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System for the management of waste batteries and accumulators in Poland

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ABSTRACT

Waste is a serious threat to the environment and calling for waste management. This work focuses primarily on the characteristics of waste and the recycling of waste batteries and accumulators and their impact on the environment. An important aspect of limiting the negative impact of waste batteries and accumulators on the environment is their proper management, therefore the study focuses on the presentation of the system for the management of waste batteries and accumulators in Poland.

***Keywords*:** waste management system, used batteries and batteries, dangerous waste

1. INTRODUCTION

The problem of environmental pollution due to increased industrial activity is the focus of attention in the country and around the world. The possibilities of recovery and recycling of waste in various sectors of the economy are manifold, and specific methods - expanded and refined, depending on the origin of such waste. [1]

In the European Union, the prevention and reduction of waste is considered to be a priority. The second place in the hierarchy of activities is the introduction of a wide range of waste recovery and recycling. According to the Directive, recycling is the reprocessing of waste materials in production processes to obtain materials for primary use or other purposes (including limited recycling except for energy recovery) As is apparent from the EU Waste

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Directive (2008/98 / EC of 19 November 2008 (r) recycling and other recovery methods should be prioritized in the context of waste disposal. Failure to comply with EU directives in this area may result in high penalties imposed by the EU in the near future. At the end it is allowed to dispose of waste in an environmentally safe way, eg for storage or incineration. The constantly increasing stream of waste places greater demands on the creators of methods for processing their various factions. [2] Therefore, recycling should be treated as one of the forms of recovery. The difference between recovery and recycling is that we get a new product as a result of recycling. On the other hand, recovery, treated as a broader concept, aims to process waste generated in the municipal and economic sector (among others in the metallurgical, metallurgical and foundry industries) resulting only in a change in their nature or composition (reclamation, mixing). The recovery also includes the processing of hazardous waste. [3]

The recovery process is characterized by the fact that the resulting waste serves a useful purpose, replaces other materials that would have to be used, thus saving natural resources. This is in line with Directive 2008/98 / EC of the European Parliament and of the Council of 19 November 2008 on waste art 6, which refers to the loss of waste status. [4] As a result of waste treatment in ZZO (waste management plants), we get products and raw materials, not waste. It should be emphasized that the activity of ZZO is not only about collecting municipal waste, but also ensures its treatment (the directive thus closes the possibility of operation consisting only in collecting and storing waste). [5]

Depending on the properties of the waste, the following forms of recycling are distinguished: raw material, material, product, energy and chemical. The basic objective of the waste management plans are primarily measures ensuring protection of the environment as a whole, using current and future technical, organizational and economic possibilities, taking into account the technical level of the existing infrastructure. [6]

Waste is a serious threat to the environment and calling for waste management. This work focuses primarily on the characteristics of waste and the recycling of waste batteries and accumulators.

2. BATTERY AND ACCUMULATORS CHARACTERISTICS

The development of modern technologies that facilitate people's lives, the growing number of electronic mobile devices (tablets, smartphones, laptops, e-cigarettes, e-books, etc.), the increase of power tools in professional and hobby applications. As well as the increasing share of electromobility - electric and hybrid passenger cars and public transport, causes various threats to the environment and human health. The heavy metals contained in batteries and accumulators are particularly dangerous (including lead, cadmium, mercury) and electrolytes. The necessity of an effective system of recovery and recycling of batteries and accumulators. They include both dangerous substances and very valuable raw materials. [7]

The Directive of the European Parliament and of the Council on batteries and accumulators and waste batteries and accumulators has imposed a number of obligations on the Member States of the European Union to take action and introduce national regulations to minimize the negative impact of batteries and accumulators on the environment. [8]

Used alkaline batteries and accumulators are hazardous waste, that is, those that pose a special threat to human health and the environment - that's why their management requires proper management and special control.

A battery is one (or more) galvanic cell designed to supply various portable devices, e.g. a light bulb in an electric torch. Looking at the battery we can see that it has two poles - one positive, marked "+", the other negative - marked "-". For typical cylindrical batteries, such as R6 / AA or R14 / C, the ends of the batteries are the poles [9]. The figure 1 shows examples of batteries separated during segregation.

