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A Comparative Analysis on Recycling Technologies for Recovery of Precious Metals from Waste Mobile Phones between China and Japan

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Abstract

The number of waste mobile phones produced in China is about 100 million every year. Waste mobile phones can release a large amount of toxic and hazardous sub-

stances, polluting the environment we live, and meanwhile, we can recycle a large quantity of precious metals from waste mobile phones. In this article, the author makes comparison of recycling technologies to recover precious metals from waste mobile phones between China and Japan, and then summarizing the experience of Japan and taking the actual conditions of China into consideration, advocates the improvement and update in processing technology, government supervision, pilot projects, publicity efforts and many other aspects so as to accelerate the continuous and health development of the recycling of waste mobile phones in China.

Keywords: Waste mobile phones; Recycling technologies; Precious metals; Comparison; China; Japan

1 Introduction

The number of mobile phone users in China is the largest in the world [1], producing a large amount of waste mobile phones which contain many different kinds of toxic and hazardous metals. These metals will do harm to environment and human beings if we don't treat them properly. However, on the other hand, we can get a large quantity of precious metals from waste mobile phones by recycling them. Considering the shortage of mineral resources and the severity of environmental issues, it is of great significance to recycle waste mobile phones.

Japan has mature technologies and extensive experience on the recycling of waste mobile phones. All the mobile operators in Japan request their mobile suppliers to consider how to use environmentally friendly and cost-effective ways to recycle waste mobile phones since the design of mobile phones. Besides, the operators also request the suppliers to submit "the treatment methods of mobile phones that out of their life cycles" [2]. However, unlike Japan, China has not built the recycling system of waste mobile phones.

By making comparison between China and Japan, the paper finds the problems on recycling technologies for recovery of precious metals from waste mobile phones in China, and then proposes suggestions on Chinese waste mobile phones' recycling system on the base of Japanese experience and Chinese actual conditions.

2 Comparative analysis on recycling technologies of precious metals

Mobile phones contain relatively high contents of precious metals, 40% of its total mass is metals, including gold (about 280g/t), silver (about 2kg/t), palladium (about 100g/t) and copper (about 100g/t) [1]. Therefore, waste mobile phones can be viewed as an important source for mining precious metals, and recovering precious metals can present a double value of both environmental protection and resource conservation.

2.1 Comparative analysis on pretreatment

To recover metals, waste mobile phones must be pretreated first, metallic components have to be liberated from non-metallic components such as plastics. In addition, the effective separation of metallic components in pretreatment makes the extraction and purification processes of metals easier. With the rapid economic growth and technological advances, the shapes of mobile phones are increasingly diverse, making it very difficult to extract metallic components from them.

In Japan, the pretreatment of waste mobile phones has experienced an evolution, from simple mechanical crushing to manual decomposition and then to joint use of a variety of decomposition methods. Using simple crusher to pretreat, the recycling rate of waste mobile phones is only 50%-60%, the recycling of non-metallic components is difficult. Moreover, the residues will be harmful to environment. On the other hand, the recycling rate can reach up to 100% by using manual decomposition, not only the extraction of metals becomes easier, but the recycling rate of non-metallic components becomes higher. Yokohama Metal Company is using manual decomposition to pretreat waste mobile phones [3]. However, the cost of manual decomposition is so high that companies are hard to obtain economic benefits. Therefore, most Japanese companies use the joint technologies composed by mechanical crushing and manual decomposition. Figure 1 shows a process used in the pilot project in Ibaraki in 2008 [4].

