DETERMINATION OF SOME HEAVY AND PRECIOUS METALS FROM PRINTED CIRCUIT BOARD (PCB) FROM A TELEVISION SET BY ATOMIC ABSORPTION SPECTROPHOMETER

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ABSTRACT

The concentrations of some heavy and precious metals from printed circuit board (PCB) of a television set were determined using Atomic Absorption Spectrophotometer (AAS) in order to identify elements with higher concentration as target source of raw materials for metal recovery. The metal fractions attached to the PCB were subjected to mechanical separation, placed inside a 75ml Kjeldahl flask and thereafter digested with a 20ml nitric acid (HNO_3). The prepared sample was filtered, then made up to 100ml using distilled water and analysed using AAS (Shimadzu model AA6300). The results showed the presence of some heavy metals such as: (Fe,0.0644mg/l, Pb, 0.0732mg/l, Cu,0.0627mg/l, Ni, 0.1076mg/l and Cd, 0.0001mg/l) in higher concentrations (apart from Cd) than the precious metals (Au, 0.0297mg/l, Pd, 0.0042mg/l, Ag, 0.0316mg/l and Li, 0.0019mg/l). This confirmed that the PCB which is an electronic waste was largely made up of heavy and precious metals. Thus, metals can be determined effectively from electronic waste using HNO_3 and AAS. It is therefore, recommended that proper recycling methods should be put in place in order to reduce the pollution caused by these electronic wastes.

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Key words: Electronic waste (e-waste), printed circuit board, metal recovery, AAS, HNO_3

1.0 Introduction

In the world today, there is an exponential increase in the consumer demand for modern electrical and electronic equipment (EEE), as a result of the latest technological development in their manufacturing and designing. This high demand as well as change in consumer tastes have unwittingly shortened the useful life of these electrical and electronic devices. Thus, these out-of-date devices are continually being discarded into the environment, where they infiltrate into soil and groundwater aquifer, causing environmental pollution. The discarded devices have contributed in no small measure to the global generation of huge quantities of waste electrical and electronic equipment (WEEE) (Sinha-Khetriwala *et al.*, 2005) that needs to be properly managed.

Isildar *et al.*, (2019) viewed electronic wastes (popularly called e-wastes) as dangerous since they contain hazardous materials such as minerals, energy and chemicals used for their manufacturing. Their hazardous natures also depend on their condition and density (Kavitha, 2014). E-waste comprises of all the components, sub-assemblies and consumables, which are part of the product at the time of discarding (Khaliq *et al.*, 2014). It contains a mixture of ferrous, nonferrous, plastic and ceramic materials (Khaliq *et al.*, 2014) and more than 1000 different substances which are classified as hazardous when discarded (Dave *et al.*, 2016). E-waste also contain precious metals (PMs) such as gold (Au), silver (Ag), palladium (Pd), platinium (Pt),rhodium (Rd), iridium (Ir), etc., and heavy metals such as lead (Pb), nickel (Ni), zinc (Zn), iron (Fe), copper (Cu), mercury (Hg), cadmium (Cd), etc. Cui and Zhang (2008) noted that precious metals are widely used in the manufacture of electronic appliances due to their high chemical stability and good conducting properties. E-wastes are categorized as discarded computers, television, call phones, refrigerators, copiers, fax machines, electrical lamps and batteries.

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The generation of e-waste globally is increasing exponentially (Debnath *et al.*, 2018) and is expected to skyrocket far beyond human imagination, in the near future (Ongondo *et al.*, 2011; Isildar *et al.*, (2019). Nowadays, 20 -25 million tons of e-waste are being generated globally each year by Europe, United States of America and Australia taking the lead (Khaliq *et al.*, 2014). In the developing countries, there is a substantial increase in e-waste generation. This is as a result of the forecasted economic growth (Yamane *et al.*, 2011). Astudy carried outby It is reported that an average of 5 million secondhand computers weighing 60,000 tons entered Nigeria through Lagos port, out of which nearly 30,000 tons were non-functional or irreparable (Schmidt, 2006).

