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Short communication

Used batteries collection and recycling in Poland

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Abstract

According to the European and other countries' legislation, e.g. USA and Japan, used batteries and accumulators are regarded as hazardous waste. In connection with these regulations spent electrochemical power sources are separately collected and sent to recovery and recycling plants. In the highly developed countries yearly collection levels achieved in practice typically surpass 100 g of spent batteries per inhabitant.

In this work we present the information about the Polish legislation concerning marketing, collection and recycling of batteries. We also characterize the Polish batteries collection system and give achieved collection levels of used electrochemical power sources in our country.

Keywords: Spent batteries and accumulators; Legislation; Recycling; Utilization

1. Introduction

Batteries supply energy to many kinds of portable electric and electronic devices such as telephones, radios, compact disk players, computers, cordless tools, flashlights and even electric and hybrid cars. The wide application of electrochemical power sources reflected by, e.g. 40 billions of batteries produced in the year 2000, brings a new problem: what to do with billions of used batteries worldwide containing millions of tons of toxic and hazardous compounds [1].

In general, we can split the batteries in to two categories: primary—for replacement after discharge, and secondary—lasting for often many hundreds of charging–discharging cycles. From an environmental preservation point of view, secondary batteries are preferable over primary. It is connected with the possibility of long time use of the same electrode materials in contrast with primary cells, where after discharge electrode materials are irreversibly converted into products. Other batteries classification splits them according to their four major markets: primary, starting lightning and ignition (SLI), industrial rechargeable and portable rechargeable. Regardless of classification, the most popular types of batteries (zinc–manganese dioxide, nickel–cadmium, lead–acid) contain hazardous element such as Hg, Cd, Pb, Ni, which, when improperly disposed of, can leach out from the waste to the landfill base [1,2]. Today, only automotive-sized lead–acid and industrial lead–acid and nickel–cadmium types are systematically collected in Poland for the sake of recycling [3,4]. Smaller, portable batteries are disposed in municipal solid waste (MSW). The same happens also in the developing countries, where regulations for production, collection, utilization and recycling of batteries were often introduced but are not kept. This situation can be explained by a small environmental education level of the societies and resulting insufficient budget spending on environmental protection.

2. Polish legislation

A Waste Act adapts Polish legislation to European waste-management laws [5–9]. It defines procedures for handling the problem of waste that ensure protection of people's health and protection of environment. This Act is in agreement with a National Sustainable Development and Education Plan, especially with its following rules: limitation of waste generation, decreasing of existing waste volume and diminishing of negative influence of the existing waste on the environment.

The Waste Act [5] creates obligation to establish national and regional Plans of Waste Management [10]. These Plans shall determine the main rules for collection, separation, materials recovery, and recycling of waste in local regions of Poland. The

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main objectives of these plans with respect to electrochemical power sources are:

1. reduction of heavy metals content in batteries,
2. promotion of marketing of batteries containing smaller quantities of dangerous substances and/or containing less polluting substances,
3. gradual reduction of spent batteries in household waste, and
4. separate disposal of spent batteries covered by respective acts.

Another important document concerning electrochemical power sources is the Decree of Minister for Economic Affairs and Labour [11]. It prohibits marketing of batteries and accumulators containing more than 0.0005% of Hg, 0.025% of Cd or 0.4% of Pb by weight of cell. Button cells and batteries composed of button cells with mercury content of no more than 2% by weight are exempt from this prohibition. These values are in agreement with the maximum levels of hazardous compound concentration in batteries introduced by European laws [7,9]. Moreover, batteries and accumulators introduced on the Polish market shall carry symbols with information about separate collection, possibility of recycling, and heavy metals content.

According to the mentioned laws [5,6], the following used batteries and accumulations have to be collected separately from other waste, as well as disposed of and/or recycled properly:

1. containing more than 0.0005% of mercury by weight,
2. containing more than 0.025% of cadmium by weight, and
3. containing more than 0.4% of lead by weight.

The obligatory collection is imposed on manufacturers, importers and end users of electrochemical power sources [5]. Individual users should dispose of these wastes to special containers free of charge. Manufacturers and importers are obliged to achieve some minimum recovery and recycling levels of batteries introduced on the Polish market. If the obligatory minimum levels are not achieved, they have to pay Polish Government fees that depend on the number of introduced batteries. The money is accumulated on dedicated account of The National Fund for Environmental Protection and Water Management and will be spent on environmental education of the society as well as promotion of separate collection of used batteries and accumulators [5]. The obligation can be fulfilled by the companies themselves or by special organizations called Recovery Organizations. For comparison, while in many other European countries e.g. Austria, Finland, France and Italy, only one Recovery Organization usually operates; in Poland there are currently 33 Recovery Organizations. Twenty-three of these organizations are involved in collection of used electrochemical power sources [12]. In 2003, the Ministry of Environment decreased the original minimum recovery and recycling levels to the following values (Table 1) [13].

