ISSN 1070-3632, Russian Journal of General Chemistry, 2012, Vol. 82, No. 5, pp. 1027–1030. © Pleiades Publishing, Ltd., 2012.
Original Russian Text © N.P. Tarasova, V.V. Gorbunova, S.A. Ivanova, V.A. Zaitsev, 2011, published in Rossiiskii Khimicheskii Zhurnal, 2011, Vol. 55, No. 1, pp. 89–92.

The Problem of Utilization of Spent Household Batteries

N. P. Tarasova, V. V. Gorbunova, S. A. Ivanova, and V. A. Zaitsev

Institute of Chemistry and Sustainable Development Problems, Mendeleev Russian University of Chemical Technology, Miusskaya pl. 9, Moscow, 125047 Russia
e-mail: tarasnp@muctr.ru, v_gorbunova@list.ru, vzaitsev@muctr.ru

Received November 1, 2010

Abstract—The results were reported for the survey undertaken in Moscow and Krasnodar krai with the aim to elucidate the users' attitudes toward collection of spent household batteries. Their utilization is one of the most important problems of municipal solid waste management, whose solution involves organization of spent battery collection as the task of the worst complication. Based on the specially designed questionnaire, the users' willingness to participate in collection of spent batteries, as well as the preferred conditions for discarding spent and purchasing new batteries were determined.

DOI: 10.1134/S1070363212050374

Due to widespread use of household batteries and their high content in heavy metals, utilization of spent household batteries is an issue of much environmental and economic significance.

According to preliminary estimates, over one billion per annum household batteries are used in Russia, which number apparently tends to increase. More accurate data cannot be provided because of the lack of accounting information on the amounts of household batteries used and spent household batteries collected in Russia.

Trends in use of household batteries are clearly seen, e.g., in Germany, where the amounts of batteries annually sold and collected for recycling purposes have been accounted for over several years. According to GRS-Batterien [1], in 1999–2006, the number of household batteries sold in Germany tended to grow from year to year: There was a 39% increase in sales volumes over this period as expressed in tons per annum. In 2006–2009, the sales volumes decreased by 7.7% but, if expressed in terms of the number of units sold per annum, the same data suggest, on the contrary, a sales growth by 1.6% over the same period. The most likely reason is that the growing use of household batteries is paralleled by their miniaturization.

In Russia, the use of household batteries will grow in the near future in terms of both the number of units and the weight. This calls for immediate action aimed to solve the problem of collection and recycling of spent household batteries (especially in big cities, including Moscow).

Four–six thousand tons of different types of household batteries are sold annually in Moscow. For this consumption level, the annual loss of metals associated with spent household batteries can be estimated at 3.3–4.0 thousand tons, in particular: man-ganese (1–1.5 thousand ton), zinc (up to 1 thousand ton), nickel (up to 200 ton), cadmium (up to 100 ton), and iron (up to 1.5 thousand ton), as well as certain amounts of copper, cobalt, and rare-earth and other elements.

In Russia, collection and subsequent recycling are not practiced for spent household batteries which, together with municipal solid waste, are landfilled, dumped and, partly, incinerated.

Relevant studies [2–5] showed that dumping of spent household batteries at municipal solid waste landfills leads to leaching of metals, thereby increasing the heavy metal content in leachate from the plot. For example, Agourakis et al. [3] reported that, metal leaching from zinc/manganese dioxide batteries caused enrichment of 70 and 11 times in the Zn and Mn concentration of the topsoil, respectively. Moreover, leaching of the electrolyte (KOH) from batteries increased the soil pH in the contaminated column. The latter factor contributed to a certain extent to the retention of metals in the topsoil, though proved to be insufficient for prevention of their migration.

Leaching tests with spent zinc/manganese dioxide batteries, in particular, by the standard leaching procedure (NEN 7343 Standard "Leaching Characteristics of Solid Earthy and Stony Building and Waste Materials")

[4] showed the following. Spent alkaline batteries are to be classed with hazardous waste (based on the presently accepted division of waste into hazardous, nonhazardous, and inert classes), which cannot be disposed of in municipal solid waste landfills. Karnchanawong and Limpiteeprakan [5] carried out evaluation of heavy metal leaching from spent house-hold batteries disposed in municipal solid waste and also found that the increasing amount of batteries disposed in landfills can contribute to the leaching of more metals, especially Mn and Zn, into the environment.

