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A Cross Sectional Study on Community Understanding of Battery Waste Impact in Vojvodina

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ABSTRACT

The issue of waste batteries as a specific type of waste poses a major challenge to the environment, mainly due to improper disposal practices among the local population. The aim of this study is to explore the local population's awareness of the environmental impact of waste batteries, which are often discarded with regular waste instead of being disposed of properly. Although 67 % of respondents express concern about the ecological consequences, 69.63 % of respondents still dispose of used batteries improperly and only 32 % feel sufficiently informed about the environmental risks. The findings highlight the urgent need for targeted education initiatives to raise public awareness of proper disposal methods and the harmful effects of poor waste management on environmental health. The study also highlights the importance of promoting rechargeable batteries and developing accessible collection points to encourage proper disposal. Collaboration with local authorities and alignment with EU regulations are essential for the introduction of sustainable waste management practices.

1. Introduction

Batteries have become an essential part of everyday life in modern society, especially in households where they are used in various devices such as remote controls, toys, clocks, household appliances, and personal care devices. The increasing dependence on portable electronic devices has resulted in the frequent use of various types of batteries. Batteries are practical and make everyday life easier, but their impact on the environment depends on their chemical composition and how they are disposed of after use. For example: zinc-carbon batteries are inexpensive and reliable but have limitations like low energy density and leakage, requiring proper recycling of zinc and manganese due to environmental concerns (Dehghani-Sanij et al., 2019). Silver-oxide batteries are stable but degrade over time, affecting their typical 1.5 V output (Wang et al., 2024). Alkaline batteries are durable and widely used, but 24 % of discarded ones still contain usable energy, causing inefficiency and waste (Sabbaghi and Behdad, 2024). Sealed Ni-Cd batteries, containing toxic cadmium, are banned in the EU but still used in emergencies (Vassura et al., 2009). Ni-Mn batteries offer higher energy density and are more eco-friendly, though recycling is needed to recover rare earth elements (Salehi et al., 2024). Lithium-ion batteries, known for high energy density, are widely used across applications, with lithium ions moving between electrodes during charge and discharge (Reiner et al., 2020). Given that batteries used in everyday applications contain different chemical compositions with hazardous metals, the importance of proper disposal and recycling is paramount to reducing

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their environmental impact. Battery waste management poses a significant environmental challenge due to the potential harm arising from improper disposal like metal leakage, toxicity and climate changes (Melchor-Martínez et al., 2021.).

To reduce the environmental impact of batteries, switching to rechargeable batteries could significantly decrease the demand for single-use batteries. Rechargeable batteries have several advantages over traditional ones. They are cost-effective because they can be reused over 500 times, (Kuchhal and Sharma, 2017) which leads to waste prevention, reducing the volume of waste, and conserving natural resources such as minerals, water, and fossil fuels used in production and transportation (Lankey and McMichael, 2000). In addition, a proper battery storage after end of life ensures a environmental safty (Kuchhal and Sharma, 2017).

In the European Union, the management of batteries and accumulators is regulated by Directive 2006/66/EC. This directive establishes basic standards and objectives for the proper management and recycling of batteries and accumulators, including a ban on placing those containing mercury and cadmium on the market. In Serbia, the transposition of this directive has been achieved through the Waste management law (Official Gazette of RS, 36/2009; 88/2010…35/2023) and the Regulation on the manner and procedure of managing used batteries and accumulators (Official Gazette of RS, 86/2010). There is, however, a gap between legal regulations and the behavior of citizens. Local governments in Serbia currently do not have adequate resources to enforce laws regarding hazardous waste management. As a result, batteries and other hazardous waste often end up in landfills alongside municipal waste. A system for the separate collection of spent batteries and accumulators has not yet been established, nor there are designated locations for their collection, except for a few exceptions. Manufacturers and distributors are responsible for ensuring proper collection and recycling, while public utility companies must organize hazardous waste collection according to local plans. Serbia aims for recycling efficiency of at least 65 % for lead batteries and 75 % for nickel-cadmium batteries (Pokimica et al., 2021). As good practices in battery waste management are sought by both the government and citizens, the results of this study will provide insights into the level of awareness of Vojvodina residents. They will also highlight areas where public education or better management systems are needed. This data will also help identify challenges in promoting sustainable practices in battery disposal and help improve environmental protection efforts.