Table 2
Collection and recycling levels of used batteries and accumulators to be achieved in Poland by the end of 2014 [14]

Used batteries and accumulators	Collection level (%)	Recycling level (%)
Lead–acid accumulators	100	100
Nickel–cadmium accumulator (industrial)	60	60
Nickel–cadmium accumulator (portable)	40	40
Nickel–iron and other accumulator (industrial)	40	40
Nickel–iron and other accumulator (portable)	20	20
Other batteries and accumulators	40	40[a]

[a] Without zinc–carbon and alkaline batteries.

The first practical results showed that the high-expectation collection levels from Table 1 wouldn't be achieved. After public consultation the Polish Parliament introduced a change to the Waste Act, which essentially decreased the minimum collection and recycling levels. These new values remaining in agreement with a new proposed Battery Directive, and shall also be achieved in a longer run, i.e. the end of 2014 (Table 2) [14].

3. Marketing, collection and recycling of batteries in Poland

One battery classification split electrochemical power sources among four major markets: primary (P), starting lightning and ignition (SLI), industrial rechargeable (IR) and portable rechargeable (PR) [1,2].

The primary battery sale account for one third of the total battery market and is increasing at a rate of 5% per year. The main popular types of electrochemical power sources in this category are alkaline manganese dioxide and zinc–carbon cells. The second (SLI) and the third (IR) markets are represented mainly by the lead–acid accumulators. Portable rechargeable batteries segment represented by Ni–Cd, Ni–MH, Li-ion, Li-polymer, and lead–acid accumulators, is the last, rapidly growing market segment (Fig. 1).

Table 1
Collection and recycling levels of used batteries and accumulators effective in Poland [13]

Used batteries and accumulators	Year 2004		Year 2005		Year 2006		Year 2007	
	Collection (%)	Recycling (%)	Collection (%)	Recycling (%)	Collection (%)	Recycling (%)	Collection (%)	Recycling (%)
Lead–acid accumulators	100	100	100	100	100	100	100	100
Nickel–cadmium accumulator (industrial)	40	40	50	50	60	60	70	70
Nickel–cadmium accumulator (portable)	25	25	35	35	45	45	50	50
Other batteries and accumulators	10	10[a]	15	15[a]	30	30[a]	50	50[a]

[a] Without zinc–carbon and alkaline batteries.

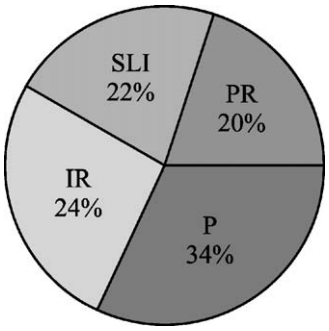

Fig. 1. A pie chart illustrating the division of world's battery market in relation to application [1–3].

In 2002, over 236 million pieces of batteries and accumulators were introduced on the Polish market [15]. It corresponds to about 6500 tons of batteries. The production and import of electrochemical power sources increased in the next years approximately by 8% each year and reached 254 million pieces in 2003 and 275 in 2004 (estimated data) [15,16]. This fast growing rate is connected with growing sales of new electric and electronic equipment that requires portable electrochemical power sources. In contrast to the world market, over 93% of all batteries and accumulators introduced in Poland in 2003 (without lead–acid accumulators) were zinc–carbon and alkaline manganese dioxide cells. These two main types of batteries have 55%- and 30%-shares in the primary batteries market, respectively. This distribution is reflected in the type and volume of collected used batteries and accumulators. The first results of the action are shown in Table 3.

Data collected in Table 3 shows that only 5.2% of all electrochemical power sources introduced in Poland in 2003 were batteries and accumulators other than the zinc–manganese dioxide cell, and the nickel–cadmium accumulator. Lithium batteries had the main share in this category. It must be noted that the presented data do not take into account electrochemical power sources introduced on the market in the form of bundles with electric and electronic equipments.

In the second year of the Recovery Organizations operation, the collection level reached a value of 9.3 g per inhabitant (Table 4) [14]. A prognosis shows that in the next years the achieved collection levels will slowly increase. For example, in 2004 12.2 g of used batteries (per inhabitant) have been collected out of 186 g of batteries introduced on the market. For comparison, the average collection level for UE countries is currently higher than 100 g per inhabitant [1]. One can also see that the actual as well as projected collection levels lay behind the minimum collection levels imposed by the original Waste Act.

