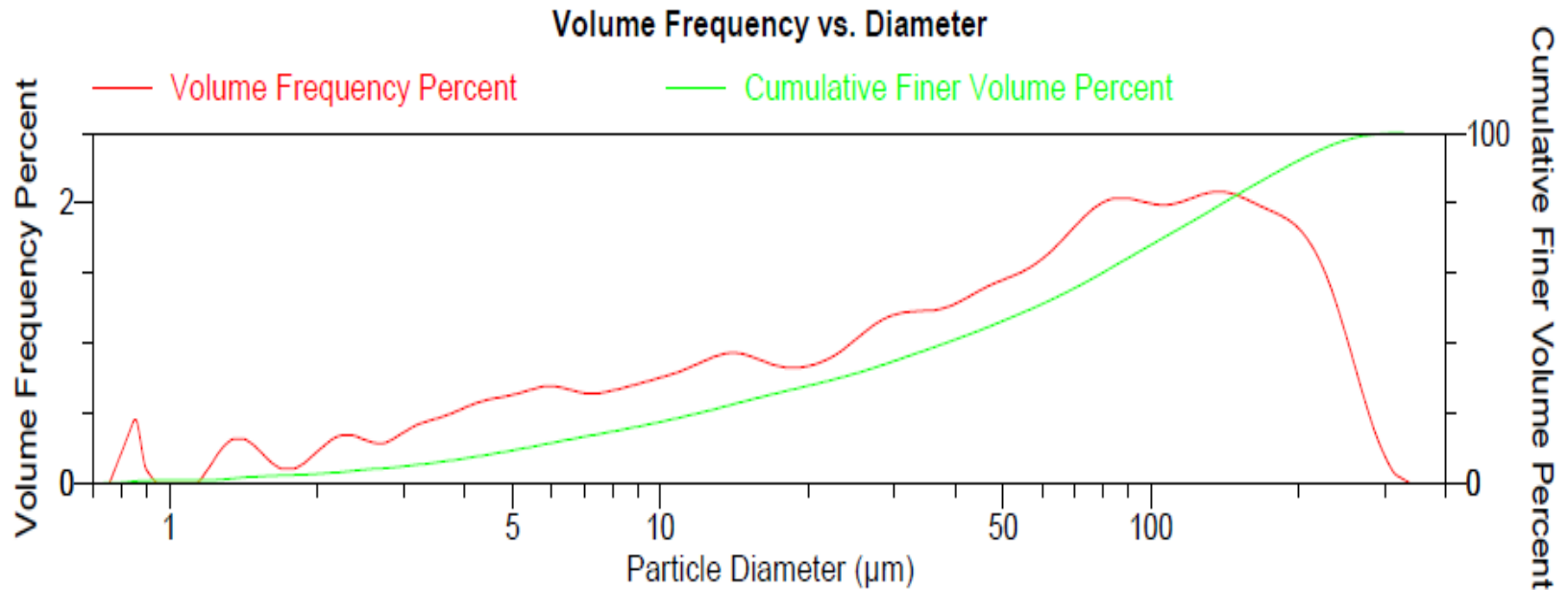
Results - Yttrium Leaching



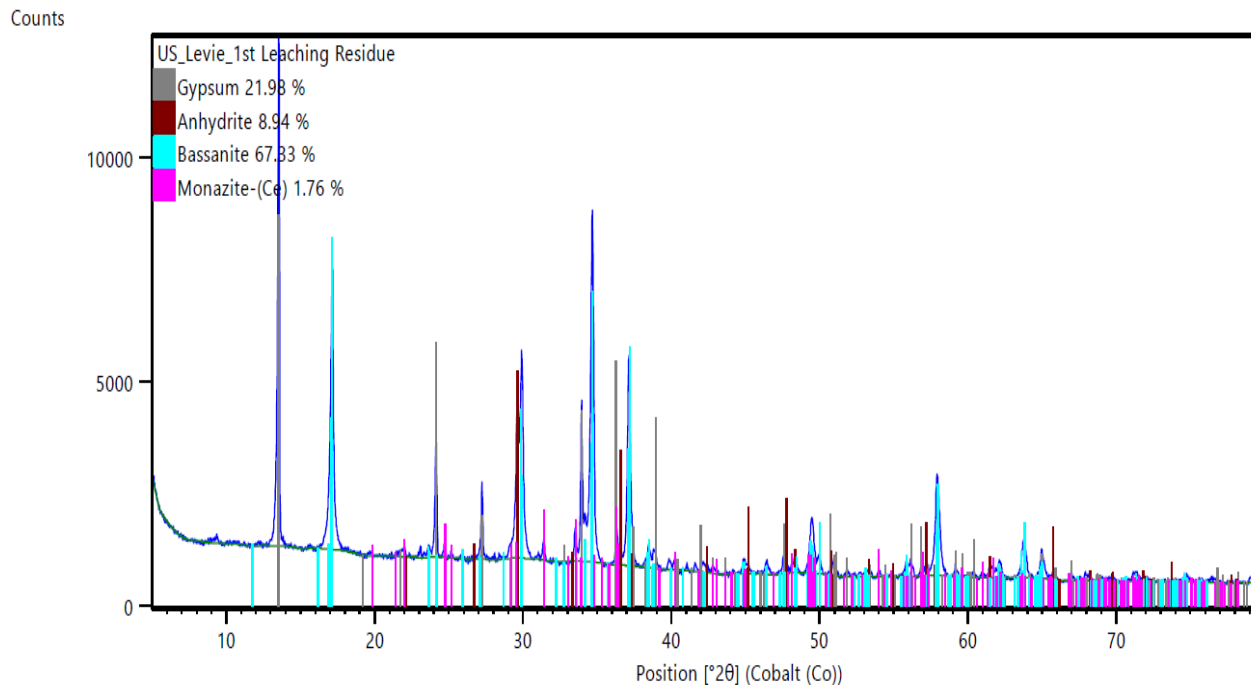
Results - Eu Leaching



Results - Leach Residue Particle Size Analysis



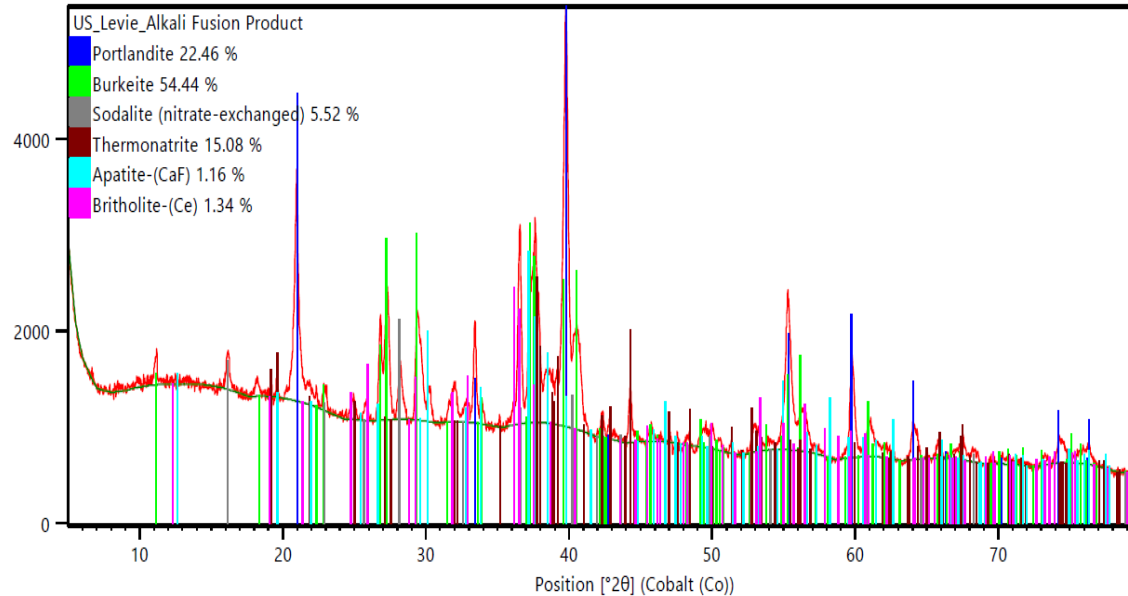
Results - Leach Residue XRD



Phase	Formula
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
Anhydrite	CaSO_4
Bassanite	$2\text{CaSO}_4 \cdot \text{H}_2\text{O}$
Monazite	$(\text{Ce}, \text{La}, \text{Nd}, \text{Th})(\text{PO}_4, \text{SiO}_4)$

