Recovery of heavy metals from waste printed circuit board

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***Abstract*—Electronic waste has been increasing proportionally with the technology. So now a days, it is necessary to consider the useful life, recycling, and disposal of these equipment. precious metals such as Au, Ag, PD, Pt are available in small amount however, Cu, Sn, Al and Ni can be found in different components of a printed circuit board. In this thesis we aim to recover different heavy metals from different components of a printed circuit board. In order to achive that different solvents will be used to extract metals. Selective recovery of the metals will be done using advanced separation of individual metal.**

***Index Terms*—Leaching Expriment, Effect of Contration, Time, Weight of E-waste, Weight of solution, etc.**

I. INTRODUCTION

In the past two decades, much attention has been devoted to the development of which are reportedly more environment friendly, predictable, and easily controlled techniques for recycling of WEEE. As a result of rapid technological advancement in recent years, newer, cheaper and more advanced electronic gadgets are continuously replacing the old ones. This has not only increased the mass consumption but also the lifespan and lifecycle of electronic products are rapidly changing due to individual's changing life style[1],[2].

Among such electronic devices, the use of mobile phones has rapidly grown in the last few years. Consequently, mobile phones are causing a large problem because they are much frequently replaced and now constitute the fastest growing component of waste electric and electronic equipment (WEEE). In the fast developing world today, technological advancements in electrical and electronic equipments (television, computers, printer, telephone, modem, fax machines, copy machines, LED/LCD monitors, laptops, printed circuit boards, medical equipments, etc.) have a lesser life span compared to olden days due to rapid increase in demand of advanced products[4][5].

Short life span of the electrical and electronic equipment (EEE) has generated huge tonnage of waste Electrical and Electronic Equipments (WEEE) called ''E-waste''. The period between 1994 and 2003 observed generation of huge E-waste due to discarding of 500 million personal computers, which contained 2.8 million tons of plastic, 0.7 million tons of lead (Pb), 1339 tons of cadmium (Cd), 848 tons of chromium (Cr) and 282 tons of mercury (Hg).High content of base metal (Fe, Cu, Al, Pb and Ni) and precious metal (Ag, Au, Pt and Pd) present in E-waste results makes it a potential source of secondary resources for metal recovery[4].

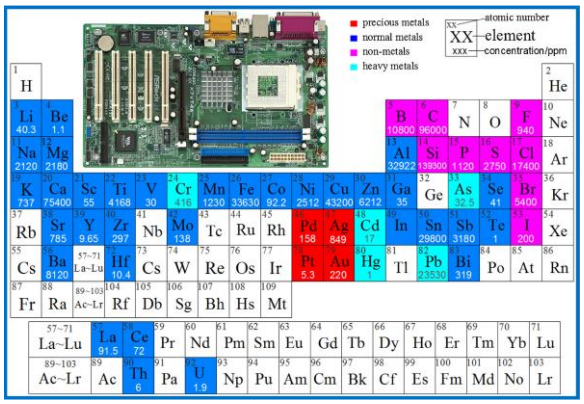


Fig.1. Metals contained in WPCBs [1]

II. MATERIALS AND METHODS

2.1. Experimental material

The waste circuit board samples of central processing unit used in the leaching were obtained from a

SRICT Collage (Fig 2). For experimental use, the scraps were shredded using stainless steel blades and pliers after manually removing the main electronic components (e.g. Electronic Chip (Fig 3)), and then Heat in a Muffle Oven At 400 ^{0}C for 25 min (Fig 4 and 5) and then crushed by the Hammer for 5 to 10 min.