2. Research Methodology

The survey was implemented in July 2024 through an online questionnaire shared via social media. The aim of the survey was to explore the awareness, opinions, and behavior of residents in Vojvodina when it comes to using and disposing of household batteries, as well as to assess their understanding of the environmental impact of used batteries. The survey consisted of 21 questions, divided into four sections with following crucial indicators:

1. **Basic demographic indicators** - This section helped to create better insights to the respondents' profiles like gender, region of province of Vojvodina, age group, employment status, education level, number of devices operating on battery in their house, and household size. These details are important for analyzing how attitudes and practices might differ among various demographic groups and regions within Vojvodina.
2. **Awareness, concern and practices indicators** - This group of questions focused on respondents' perception of their awareness and concerns of harmful effects of used batteries, and their current disposal habits as well.
3. **Knowledge indicator** - These questions explored their real knowledge on topics such as whether batteries contain hazardous materials (like lead, cadmium, and mercury), whether and how improper disposal affects the environment. Additionally, the survey also investigated their knowledge on recycling systems in Serbia.
4. **Willingness and familiarity indicator** - These questions are designed to reveal willingness to comply with regulations on battery disposal if such laws were enforced, willingness to switch to rechargeable batteries to reduce pollution and questions that indicate if they were informed about collection points.

Most of the answers to the questions were formatted in statements using a Likert scale (from 1 - strongly disagree to 5 - strongly agree), except the question that indicate the knowledge which was formulated in three response options (yes, no, I don't know).

Although each group of questions included several items, we decided to randomly select one question from each group for the analysis:

1. Indicator of **awareness**: What is your opinion on how well-informed you are about the environmental impact of waste batteries?
2. Indicator of **concern**: I am concerned, so I will try to dispose of batteries properly in the future, in designated places.
3. Indicator of **practice**: I throw batteries in the waste bin with other household waste/I dispose of batteries in designated collection places.
4. Indicator of **knowledge**: What is your opinion on

whether cadmium, lead, and mercury are classified as hazardous materials?

5. Indicator of **familiarity**: I am familiar with the locations (in my place of residence or the nearest city) where waste batteries are collected.
6. Indicator of **willingness**: Since rechargeable batteries significantly reduce potential environmental pollution caused by improper disposal, would you be willing to change your lifestyle habits and invest more money in purchasing rechargeable batteries and chargers to help reduce the generation of this type of waste?

To reveal the main correlations between indicators (awareness, concern, practices, knowledge, familiarity and willingness), an analysis was conducted through various respondent variables (age, education and number of devices that operate on battery in household). For this comparative analysis only affirmed answers of selected questions were analyzed.

3. Results and discussion

3.1. Respondents' profile

A total of 110 respondents participated in the survey, representing all three regions of the province of Vojvodina: Srem, Banat, and Bačka. The majority of respondents were female (72.7 %). Regarding the regions in Vojvodina where respondents live, 76.4 % reside in Banat, 18.2 % in Bačka, and 5.5 % in Srem. The respondents' employment status, education, age, and the distribution of battery-powered devices in households are presented in Table 1. The majority of participants (71.8 %) were employed, while only 14.5 % were students. A total of 10 % of respondents declared themselves unemployed, and 3.6 % were retirees. The majority of participants in the survey (52.7 %) completed secondary education, followed by 29.1 % who had higher education. Answers also revealed that batteries of various sizes and types are used in households to power different devices. Among the respondents, 36.4 % have more than seven devices that operate on batteries, while 33.6 % have five to six devices. Slightly fewer respondents, 26.4 %, use batteries to operate three to four devices, and 3.6 % use them for one to two devices.

Effective management of battery waste is a pressing environmental concern. A comprehensive study conducted in Sydney (Islam et al. 2022) involved a sample of 400 respondents, representing a population of approximately 5.18 million. In contrast, the research conducted in Vojvodina had a sample of 110 respondents, corresponding to a smaller population of around 1.8 million. Although the sample size in Vojvodina is smaller, it can still yield relevant results as it reflects the specific characteristics of the local community. The sampling approach in Vojvodina was adapted to the size and context of the targeted communities, allowing for meaningful insights despite the differences in sample size.

Table 1.
Employment status, education, household size, and age distribution of respondents

Category	Subcategory	Percentage (%)
Age Group	41 to 50 years	30.0
	21 to 30 years	29.1
	31 to 40 years	21.8
	51 to 60 years	11.8
	Under 20 years	4.5
	61 to 70 years	1.8
	Over 70 years	0.9
Employment Status	Employed	71.8
	Students	14.5
	Unemployed	10
	Retired person	3.6
Educational Attainment	Secondary Education	52.7
	Higher Education	29.1
	Master's Degree	5.5
	Primary Education	2.7
	Doctoral Degree	1.8
Number of devices on battery in households	1-2	4
	3-4	29
	5-6	37
	>7	40

3.2. Analysis of indicators and their correlation to the variables

Data obtained within this research are analyzed in order to reveal main challenges in battery waste management and public participation. Hence, correlation between indicators for awareness, concern, practice, knowledge, familiarity and willingness was analyzed through different variables of respondents: age, education and number of devices of battery in household.

