SILVER RECOVERY FROM END-OF-LIFE LED LAMPS BY THIOUREA LEACHING

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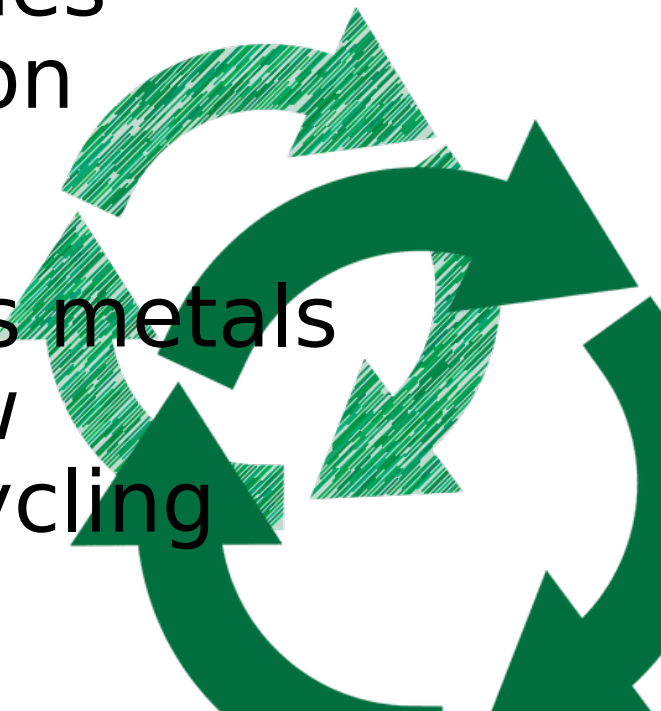
Introduction

- Light Emitting Diode (LED) are gradually replacing the conventional lamps (fluorescent and incandescent) due to their saving on energy bill of up to 85%, their lifetime 5 to 8 times longer and their mercury free composition

- Due to the recovery potential of precious metals and rare-earths, end-of-life LEDs are now interesting from the point of view of recycling



Objective

Study the behaviour of thiourea as an alternative lixiviant to cyanide, optimizing experimental conditions for greater efficiency in the recovery of silver from printed circuit boards (PCB) and electronic components of LED lamps

Material and Methods

Stage 1 - Characterization of LED lamps

1. LED lamps manually disassembled
2. Mechanical processing of the PCBs and electronic components (comminution by a ring mil)
3. Aqua regia digestion
4. Solubilized metals were analysed by the ICP OES

Material and Methods

Stage 2 - Silver recovery from thiourea leaching

- The experimental procedure of silver leaching by thiourea was adapted according to the methodology proposed by Jing-Ying et al. (2012)

Parameters	Levels		
Code	-1	0	+1
Thiourea concentration ($g.L^{-1}$)	10	20	30
Fe^{3+} concentration (%)	0.2	0.4	0.6
Temperature (ºC)	25	30	35
Time (h)	1	2	3

Material and Methods

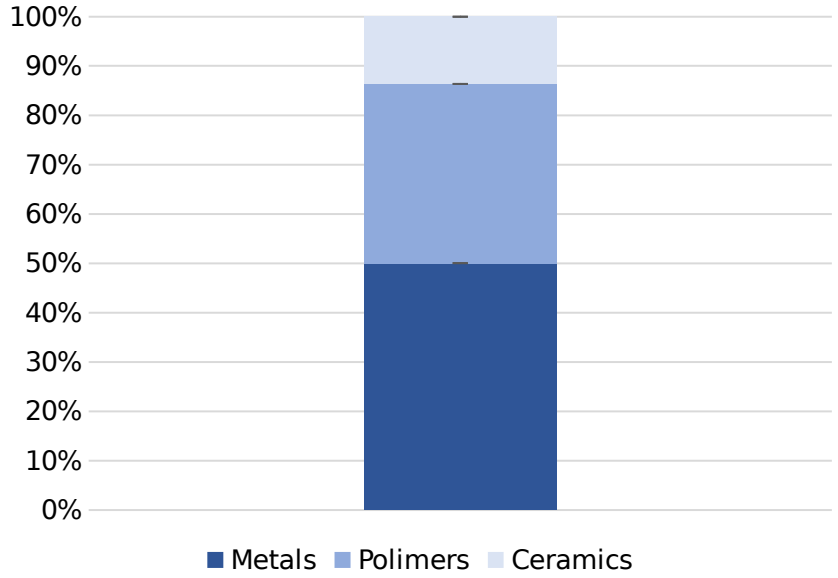
Stage 2 - Silver recovery from thiourea leaching