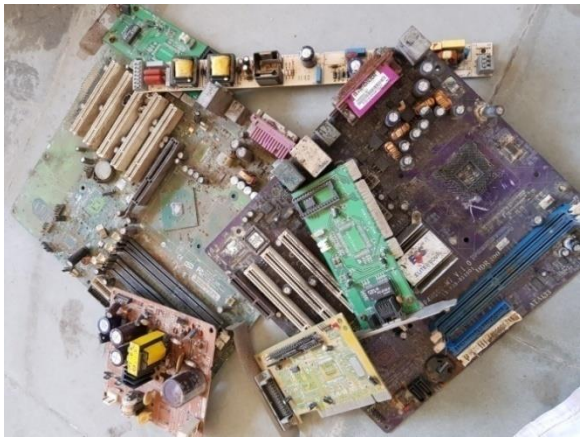


Fig 2- E-waste of CPU

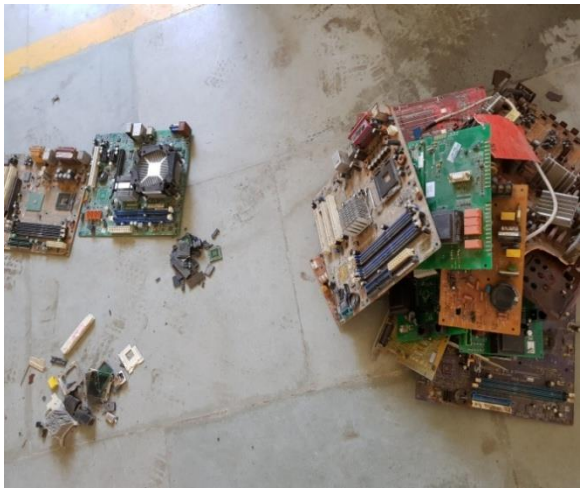


Fig 3- Rmoved Electronic Chip

The sample (5 g) was digested with 0.5M Thiourea Sollution In 1Lit Beaker, and then digestion solution was filtered through filter paper and Atomic absorption spectrophotometer (AAS) was applied to determine copper, zinc, nickel, gold and silver contents present in the digestion solution.

Fig 4- Muffle Furnace

Fig 5- Heated Electronic Chip

2.2. Leaching experiments

The powdered waste PCBs samples were pretreated and filtered according to the following procedure. The leaching of gold and silver were carried out in the beaker containing the pretreatment power and 100 ml of leaching solution (the mixture solution of thiourea and Crusshing Chip Powder). The beakers were shaken in a constant temperature shaker at certain temperature. Then the samples were filtered. The concentration of gold and silver in the leaching solution was determined using atomic absorption spectrophotometry. Firstly, the effect of different Time at 30, 45 Min and, 1, 1 hr 30 min, 2, 3, 4, 5 hr.

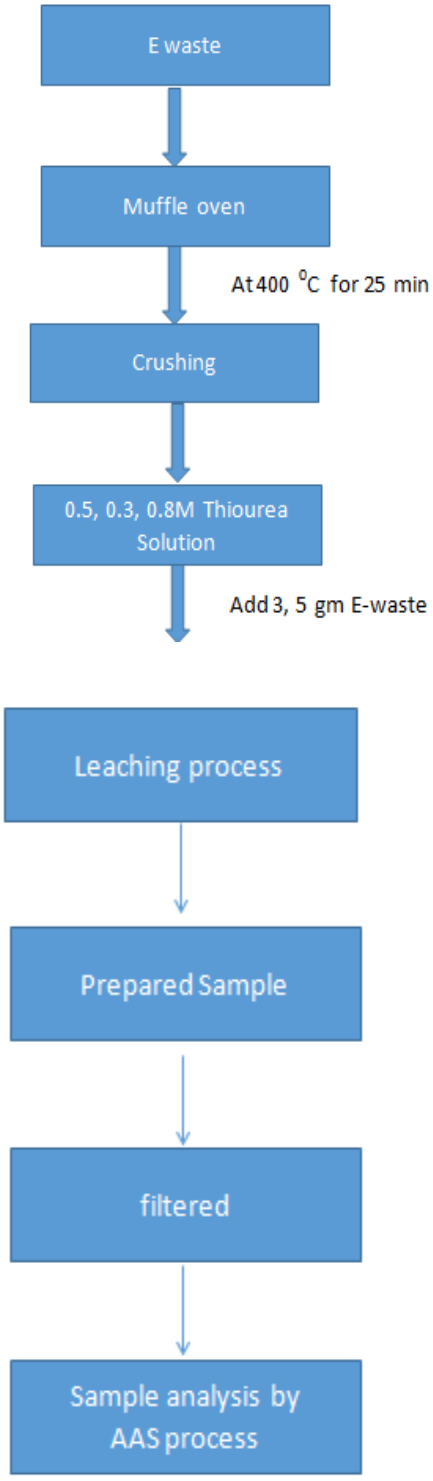
Then in order to investigate the effect of thiourea Concentrtion under different time, initial concentration of TH Solution at 0.5 and 0.8M.

