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ASSESSMENT OF SPENT BATTERIES STREAMS IN UKRAINE

Abstract. *The goal of this study is the analysis of quantitative parameters and dynamics of spent batteries generation in Ukraine and mass balance assessment of their streams. The assessment used statistical data from international trade organizations and the State Statistics Service of Ukraine on the number of produced, imported, exported batteries, and spent batteries generated. Analysis of statistics on spent batteries generation in the world shows a significant difference in quantity, which is due to different ways of spent batteries management and approaches to counting. The estimated mass of batteries sold in Ukraine is about 20 thousand tons per year. The weight of household batteries (excluding car batteries) is estimated as 4.5-7 thousand tons per year (110-170 grams per year per person) and corresponds to the data of some EU countries. Among household batteries, alkaline and lithium-ion batteries are the most common. Study of batteries quantity in the waste has shown a significant data divergence between the expected mass of batteries in the waste and official statistics. This is probably due to the low efficiency of the waste accounting system. In recent years, there is a trend of reducing the mass of batteries placed on the market and reducing their share in the waste (but such trends are not a case for household batteries). According to unofficial data, the weight of the collected spent household batteries is 2-3 tons per year or 0,05-0,08 grams per year per 1 person. The level of spent batteries collection (including car batteries) is estimated at 19%, and household batteries – only 0.1% that is much lower than in the EU countries. About 75–80% of spent batteries (99% of spent household batteries) are not accounted in waste streams. Besides, batteries in the waste of electrical and electronic equipment remain unaccounted.*

The scientific novelty of the study is the development of mass balance of spent batteries in Ukraine, which will ensure more efficient management of their flows. The practical value of the paper includes assessment of spent batteries volume in Ukraine for further analysis of the possibilities of their recycling.

Key words: *batteries; waste; spent batteries; waste management; mass balance*

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Introduction

Efficient household waste management is very important for the environment. However, in many countries (including Ukraine), hazardous household waste is not separated from other categories of household waste despite many years implementing of legislation and waste management processes, as well as information campaigns around the world. Therefore, hazardous household waste (e.g. batteries, fluorescent lamps and many others) accumulates mainly at landfills causing big environmental risks if these landfills are not constructed and do not operate in accordance with environmental requirements. Among hazardous household waste, batteries account for the largest share (excluding waste electrical and electronic equipment if considering them as a separate category). According to reference data [1], batteries and accumulators constitute about 0.25% of all household waste mass

and about 50% of hazardous components of household waste. Different types of batteries contain compounds of zinc, manganese, mercury, copper, lead, cadmium, nickel, and acids [2]. In Ukraine, the main component in hazardous household waste is also batteries – about 25% [3]. In Poland, about 6000 tons of spent household batteries are generated annually [4]. In 2018, less than half of spent batteries (47.4%) were collected in EU countries [5]. Denmark, one of the leaders in waste management, still has 39% of batteries collected together with other household waste [6]. Other countries have much worse performance. The accumulation of this waste at landfills can lead primarily to the environmental pollution by heavy metals. For example, authors from the United States [7] have found lead and chromium in majority of spent batteries, despite the contrary information from the manufacturers. Moreover, the authors [8] have determined that the permissible heavy metals content in many spent batteries has been exceeded. The goal of this paper study is the analysis of quantitative parameters and dynamics of spent batteries generation in Ukraine and mass balance assessment of their streams.

Methodology of research

In order to assess the generation of spent batteries, the literature, UN statistical data on the sale, import and export of batteries [9], and data from the State Statistics Service of Ukraine on waste generation [13] were analysed.

The complexity of waste batteries estimating volume is explained by 3 main factors: 1) the accounting systems exists only for spent batteries generated in products manufacturing; 2) lack of efficient separate collection of household batteries; 3) lack of relevant research.

Research results are likely to be significantly underestimated due to the large amount of unaccounted waste. Statistical information is provided by waste-generating companies. Therefore, the reliability of the data is under the question in case of insufficient control.