Box-Behnken planning matrix

Experiment	Temperature (°C)	Time (h)	Thiourea concentration (g.L^{-1})	Fe^{+3} (%)
7	30	2	10	0.6
1	25	1	20	0.4
6	30	2	30	0.2
2	35	1	20	0.4
4	35	3	20	0.4
8	30	2	30	0.6
3	25	3	20	0.4
9	30	2	20	0.4
5	30	2	10	0.2
15	30	3	10	0.4
10	25	2	20	0.2
11	35	2	20	0.2
14	30	1	10	0.4
16	30	1	30	0.4
13	35	2	20	0.6
18	30	2	20	0.4
12	25	2	20	0.6
17	30	3	30	0.4
20	35	2	10	0.4
22	35	2	30	0.4
26	30	3	20	0.6
19	25	2	10	0.4
21	25	2	30	0.4
27	30	2	20	0.4
24	30	3	20	0.2
25	30	1	20	0.6
23	30	1	20	0.2

Results and Discussion

Stage 1 - Characterization of LED lamps



Composition of PCB and electronic components of end-of-life LED lamps leached by aqua regia.

Metal	Average concentration (mg.kg^{-1})
Alumminium	110.923,00 ± 3.641,78
Antimony	212,50 ± 14,41
Arseny	66,00 ± 2,65
Cerium	Not detected
Cooper	94.492,00 ± 6.255,39
Galium	Not detected
Itrium	Not detected
Nickel	761,00 ± 425,54
Gold	348,50 ± 55,06
Silver	384,00 ± 22,00

Metals concentration (mg.kg^{-1}) in PCB and electronic components of LED lamps.

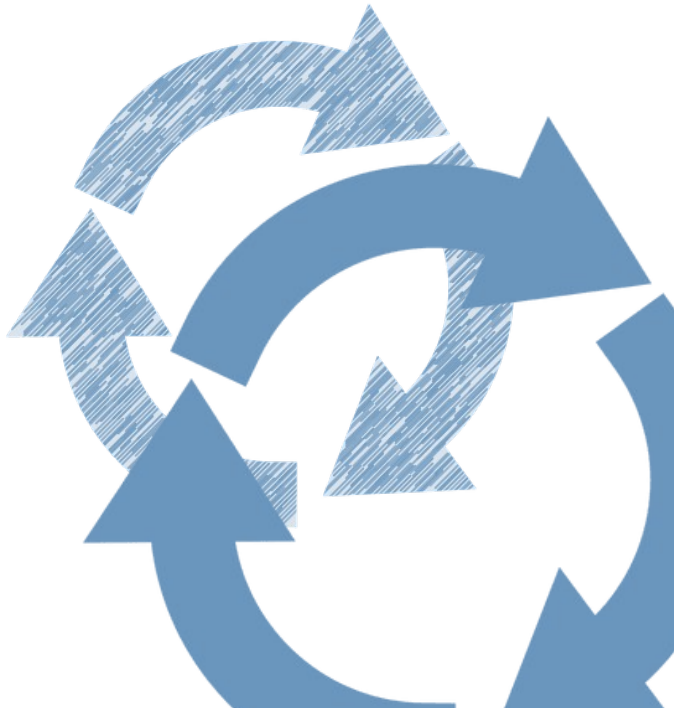
Results and Discussion

Experiment	Silver recovery (%)
7	30.92
1	69.58
6	17.05
2	30.54
4	15.39
8	52.68
3	16.98
9	32.29
5*	11.96
15	32.51
10	42.75
11*	11.96
14	66.85
16	75.11
13	24.56
18	38.50
12	39.56
17	49.26
20*	11.96
22	19.40
26	23.95
19	37.21
21	44.34
27	28.35
24*	11.96
25	42.44
23	39.11

Stage 2 - Silver recovery from thiourea leaching

75.11% Silver extraction:

