Waste Management xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Battery collection in municipal waste management in Japan: Challenges for hazardous substance control and safety

Atsushi Terazono [a,*], Masahiro Oguchi [a], Shigenori Iino [b], Satoshi Mogi [c]

[a] National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan
[b] Tokyo Metropolitan Research Institute for Environmental Protection, 1-7-5 Shinsuna, Koto-ku, Tokyo 136-0075, Japan
[c] Bureau of Environment, Tokyo Metropolitan Government, 2-8-1 Nishi-shinjuku, Shinjuku-ku, Tokyo 163-8001, Japan

ARTICLE INFO

Article history:
Received 10 October 2014
Accepted 27 January 2015
Available online xxxx

Keywords:
Battery
Small waste electric and electronic equipment
Collection rules
Hazardous substances
Safety

ABSTRACT

To clarify current collection rules of waste batteries in municipal waste management in Japan and to examine future challenges for hazardous substance control and safety, we reviewed collection rules of waste batteries in the Tokyo Metropolitan Area. We also conducted a field survey of waste batteries collected at various battery and small waste electric and electronic equipment (WEEE) collection sites in Tokyo. The different types of batteries are not collected in a uniform way in the Tokyo area, so consumers need to pay attention to the specific collection rules for each type of battery in each municipality. In areas where small WEEE recycling schemes are being operated after the enforcement of the Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment in Japan in 2013, consumers may be confused about the need for separating batteries from small WEEE (especially mobile phones). Our field survey of collected waste batteries indicated that 6–10% of zinc carbon and alkaline batteries discarded in Japan currently could be regarded as containing mercury. More than 26% of zinc carbon dry batteries currently being discarded may have a lead content above the labelling threshold of the EU Batteries Directive (2006/66/EC). In terms of safety, despite announcements by producers and municipalities about using insulation (tape) on waste batteries to prevent fires, only 2.0% of discarded cylindrical dry batteries were insulated. Our field study of small WEEE showed that batteries made up an average of 4.6% of the total collected small WEEE on a weight basis. Exchangeable batteries were used in almost all of mobile phones, digital cameras, radios, and remote controls, but the removal rate was as low as 22% for mobile phones. Given the safety issues and the rapid changes occurring with mobile phones or other types of small WEEE, discussion is needed among stakeholders to determine how to safely collect and recycle WEEE and waste batteries.

1. Introduction

Portable batteries, such as dry (primary) and rechargeable batteries, are widely used in various types of electric and electronic equipment. Although the collection and recycling of waste batteries are important both in terms of hazardous substance control and resource recovery, the collection rate of small primary and rechargeable batteries in Japan was reportedly only 26% in 2008 (Asari et al., 2011).

In Japan, there is no specific regulation on battery collection. Municipalities are responsible for municipal solid waste management according to Waste Management Law. Collection and recycling of small rechargeable batteries (nickel–cadmium [NiCd], nickel–metal hydride [NiMH], lithium (Li)-ion and part of lead (Pb) acid batteries) by relevant producers is required by Act on the Promotion of Effective Utilization of Resources that came into force in 2001. This act aims at resource utilization, but in case of the batteries it intends substantially control of hazardous substances such as Cd of NiCd battery. Thus, municipalities collect and dispose of dry batteries, whereas the Japan Portable Rechargeable Battery Recycling Center (JBRC), which is a branch organization of the Battery Association of Japan (BAJ), is responsible for the collection and recycling of those small rechargeable batteries. This is a major contrast with the collection procedures of EU member states, where all types of portable batteries are collected together through a designated collection scheme under the EU Batteries Directive (2006/66/EC) (European Portable Battery Association, 2013).

* Corresponding author. Tel.: +81 29 850 2506.
E-mail address: terazono@nies.go.jp (A. Terazono).

http://dx.doi.org/10.1016/j.wasman.2015.01.038
0956-053X/

With regard to safety during waste battery collection, information and data on actual accidents is not sufficient. Tokyo Fire Department reports that 7 fire cases of coin type Li metal batteries have happened from storage stage during 10 years (2003–2012) in Tokyo (Tokyo Fire Department, 2013). Tomita of Nagoya City, Moriyama Fire Station, reported that 19 fire cases of Li metal batteries have happened during 10 years (1993–2002) in Japan, including one case of coin type and cylindrical type Li metal batteries and square type (9V) dry batteries in Nagoya City (Tomita, 2005). In February, 2013, one case of fire happened at collection box mainly for dry batteries of home appliance store in Yamagata prefecture. From the author's interview with relevant fire station, coin type Li metal batteries and square type (9V) dry batteries are suspected to be cause of the case.