Research results

Analysis of statistical data on spent batteries generation in the world

The data on spent batteries quantity in different countries often differ in large scale. This is due to the presence/absence of special schemes for the collection of such waste, and different efficiency of data accounting. For example, the authors [6] have determined the content of spent batteries in household waste in Denmark at 0.02–0.06% that corresponds to an average of 208 grams (9 pcs) of batteries per year per household. This is 39% of all generated waste batteries. Thus, the total number of spent batteries can be estimated at 0.1% of household waste weight. However, it should be noted that every municipality in Denmark has an access to special waste collection points. Therefore, majority of spent batteries are collected separately with relatively little share in residual household waste. A study [10] conducted in Germany also has shown an average 0.04% of spent batteries in household waste. In Poland, as of 2004, only 6.5% of batteries (12.2 g/year per person) were collected separately [4]. Accordingly, about 190 g/year of batteries remained in the mixed waste. However, as of 2018, the level of spent batteries collection has risen to 80% [5], which is one of the highest in the EU. The content of spent batteries in household waste in China (250 g/year per person) [11] are much higher.

In general, according to the European Association of Portable Batteries [5], the average weight of batteries placed on the markets of EU countries, after a slight decrease in 2010-2013, continues to grow and was 453 g/year per person in 2018.

Assessment of volumes of batteries and accumulators placed on the market in Ukraine

The difficulty of processing statistical data is due to the fact that there is only information on the total mass of batteries and accumulators produced in Ukraine. The data also include car batteries accounting for the main share of production. Car batteries are not included in household waste.

Some part of household batteries on the Ukrainian market are imported. According to the UN [9], Ukraine annually imports about 4000 tons of household batteries. Most of them are manganese batteries (over 2000 t/year) and lithium-ion batteries (the number is constantly increasing, currently – more than 1000 t/year). The data on batteries placed on the Ukrainian market in 2016-2018 are given in the Table 1. However, these data include only batteries imported as separate products and do not take into account the batteries in the goods (e.g. household appliances, electronic devices, toys, etc.). Therefore, the total import of batteries is probably much higher than shown in the Table 1.

Table 1 – Weight and number of batteries imported in Ukraine, 2016-2018

Type of battery (code)	2016		2017		2018	
	Weight, tons	Number, thous. pcs.	Weight, tons	Number, thous. pcs.	Weight, tons	Number, thous. pcs.
Alkaline batteries (850610)	2220	N/a	2072	116592	1939	109917
Mercury batteries (850630)	0	0	0,07	0,2	0,04	0.072
Zinc-silver batteries (850640)	0,3	527	0,48	532	0,63	484
Lithium batteries (850650)	42	11758	46	7733	76	11018
Zinc-air batteries (850660)	1,6	1186	1,9	1380	2,3	1586
Other types of primary batteries (850680)	1000	56233	912	53237	1200	65961
Lead-acid accumulators (850710)	19495	1897	20565	2120	13252	876
Nickel-cadmium accumulators (850730)	30	139	16	62	28	63
Nickel-iron accumulators (850740)	26	39	10	30	17	18
Nickel-metalhydride accumulators (850750)	36	1360	42	1506	27	748
Lithium-ion accumulators (850760)	409	3633	799	6344	1371	11555
Other types of accumulators (850780)	13	211	20	206	45	278
Total	23273	76983	24485	189742	17958	202504
Total excl. lead-acid accumulators	3778		3920		4706	

Besides, some batteries are manufactured in Ukraine, but data on their weight or quantity are not available. The weight can be estimated through the cost of the batteries produced. For example, the total cost of batteries and accumulators produced in Ukraine in 2018 was UAH 2.837 billion. At the same time, the value of batteries exported was UAH 625 million. Thus, Ukrainian batteries and accumulators with cost of UAH 2.212 billion remained on the market. At the UN base [9], the weight of exported batteries and accumulators in 2018 amounted to 25 429 tons. Making appropriate comparisons, we obtain the estimated weight of Ukrainian batteries and accumulators on the domestic market of about 89 998 tons. Taking into account imported batteries and accumulators, their total weight in 2018 was 106 016 tons. Most of this weight is accounted for car batteries, but exact data are unknown since Ukrainian statistics contains only aggregate information on batteries and accumulators. Relevant calculations were also made for 2016 and 2017 (see Table 2).

