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Estimation of obsolete cellular phones generation: A case study of China

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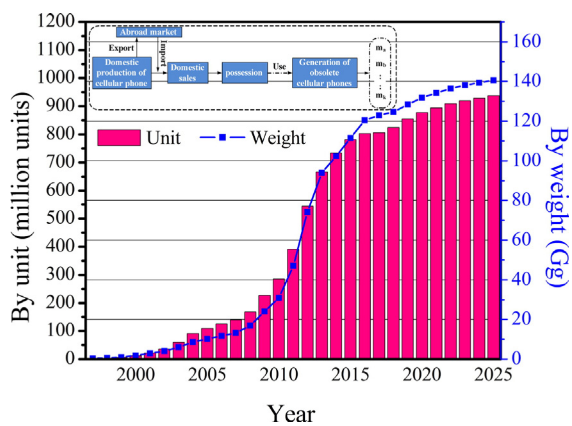
HIGHLIGHTS

- Future average possession and possession amount of cellular phones are predicted in China.
- Generation amount of obsolete cellular phones in China from 1997 to 2025 are estimated.
- The metals contain in obsolete cellular phones in China from 1997 to 2025 are analyzed.

GRAPHICAL ABSTRACT



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ABSTRACT

Rapid development of electronic technique has led to decreasing lifespan of electronic products. Meanwhile, the amount of waste electrical and electronic equipment (WEEE) is rapidly growing in recent years especially in China. The generation amount of WEEE is one of the basic information for waste management. In our study, the generation of obsolete cellular phones and metals containing of cellular phones were estimated from 1997 to 2025. The future average possession in per 100 inhabitants of cellular phones was predicted using logistic model. Moreover, the lifespan distribution of cellular phones was analyzed using Weibull distribution. Meanwhile, the generation amount of obsolete cellular phones and its metals containing were estimated by using population balance model (PBM) and substance flow analysis (SFA), respectively. The estimated results indicate that the average possession in per 100 inhabitants will reach to 111.2 and 118.3 units in 2020 and 2025, respectively, which is about two times higher than the average possession in 2010. In addition, the total possession amount of cellular phones are expected to exceed 1.64 billion units in 2025. Moreover, the estimated results show that 781 million units obsolete cellular phones were generated in 2015, and the number will grow up to 877 and 937 million units in 2020 and 2025, respectively. In 2025, the total weight of annual generation amount of obsolete cellular phones will exceed 140 Gg. The precious metals such as silver, gold contains in obsolete cellular phones will reach 56,250 and 28,130 kg, respectively, in 2025. The obsolete cellular phones are the typical secondary metal resources especially for precious metals. In order to improve the recycling efficiency, it is necessary to establish a comprehensive system of waste management.

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1. Introduction

Waste electrical and electronic equipment (WEEE) refer to electrical devices approached to the end of lifespan, including waste computer, television, washing machine, mobile phone, communication device et al. The market demand for electronic products is increasing with the rapid development of science and technology. However, the constantly updating function and design of electronic products and the gradual shortening of service lifespan increase the scrap generation. A large amount of WEEE is generated after the products reach the end of their life (Osibanjo and Nnorom, 2008). WEEE is one of the fastest growing solid wastes in the world (Wei and liu, 2012; Guo et al., 2015). The management of WEEE has gained increased attention from the government. Laws and regulations are formulated to promote the management and recycling of WEEE in developed countries and developing countries (Duan et al., 2016; Sarath et al., 2015; Zeng et al., 2016; Li et al., 2015c). The cellular phone is the most ubiquitous electronic product worldwide and is an essential communication and entertainment tool. The numbers of sold and discarded cellular phones are increasing with the mobile penetration rate and rapid update speed (Jang and Kim, 2010; Paiano et al., 2013; Tanskanen, 2012). China is the largest cellular phone production and sales country in the world since 2004. The cellular phone subscriptions worldwide are over 7.08 billion, and those in China have reached 1.30 billion (ITU, 2015). Obsolete cellular phones are a special electronic waste. The amount of such waste is growing faster than that form other household appliances, because the number of cellular phone subscribers has exponentially grown in the past two decades. Because of rapid popularization and frequent function updates, most cellular phones have not completely lost function when replaced by users (Ongondo and Williams, 2011a). Obsolete cellular phones have become an important part of WEEE (Sarath et al., 2015).