Fig 6- Expriment

Fig 7- Sample Expriment

Fig 8- samples filtered

EXPERIMENTAL PROCEDURE



2.3. Work detail

In this research paper conclude Twenty two Expriment. Different concentration, time, weight of solution and waste are show in Table 1.

Sr. No.	Concentration	Time	Weight of E-Waste	Weight of Solution
1	0.8M	30 min.	3 gm	100 ml
2		45 min.		
3		1 hr.		
4		1 hr 30 min.		
5		2 hr.		
6		3 hr.		
7		4 hr.		
8		5 hr.		
9	0.5M	30 min.		
10		45 min.		
11		1 hr.		
12		1 hr 30 min.		
13		2 hr.		
14		3 hr.		
15		4 hr.		
16		5 hr.		
17	0.5M	2 hr.	5 gm	250 ml
18		3 hr.		
19		5 hr.		
20	0.8M	2 hr.		
21		3 hr.		
22		5 hr.		

III. RESULTS AND DISCUSSION

3.1. Results

The effect of different Time at 30, 45 Min and, 1, 1 Hr 30 Min, 2, 3, 4, 5 hr. Then in order to investigate the effect of thiourea Concentrtion, and temperature under different time, initial concentration of TH Solution at 0.5 and 0.8M, and the results were shown in Table NO. 3.1

		30 Min		45 Min		1 Hr	
Sr. No	**PARAMETERS**	**SAMPLE 1**		**SAMPLE 2**		**SAMPLE 3**	
UNIT		**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
1	GOLD (Au)	**0.280**	0.115	**0.130**	0.147	**0.177**	0.1785
2	SILVER (Ag)	**4.958**	0.9851	**9.775**	0.5125	**4.882**	2.2949
3	CHROMIUM (Cr)	**0.103**	0.2441	**0.125**	0.2392	**0.109**	0.2392
4	LEAD (Pb)	**1.132**	0.3654	**0.362**	0.2622	**0.226**	0.2219
5	NICKEL (Ni)	**0.152**	0.0907	**0.139**	0.1337	**0.128**	0.2229
6	ZINC (Zn)	**0.039**	0.115	**0.029**	0.0718	**0.021**	0.1436
7	COPPER (Cu)	**112.431**	37.204	**166.655**	130.43	**209.618**	73.276
8	IRON (Fe)	**0.254**	0.2212	**0.212**	0.2481	**0.166**	0.1793
9	MANGANESE (Mn)	**0.076**	0.014	**0.078**	0.0034	**0.054**	0.014
10	ALLUMINIUM (Al)	**BDL**	<0.05	**BDL**	<0.05	**BDL**	<0.05