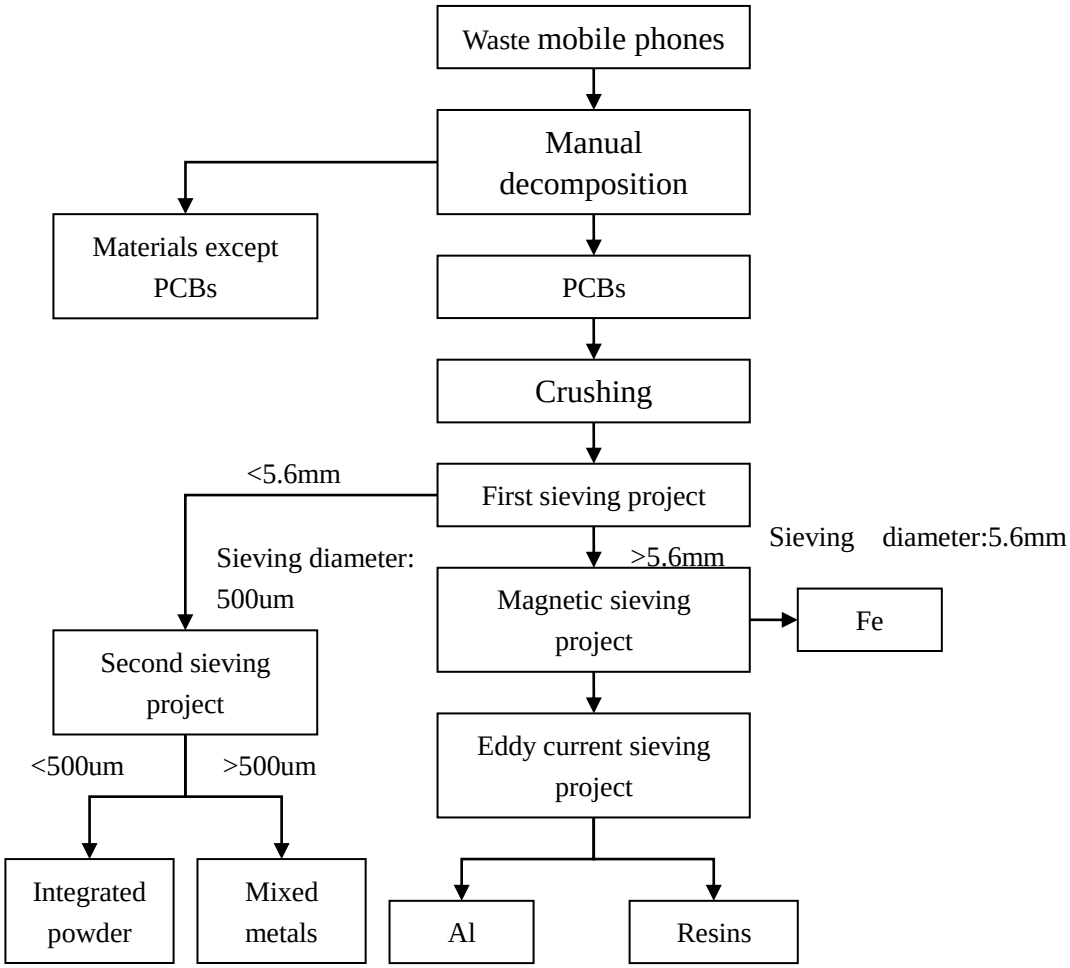

Figure 1. Pretreating processing used in the pilot project in Ibaraki

Unlike Japan, the main pretreating technology of waste mobile phones in China is manual decomposition, and most processes are operated in family workshops which are not standardized and lack machines and mature technologies [1]. This pretreatment method causes secondary pollution and do harm to operators' health as well.

As the number of waste mobile phones in China increases rapidly, some environmental companies and pilot projects start to treat waste mobile phones with advanced technologies. However, due to the small size, waste mobile phones are hard to be dismantled in large scale. Therefore, companies in China treat the waste mobile phones with other waste home appliances such as waste televisions, computers and so on. Figure 2 shows a process used in an environmental company to pretreat waste electrical and electronic products in Tianjin[5].