There also exists the opposite view: The most common zinc/manganese dioxide household batteries can be safely buried at municipal solid waste plots, which attitude is held, in particular, by the National Electrical Manufacturers Association and Environmental Protection Agency in the United States [6].

Almeida et al. [7] reported on the special risk posed by incineration of municipal solid waste containing spent household batteries, because, in that case, most of metals, including mercury, cadmium, manganese, and zinc, are stored in both bottom ash and flue ash. Hence, these latter should be attributed to a higher (no lower than 3) hazard class, which significantly increases difficulties in their processing.

Hydrogen chloride is usually formed when chlorinated materials burn, but most of the HCl from the polyvinyl chloride plastic sleeve combustion combines with KOH and metals in the batteries to form chlorides; 60% of metal chlorides enters the composition of bottom ashes, and the remaining chlorides occur in the fly ashes (especially zinc oxide and, to a lesser extent, manganese, iron, and other metal oxides and chlorides). The HCl formed in polyvinyl chloride plastic sleeve incineration is partly neutralized with KOH which, due to its corrosive action, contributes to the rapid wear of the furnace materials.

Thus, spent household batteries represent a substantial source of heavy metal contamination for surface and ground water, air, and soil. Without a collection and processing system in place, they inflict an obvious damage to the environment and human health. Heavy metal contaminants will inevitably be absorbed by living organisms, in particular, will enter human body and cause both acute poisonings and chronic diseases.

On the other hand, spent household batteries contain high levels (35–50%) of nonferrous metals and thus can be regarded as a secondary source of these metals.

The problem of collection and recycling of spent household batteries has been successfully solved in many countries [8]. The realistically attainable proportion of this waste collected is 30–40%, as demonstrated by the example of Germany and the Netherlands. According to our estimates, with this level achievable in Moscow, it would be possible to carry out recycling of 1.3–2.0 thousand ton of household batteries per annum with 300–400 ton of manganese, 200–300 ton of zinc, 20–30 ton of nickel, 400–450 ton of iron and other metals recovered.

Organization of collection of spent household batteries represents the most complicated step in solving their utilization problem. In Germany, France, the Netherlands, and the United States the collection and recycling of batteries is a matter of regulation by relevant legislation, which prohibits the placing on the market of certain batteries and accumulators with a proportional mercury, cadmium, or lead content above a fixed threshold [7] and obliges end-users to discard spent batteries at collection points [8].

As regards recycling of collected spent household batteries, there exist quite a lot of procedures for recovery of metals therefrom, among which all the commercially implemented procedures are based on pyrometallurgical and/or hydrometallurgical methods [8–11].

Some types of household batteries (in particular, zinc/manganese dioxide batteries which account for ~80% of spent household batteries collected) can be recycled not only by specialized enterprises but also by existing metallurgical works [8].

To solve the problem of utilization of spent household batteries in Russia it is necessary, above all, to organize their collection. The most important factor determining the collection efficiency is the willingness of end-users (population) to discard spent household batteries at collection points rather to dispose of them with household trash in their accustomed way. In order to evaluate the willingness of Russian users to participate in the collection and to identify the relevant (preferred) conditions for discarding spent household batteries, we undertook a questionnaire survey. The main purposes of the survey were as follows: estimate the population's willingness to participate in the collection of spent household batteries; identify the preferred conditions for discarding spent batteries; determine the degree of population's awareness of the environmental hazard posed by spent household batteries; determine the preferred places of purchasing household batteries; and identify preferences in choosing between rechargeable (accumulators) and disposable batteries, if interchangeable.

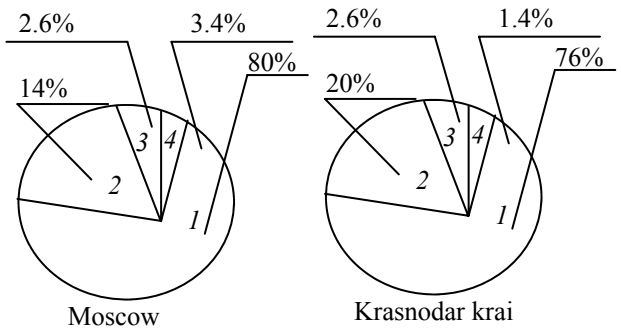

Fig. 1. Users' willingness to participate in collection of spent household batteries. Proportion of users (*1*) willing to discard spent batteries on various conditions, (*2*) not willing to discard spent household batteries (preferring to "dispose with household trash"), (*3*) willing to discard spent household batteries, if refunded, though preferring to "dispose with household trash", and (*4*) uncertain of their choice.