Table No. 3.1

1Hr.30 Min		**2 Hr**		**3 Hr**		**4 Hr**		**5 Hr**	
SAMPLE 4		**SAMPLE 5**		**SAMPLE 6**		**SAMPLE 7**		**SAMPLE 8**	
mg/l	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
0.252	0.1465	**0.103**	0.149	**0.102**	0.1923	**0.037**	0.3205	**0.252**	0.2289
6.86	1.0689	**3.451**	9.408	**2.614**	4.0077	**2.681**	1.5766	**2.838**	1.7343
0.103	0.2197	**BDL**	0.049	**0.076**	0.2441	**0.114**	0.2148	**0.125**	0.2245
0.373	0.2622	**0.385**	0.022	**0.237**	0.1009	**0.351**	0.0202	**0.169**	0.1009
0.132	0.1091	**0.174**	0.422	**0.130**	0.195	**0.119**	0.475	**0.150**	0.1061
0.024	0.0794	**0.028**	0.013	**0.018**	0.0623	**0.015**	0.0667	**0.032**	0.0565
174.971	108.3	**135.645**	81.075	**163.537**	236.21	**188.916**	413.43	**250.589**	270.36
0.210	0.194	**0.149**	0.077	**0.091**	0.1943	**0.144**	0.1913	**0.338**	0.2541
0.058	0.0015	**0.06**	0.052	**0.054**	0.0053	**0.063**	0.0092	**0.072**	0.0092
BDL	<0.05	**0.095**	0.063	**0.255**	<0.05	**0.0319**	<0.05	**BDL**	<0.05

Table No. 3.2

All are Results in 100 ml solution, and 3 gm E-waste.

All Results in PPM. Fig No. (9 to 13)

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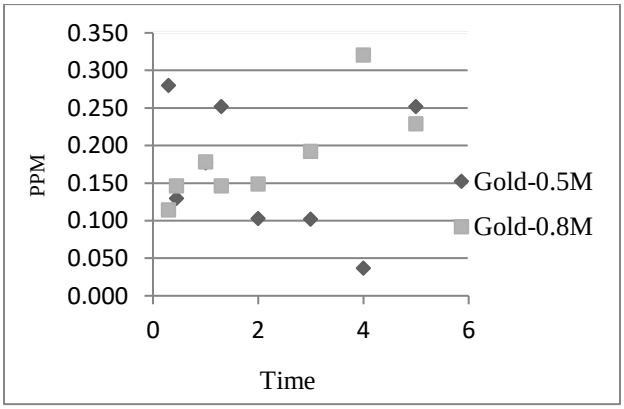