For **Indicator of awareness**, we selected question "What is your opinion on how well-informed you are about the environmental impact of waste batteries?". According to respondents answers only 32 % affirmatively responded that they believe that they are aware about environmental impact of battery waste (Figure 1). Compared to studies in China, where over 90 % of 1,874 respondents are aware of the health and environmental risks of spent batteries, this percentage is significantly low (Sun et al., 2015). In order to indicate profile of that group of respondents we investigated their age, education and the number of

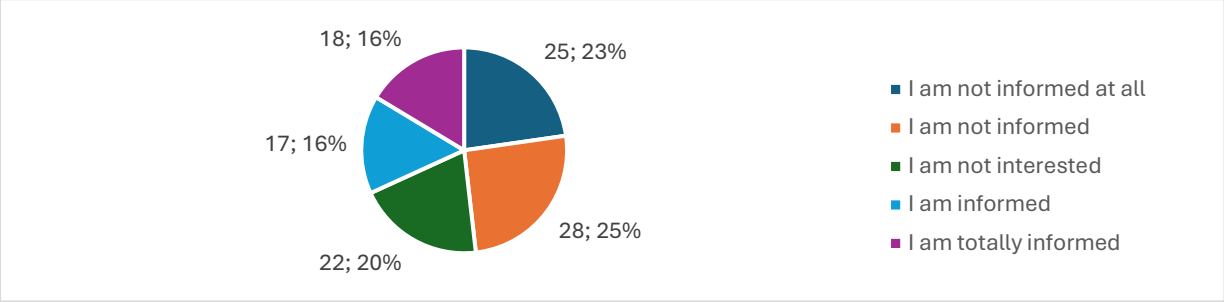


Figure 1. Structure of the answers on question What is your opinion on how well-informed you are about the environmental impact of waste batteries?

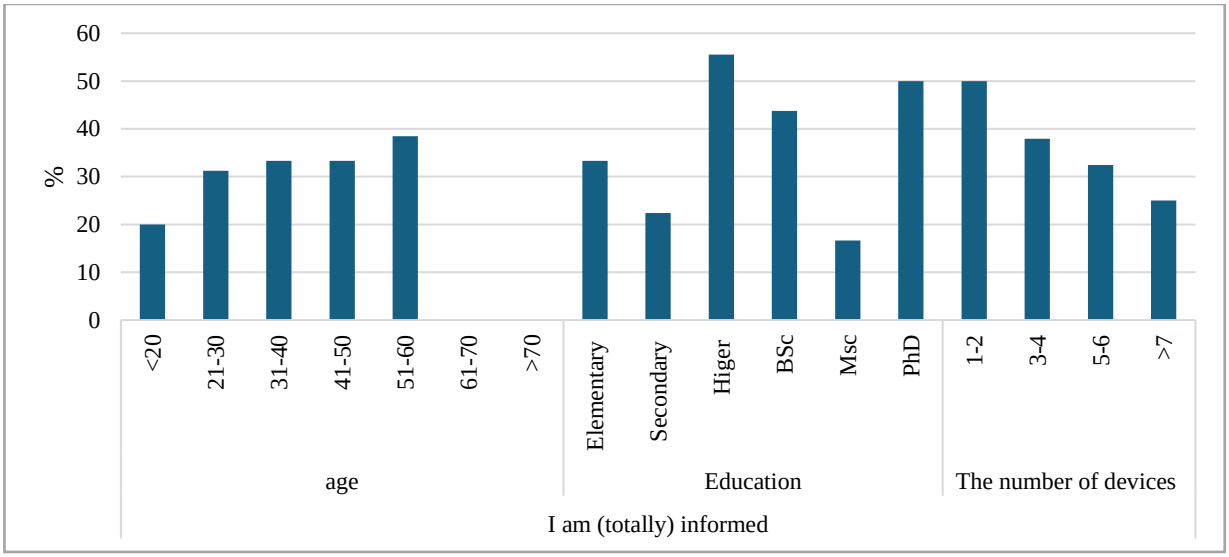


Figure 2. Incubator awareness in correlation to the participants variables

devices powered by batteries of various types and sizes in household. Results revealed that younger people (less than 20-year-old) are the group that is the least aware of battery waste impacts.