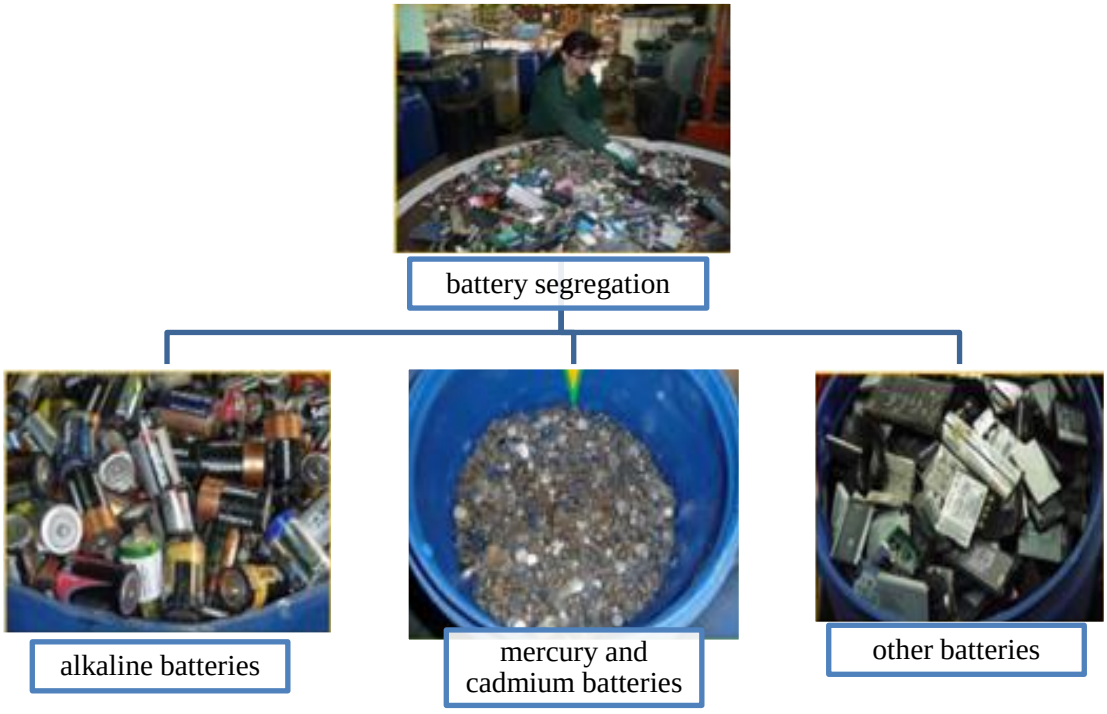

Figure 1. Battery segregation.
[Source: EKO HARPOON, Recycling Sp.z o.o.]

In car batteries, poles are heavy leaden pins. Electrons collect on the negative pole of the battery. If we connect the negative and positive poles with the wire, the electrons will move as quickly as possible from the negative pole to the positive pole - the battery will run out very quickly. An electric accumulator is a device used to store electricity in the form of chemical energy and is a reversible galvanic cell; Electricity supplied from the outside causes reversible chemical transformations (charging), which are a source of electric energy that can be drawn from the battery (discharging).

The most important battery sizes are: electromotive force (SEM) and capacity (the amount of electric charge that can be drawn from a charged battery until it is discharged). The batteries are connected to batteries constituting a direct current source; are used, among others for electric trolleys, for powering electronic devices, portable measuring apparatus, etc., the most commonly used are acidic (lead) batteries and lighter, more durable and larger capacity alkaline batteries (iron-nickel, silver-zinc, cadmium-nickel). [10]

In batteries, for voltage to be generated, complicated chemical reactions take place. Many elements take part in them - depending on the type and type of batteries. In addition, the battery construction uses a number of substances that ensure safety and their functionality. Proper management of waste batteries and accumulators is particularly important due to the danger associated with elements found in batteries and accumulators.