As it was mentioned above, apart from the classification, the most popular kinds of batteries (zinc–manganese dioxide, nickel–cadmium, lead–acid) contain hazardous materials such as heavy metals Hg, Cd, Pb, Ni, which can leach out from the waste to the landfill base [1,2]. For example, Zn–C batteries mainly consist of Zn, Mn and Fe, but still contain small additives of lead, cadmium and mercury. If we know the percentage share of elements in battery constitution we can calculate approximately quantities of elements to recover from the waste batteries. Analysis performed in Poland at the end of the 1990's showed that in mixed batteries waste, there were mainly zinc, iron, and manganese compounds [3]. The comparison of data

Table 3
Collection and recycling levels achieved in Poland in the last 3 years [15,16]

Used batteries and accumulators	Year 2002			Year 2003			Year 2004[a]		
	Introduced batteries (million pieces)	Collection level (%)	Recycling level (%)	Introduced batteries (million pieces)	Collection level (%)	Recycling level (%)	Introduced batteries (million pieces)	Collection level (%)	Recycling level (%)
Nickel–cadmium accumulators (industrial)	0.005	43.4	43.4	0.081	98.1	98.1	0.025	40.8	41
Nickel–cadmium accumulator (portable)	2.286	5.4	5.4	2.512	10.7	11.5	3.168	35	39.3
Zinc–carbon and alkaline manganese batteries	203.139	1	–	238.748	4.9	–	–	–	–
Other batteries and accumulators	30.728	0	0	13.129	0.1	4.1	–	–	–
Batteries and accumulators without Ni–Cd accumulators	233.867	1	0	251.877	5	4.1	253.183	9.7	6.8

[a] Estimated data waiting for official confirmation.

Table 4
Collection levels of used batteries and accumulators required to be achieved, achieved and projected to be achieved in Poland in the years 2002–2006 [15,16]

	Year 2002		Year 2003		Year 2004[a]		Year 2005		Year 2006	
	Minimum	Achieved	Minimum	Achieved	Minimum	Achieved	Minimum	Projected	Minimum	Projected
Weight of collected batteries (tons)	325	65	500	354	710	465	1131	653	2292	985
Weight of collected batteries per inhabitant (g)	8.8	1.7	13.1	9.3	19.7	12.2	29.6	17.1	60	25.8

[a] Estimated data waiting for official confirmation

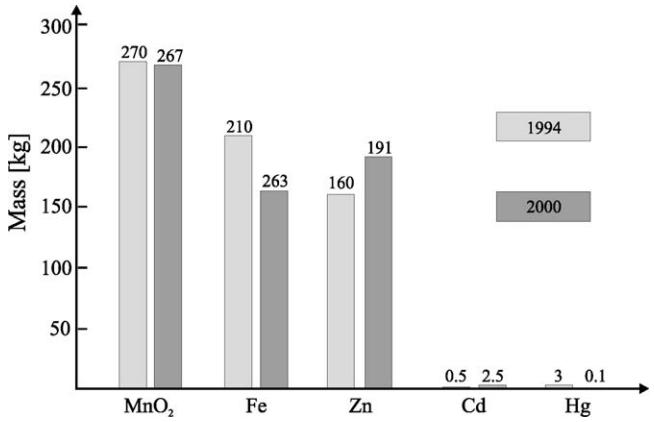

Fig. 2. Approximate components mass share in 1000 kg of typical battery waste [1–3].

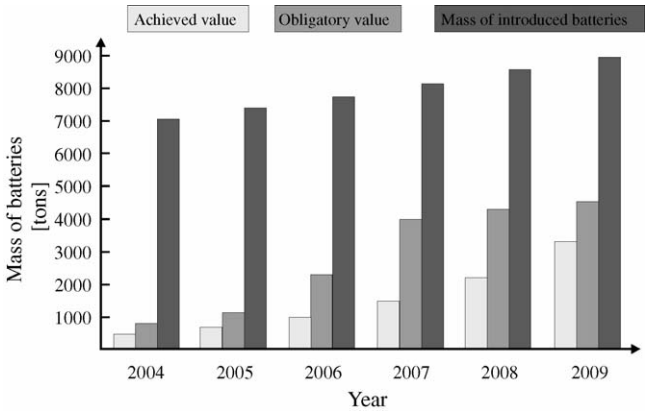

Fig. 3. Portable batteries collection levels in Poland. Current situation and prognosis [13–16].

collected in years 1994 and 2000 shows that the concentration of cadmium in batteries waste increased. We can explain this phenomenon by slow uncontrolled disposal of Ni–Cd accumulators that were sold in Poland in the 1980's and at the beginning of the 1990's. Batteries manufacturers calculated that in the last 25 years 170 thousand tons of cadmium were introduced to the environment via incorporation in electrochemical power sources [1]. Another factor is slow increase in total production of Ni–Cd accumulators at the end of previous century. This production still rises despite of new restriction concerning marketing of these type cells and decreasing production Ni–Cd accumulators that supply energy to electric and electronic equipments. The decrease of mercury introduction over the same period is a result of the laws introduced in many countries that restricted marketing of batteries containing mercury (Fig. 2).