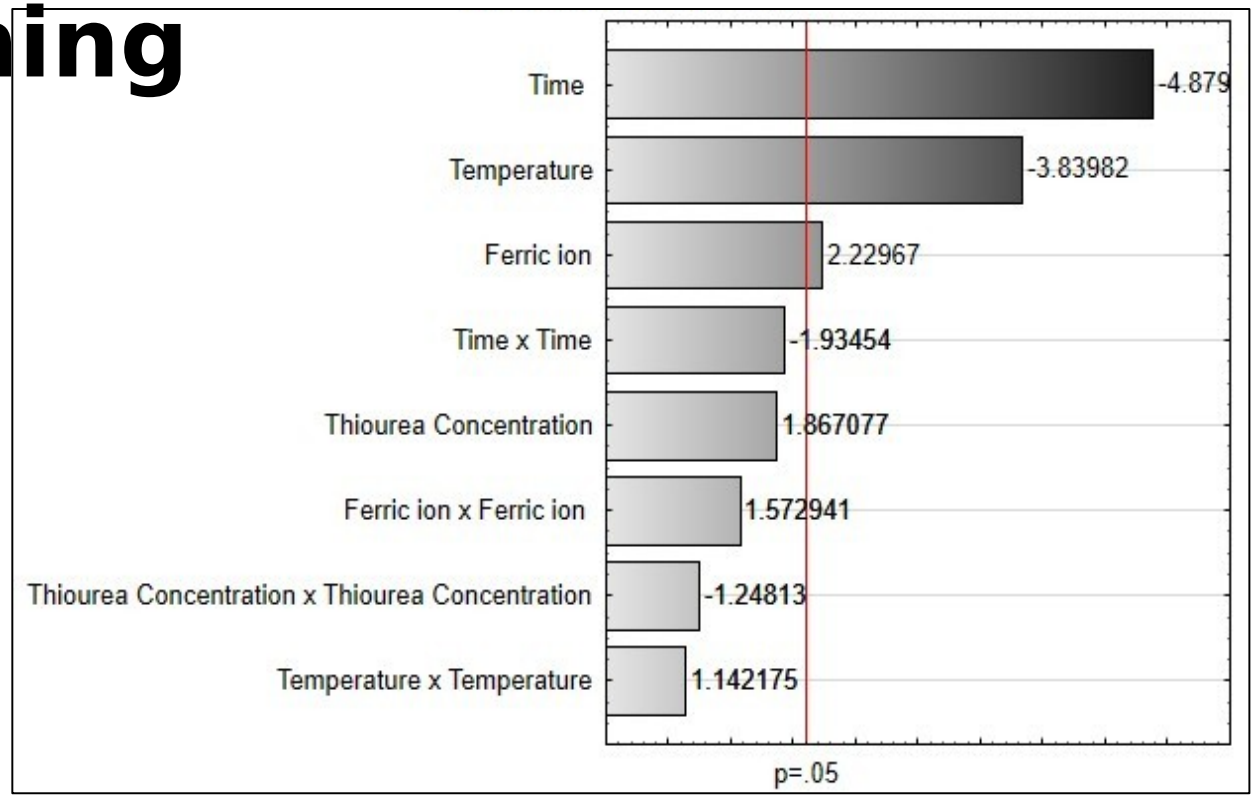
- temperature of 30°C,
- digestion time of 1 hour,
- concentration of thiourea 30 g.L-1
- 0.4% of ferric ions



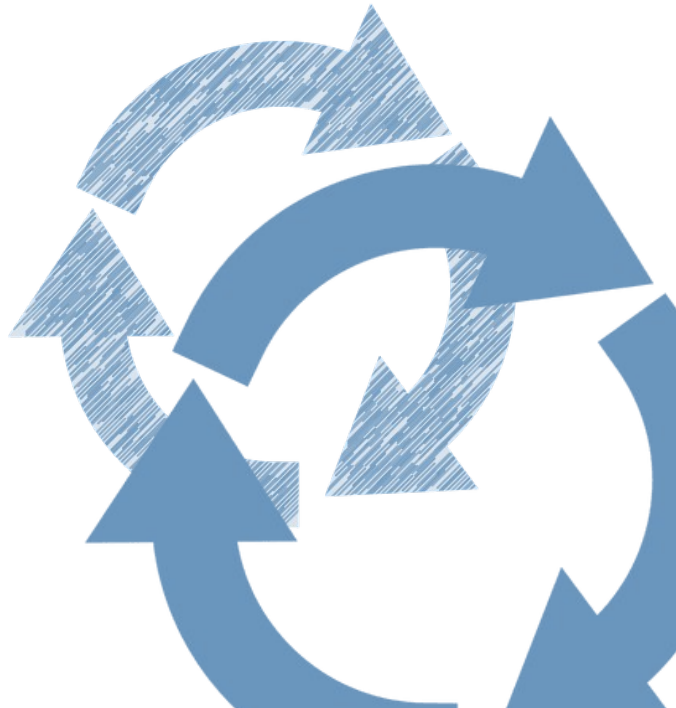
Silver recovery (%) obtained in each experiment.