On average, in one ton of currently collected, used batteries we will meet [11]:

- manganese dioxide 270.0 kg;
- zinc 190.0 kg;
- iron 160.0 kg;
- graphite 60,0 kg;
- ammonium chloride 35.0 kg;
- copper 20.0 kg;
- potassium hydroxide 10.0 kg;
- a few kilograms of cadmium, nickel and lithium;
- silver (silver oxide) 0.3 kg;
- mercury (mercury oxide) 0.1 kg;
- small amounts of Ce, Nd, Pr, Gd, Y, Mo, V, Ti, Co
- and rare earth elements;
- in addition, tar, silica, paper, foil and even hydrogen.

Some of these compounds are not neutral to the environment and this is one of the important reasons why they should be selectively collected and disposed of for proper disposal after use. The second is the economic reason. The market value of the above components if they are recovered is over USD 800. The table shows the elements that can be extracted in batteries and their impact on the environment and human body.

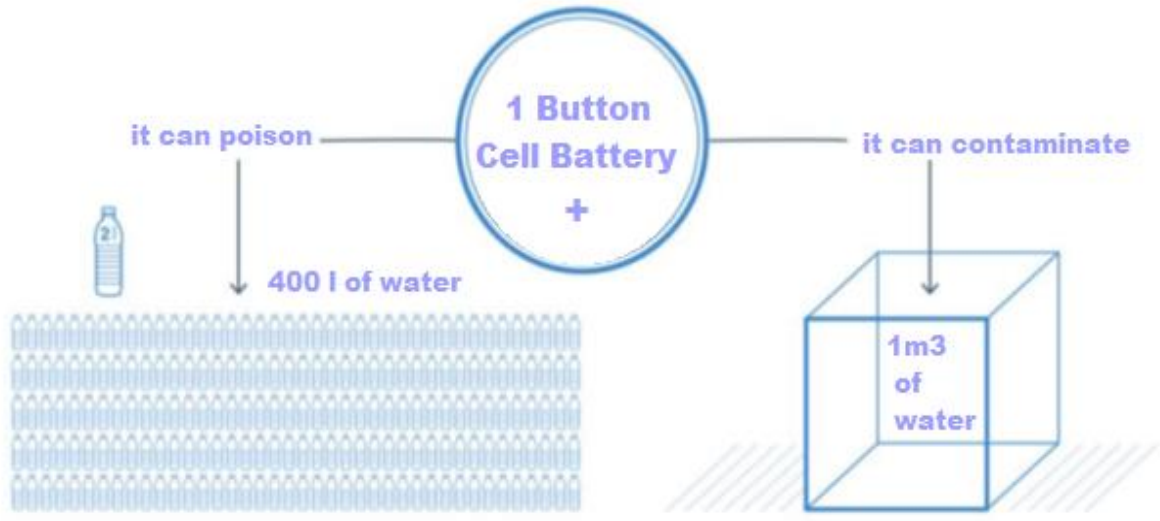

Figure 2. Battery impact on the environment
[Source: Supreme Audit Office, Management systemused batteries and accumulators, Warsaw 2018]

Table 1. The effect of elements contained in batteries on the body

Element	Impact
LEAD	It has strong mutagenic, neurotoxic and carcinogenic properties. Accumulates in the body going to the blood by connecting to plasma proteins. It is deposited in bones and soft tissues. It lowers fertility and interferes with ovulation, causes chronic kidney diseases, gastrointestinal and cardiovascular dysfunctions. Lead is also associated with anemia, which is particularly vulnerable to children.
CADMIUM	Toxic effects of cadmium (to a large extent) consist in: impaired renal function, hypertensive disease, neoplastic changes (especially prostate and kidney), disorders calcium metabolism (skeletal deformation), dysfunction reproductive. Cadmium interferes with the metabolism of calcium and phosphorus in bone tissue – contributes to thinning the bone structure. It displaces zinc from the walls of the arteries, reduces their elasticity, accelerates the development of atherosclerosis and leads to hypertension.
MERCURY	The strongest harmful effect of mercury affects the central nervous system. The harmful effects of mercury are very durable, because mercury compounds combine with enzymes. Mercury exerts a negative effect on the cell membrane by blocking its permeability. Conditions associated with the toxic effects of mercury include insomnia, dizziness, fatigue, depression, weakness of memory and coordination of movements, impairment of visual acuity and hearing, emotional lability, shaking hands. It is a highly toxic element. Causes kidney damage, hypertension, deforms bones, causes neoplastic changes. Causes kidney damage, bone deformation and changes Cancer.
NICKEL	Nickel in too high concentration damages mucous membranes, causes allergic reactions, changes in chromosomes and in the bone marrow, may contribute to the development of cancer cells. Excess nickel also adversely affects the proportions of other elements. First of all, it lowers the level of magnesium and zinc in the parenchymal organs.