Table 2 – The estimated weight of batteries place on Ukrainian market, 2016-2018

Year	Batteries and accumulators produced in Ukraine, mio UAH	Batteries and accumulators exported from Ukraine		Batteries and accumulators remained on the market	
		mio UAH	tons*	mio UAH	tons*
2016	1954	624	691**	1330	45025
2017	2413	764	25864	1649	55824
2018	2837	625	25429	2212	89998

*estimated data

**the data on weight of some types of batteries and accumulators are not available

The data listed in the Table 2 also include lead-acid car batteries, which do not belong to household batteries as was mentioned above. Therefore, it is necessary to assess the weight of Ukrainian batteries remained on the Ukrainian market without taking into account lead-acid batteries. In 2018, 25 429 tons of batteries were exported from Ukraine, while the share of household batteries is about 1.5% (373 tons) according to [9]. If we assume the share of household batteries as 1.5% among batteries produced in Ukraine (due to the lack of other data), then the residual weight of Ukrainian batteries on the Ukrainian market excluding lead-acid batteries is 1350 tons (1.5% of 89 998 tons). Along with imported household batteries (see Table 1), the total weight of the batteries is 6056 tons. Similar calculations were also done for 2016 and 2017. The results are presented in the Table 3.

Table 3 – Calculation of the weight of batteries placed on Ukrainian market

Year	Batteries exported from Ukraine, tons	Batteries exported from Ukraine (excl. lead-acid accumulators), tons (%)	Ukrainian batteries remained, tons	Ukrainian batteries remained (excl. lead-acid accumulators), tons	Batteries imported, tons	Total weight batteries placed on Ukrainian market, tons
2016	691	53 (7,7)	45025	3453	3778	7231
2017	25864	230 (0,9)	55824	496	3920	4416
2018	25429	373 (1,5)	89998	1350	4706	6056

Besides, if we assume that the majority of lithium-ion batteries (especially by weight) on the market are car batteries, they can also be excluded from the calculation. Then, the weight of household batteries in Ukraine account for about 6000 tons/year (see Table 4).

Table 4 – Calculation of the weight of household batteries placed on Ukrainian market (excluding lithium-ion accumulators)

Year	Batteries exported from Ukraine, tons	Batteries exported from Ukraine (excl. car batteries), tons (%)	Ukrainian batteries remained, tons	Ukrainian batteries remained (excl. car batteries), tons	Batteries imported, tons	Total weight batteries placed on Ukrainian market, tons
2016	691	48 (6,9)	45025	3127	3778	6905
2017	25864	227 (0,87)	55824	490	3920	4410
2018	25429	369 (1,45)	89998	1306	4706	6012

From the data in Table 4, one can conclude that the share of household batteries in Ukraine ranges from 110 to 170 g/year per person in recent years (Fig. 1). For comparison, in some EU countries (Romania, Bulgaria, Greece, Croatia), the weight of household batteries placed on the market is about the same, although the EU average value is much higher – 453 g/year per person [5].