The challenges facing WEEE management are not only the outcomes of the growing quantities of waste but also the complexity of WEEE (Rahmani et al., 2014). Cellular phones contain both hazardous and valuable materials (Araújo et al., 2012; Suckling and Lee, 2015; Maragkos et al., 2013; Zeng and Li, 2014). The structural material of a cellular phone is plastic, which is extremely difficult to naturally degrade. Plastic incineration can cause pollution, particularly air pollution, which can affect human health (Gullett et al., 2007; Bian et al., 2016). Plastic can also exist for a long time if scattered in the environment. The circuit board of a cellular phone contains a large number of hazardous substances, such as lead, cadmium, and other chemicals, which significantly harm the environment when leaked into the soil and groundwater of landfills or pollute the air when recycling disposal is unwarranted (Yadav and Yadav, 2014; Nnorom and Osibanjo, 2009). At the same time, obsolete cellular phones contain dozens of precious metals such as gold, silver, palladium, indium and copper, which have a metal grade equivalent to several times of that of ordinary minerals, have an extremely high recycling value, and are typical "urban mining" (Polák and Drápalová, 2012; Silveira et al., 2015; Wang et al., 2016; Oguchi et al., 2011).

The generated quantity of waste cellular phones is relatively large, but the unit size is rather small, and easily thrown out with municipal waste (Ongondo and Williams, 2011b). The process and management of waste cellular phones are moderately different from those of other household appliances. The management of waste cellular phones cannot be neglected from the perspectives of resource conservation and environmental pollution control (Oguchi et al., 2011). The estimation of the generated WEEE is the foundation of sustainable management (Zhang et al., 2012). Therefore, the amount of retired cellular phones should be estimated and forecasted to grasp the information on the material flow of waste cellular phones and provide the basic information to formulate an efficient waste management policy and recycling system of obsolete cellular phones in China.

At present, the amount of WEEE generation lacks reliable statistical data, which typically rely on mathematical models based on the sales, inventory, lifespan or average lifespan, and other parameters of electrical and electronic equipment products used to estimate or predict the amount of WEEE. The models used to estimate WEEE generation are market supply method, market supply A method, Stanford method, Carnegie Mellon method, consumption and use approach, time-step method, material flow analysis (MFA) method, time-series model (Li et al., 2015b; Ikhlayel, 2016; Dwivedy and Mittal, 2010a). Many studies on estimate the generation of obsolete cellular phones at the national level have been conducted (Kang and Schoenung, 2006; Lau et al., 2013; Habuer and Moriguchi, 2014; Elshkaki et al., 2004; Steubing et al., 2010). Jang and Kim (2010) estimate the number of retired cellular phones every year by using information about subscribers, average lifespan, and domestic demands of cellular phones. Approximately 14.5 million cellular phones are retired annually in Korea (Jang and Kim, 2010). Time-series multiple lifespan model was used to estimate the outflows of obsolete cellular phones in Iran, the amount of waste cellular phones generated was 39 million until 2014 (Rahmani et al., 2014). Delay model was applied to assess the generation of obsolete cellular phones in Czech Republic. From only 45,000 obsolete cellular phones generated in the year 1990–2000, the number grew to 6.5 million in 2000–2010, and the number is predicted to reach to 26.3 million in 2010–2020 (Polák and Drápalová, 2012).

Several studies have concentrated on estimating the quantities of retired cellular phones generated in China (Liao and Zhang, 2012; Yu et al., 2010a; Gao, 2010; Guo and Sun, 2013). Most of the previous studies have only focused on estimating obsolete cellular phones. Studies on forecasting the future generation and substance flow analysis (SFA) of obsolete cellular phones are rare because of estimation complexity and data availability. The average lifespan of products continues to shorten and the annual generated amount of obsolete cellular phones increases with the advancement of information technology. The prediction of the future generation is indispensable information for waste management. Waste cellular phones are typical secondary metal resources. Thus, the number of metals contained in obsolete cellular phones should be clear.

This research aims to confirm the lifespan of cellular phones in China, estimate and forecast the volume of obsolete cellular phones from 1997 to 2025, and simultaneously ascertain the metals contained in the annual generation of obsolete cellular phones to present the basic information on their management in China.

2. Materials and methods

2.1. Definition and system boundary

Lifespan has various definitions, including "total lifespan", "possession lifespan", and "service lifespan", among others (Murakami et al., 2010; Oguchi et al., 2010). To simplify the product lifespan in this study, cellular phone lifespan refers to the domestic service lifespan and obsolete cellular phones refer to cellular phones that complete the service for consumer and leave the telecommunication networks system.

Considering the large scale of cellular phones used since the 2000s in China, this paper is dedicated to estimating the annual obsolete cellular phones generated from 1997 to 2015 in China and forecast the generation amount of obsolete cellular phones from 2016 to 2025. The spatial boundary covers the geographical border area of mainland China, excluding Taiwan, Hong Kong and Macao. Fig. 1 shows the system boundary of substance flow analysis of obsolete cellular phones in this study.

2.2. Estimation of annual possession amount of cellular phones

Logistic model was used to predict the future possession amount of cellular phones in this study. Logistic growth curve is obvious "S" sharp curve, which is very much in marketing for description of the product life cycle (Habuer and Moriguchi, 2014; Yang and Williams,