LITHIUM	Toxic symptoms may affect many organs: the nervous system of the cardiovascular system, the digestive system (nausea, vomiting, diarrhea, swelling of the salivary glands, abdominal pain, salivation, abdominal distension), urinary tract (glycosuria, proteinuria, diabetes insipation), skin (acne, dryness, hair loss, pruritus, ulcerations, edema), endocrine system (goiter, hypothyroidism, overactive parathyroid glands, impotence), hematopoietic system (increased leukocytosis).

[Source: Supreme Audit Office, Management system used batteries and accumulators, Warsaw 2018]

The figure shows an example of the impact of the introduction of used batteries into the environment.

3. SYSTEM FOR THE MANAGEMENT OF WASTE BATTERIES AND ACCUMULATORS IN POLAND

Batteries and accumulators are hazardous waste containing selected heavy metals such as lead, cadmium and mercury that are toxic to our body. In the case of getting into it, they cause kidney diseases and dysfunctions of various systems, for example: digestive and nervous. For this reason, it is necessary to ensure proper protection of this waste and eliminate it from the environment, by delivering it to a collection point. [12]

Poles consume annually 240 million single-use batteries, in most cases containing heavy metals (lead, cadmium, nickel, zinc and mercury), which are not subject to neutralization and reduction, and harmful substances such as lithium and manganese. The batteries have a very short life and quickly get into the basket, and the heavy metals released from them and a whole range of toxic or corrosive substances that make up the batteries pose a serious threat to the environment. Unfortunately, 90% of batteries used in Poland are disposable batteries, usually zinc-manganese. Alkaline batteries are still rarely used in Poland compared to other European countries. However, since all batteries used by us contain a different amount of substances harmful to the environment, it is imperative to collect all of them and pass them to separate collection points. Regardless of the chemical composition of the batteries, their impact on our lives and health is not indifferent. The recovery of batteries and their proper processing is possible only after separating them from the stream of residual municipal waste. It is the responsibility of each waste producer to separate this waste and hand it over for disposal. [13]

In Poland, used batteries and accumulators can be [14]:

- give this waste to the collector;
- leave free of charge at the place of collection. (The places of receipt may be, for example, schools and educational, cultural and educational establishments as well as offices and institutions.) They may collect used batteries and accumulators, if they so wish and if they have a contract with used batteries and accumulators);
- return for free in a store with an area of over 25 m2 and wholesalers, if they sell such products, without having to buy a new battery or a battery;

- leave it free of charge to the entrepreneur providing services in the field of replacement of used batteries or used batteries.