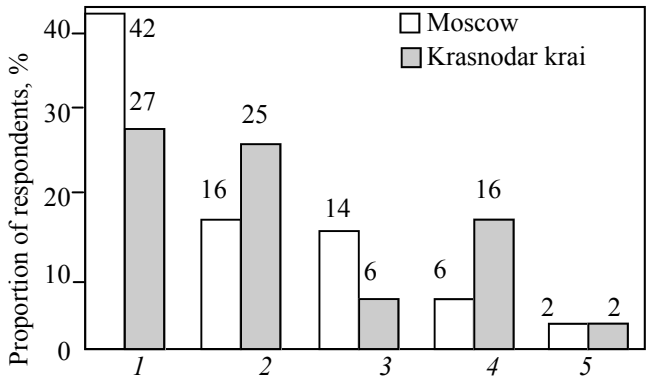

Fig. 2. Users' preferred conditions for discarding spent household batteries: (*1*) for free, (*2*) if refunded by new batteries, (*3*) on any condition, in particular, for free, (*4*) if refunded monetarily, and (*5*) if refunded by new batteries or monetarily.

The survey whose participants were only required to be users of household batteries was held in January–February 2010, in Moscow and Krasnodar krai.

Among the 315 survey participants in Moscow, most (86%) were Moscow residents and/or members of Moscow's economically active population; 8% of respondents were Moscow oblast residents, and 6% were residents of other Russia's regions; 64% of the respondents belonged to economically active population, 24%, to students, and 9%, to economically active students; the average age of respondents was 34 years; the proportion of high school graduates was 43%. Among the 211 participants of the survey held in Krasnodar krai there were 41% economically active respondents and 57% students with the average age of 25 years, among which the proportion of high school graduates was 34%.

Eighty per cent of the Moscow participants of the survey (Fig. 1) expressed a willingness to discard spent household batteries on certain conditions, provided there are conveniently located (in particular, "en route") collection points. Hence, the main prerequisite to efficient discarding of household batteries by their users is the convenient organization, i.e., the availability of collection points located "en route", in particular, at purchasing places. This conclusion does not interfere with the importance of a refund as an additional major factor motivating the discarding of spent household batteries: 2.6% of respondents, while choosing the "disposal with household trash" option, expressed a willingness to discard spent household batteries if refunded by new batteries. Neither of the proposed options (including all the discarding options, as well as "disposal with household trash" option) was chosen by 3.4% respondents; 14% of respondents will participate in the collection on no condition.

Similar results were obtained from the questionnaire survey in Krasnodar krai (see Fig. 1). A willingness to discard spent household batteries on certain conditions, provided conveniently located collection points, was expressed by 76% participants. The importance of refund, as revealed by the Moscow survey, was confirmed by the results of the survey in Krasnodar krai: While choosing the "disposal with household trash" option, 2.6% respondents in Krasnodar krai expressed a willingness to discard spent household batteries if refunded by new batteries. The proportion of respondents uncertain of their choice was 1.4%; 20% of respondents will participate in the collection on no condition.

With collection of spent household batteries still lacking in practice for Russia, the only possible way to eliminate them is via disposal with household trash. At the same time, 2.4% of the respondents in Moscow and 4.3% in Krasnodar krai, being aware of the potential environmental hazard posed by household batteries, accumulate used batteries in their homes for further discarding, if possible, rather than immediately disposing of them.

As regards the preferred conditions of spent household battery discarding (Fig. 2), nearly 42% of the respondents in Moscow and 27% in Krasnodar krai preferred the discarding for free, provided convenient (in

particular, "en route") location of collection points. For several participants the "en route" condition was of principal importance. The proportion of respondents willing to discard if refunded (either monetarily or by new batteries) was 24% in Moscow and 43% in Krasnodar krai.

The histogram in Fig. 2 left aside the proportions of the respondents who were willing to participate in the collection on no condition (14% in Moscow and 20% in Krasnodar krai), as well as of those who were uncertain of their choice by the time of survey (3.4% and 1.4%, respectively) and those willing to "discard for free" and "dispose of with household trash" simultaneously (2.6% for both Moscow and Krasnodar krai).