Fig 9- The exteaction percentage 0.5 vs 0.8M Gold

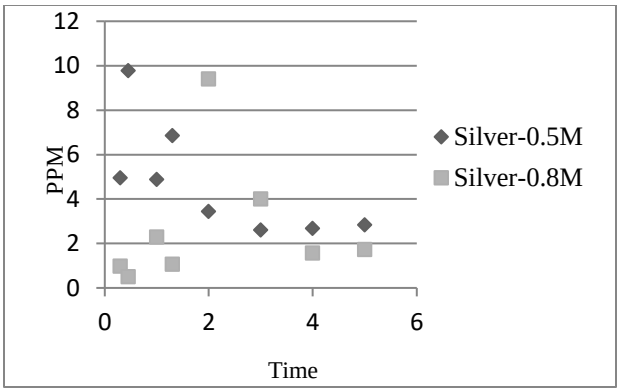

Fig 10- The exteaction percentage 0.5 vs 0.8M Silver

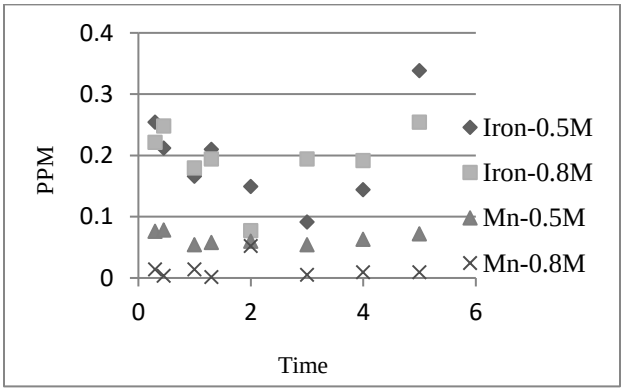

Fig 11- The exteaction percentage 0.5 vs 0.8M Fe and Mn

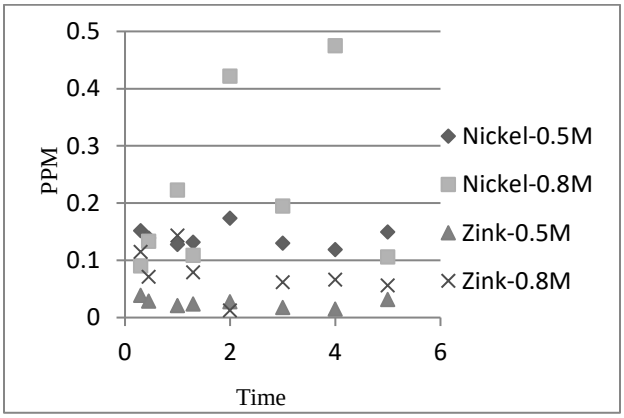

Fig 12- The exteaction percentage 0.5 vs 0.8M Ni and Zn

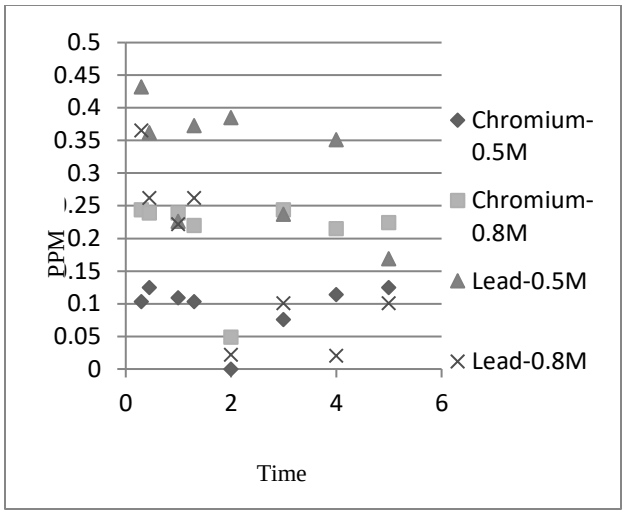

Fig 13- The exteaction percentage 0.5 vs 0.8M Cr and Pb

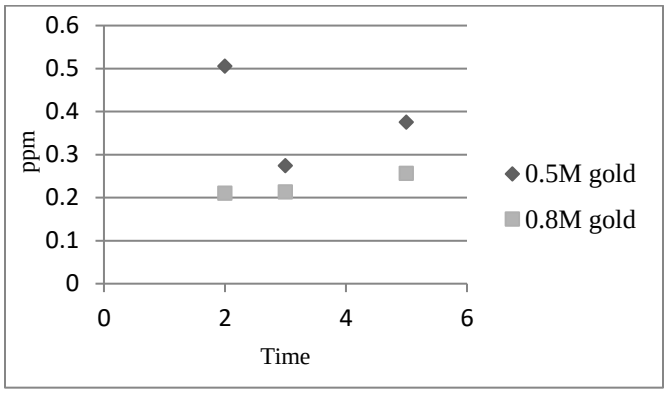

Fig 14- The exteaction percentage 0.5 vs 0.8M Au.5gm E-waste and 250ml solution.

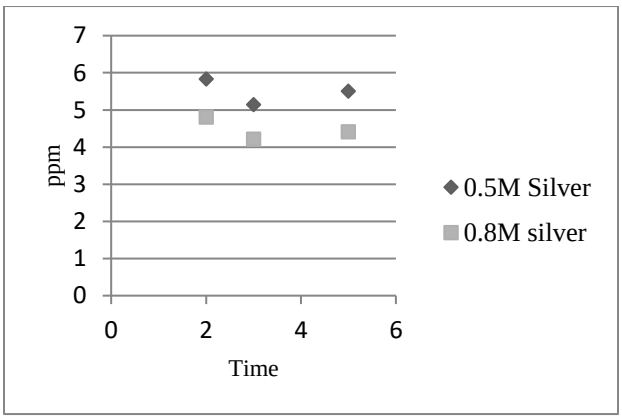

Fig 15- The exteaction percentage 0.5 vs 0.8M Ag. 5gm E-waste and 250ml solution.