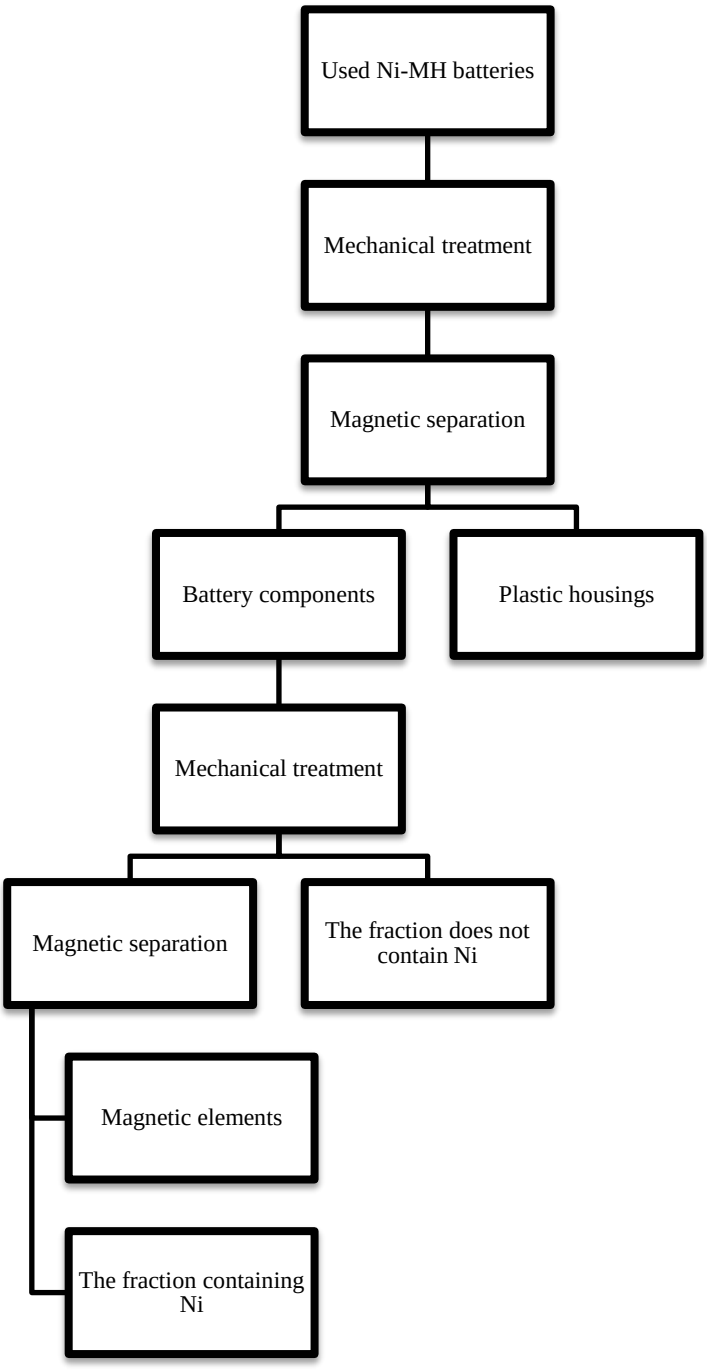

Figure 3. An example of a mechanical process for recovering a nickel-rich fraction from the Ni-MH battery stream.
[Chen, Wei Sheng, Chin Ting Liao, and Chen Hsi Chang. "Recovery of Zinc and Manganese from Spent Zn-Mn Batteries Using Solvent Extraction." Key Engineering Materials. Vol. 775. Trans Tech Publications, 2018, 427-433]

All collected batteries and accumulators are segregated and sent for recycling or neutralized and properly stored. Recycling is a recovery that involves the reprocessing of substances or materials contained in the wastein the production process to obtain a substance or material for primary or other purpose. Methods for recycling batteries and accumulators [15]:

- Mechanical method - crumble and separate into individual fractions: ferromagnetics - steel and other metals, diamagnetics - paper and plastics, paramagnetics - other impurities.
- Hydrometallurgical method - consists in recovering materials as a result of dissolving waste in acids or bases.
- Thermal method - it consists in recovering materials thanks to metal melting in furnaces at a temperature of about 1400 °C. Due to the possibility of release of toxic substances from the waste, the process is carried out in such a way as to exclude direct contact with the skin, respiratory tract and mucous membranes.