As regards the household batteries purchasing places, the preferred option for Moscow and Krasnodar krai respondents was represented by specialized shops (27% and 39%, respectively), followed by non-specialized shops (19% and 27%, respectively, with 10% users treating both options identically) and, further, by small point of sales, e.g., kiosks, in particular, market stalls (18% and 7%, respectively). A significant proportion of users (26% and 17%, respectively) do not have certain preferences. This breakdown of survey participants' responses, on the one hand, facilitates the organization of collection of spent household batteries via the trade network (because most of batteries are sold in stores) and, on the other hand, gives insight into certain difficulties associated with kiosk and market stall purchasing.

One of the objectives pursued by the questionnaire survey was to identify the household battery users' motivations behind choosing between disposable and rechargeable batteries. The questionnaire contained this question because, both economically and ecologically, rechargeable batteries are often more profitable due to a longer lifetime (except for extremely toxic nickel-cadmium batteries[1]), and it was expedient to elucidate what is the users' preferred type of batteries.

The survey showed that a significant proportion of users (34% in Moscow and 27% in Krasnodar krai) purchase batteries without giving a serious thought to this matter: They either rely on advices given by sellers or give preference to batteries similar to those they previously used in the device. It should also be noted that 6% of respondents in Moscow and 12% in Krasnodar krai make their choices with taking into account the potential environmental hazard posed by household batteries they purchase.

The proportion of respondents (14% in Moscow and 20% in Krasnodar Krai, see above) who preferred the "disposal with household trash" option deserves special attention. In Moscow, more than half (10%), and in the Krasnodar krai, a half of this group (10%) were totally unaware of, or underinformed about, the potential environmental hazard posed by spent household batteries. This suggests the need for relevant information events and advertising campaigns. The remaining respondents (4% in Moscow and 10% in Krasnodar krai) were aware of the hazard but still prefer to "dispose with household trash." Though unable to completely overcome this users' attitude to the problem, information campaigns could probably lead to somewhat better outcomes.

Thus, despite some variations observed, the survey data available from different regions (Moscow and Krasnodar krai) suggest that it is already now possible to bring into practice the collection of household batteries both in Moscow and Krasnodar krai (and so in many other regions of Russia as well). There exist a sufficient number of streamlined technologies for recycling of the household batteries collected, most of which could be processed at existing nonferrous and ferrous metallurgical works.

[1] According to GRS-Batterien, the recent trend has been toward decreased use of nickel-cadmium batteries (in the period 2004–2009 there was a 66% decrease in terms of weight) in favor of other types of rechargeable batteries [1].

REFERENCES

1. *GRS-Batterien. www.grs-batterien.de.*
2. Slack, R.J., Gronow, J.R, and Voulvoulis, N., *Sci. Total Environ*., 2005, vol. 337, p. 119.
3. Agourakis, D.C., Camargo, I.M.C., Cotrim, M.B., and Flues, M., *Quimica Nova*, 2006, vol. 29, no. 5, p. 960.
4. Xará, S.M., Delgado, J.N., Almeida, M.F., and Costa, C.A., *Waste Management*, 2009, vol. 29, no. 7, p. 2121.
5. Karnchanawong, S. and Limpiteeprakan, P., *Waste Management*, 2009, vol. 29, no. 2, p. 550.
6. *Sound Environmental Management of Spent Primary Batteries*, Rosslyn (VA), 2001.
7. Almeida, M.F., et al., *Waste Management*, 2009, vol. 29, no. 1, p. 342.
8. Gorbunova, V.V. and Zaitsev, V.A., *Khim. Tekhnol*., 2005, no. 9, p. 33.
9. Zaitsev, V.A. and Gorbunova, V.V., *Energiya: Ekonomika, Tekhnika, Ekologiya*, 2007, no. 11, p. 42.
10. Zaitsev, V.A. and Gorbunova, V.V., *Energiya: Ekonomika, Tekhnika, Ekologiya*, 2008, no. 1, p. 30.
11. Zaitsev, V.A. and Gorbunova, V.V., *Energiya: Ekonomika, Tekhnika, Ekologiya*, 2008, no. 2, p. 57.