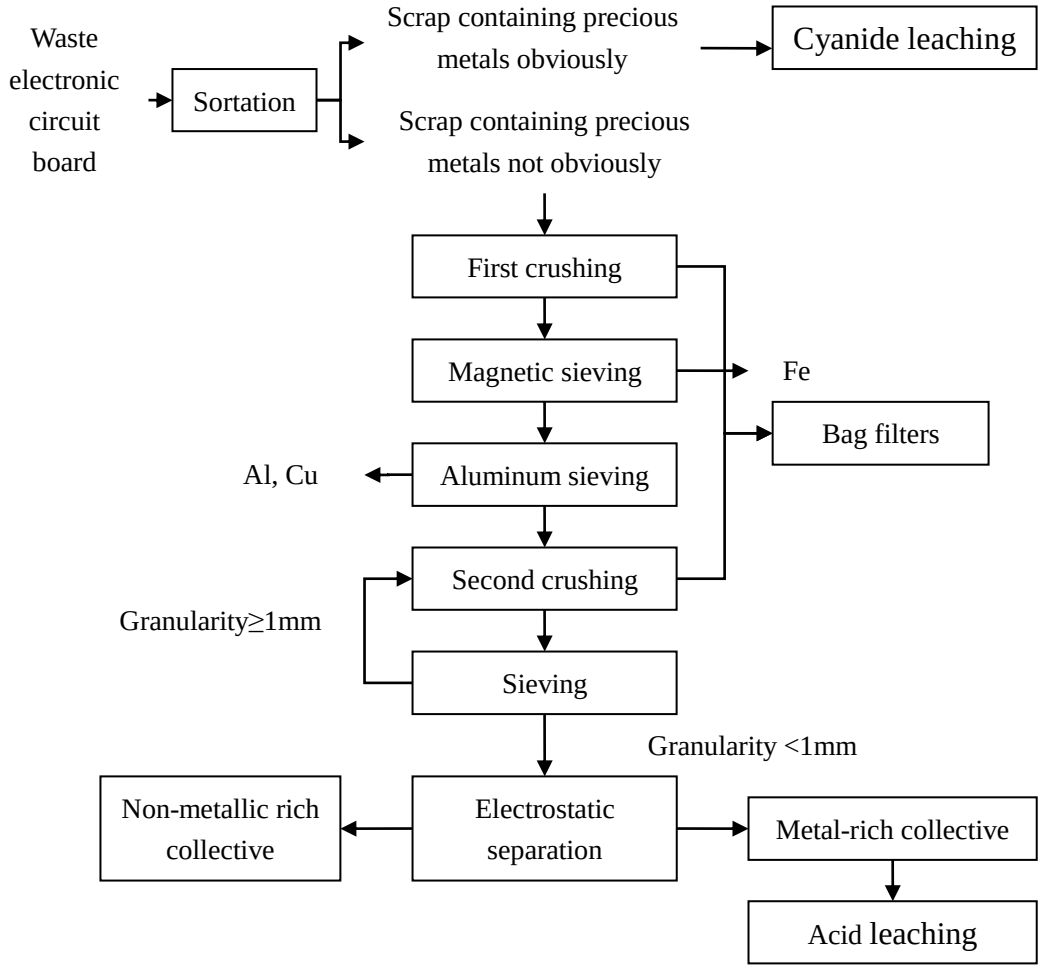

Figure 2. Process flow diagram of an environmental company in Tianjin

By making comparison, we can conclude that the pretreatment of waste mobile phones in Japan is mature technologies, while in China the main pretreating technology is manual decomposition, and most processes are operated in family workshops that are not standardized [1]. Although some environmental companies and pilot projects begin to use advanced technologies, they don't treat waste mobile phones separately, they treat them together with other waste electrical and electronic products.

2.2 Comparative analysis on recycling technologies of precious metals

Recycling technologies to recover valuable metals from waste mobile phones are generally classified into the following methods: pyrometallurgical process, hydrometallurgical process, and biometallurgical process. Pyrometallurgical process is the first technology used to recycle precious metals from electronic wastes [2]. This method extracts metallic components by high temperature and refines them by electrolysis treatment or other ways. Pyrometallurgical process has advantages such as simplify operation, high metal recoveries (>90%), but from the point of environment, it has notable disadvantages. Hydrometallurgical process uses cyanide, aqua regia and other strong oxidizing agents to leach precious metals, which has been widely used in recycling precious metals from waste mobile phones. Biometallurgical process, a new process developed in 1980s, is a technology that makes use of microorganisms' sorption and oxidation to extract metals. This process has many advantages such as low cost, simple process and easy operation. It is believed that biotechnology has been one of the most promising technologies in metallurgical process and some researches have been carried out on the bioleaching of metals from electronic wastes. Bioleaching of gold and copper from waste mobile phone PCBs by using a cyanogenic bacterium (Tran D. Chi et al., 2011, Tran, CD et al., 2011) was investigated. The best bioleaching condition, the catalytic roles of metal irons and the effect of Na_2HPO_4 nutrient addition was elucidated. However, this technology is rarely put into use due to its long leaching time and low leaching rate.

Unlike pretreating technology, recycling technology of precious metals remains basically unchanged compared with the past [8], most practitioners use hydrometallurgical process, aqua regia leaching to extract gold and platinum, nitric acid leaching for silver extraction. If alloy includes gold and silver, using cyanide leaching first and then extract gold by hydrazide [8]. Figure 3 shows a process to leach metals from waste mobile phones in Japan [9].