Because batteries are used in electric and electronic equipment, the waste electric and electronic equipment (WEEE) collection and recycling system is an important element in the proper management of waste batteries. The Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment (hereafter "Small WEEE Recycling Act") came into force in April 2013 in Japan. The act does not mandate collection but promotes voluntary separate collection of small WEEE by municipalities. The Ministry of the Environment listed 28 categories of WEEE including mobile phones, digital cameras, and personal computers, but excluding air conditioners, refrigerators, television sets, and washing machines, which are covered by the existing Home Appliance Recycling Act (Aizawa et al., 2008). Each municipality determines the collection targets from the list, taking into consideration their capabilities and local conditions. Of the 23 special wards and the other 39 municipalities in the Tokyo Metropolitan Area, 21 wards and 28 municipalities had begun small WEEE collection by February 2014. The primary collection methods are collection boxes at designated public institutions for consumers' separate discarding and/or pick-up from collected bulky waste at waste management facilities.

In the worst cases of WEEE recycling and/or disposal, they are handled with mixed metal scrap to be exported, and many fires have occurred in mixed metal scrap at stockyards, ports, and on bulk freighters (Koseki et al., 2008; Terazono and Yoshida, 2012). Although the actual causes have not usually been identified, there are some indications that some of the fires may have been caused by different types of batteries, including Pb acid batteries, Li metal batteries, and Li-ion batteries. Proper handling of materials is therefore also a safety concern in the collection and recycling of waste batteries as well as WEEE.

The objectives of this study were to clarify current collection rules of waste batteries by municipalities in Tokyo and discuss future challenges for hazardous substance control and safety. In this paper, we focus on portable batteries that are mainly discarded from households and not industrial and automotive batteries unless otherwise specifically noted.

2. Materials and methods

2.1. Review of battery collection rules

We reviewed the battery collection rules for each ward in the Tokyo Metropolitan Area (23 special wards) in 2013 based on information provided on their websites. The batteries include dry batteries, Li metal batteries, button batteries (cells), small rechargeable batteries, Pb acid batteries, and other types of battery.

2.2. Field survey of waste battery characteristics from battery and small WEEE collection

2.2.1. Waste battery characteristics from battery collection

The collection routes and investigated items for the field survey are summarized in Table 1. We investigated the characteristics of waste batteries collected through the battery collection scheme in Ward A of Tokyo, which has a population of approximately 500,000 in 2014. In Ward A, waste battery collection boxes for dry batteries (zinc carbon and alkaline) are placed at public institutions such as city hall and libraries. Residents can discard used dry batteries into these boxes. Button batteries and small rechargeable batteries are required to be disposed of at special boxes provided by BAJ and JBRC, respectively, at local shops. How to discard Li metal batteries is not clearly instructed in Ward A. For our survey, five boxes were selected as a representative sample of the 26 total collection boxes. The survey was conducted during approximately 30 days in November and December 2013.

Approximately 9400 pieces and 271 kg of batteries were collected and investigated from five collection boxes in Ward A. Because cylindrical primary batteries were predominant, the original total samples were divided such that the cylindrical primary batteries were treated as reduced samples whereas the remaining samples were not reduced. While maintaining representativeness, sample sizes for most cylindrical primary batteries were reduced to approximately 1/2 to 1/8 of original sample size for each of the five collection boxes by the quartering method (Environmental Protection Agency, Ireland, 1996) to simplify the investigation (Table A.1). With this quartering method, the first pile of samples on the floor was divided into four quarters and either pair of opposite corners was removed, repeating this until the desired sample size was obtained. After the detailed investigation, the rates of occurrence of each battery type and shape were also calculated for the original samples.

The following characteristics were investigated for waste batteries in Ward A: number, weight, shape (cylindrical, square, coin,[1] button, pack, and other), size, type (primary: zinc carbon,[2] alkaline, Li metal, silver oxide, zinc air, total mercury [Hg]; rechargeable: NiCd, NiMH, and Li-ion), production country, expiration date (month–year) of recommended use, hazardous substance labelling, and insulation.

The metal contents in selected batteries were obtained by analyzing the metal concentration for each battery component and aggregating them for one whole battery. The batteries were first dismantled manually into each component such as anode, cathode, negative terminal, positive connection, current pick up, and separator. Referring to JIS K 0102: 2013 (Japanese Industrial Standard for Testing methods for industrial wastewater), flame atomic absorption spectrometry (AAS), inductively coupled plasma mass spectrometry (ICP-MS), and reducing-vapor atomic absorption spectrometry were applied to determine the copper, Ni, and manganese (Mn); Cd, cobalt, chromium, neodymium, and Pb; and Hg contents, respectively. For the analysis by AAS and ICP-MS, 1–2 g of dry sample materials were dissolved with sulfuric acid and nitric acid, and heated. After the solution was filtered, residual materials were dissolved with hydrochloric acid and nitric acid, and the sample solution was obtained for analysis. For Hg analysis, 1–2 g of wet sample materials were dissolved with sulfuric acid, nitric acid and potassium permanganate solution. After hydroxylammonium chloride solution was added for reducing extra potassium permanganate solution in the sample solution, it is applied for reducing-vapor atomic absorption spectrometer.

2.2.2. Waste battery and small WEEE characteristics from small WEEE collection

We also investigated the characteristics of waste batteries collected with small WEEE through the small WEEE collection schemes in Wards A and B and City C. Wards A and B are located

[1] In Japan, the name of "coin" cell or batteries are used only for Li metal batteries by BAJ.

[2] So called "manganese" batteries in Japan.