Results - Alkali Fusion Product XRD

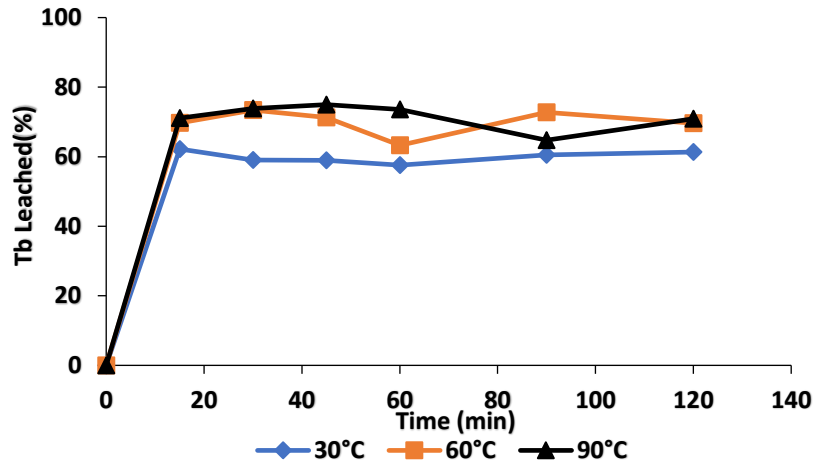
Counts



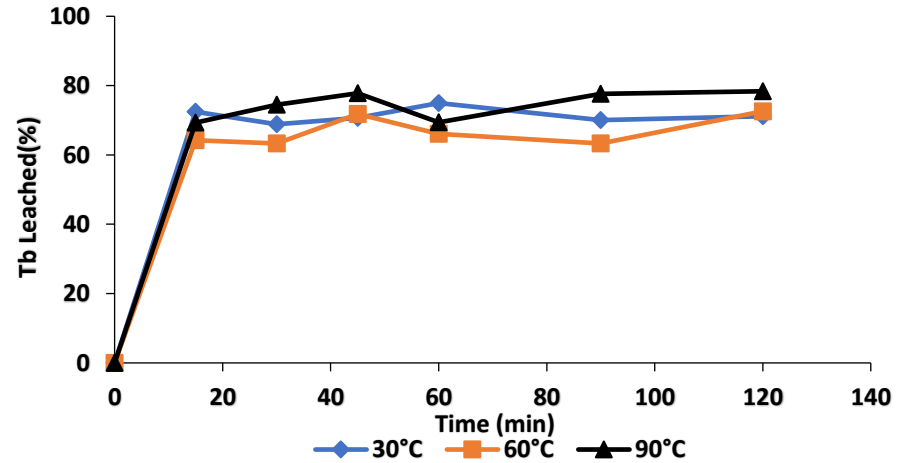
Phase	Formula
Portlandite	$\text{Ca}(\text{OH})_2$
Burkeite	$\text{Na}_6(\text{CO}_3)(\text{SO}_4)_2$
Sodalite	$\text{Na}_8(\text{Al}_6\text{Si}_6\text{O}_{24})\text{Cl}_2$
Thermonatrite	$\text{Na}_2\text{CO}_3 \cdot (\text{H}_2\text{O})$
Apatite	$\text{Ca}_5(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl})$
Britholite	$(\text{Ce}, \text{Ca})_5(\text{SiO}_4)_3\text{OH}$