Depending on the type of waste (cells of one type or mixture of cells) in the battery recycling process, the above three types of recovery processes of materials from waste batteries are used. The most common are mechanical processes, especially for large batteries (industrial type) and as a preliminary operation in most processing technologies. They consist in mechanical loosening of the battery structure and separation of components with characteristic physical properties (density, size, magnetic properties). [16] These activities are usually simpler and cheaper than other processes and, for that reason, should be used to prepare the material stream for further chemical processing. Mechanical methods most often boil down to grinding and separation into individual fractions of mass of used batteries: ferromagnetics - steel and other metals, diamagnetics - paper and plastics, and paramagnetics - other impurities. [17] An example of the mechanical recovery process of the nickel-rich fraction from the Ni-MH spent battery stream is shown in Figure 3.

Waste in the form of batteries or accumulators is disposed of separately from other types of waste. The holder of such waste, created as a result of his business activity, is obliged to selectively collect it, enabling its subsequent recovery or disposal. A waste holder in the form of batteries or accumulators, which is a natural person who is not an entrepreneur or an organizational unit that is not an entrepreneur, should return this waste to collection points or throw it in containers intended for such waste.

Used batteries are hazardous waste and should not end up in a landfill. It is estimated that about 300 million units (7.5 thousand tonnes) of small-size batteries and accumulators are sold annually. Battery collection is carried out in Poland. A big role in the field of collection of used batteries is played by the so-called recovery organizations. Among them is the Recovery Organization founded by the five largest producers of batteries present on the Polish market (including Panasonic Energy Europe N.V.). The organization undertakes a number of activities aimed at promoting battery collection among adults, youth and children. [18]

Storage and processing of used batteries and accumulators should take place in places with hardened, impermeable surface, resistant to weather conditions or in suitable containers that do not conduct electricity, resistant to substances contained in batteries or accumulators and atmospheric conditions.

However, the storage of used lead-acid batteries and accumulators should take place on impermeable surfaces, connected to a sewage system operating in a closed circuit, directing sewage to special tanks or to a plant processing used batteries or accumulators. [19]

The processing and recycling process is divided into two stages: [20]

- sorting of waste batteries and accumulators at least with lead-acid and nickel-cadmium batteries and accumulators, and the remaining minister, in agreement with the minister responsible for environmental affairs, may specify, by regulation, other types of waste batteries or used batteries that should be separated in the sorting process;
- processing of individual types of waste batteries and accumulators into appropriate material fractions and recycling of at least separate metals in installations and using technologies ensuring at least minimum recycling efficiency levels.

The above requirements do not apply to waste acid-lead batteries and accumulators, for which the processes to be handled during processing will be defined in more detail.