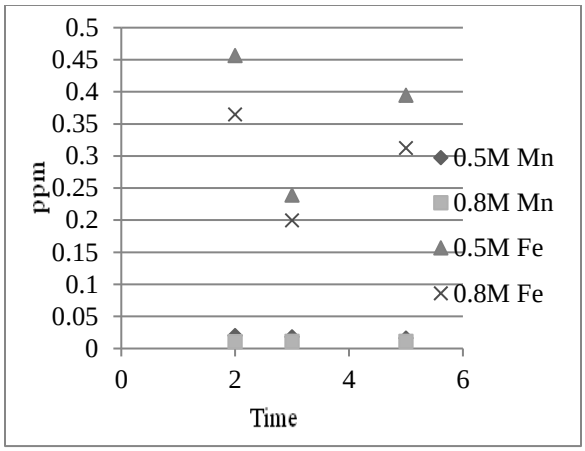

Fig 16- The exteaction percentage 0.5 vs 0.8M Mn and Fe. 5gm E-waste and 250ml solution.

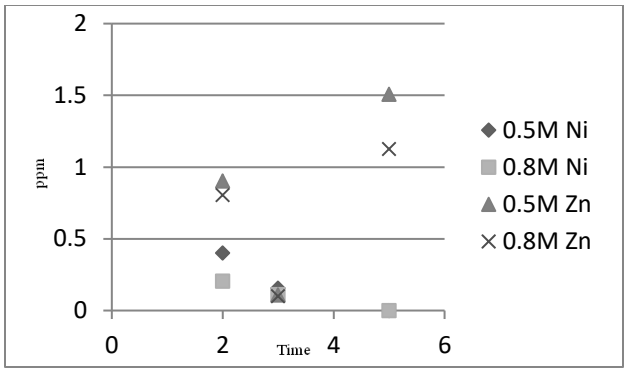

Fig 17- The exteaction percentage 0.5 vs 0.8M Ni and Zn. 5gm E-waste and 250ml solution.

		2 hr		3 hr		5 hr	
Sr.No	**PARAMETERS**	**5 gm & 250 ml**		**5 gm & 250 ml**		**5 gm & 250 ml**	
UNIT		**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
1	GOLD (Au)	**0.506**	0.2106	**0.2746**	0.2136	**0.3754**	0.2564
2	SILVER (Ag)	**5.8284**	4.8046	**5.1418**	4.2123	**5.507**	4.407
3	CHROMIUM (Cr)	**0.531**	0.371	**0.41**	0.31	**0.3612**	0.2654
4	LEAD (Pb)	**0.0986**	0.0806	**<0.04**	<0.04	**0.1614**	0.1211
5	NICKEL (Ni)	**0.402**	0.206	**0.1568**	0.1122	**<0.04**	<0.04
6	ZINC (Zn)	**0.9036**	0.8046	**0.1092**	0.0998	**1.507**	1.126
7	COPPER (Cu)	**406.89**	306.17	**863.11**	723.31	**769.9**	710.2
8	IRON (Fe)	**0.4567**	0.3646	**0.2392**	0.1998	**0.3946**	0.3124
9	MANGANESE (Mn)	**0.0202**	0.0106	**0.0184**	0.0112	**0.0164**	0.0112
10	ALLUMINIUM (Al)	**<0.1**	<0.1	**<0.1**	<0.1	**<0.1**	<0.1

Table No. 3.3
All are Results in 250 ml solution, and 5 gm E-waste.
All Results in PPM. And show Fig No (14 to 18)
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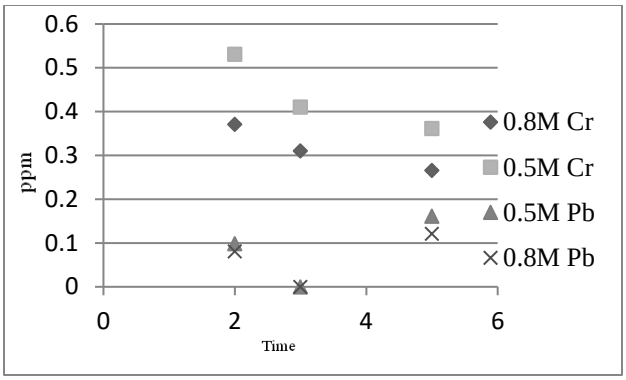

Fig 18- The exteaction percentage 0.5 vs 0.8M Cr and Pb. 5gm E-waste and 250ml solution.

