Elementary analysis of mobile phones for optimizing end-of-life scenarios

K. I. Takahashi[1,3], M. Tsuda[1],J. Nakamura[1], K. Otabe[2], M. Tsuruoka[2], Y. Matsuno[3] and Y. Adachi[3]
[1] NTT Energy and Environment Systems Laboratories, NTT Corporation
[2] Tsuruoka Co., Ltd., [3] Graduate School of Engineering, The University of Tokyo

***Abstract*—The metals contained in various mobile phones were analyzed. More than 20 elements were detected and their net amounts were found to increase year by year. The environmental and economic impacts were assessed based on an elemental analysis. The CO_2 emissions generated by the incineration of plastics were estimated to be almost the same as those avoided by recovering the metals. Gold had the biggest economic impact. However, the amount of gold is decreasing and an eco-design for improved recycling is an urgent problem.**

***Index Terms*—Mobile phone, Chemical analysis, LCA, Recycle**

I. Introduction

Despite the widespread use of mobile phones in Japanese society, the recovery rate of used phones is less than 20% and the rest remain in dead storage. However, mobile phones contain precious metals including gold, silver, and palladium, and other useful nonferrous metals such as barium, nickel, and chromium. The concentrations of these metals in mobile phones are generally much higher than in natural ore, so they have been recognized as attractive “urban mines”. Therefore, promoting the recycling of the resources found in mobile phones will become of prime importance.

Some previous researches have focused on the metal content of mobile phones. Lindholm revealed the metal content of mobile phones and assessed their recyclability [1]. Bhuie et al. reported the weights of materials found in cell phones and estimated the recycling cost [2].In Japan Nakano et al. analyzed the precious metals, rare metals and low-toxicity substances present in a few mobile phones, and estimated the amount of useful material in unused phones kept in offices and homes. They also employed a user questionnaire to attempt to determine why people keep unused mobile phones. Moreover, they estimated the possible recycling rate of the substances [3], [4]. Nakajima et al. estimated the value of recycled substances based on Total Material Requirement (TMR) by using Nakano’s substance content data. The material recovery rate was 11% based on weight and 90% based on TMR. They mentioned that the values of substances do not correspond to their weight [5]. In China, Wu et al. analyzed the metal content of mobile phones and estimated a toxicity potential indicator [6].

During the last decade, the components of mobile phones have been upgraded as their performance has been improved, and the metal content may have changed. For example, multifunctional mobile phones have large high-resolution liquid crystal displays and they are expected to contain more indium than before. Therefore, detailed analyses of the material content of mobile phones are needed if we are to encourage the further recovery of mobile phone material. The aim of this study is to conduct detailed elementary analyses of various mobile phones to obtain fundamental information about their metal content. In addition, we assessed the environmental and economic impacts with a view to optimizing end-of-life scenarios.

II. Methods

More than 100 used mobile phones made between 1996 and 2008 were collected and classified into 8 groups depending on their functions (Table 1). The oldest of these mobile phones have only calling and short mail functions, whereas the more recent devices have many functions including camera, music and e-cash capabilities. We dismantled each of them into their component parts by hand. The average time needed to dismantle one mobile phone was 12.4 minutes.

The parts were crushed and pretreated and then subjected to elemental analyses with ICP-OES and ICP-MS that focused on particular metals (Table 2).

The environmental impact of recycling was assessed by using LCA. We assumed that all the detected metals were recovered by incinerating the plastics. Other processes, such as collection, separation and refinement, were not included.

The economic impact was assessed as the value of the recovered metals. We assumed the all the detected metals were recovered. We did not consider the costs related to collection, separation and refinement.

III. Results and discussion

A. Elementary Analysis

The elementary analysis result is shown in Fig. 1. The amounts of precious and rare metal increased as more functions were added to the phones. The boards, motors, liquid crystal displays, flexible substrates, speakers/microphones and cameras had more metal content in this order. In most groups, copper had the highest concentration of the metals found in the mobile phones followed by barium and nickel in recent models. The average gold content was 44 mg, which is equivalent to

0.04 wt.% of the mobile phone sets. This Au concentration is approximately 200 times greater than that in a South African gold mine. The lead content has decreased year by year. During this period Japanese companies have taken measures related to the Restriction of Hazardous Substances (RoHS) and have reduced the use of lead not only in home appliances but also in mobile phones.

B. Environmental / Economic impact

The environmental impact assessment result is shown in Fig. 2. The reduced CO_2 emissions of recycled material are shown as negative values and the additional CO_2 emissions resulting from the incineration of plastic are shown as positive values. CO_2 emissions generated by the incineration of plastics are estimated to be nearly the same as those avoided by recovering the metals.

The economic impacts assessment result is shown in Fig. 3. The average value of the recyclable metals was 112 yen (U$ 1.1). The manpower cost, estimated in terms of wages, exceeded the value of the recovered metals.

These results suggest that an improved recycling process and an easy to dismantle eco-design are needed if we are to improve the recyclability of mobile phones.