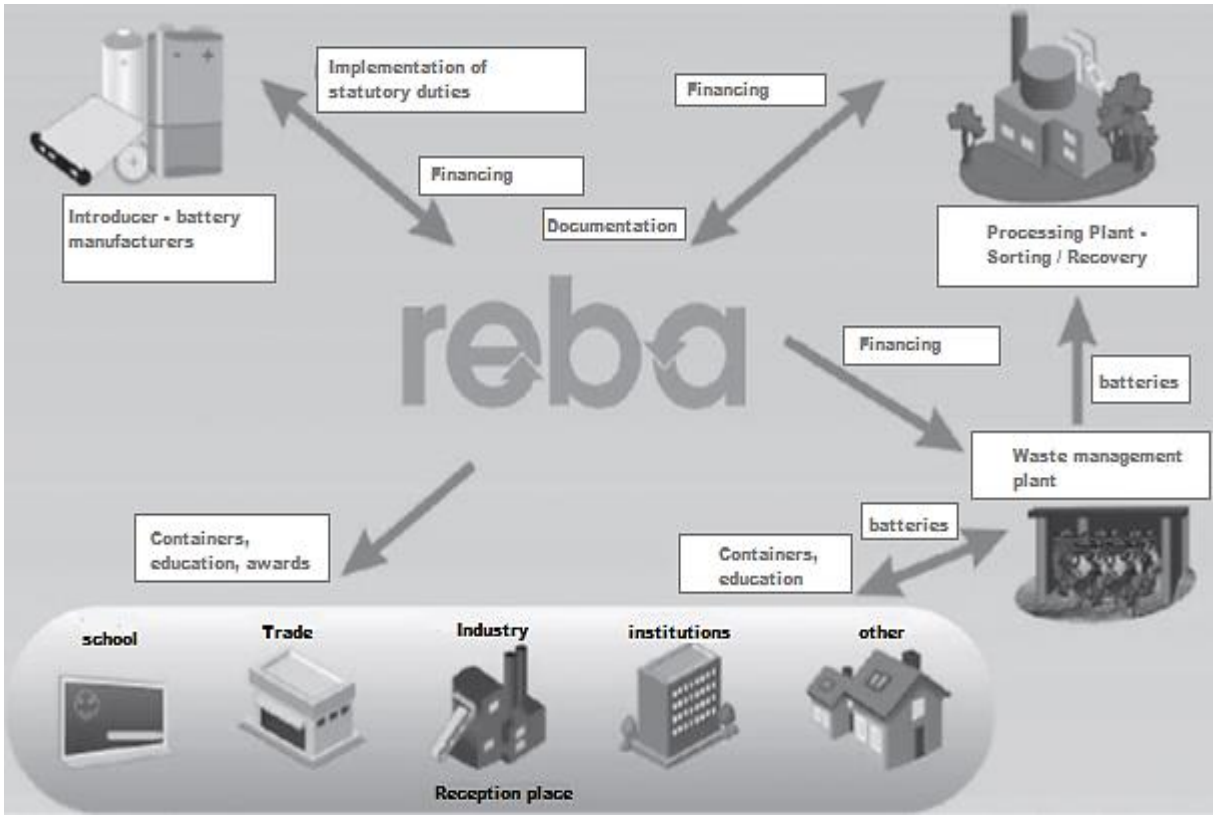

Figure 4. Diagram of the operation of the collection and processing system for portable batteries and accumulators promoted by Reba S.A.
[Source: Informational materials Reba Organizacja Odzysku S.A.]

On June 12, 2009, the Act on batteries and accumulators entered into force in Poland. The new regulation introduces the principle of extended producer responsibility for the products it has marketed. Introducing batteries or accumulators are obliged to conclude agreements with entities that collect and operate a processing plant in order to create a collection system for used batteries and accumulators. [21]

On September 27, 2011, the provisions contained in art. 15 para. 1 points 2 and 3 above Act. According to them, the following minimum recycling efficiency levels have to be achieved through technologies and installations for the treatment and recycling of individual types of waste batteries or accumulators: [22]

- in the case of nickel-cadmium accumulators and nickel-cadmium accumulators - 75% of the weight of nickel-cadmium accumulators or nickel-cadmium accumulators used, including recycling of the cadmium content to the highest degree, while avoiding excessive costs;
- in the case of other used batteries and accumulators - 50% of the weight of used batteries and accumulators (excluding used lead-acid batteries and used lead-acid batteries).

The Figure 5 below presents a flow chart of the management system for used portable batteries and accumulators.