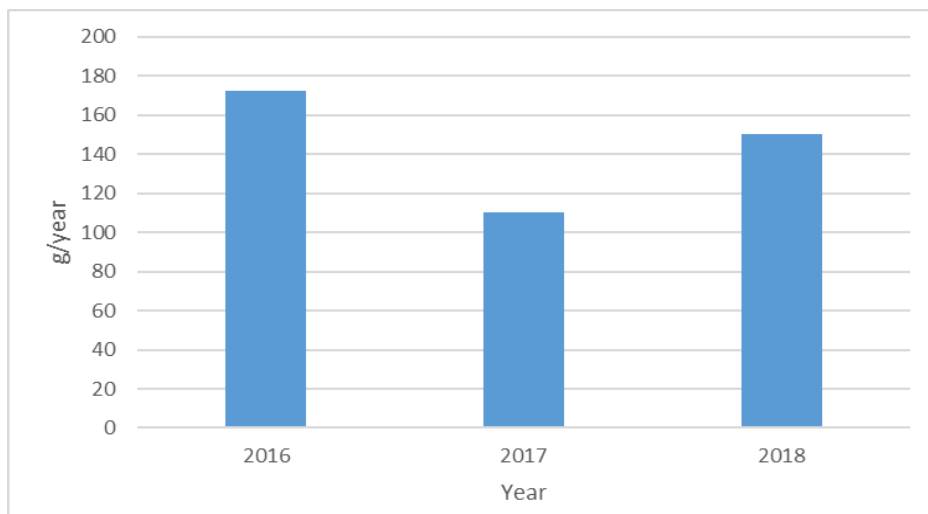


Fig. 1 – Unit weight of household batteries in Ukraine, g/year per 1 person

Among the batteries, alkaline and lithium-ion types constitute the majority (excluding car batteries), their weight in 2018 was 40% and 29%, respectively. For comparison, in Japan, the largest share goes to alkaline and zinc batteries – 77% and 20%, respectively [12].

Spent batteries generation in Ukraine

According to official statistics [13], about 4000-4500 t/year of spent batteries and accumulators are generated in Ukraine (see Tables 5–7, no data available for 2016).

Table 5 – Weight of spent batteries in waste, 2017

Type of batteries	Weight, tons
<i>Waste of batteries manufacturing</i>	1315
Nickel-iron accumulators	0,2
Lead-acid accumulators	1273.9
Alkaline accumulators, incl. nickel-cadmium	1
Other accumulators	39.9
<i>Waste of car exploitation</i>	3260.8
Lead batteries	1806.9
Nickel-cadmium batteries	55.5
Alkaline batteries	74.9
Other batteries and accumulators	480
Waste electrolyte from batteries and accumulators	843.5
<i>Batteries in household waste</i>	7.2
Total	4583

Table 6 – Weight of spent batteries in waste, 2018

Type of batteries	Weight, tons
<i>Waste of batteries manufacturing</i>	924.7
Nickel-iron accumulators	0.1
Lead-acid accumulators	897
Alkaline accumulators, incl. nickel-cadmium	6.4
Other accumulators	21.2
<i>Waste of car exploitation</i>	3664.3
Lead batteries	1777.8
Nickel-cadmium batteries	59.9
Alkaline batteries	58.7
Other batteries and accumulators	572.2
Waste electrolyte from batteries and accumulators	1195.7
<i>Batteries in household waste</i>	11.4
Total	4596

Table 7 – Weight of spent batteries in waste, 2019

Type of batteries	Weight, tons
<i>Waste of batteries manufacturing</i>	795.2
Nickel-iron accumulators	0.5
Lead-acid accumulators	754.1
Alkaline accumulators, incl. nickel-cadmium	10.4
Other accumulators	30.2
<i>Waste of car exploitation</i>	3444.1
Lead batteries	1687
Nickel-cadmium batteries	71.5
Alkaline batteries	47.4
Other batteries and accumulators	517.1
Waste electrolyte from batteries and accumulators	1121.1
<i>Batteries in household waste</i>	11.4
Total	4246

In general, there is a correlation between the weight of batteries placed on the market and weight of batteries in waste. Thus, there was reducing of the total number of batteries placed on the market and reducing of their weight in waste in recent years (although, this is not a case for household batteries). A more detailed comparison is

difficult to make since the data on the number of batteries placed on the market and those contained in the waste are presented for different categories of batteries.

Comparing the data from the Table 1 to the data on waste generation, it can be concluded that about 75–80% of batteries are not taken into account in waste streams, and for household batteries this figure reaches 99% (i.e. batteries in household waste are mostly not taken into account in official statistics). Besides, batteries in the waste electrical and electronic equipment remain unaccounted for [14]. For example, in [6] it was determined that about 20% of all spent batteries are found in electrical and electronic equipment. According to [10], the share of spent batteries in e-waste is about 1%. According to research [12], in Japan, the average weight of batteries in small electronic equipment is 4.6%. A large number of used equipment remains unaccounted for. Besides, a lot of old equipment is imported into Ukraine illegally. The absence of electronic waste separate collection and relevant collection points does not allow to assess the electronic waste flow from households (and batteries inside as well). These facts confirm the low coverage of spent battery streams by official statistics in Ukraine.

There is no official statistics on separately collected spent household batteries in Ukraine. According to non-governmental and private organizations collecting spent batteries, their annual weight is 2-3 tons per year (or 0.05-0.08 g/year per 1 person). For comparison, EU countries have 210 g/year of collected spent batteries per 1 person. Even taking into account the smaller number of batteries sold in Ukraine, the difference is very large. This confirms the discordance between the actual number of spent batteries in the waste and official data.