Results - Tb Leaching

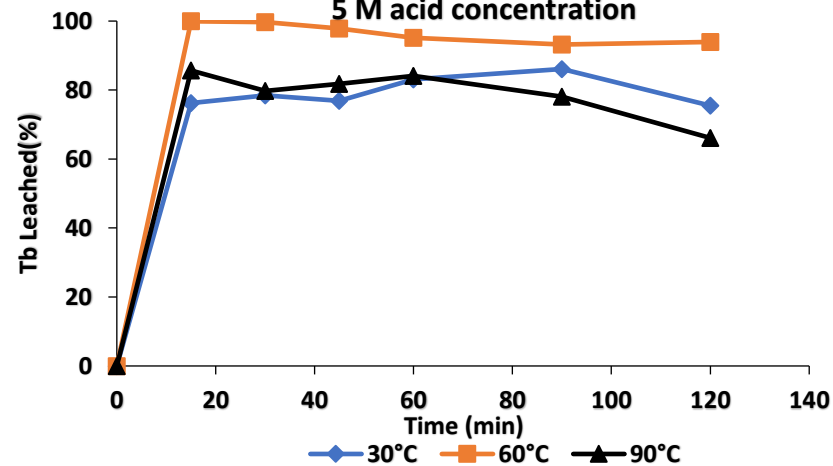
1 M acid concentration



3 M acid concentration

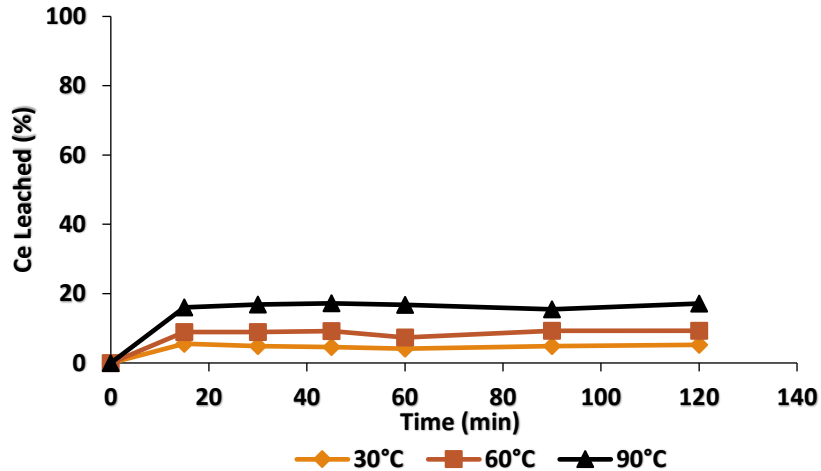


5 M acid concentration

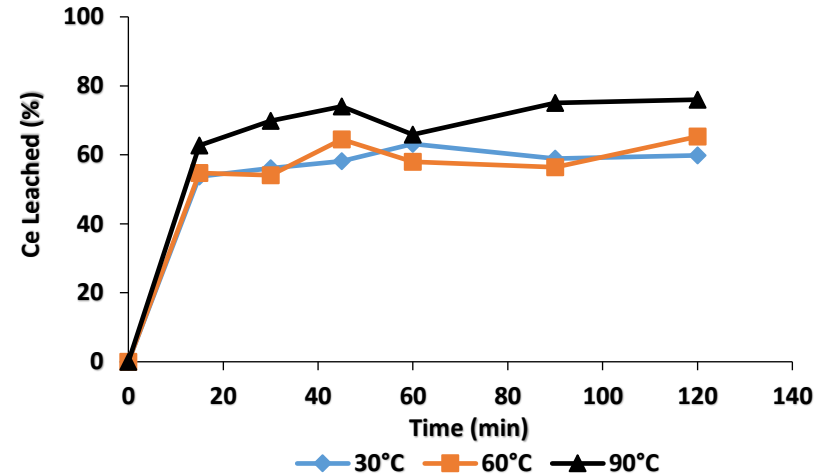


Results - Ce Leaching

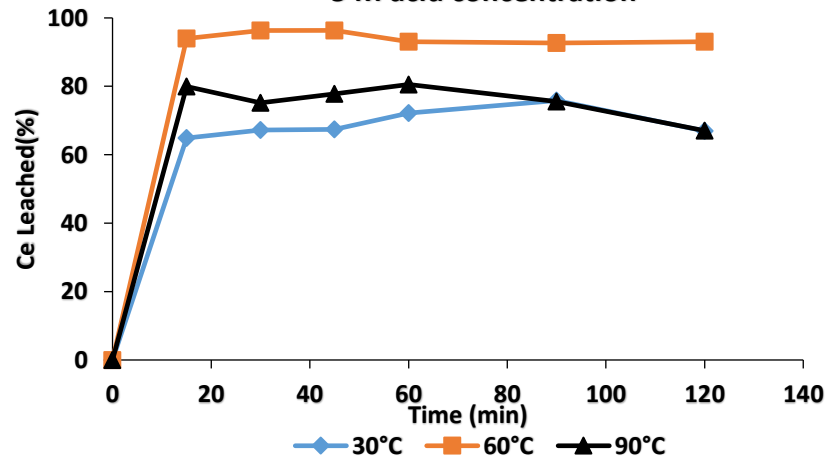
1 M acid concentration



3 M acid concentration



5 M acid concentration



Conclusions

- The red phosphor powder can be readily leached by sulphuric acid since they exist as oxides
- Over 98 % Y and 94 % Eu recoveries obtained using a temperature of 60°C and acid concentration of 3.5 M
- The green and blue phosphors could only be leached after alkali fusion
- Over 99 % Tb and 96% Ce recoveries obtained using an HCl concentration of 5 M and temperature of 60°C

Thank you for your attention

Questions