IV. CONCLUSION

We analyzed the precious and rare metals in mobile phones and revealed the tendency as regards the use of each material. Mobile phones contain an abundance of various metals including gold, copper, nickel, barium and indium. However the recycling system is imperfect, and hibernating mobile phones are a hidden resource. By using information about the metal content of various mobile phones, we believe that an effective approach to end-of-life cycle management can be developed.

REFERENCES

[1] M. Lindholm, “Toward Environmentally Conscious Product Design – a Comprehensive DfE Implementation in New Generation Cellular Phone”, in *Proc. 2003 IEEE International Symposium on Electronics and the Environment & The IAER Electronics Recycling Summit*, Boston, 2003, pp. 251–254

[2] A. K. Bhuie, O. A. Ogunseitan, J-D. M. Saphores, and A. A Shapiro, “Environmental and Economic Trade-offs in Consumer Electronic Products Recycling: A Case Study of Cell Phones and Computers”, in *Proc. 2004 IEEE International Symposium on Electronics and the Environment & The IAER Electronics Recycling Summit*, Phoenix, 2004, pp. 74–79

[3] K. Nakano, K. Nakajima, S. Miyabe, Y. Wada, and T. Nagasaka, “Recovery of precious and rare metal from used mobile phones”. Environmental Management, Vol. 42, No 11, pp. 49-62, 2006

[4] K. Nakano, S. Miyabe, T. Ozaki, Y. Wada, K. Nakajima, and T. Nagasaka , “Substance Flow Analysis on Diffused Toxics Contained in End-of-Life Cellular Phone” , Japan Inst. Metals 71, (9), pp. 801-808, 2007

[5] K. Nakajima, K. Yamamoto, K. Nakano, K. Kuroda, K. Halada, and T. Nagasaka, “Recycle-Flow Analysis on Used Cellular Phone Based on Total Materials Requirement”, J. Life Cycle Assessment, Japan, 2, (4), pp. 341-346, 2006

[6] B. Y. Wu, Y. C. Chan, A. Middendorf, X. Gu, H. W. Zhong, “Assessment of Toxicity Potential of Metallic Elements in Discarded Electronics: A Case Study of Mobile Phones in China”, J. Env. Sci., 20, pp. 1403-1408, 2008

Table 1 Mobile phone groups

	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8
Call	*	*	*	*	*	*	*	*
Short email		*						
e-mail			*	*	*	*	*	*
IRC				*		*	*	*
Camera					*	*	*	*
Music							*	*

IRC: Infrared communication

Table 2 Elemental analysis

Name of part	Detected element
Board	Au, Ag, As, Ba, Bi, Cr, Cu, Ga, Mn, Ni, Pb, Pd, Pt, Si, Sn,Ta, Ti, Zn, Zr
Flexible substrate	Au, Ag, Cu, Pt
Liquid crystal display	Au, Ag, As, Ba, Ca, Cu, In, Ni, Sb, Si, Sn,
Motor	Au, Ag, Cu, Pt
Camera	Au, Cu, Ni
Speaker/microphone	Cu, Mn, Zn

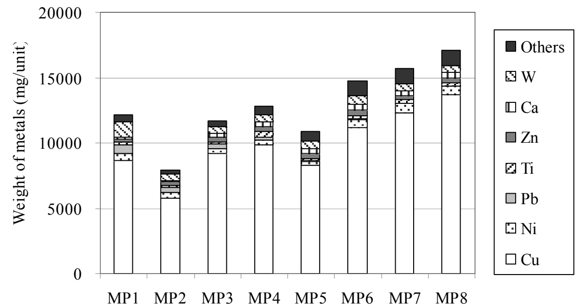

Fig. 1. Metal content of mobile phones.

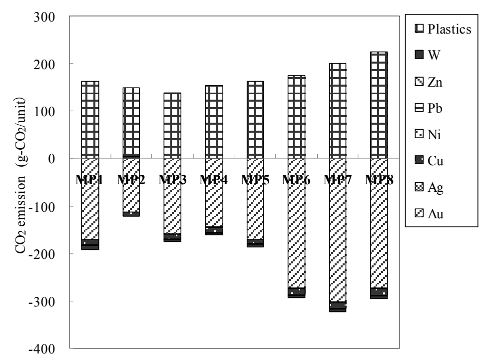

Fig. 2. Environmental impact assessment.

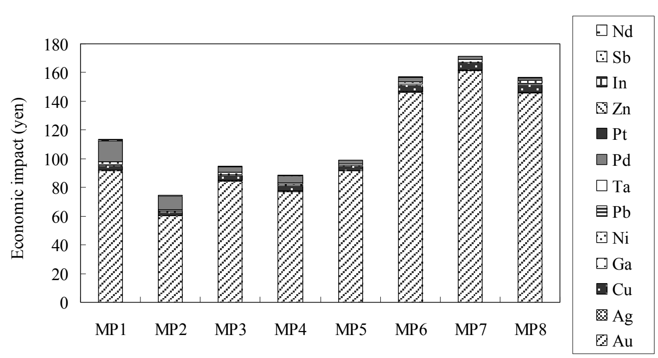

Fig. 3. Expected recovered cost.