The composition of e-waste differs chemically and physically from domestic and industrial wastes. Chemically Theses waste include metals, metalloids, halogenated compounds and radioactive elements, printed circuit boards (PCBs), cathode ray tubes (CRTs), epoxy resins, rubber, etc., (Dave *et al.*, 2016; (Privadarshini, 2011).Physically, we have and so on PCBs are commonly found in consumer electronics such as televisions, mobile phones, laptops and computers (Khaliq *et al.*, 2014). PCBs are essential parts of almost all electrical and electronic equipment. and They constitute about 3% by weight of the total electronic scraps (Li *et al.*, 2004). PCB contains noble metals and rare metals such as platinum group metals (PGMs), resin and glass (Itoh, 2014). Ogunniyi *et al.*, (2009) and Khaliq *et al.*, (2014) discovered that PCBs are 40% metals, 30% plastics and 30% ceramics. Yamane *et al.*, (2011) investigated the composition of spent PCBs from mobile phones and personal computers and discovered that PCBs from mobile phones had higher cupper contents (34.5%) while personal computer had 20% of cupper.

Although, it is on record that researchers from countries like India, Japan, Korea, Australia, Turkey and Norway have extracted, recovered and even recycled wastes and precious, base and heavy metals from electrical and electronic equipment in their countries, according to their legislation, employing mechanical processing, hydrometallurgical (Kim et al., 2011), pyrometallurgical (Hall and Williams, 2017, electrometallurgical routes and biometallurgy (Ilyas and Lee, 2014), there is no report on the determination and recovery of potentially toxic elements from e-wastes obtained from electronic or computer villages in Nigeria using Atomic Absorption Spectroscopy (AAS). For this reason, the PCB from a discarded television set was chosen to be studied. Therefore, this study is aimed at determining heavy and precious metals from PCB of a television set by the use of AAS. This study will be beneficial economically and environmentally. The determined metals will help to provide a

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new source of cheap and easily available metals which might be relevant for use in our industries.

2.0 Materials and Methods

2.1 Materials

The materials and equipment used include 5g of sample, 20ml HNO_3, 75ml Kjeldahl flask, 100ml volumetric flask, whatman No. 42 filter paper, AAS, analytical weighing balance, pipette, distilled water.

2.2 Methods

2.2.1 Sample collection

The PBC part attached to the Sony television waste were separated and collected at a refuse dumb at computer village Port Harcourt, Rivers State, Nigeria and transported to Jach Petro-Analytical Laboratory Limited, Rumuokwurusi, Port Harcourt for sample preparation and analysis.

2.2.2 Sample preparation

The e-waste was subjected to mechanical separation were the plastic parts and hazardous parts were separated and disposed safely without creating any harm to the environment. After the separation, 5g of the sample was weighed and placed in a 75ml kjeldahl flask. 20 ml of HNO_3 was measured using a pipette and poured into the flask containing the weighed sample. The mixture was allowed to stay for 48hours ~~in order for the sample to properly digest all of its oxidizable metals~~ into the solvent (HNO_3) until the contents of the flask were completely digested to brown fumes of nitrous oxide. The prepared samples were filtered using Whatman No.42 filter paper into a 100ml volumetric flask. Distilled water was used to make up the solution to 100ml.

2.2.3 Sample Analysis

The concentrations of Fe, Pb, Cu, Ni, Cd, Au, Pb, Ag and Li were analyzed using AAS [Shimadzu model AA6300]. The instrument was calibrated based on the individual metals. The data were analyzed in triplicate and the mean concentration values were recorded.

2.3 Results and Discussion

The concentrations of each of the metals analysed in mg/l, mg/kg and weight percent are shown in Table 1 ~~below~~.

Table 1: Concentration of metals from PCB of a television

S/N	Metals	Concentration (mg/l)	PPM (mg/kg)	Weight percent (wt %)
1	Fe	0.0644	1.288	0.0001288
2	Pb	0.0732	1.464	0.0001464
3	Cu	0.0627	1.254	0.0001254
4	Ni	0.1076	2.152	0.0002152
5	Cd	0.0001	0.002	0.0000002
6	Au	0.0297	0.594	0.0000594
7	Pd	0.0042	0.084	0.0000084
8	Ag	0.0316	0.632	0.0000632
9	Li	0.0019	0.038	0.0000038

The results indicate that the PCB of a television set contains higher amount of Ni (0.1076mg/l), followed by Pb (0.0732mg/l) as compared to other heavy metals analysed. Among the heavy metals analysed, Cd (0.0001mg/l) was the least metal found in a television PCB. Amongst the precious metals analysed, Ag (0.0316mg/l) had the highest concentration while Li (0.0019mg/l) recorded the least concentration. Although, the values of the concentrations in weight % of the heavy metals differ significantly from those recorded by Debnath *et al.*, (2018): Fe (20.4712%), Pb (6.2988%),Cu (6.9287%), Ni (0.8503%), the weight ~~precent~~percent values of only Ni matched with the weight percent values recoded for rare earth and valuable metals by Debnath *et al.*, (2018): Au (0.0016%), Pd (0.0003%), Ag (0.0189%), Ni (0.0002%) and Cd (0.0094%). The high concentrations of heavy metals such as Pb and Cu as shown in Table 1. could be attributed to their use for soldering or preventing oxidation and conductive properties respectively. Also, the weight % value obtained in this study fall within the values obtained by Isildar *et al.*, (2019) for PCBs: Au and Pd (1-100ppm), Fe and Ni (100-10,000ppm) and Cu (>10,000ppm).