Results and Discussion

Stage 2 - Silver recovery from thiourea leaching



Pareto Diagram of parameters effects on silver recovery



Results and Discussion

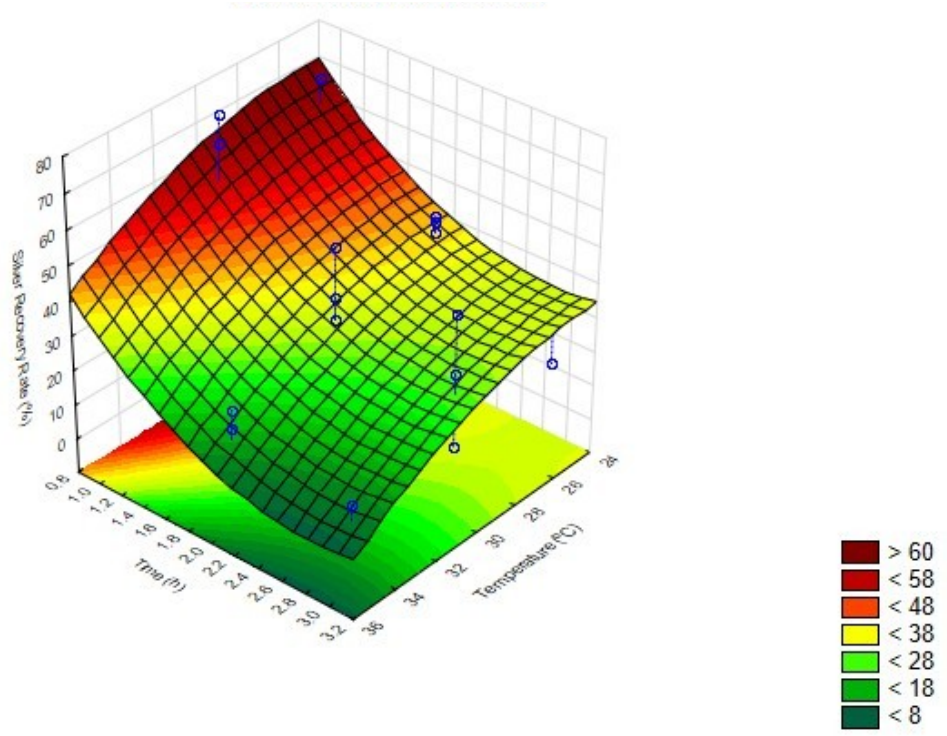
Stage 2 - Silver recovery from thiourea leaching

Source	Freedom degrees	Sum of squares (Adjusted.)	Average squares (Adjusted)	Value F	Value p
Temperature (°C)	2	1692.71	846.36	8.02	0.003
Time (h)	2	2905.50	1452.75	13.77	0.000
Tiourea concentration ($g.L^{-1}$)	2	531.98	265.99	2.52	0.108
Fe $^{3+}$ concentration (%)	2	785.30	392.65	3.72	0.044

Analysis of variance (ANOVA) for silver recovery

Results and Discussion

Stage 2 - Silver recovery from thiourea leach



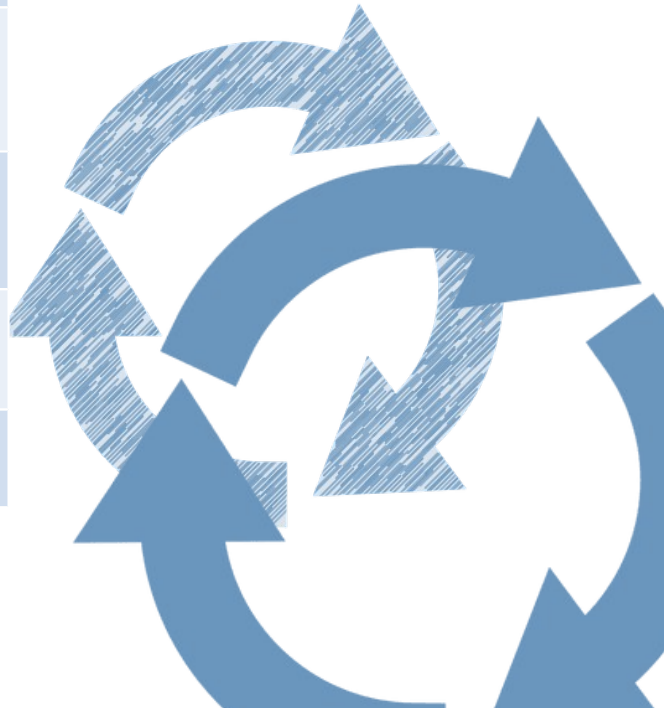
Response surface as a function of time and temperature in silver recovery rate