What happens with collected batteries and accumulators? We can distinguish three basic methods of battery recycling [1]. Mechanical methods consist of mechanical separation of various bulk materials from batteries waste, especially from large sized batteries. Additionally, this method is used as a pre-treatment method in the pyro- and hydro-metallurgical processes. Hydrometallurgical processes are based on leaching the elements from batteries in acid or alkaline medium and on subsequent recovery of material by chemical or electrochemical methods. Pyrometallurgical methods are usually associated with the production of steel, ferromanganese alloys or other metallic alloys. These methods employ high temperature and lower pressure. Pyrolysis furnaces are also used in a pre-treatment step to remove mercury and organic compounds from batteries waste.

Presently, we can distinguish three methods of spent batteries and accumulators utilization and recycling in Poland. Collected electrochemical power sources are:

1. stored on dangerous waste dumps,
2. recycled in a pyrometallurgical process (Wealtz method – Zn–C and Zn–MnO_2 batteries; Ni–Cd and lead–acid accumulators), and
3. sent abroad.

4. How can we improve efficiency of spent batteries collection?

The recycling process consists of the following stages: collection, sorting and adequate recovery steps. The experience of the European countries showed that the key factor influencing collection efficiency is organization a smart collection system that will guarantee a constant supply of batteries waste to recyclers. In Poland, the next main collection channels for spent batteries and accumulators exist: schools (72%), retail and wholesale, service points, company that collect and segregate municipal solid waste (MSW) (11%), end users (17%) [16].

As it was shown in Table 4, in the first year of Recovery Organizations operation the collection level reached 9.3 g per inhabitant. The differences between obligatory and projected achieved levels are clearly visible in Fig. 3. We see that with the current collection system we won't achieve obligatory minimum collection levels.

How can we improve the achieved collection levels? From the experience of the European countries we learn that it is possible by implementing effective education campaigns of the society. For three countries presented in Table 5 (without Netherlands) the collection figures increased in subsequent years of Recovery Organization operation. The high level obtained in 1998 in Netherlands was due to one-time collection of accumulated electrochemical power sources from households. In the next years, the collection level reached a constant value [17].

In order to organize an efficient collection system we must have the whole society involved. It can only happen if people are informed about the laws and regulations regarding the marketing of batteries and accumulators, as well as the importance of proper disposal of batteries with higher concentrations of heavy metals or toxic substances separately from other household waste.

A document entitled "National Environmental Education Strategy" contains the main principles concerning environmental education of the Polish society [18]. This education is becoming an important element of education system, which is aimed at creating a sensible, enlightened society that accepts the princi-

Table 5
Relation between educational activity of various Recovery Organizations and the collection levels of batteries in European countries [17]

Organization	Country	Sales 2000 (tons)	Collection 2000 (tons)	% of collected batteries	Weight of collected batteries per inhabitant (g)		
					1998	1999	2000
UFB (1998)	Austria	2300	1441	62	155	158	177
BEBAT (1995)	Belgium	3878	2100	54	153	179	205
GRS (1998)	Germany	29248	9322	32	–	101	114
STIBAT (1994)	Netherlands	5808	1856	32	161	117	116

ples of sustainable development, is capable of assessing the state of ecological safety, and can participate in the decision-making processes. Education for sustainable development entails the following major objectives:

1. Developing full awareness and stimulating public interest in mutually related economic, social, political and ecological issues.
2. Enabling each human being to acquire knowledge and skills necessary to improve the state of the environment.
3. Creating novel behavioral patterns as well as shaping individual, group, and social attitudes, values and beliefs which carry concerns for the quality of the environment.

5. Conclusion

Since batteries and accumulators are products used broadly in many kinds of portable electric and electronic devices, it is very difficult to control their disposal. In 2001, Poland adapted the national law concerning marketing, collection and recycling of batteries and accumulators to the EU law. Data obtained in the second year of national Recovery Organizations operation shows that the major type of introduced batteries is the zinc–manganese dioxide cell system. In the same period, spent battery collection level reached 9.3 g per inhabitant, and is predicted to slowly increase in the next years. Minimum collection levels of used batteries introduced by Polish Parliament are too high to be achieved in the next 4 years. To achieve the required collection levels it is necessary to carry out extensive environmental education programs in the society that will be in line with the "National Environmental Education Strategy".

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