3.2. Discussion

❖ Effect of Time

The effect of different Time at 30, 45 Min and, 1, 1 Hr 30 Min, 2, 3, 4, 5 hr. The thiourea concentration 0.5M and 0.8M and 100ml, 250ml Solution, E-Waste 3gm, 5gm, reaction temperature of 50^0C, and the results were shown in Table NO. 3.1, 3.2 and 3.3. As shown in Table 3.1, the Different Time had a effect on Metals Recovery leaching rates. Therefore, in the next experiments, the Time should be at least Below 2Hr in order to acquire high leaching rate.

❖ Effect of thiourea concentration on leaching rate of metals

To reveal the effect of thiourea concentration on leaching rate of Metals, the experimental were carried out with different thiourea concentration of 0.5 and 0.8M. The experimental results is shown in Fig No. 9 to 18. The leaching rate increased when the thiourea concentration is lower. When the thiourea concentration was more. The leaching rate of metals was almost higher. which indicated that the optimal concentration is the give best result.

IV. CONCLUSION

Thiourea leaching has the advantages of quick leaching speed, low-toxicity, low-cost, high efficiency, environmental friendly, less interference ions, is becoming a green leaching of gold method. In the present study,Laboratory scale experiments were carried out to study the leaching of gold and silver from the PCBs collected from E-waste. Various parameters, such as concentrations of thiourea, stirrier time were studied. Solution chemistry had more influence on the leaching of gold and silver from the PCBs. The solution containing 0.5M thiourea and 5gm E-Waste and 2Hr Time concentration were found to be suitable for gold leaching. Under this condition, Better gold was leached out from E-Waste scraps by the reaction of 2 h. Therefore, with more development of thiourea leaching, it would be an effective, alternative and less toxic methodology for gold extraction from PCBs of waste.

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REFERENCES

(1) H.Y., Kim, S.G., Oh, J.K., 1997. Cemenation behavior of gold and silver onto Zn, Al,and Fe powders from acid thiourea solutions. Can. Metall. Q. 36, 149–155.

(2) L., Shirley, J., 1996. Russian resin-in-pulp technology, current status and recent developments. Randol Gold Forum '96. Randol International, Golden, CO, USA, pp. 419–423.

(3) Cui, J., Zhang, L., 2008. Metallurgical recovery of metals from electronic waste: a review. J. Hazard. Mater. 158 (2–3), 228–256.

(4) Zhang, S., Forssberg, E., 1998. Mechanical recycling of electronics scrap – the currentstatus and prospects. Waste Manage. Res. 16 (2), 119–128.

(5) BCC, 2005. Electronic Waste Recovery Business. Report ID: MST037A, 182. BusinessCommunications Company Inc.

(6) Qin, H.S., Ren, Z.J., 2000. Cyanide waste pollution and prevention measures of rock heap leaching gold. Journal of Qinghai Environment 10, 78–80 (in Chinese).