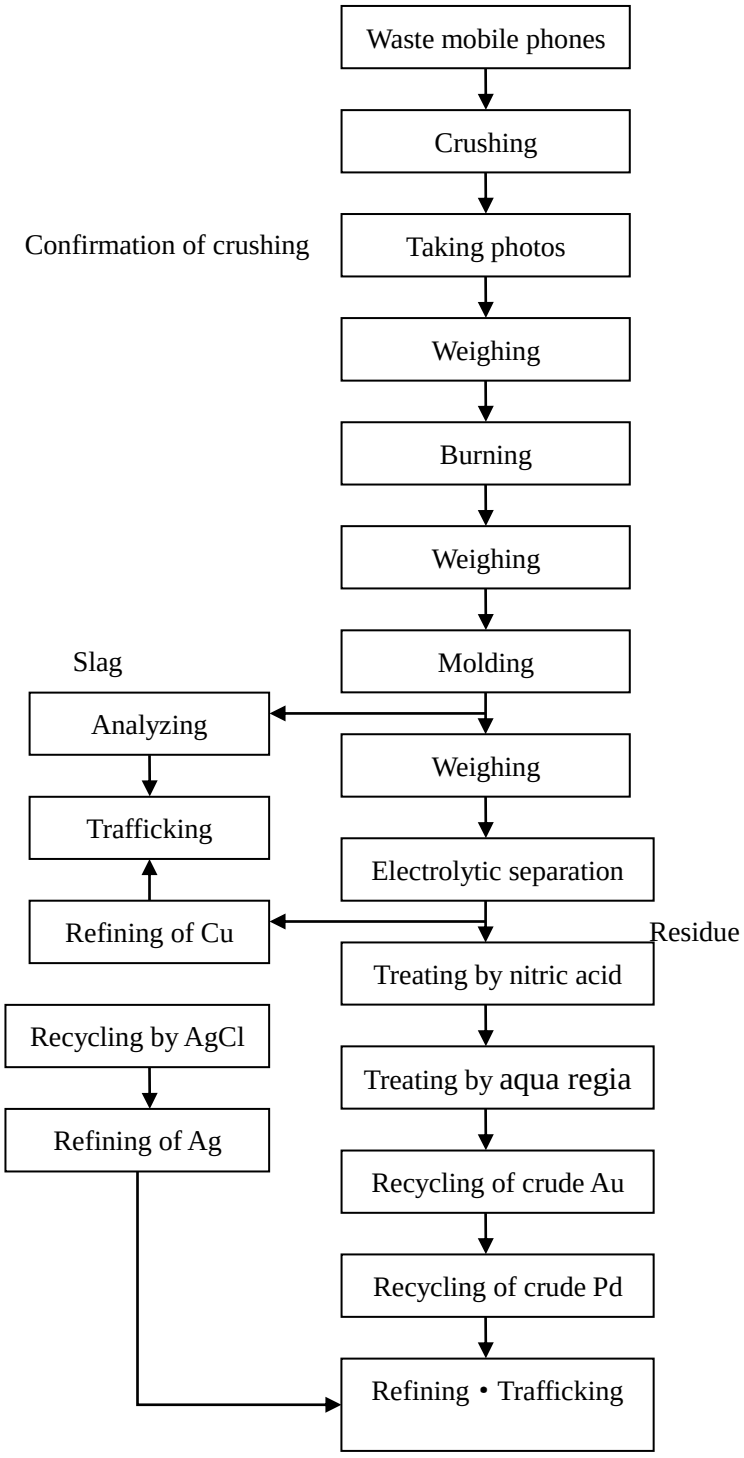

Figure 3. A process to leach metals from waste mobile phones in Japan

Similar to Japan, China also uses hydrometallurgical process to recycle precious metals from electronic wastes. Technologies that have been applied to leach gold

from electronic wastes are nitric acid-aqua regia leaching, hydrogen peroxide-sulfuric acid leaching and oxygen-cyanide leaching [2]. However, in Chinese coastal areas such as Zhejiang, Guangdong, some private and small enterprises extract metals just by putting waste mobile phones into sulfuric acid pools or burning them [10]. These treatments will produce a large amount of waste liquid, gas and residues, causing serious environmental pollution.