The collection rate of spent batteries is also an important indicator. According to the methodology [15] it can be calculated by the formula:

$$N = W/M, \quad (1)$$

where W is the weight of collected batteries, t/year, M is average weight of batteries placed on the market in previous 3 years, t/year.

Thus, taking into account the data in the Tables 1–7, in 2019 the collection rate of spent batteries in Ukraine was about 19% by weight in 2019. However, this data was achieved primarily due to the well-established system of car batteries collection. For household batteries, according to unofficial data, the collection rate is much lower – 0.1%. This is due to the lack of organized system of spent household batteries collection, which is provided only by the public and private initiatives. At the same time, the collection rate in the EU ranges from 26 to 70%.

Conclusions

According to the research results, the collection rate of spent household batteries in Ukraine is very low – less than 1%. This is a logical consequence of the lack of an efficient system of spent household batteries collection. Such a system exists only for car batteries providing the total collection rate at 19%. The unit weight of household batteries in Ukraine ranges from 110 to 170 g/year per 1 person in recent years corresponding to the data from Eastern and Southern Europe. Among household batteries, alkaline and lithium-ion constitute the majority. Therefore, the data on the number of batteries placed on the Ukrainian market are adequate. The weight of household batteries in waste is about 11 t/year according to official data.

This figure is definitely underestimated since non-governmental organisations report 2-3 thousand t/year of collected household batteries. This is probably due to the low efficiency of the waste accounting system. About 75-80% of batteries (99% of household batteries) are not taken into account in waste streams. The main obstacles to the correct assessment of spent battery streams are the low level of monitoring of their generation and collection, which leads to incorrect data.

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ОЦІНЮВАННЯ ПОТОКІВ ВІДПРАЦЬОВАНИХ БАТАРЕЙ В УКРАЇНІ

Анотація. Метою дослідження є проведення аналізу кількісних показників та динаміки утворення відпрацьованих батарей в Україні та оцінювання матеріального балансу їх потоків. Для проведення оцінювання використовувались статистичні дані міжнародних торговельних організацій і Державної служби статистики України щодо кількості вироблених, імпортованих і експортованих батарей, а також утворення відпрацьованих батарей. Аналіз статистичних даних утворення відпрацьованих батарей у країнах світу показує значну розбіжність у кількісних показниках, що пов'язано із різними способами поводження з такими відходами і підходами до ведення обліку. У роботі оцінена маса батарей, які продаються в Україні (близько 20 тис. тон щорічно). При цьому маса побутових батарей (без врахування автомобільних акумуляторів) оцінена в 4,5–7 тис. тон/рік (110-170 г/рік на 1 людину), що відповідає показникам окремих країн ЄС. Серед побутових батарей найбільше представлені лужні і літій-іонні. Дослідження кількості батарей у відходах показало значну розбіжність очікуваної маси батарей у відходах і офіційних статистичних даних, що, ймовірно, пов'язано із низькою ефективністю системи обліку відходів. В останні роки спостерігається тенденція до зменшення загальної кількості батарей на ринку і зменшення їх маси у відходах (хоча, наприклад, для побутових батарей такі тенденції відсутні). За неофіційними даними, маса зібраних відпрацьованих побутових батарей становить 2-3 т/рік або 0,05-0,08 г/рік на 1 людину. Рівень збирання батарей (із врахуванням автомобільних акумуляторів) оцінено в 19%, а побутових батарей – 0,1%, що є значно нижчим за показники країн ЄС. Близько 75–80% батарей (99% побутових батарей) не враховується в потоках відходів. Крім того, залишаються необлікованими батареї у складі відходів електричного та електронного обладнання.

Наукова новизна дослідження полягає у розробленні масового балансу відпрацьованих батарей в Україні, що дозволить більш ефективно управляти їх потоками. Практична цінність роботи включає оцінювання обсягів утворення відпрацьованих батарей в Україні для подальшого аналізу можливостей їх утилізації використання як ресурсу.

Ключові слова: батареї; відходи; відпрацьовані батареї; поводження з відходами; матеріальний баланс

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