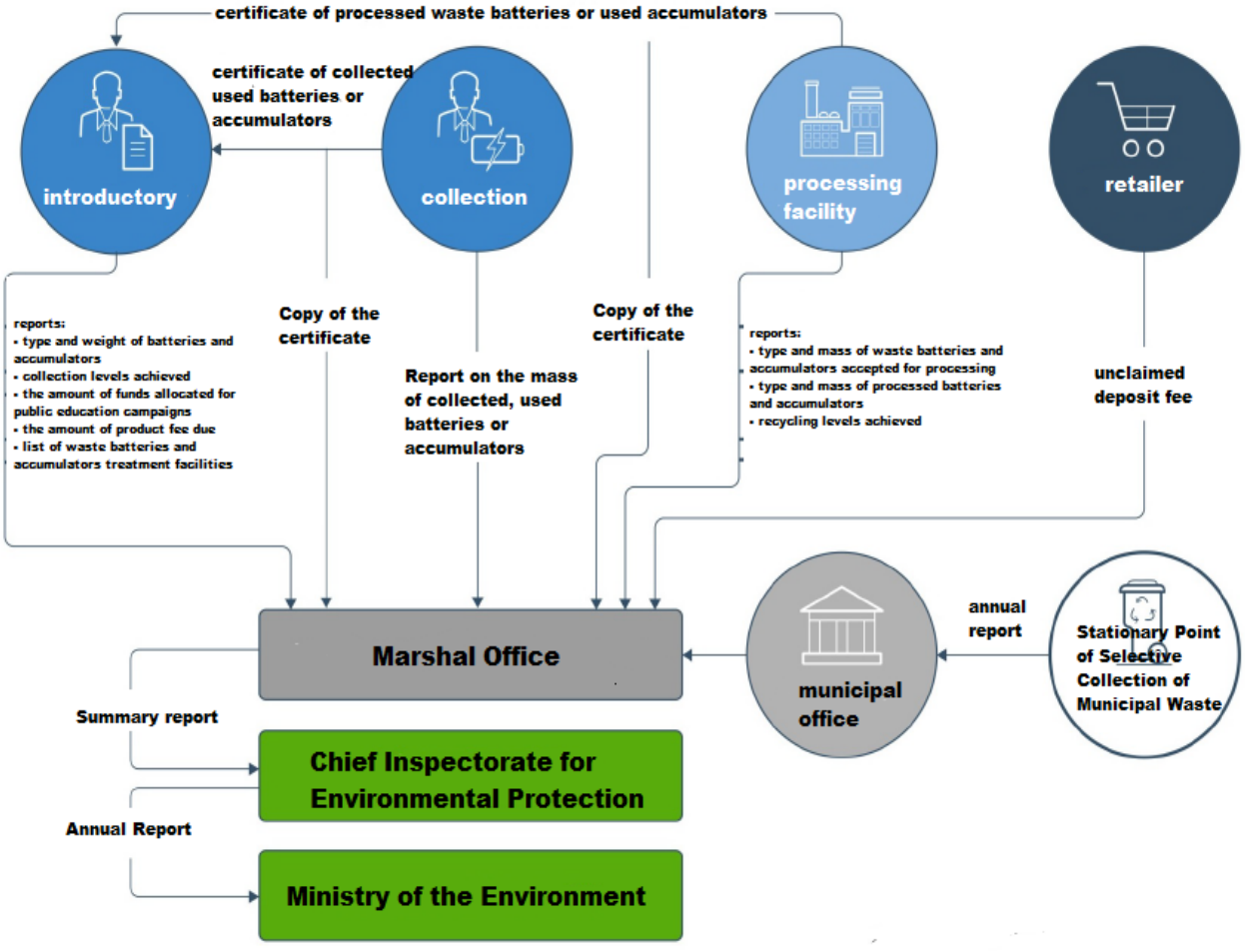

Figure 5. Scheme of the management system of used portable batteries and accumulators.
[Source: Supreme Audit Office, Management system used batteries and accumulators, Warsaw 2018]

4. CONCLUSIONS

The heavy metals contained in batteries and accumulators (including lead, cadmium, mercury) and electrolytes are dangerous for the environment and human health. That is why it is important to deal with them properly. The Member States of the European Union are obliged to to introduce a collection and disposal system based on the "polluter pays" principle. Introducing them to the market have the obligation to organize and finance a system for the collection, processing, recycling and disposal of waste batteries and accumulators.

Used portable batteries and accumulators should be passed on to end users (collection containers located eg in educational and commercial facilities, post offices, administration and others). However, used automotive and industrial batteries and accumulators should be returned to retailers or wholesalers. These wastes are collected by collecting waste batteries and accumulators, and then delivered to operators of processing plants, where they are recycled or disposed of.

In Poland, both entrepreneurs marketing batteries and accumulators, collecting organizations and entities owning waste batteries and accumulators plants - operate on the basis of national legal norms, which order the nature of their activities by means of laws and regulations. The institution coordinating and controlling all activities in this area is the Chief Inspectorate for Environmental Protection. The systemic solutions introduced in Poland regarding recycling of used batteries and used batteries cause that the economy of these hazardous wastes becomes efficient, which in the future may bring tangible benefits for the natural environment.

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