Although hydrometallurgical process is the technology that most widely used, aqua regia, cyanide and other strong oxidizing agents used in the process will produce secondary pollution. Several substitutes have recently been proposed as the environmentally friendly leaching solution such as thiosulfate (Vinh Hung Ha et al., 2010) and thiourea (Li Jing-ying et al., 2012). Vinh Hung Ha et al. [11] reported the leaching of gold from PCBs of waste mobile phones by using a copper–ammonia–thiosulfate solution, Li Jing-ying et al. [12] investigated the influence of particle size, thiourea and Fe^{3+} concentrations and temperature on the leaching of gold and silver from waste mobile phones. Compared with the traditional solutions, these solutions produce less pollution, but have not been applied to industrial processes. Besides, Optimization of hydrometallurgical process (Eun-young Kim et al.,2011)was developed, the leaching of gold from waste mobile phone PCBs by 2 stages' selective leaching (the 1st stage for copper, the 2nd stage for gold) and its recovery by ion exchange process was investigated.

3 Comparative analysis on environmental management in recycling process

Although the recycling of waste mobile phones is a process of resource regeneration, chemicals used in the process and intermediates have harmful effects on environment. In order to reduce these effects, some measures have been taken in Japan. For instance, using dust collection device and enclosed structure to control dust. Moreover, in the recycling process, Japan also makes management of hazardous substances such as some rare metals and intermediates.

Management of hazardous substances includes environmental risk assessment, content analysis and dissolution test. Environmental risk assessment consists of hazard assessment, emission assessment, exposure assessment and risk characterization [14]. Hazard assessment is an assessment of substances' hazardous nature including physical hazard, health hazard and ecological hazard. Emission assessment is to assess the sources and quantities of emissions. Exposure assessment is to assess the exposure frequencies, ranges and quantities of hazardous substances. Risk characterization is to determine the possibility and size of environmental impact considering substances' hazards and exposures.

Content analysis is to determine the concentration of hazardous substances according to regulations. Dissolution test is a test to assess the risk of Pb、Cd、Cr^{6+}、As、Hg、Ni、Zn、Sb、Cl、Br、P、Fe、Cu、Al and other substances according to the notices of the 13th test, 18th test and 19th test that promulgated by the Japanese Department of Environmental Protection.

In China, environmental management has not been carried out in the process of recycling of waste mobile phones, except some companies use dust removal device to reduce dust. Although the management of hazardous substances in Japan is just conducted in pilot projects, and the toxicity and concentration of some substances have not been cleared, the try that made by Japan gives a significant enlightenment to China.

4 Conclusions and suggestions

By analyzing the differences of recycling technologies for recovery of precious metals from waste mobile phones between China and Japan, we can conclude that: Japan has mature technologies and has carried on many pilot projects and practice of industrial applications across the country, while in China, the recycling technologies are backward and the treatment of waste mobile phones is not standardized.

Based on the comparative analysis in this paper, we can propose following suggestions for the development of Chinese waste mobile phone recycling system:

(1) Bringing in and developing recycling technologies, especially the pretreating technologies. Japan has increased the recoveries and purification rate of metals by controlling the parameters such as the ratio of liquid to solid, temperature and time in the process. In pretreatment, Japan uses a variety of decomposition methods to improve the recycling rate. Same as Japan, China also use hydrometallurgical process to leach metals, but Chinese technologies are immature causing secondary pollution easily. In pretreatment, China mainly uses manual decomposition, and most processes are operated in family workshops. Therefore, it is urgent for China to bring in and develop environmentally friendly and cost-effective technologies. Additionally, in the process of recycling precious metals from waste mobile phones, China can learn from Japanese experience and put the environmental management of hazardous substances into practice

(2) Strengthening the supervision for private and enterprises engaging in the recycling of waste mobile phones. One of the reasons that China couldn't build a recycling system is that some private and enterprises recycle waste mobile phones by themselves and don't use advanced technologies to treat them. Government should strengthen the supervision for these private and enterp-

rises, ban the illegal practitioners and assist formal recycling companies.

(3) Developing pilot projects. The recycling of waste mobile phones in China is still in its infancy, policies and technologies are immature. It is difficult for China to build recycling system throughout the country at the same time. Thus, China can firstly choose some developed areas as pilot projects to conduct the recycling of waste mobile phones, and then expand the scope gradually.

(4) Intensifying propaganda and raising awareness of recycling. The recycling of waste mobile phones needs people's coordination. Only people have the awareness and enthusiasm for recycling, the recycle of waste mobile phones can run smoothly. Therefore, government and medium should intensify propaganda and help raise people's awareness of recycling. Without the support of government, medium, mobile phone operators and all citizens, the recycling of waste mobile phones can't be conducted successfully.

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