Results and Discussion

Stage 2 - Silver recovery from thiourea leaching

Reference	E-waste	Optimal conditions	Silver extraction (%)
Ficeriová et al. [24]	Electrical and eletronics PCB	20ºC; 2h; 10 $g.L^{-1}$ $CS(NH_2)_2$;	83%
Lee et al. [1]	Computer PCB	Room temperature; 7h; 5$g.L^{-1}$ $CS(NH_2)_2$; 0.7% Fe^{+3}	100%
Jing-Ying et al. [7]	Cell phone PCB	25ºC; 2h; 24 $g.L^{-1}$ CS(NH2)2; 0.6% Fe^{+3}	50%
Lee et al. [25]	Secondary source from PCB	60ºC; 4h; 60 $g.L^{-1}$ $CS(NH_2)_2$; 0.5 M H_2O_2	100%
Present study	LED lamp PCB	30ºC; 1h; 30 $g.L^{-1}$ $CS(NH_2)_2$; 0.4% Fe^{+3}	75%

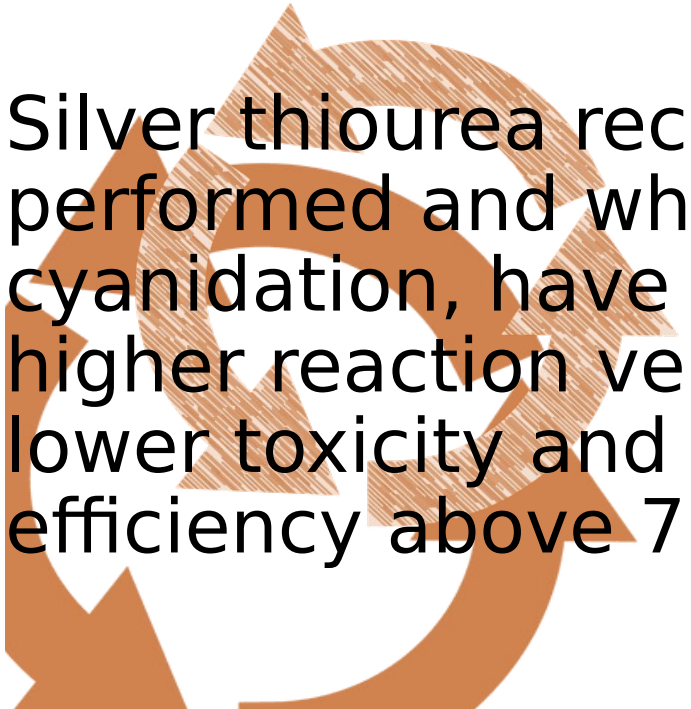
Results compilation about silver extraction by thiourea in e-waste



Conclusions

- Due to the trend of use, application variety and replace of conventional lamps, the LED lamps recycling is both environmentally and economically necessary.

- Silver thiourea recovery tests were performed and when compared to cyanidation, have advantages such as: higher reaction velocity associated with lower toxicity and cost with resulting in an efficiency above 75%.



Conclusions

- From the parameters evaluated the sample digestion time and the solution temperature had a higher influence on silver leaching when compared to the other parameters.
- The solution containing 30 $g.L^{-1}$ of thiourea and 0.4% of Fe^{3+} was the most efficient for the leaching of silver. Under this condition, 75.11% of the silver was extracted from the LED bulbs of LEDs in 2h and at 30 ºC.
- The results obtained in the present study confirmed the high recycling potential of end-of-life LED lamps, the technical viability for silver recovery by thiourea and the possibility of gold recovery.

Acknowledgments

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