(7) S. Laskin, R.T. Drew, V. Cappiello, Inhalation carcinogenicityof alpha halo ethers, Arch. Environ. Health 30 (1975).
(8) A. Tuncuk, V. Stazi, A. Akcil, E.Y. Yazici, H. Deveci, Aqueous metal recovery techniques from e-scrap: Hydrometallurgy in recycling, Miner. Eng. 25 (2012) 28–37.
(9) P. Cyganowski, D. Jermakowicz-Bartkowiak, M. Bryjak,Method of synthesis of polymeric supports with reactive chloromethyl groups (in polish: Sposobwytwarzanianosnikow polimerowych z reaktywnymigrupamichlorometylenowymi), Polish patent office, Patent application under number P.410196, 2014.
(10) Groenewald, T., 1976. The dissolution of gold in acidic solutions of thiourea.Hydrometallurgy 1, 277–290.
(11) Lee, H.Y., Kim, S.G., Oh, J.K., 1997. Cemenation behavior of gold and silver onto Zn, Al,and Fe powders from acid thiourea solutions. Can. Metall. Q. 36, 149–155.
(12) Li, J., Miller, J.D., 2007. Reaction kinetics of gold dissolution in acid thiourea solution using ferric sulfate as oxidant. Hydrometallurgy 89, 279–288.
(13) Li, J., Lu, H., Guo, J., Xu, Z., Zhou, Y., 2007. Recycle technology for recovering resources and products from waste printed circuit boards. Environ. Sci. Technol. 41, 1995–2000.
(14) Liew, F.C., 2008. Pyrometallurgyversus hydrometallurgy. TES-AMM Singapore. (www. tes-amm.com.au/downloads/TES-AMM_analysis_pyrometallurgy_vs_hydrometallurgy _ April_2008.pdf).
(15) Li J., Xu Z.M., Zhou Y.H. Application of corona discharge and electrostatic force to separate metals and nonmetals from crushed particles of waste printed circuit boards. *J Electrostat.*2007b, 65 (4), 233-238.
(16) 6. Oh C.J., Lee S.O., Yang H.S., Ha T.J., Kim M.J. Selective leaching of valuable metals from waste printed circuit boards. *J Air Waste Manage*, 2003, 53 (7), 897-902.
(17) Woollacott, L.C., Eric, R.H., 1994. Hydrometallurgy. Mineral and Metal Extraction: An Overview. The South African Institute of Mining and Metallurgy, Johannesburg, pp. 321 370
(18) Marchbank, A.R., Thomas, K.G., Dreisinger, D., Fleming, C., 1996. Gold recovery from refractory ores by pressure oxidation and thiosulfate leaching. US Patent 5,536,297. Barrick Gold Corporation, Toronto, Canada. 12 pp., 5 drawing sheets.
(19) Awadalla, F.T., Ritcey, G.M., 1990. Recovery of gold from thiourea, thiocyanate or thiosulfate solutions by reduction-precipitation with a stabilized form of sodium borohydride. Randol Gold Forum, Sept. 1990, Squaw Valley, USA. Randol International, Golden, CO, USA, pp. 295– 306.
(20) Abbruzzese, C., Fornari, P., Massidda, R., Veglio, F., Ubaldini, S., 1995. Thiosulfate leaching for gold hydrometallurgy. Hydrometallurgy 39, 265–276.
(21) Aylmore, M.G., 2001. Treatment of a refractory gold– copper sulfide concentrate by copper ammoniacal thiosulfate leaching. Miner. Eng. 14 (6), 615– 637.
(22) Aylmore, M.G., Muir, D.M., 2001. Thiosulfate leaching of gold—a review. Miner. Eng. 14 (2), 135– 174.
(23) Chen, J., Deng, T., Zhu, G., Zhao, J., 1996. Leaching and recovery of gold in thiosulfate based system—a research summary at ICM. Trans. Indian Inst. Met. 49 (6), 841– 849.
(24) Zhao, J., Wu, Z.C., Chen, J.Y., 1997. Extraction of gold from thiosulfate solutions with alkyl phosphorus esters. Hydrometallurgy 46 (3), 363–372.
(25) Fleming, C.A., 1998. The potential role of anion exchange resins in the gold industry. EPD Congress 1998. The Minerals, Metals and Materials Society, Warrendale, PA, USA, pp. 95– 117.
(26) Bolinski, L., Shirley, J., 1996. Russian resin-in-pulp technology, current status and recent developments. Randol Gold Forum '96. Randol International, Golden, CO, USA, pp. 419–423.
(27) Schmitz, P.A., Duyvesteyn, S., Johnson,W.P., Enloe, L., McMullen, J., 2001. Ammoniacal thiosulfate and sodium cyanide leaching of preg-robbing Goldstrike ore carbonaceous matter. Hydrometallurgy 60, 25–40.