3.0 Conclusion

Heavy and valuable metals are found in printed circuit board of a television set. ~~Among the heavy metals analysed~~In this investigation, Ni recorded the highest concentration while Ag had the highest concentration among the precious metals. Determination of these metals from television PCB using $HN0_3$ as a solvent and AAS showed ~~favourable~~ significant presence ~~for the~~of metals. Therefore, AAS is another promising analytical technique for the determination of metals ~~from~~ in electronic waste.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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References

Cui, J. and Zhang, L. (2008). Metallurgical Recovery of Metals from Electronic Waste: A Review. *Journal of Hazardous Materials*, 158: 228-256.

Dave, S. R., Shah, M .B. and Tipre, D. R. (2016). E-waste: Metal Pollution Threat or Metal Resource? *Journal of Advanced Research in Biotechnology*, 1(2): 1-14.

Debnath, B., Chowdbury, R. and Ghosh, S .K. (2018). Sustainability of Metal Recovery from E-waste. *Front Environ. Sci. Eng*., 1 (6): 1-12.

Hall, W.J. and Williams, P.T. (2007). Analysis of products from the pyrolysis of plastics recovered from the commercial seele recycling of waste electrical and electronic equipment. *J. Anal Appl. Pyrolysis*, 79(1): 375-386.

I lyas, S. and Lee, J.C. (2014). Biometallurgical recovery of metals from waste electrical and electronic equipment: a Review.*ChemBioEng Reviews*, 1(4): 148-169.

Isildar, A., Hullebusch, E. D. V., Lenz, M., Laing, G. D., Marra, A., Cesaro, A., Panda, S., Akcil, A., Kucuker, M. A. and Kuchta, K. (2019). Valuable and Critical Raw Materials from Waste Electrical and Electronic Equipment (WEEE)-A Review. *Journal of Hazardous Materials*, 362: 467-481.

Itoh, H. (2014). The Recent Trend of E-waste Recycling and Rare Metal Recovery in Japan. *WIT Transactions on Biology and the Environment*, 180: 3-14.

Kavitha, A. V. (2014). Extraction of Precious Metals from E-waste. *Journal of Chemical and Pharmaceutical Sciences*, 3: 147-149.

Khaliq, A., Rhamdhani, M. A., Brooks, G. and Massod, S. (2014). Metal Extraction Processess for Electronic Waste and Existing Industrial Routes: A Review and Australian Perspective. *Resources*, 3: 152-179.

Kim, E.Y., Kim, M.S., Lee, J.C. and Pandey B.D. (2011). Selective recovery of gold from waste mobile phone PCBs by hydrometallurgical process. *J hazard mater*. 198: 206-215.

Li, J., Shrivastava, P., Gao, Z. and zhang, H.C. (2004). "Printed circuit board recycling: A state of the art survey."*IEEE transactions on electronics packaging manufacturing*, 27,1:33-42.

Ogunniyi, I. O., Vermaak, M. K. G. and Groot, D. R. (2009). Chemical Composition and Liberation Characterization of Printed Circuit Board Comminution Fines for Beneficiation Investigations. *Waste Manag*., 29: 2140-2146.

Privadarshini, S. (2011). A Survey on Electrical Waste Management in Coimbatore. *International Journal of Engineering, Science and Technology*, 3(3):99-104.

Schmidt, C. W. (2006). Unfair Trade: E-waste in Africa. *Environ Health Perspect*, 114 (4): 232-l.

Sinha-Khetriwala, D., Kraeuchib, P. and Schwaninger, M. (2005). A Comparison of Electronic Waste Recycling in Switzerland and India. *Environ. Imp. Assess. Rev*., 25 (5): 492-504.

Yamane, L. H., De-Moraes, V. T., Espinosa, D. C. R. and Tenorio, J. A. S. (2011). Recycling of WEEE: Characterisation of Spent Printed Circuit Boards from Mobile Phones and Computers. *Waste Management*., 31: 2553-2558.