Concerning the respondent's education, citizens with higher education and the group of people that have only 1-2 device that uses battery in their houses think that they are totally aware of the influence battery waste has on environment (Figure 2). This suggests the need for stronger educational campaigns to raise awareness on this topic, especially among younger respondents. **For indicator of concern**, we selected question: "I am concerned, so I will try to dispose of batteries properly in the future, in designated places. Results showed that majority of respondents (67 %), confirmed that they are concerned about environmental damage that old battery cause (Figure 3).

In addition, we analyzed the group of respondents who were very concerned based on the variables mentioned above. According to the analysis, participants in the 61-70 age group are the most concerned group. This group also includes the more educated participants and those who own 3-4 devices that run on batteries.

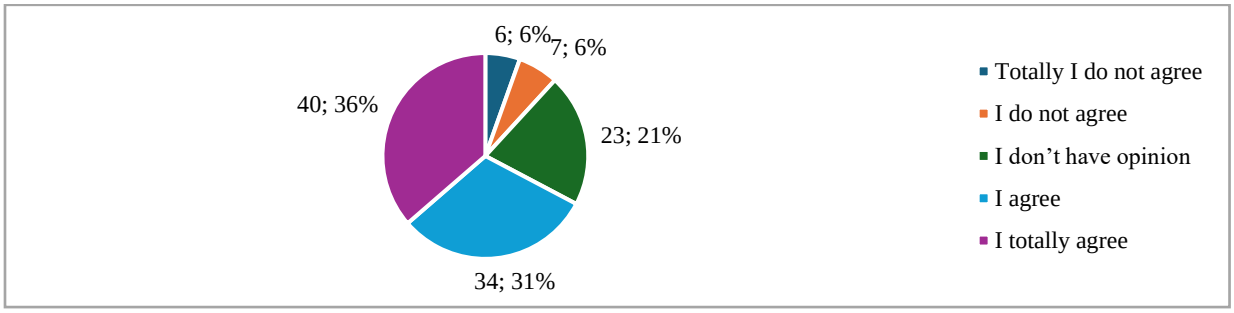


Figure 3. Structure of the answers on question

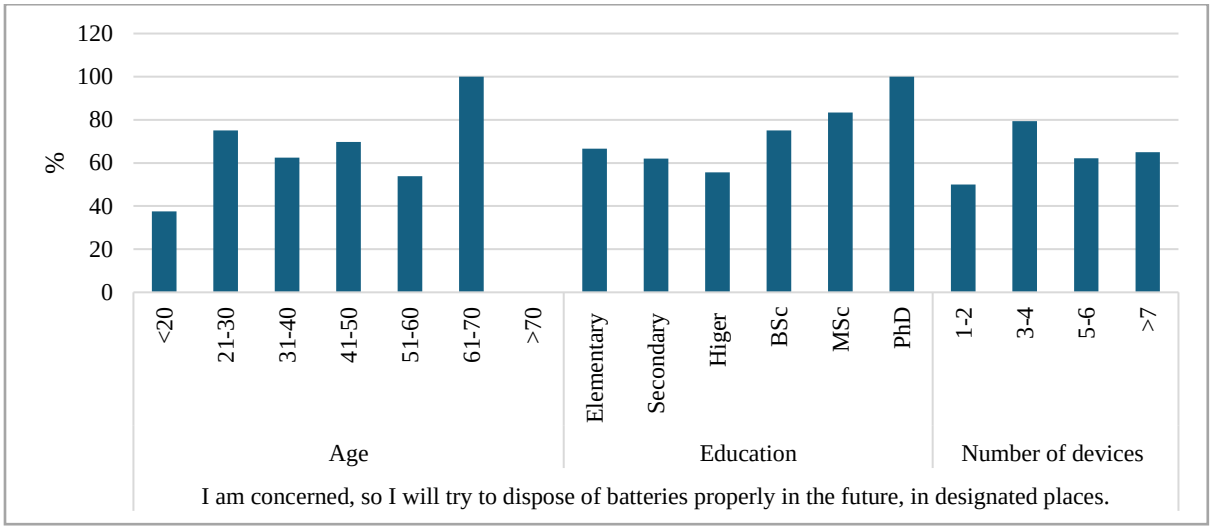


Figure 4. Indicator concern in correlation to the participants variables

Answers for **indicator of practice**: "I throw batteries in the waste bin with other household waste/I dispose of batteries in designated collection places" showed that, majority of respondents throw the batteries the trash with household waste (69.63 %). Affirmatively we choose to analyze the profile of respondents who stated that dispose batteries at special points designated for used batteries (39.35 %) (Figure 5). A comparable study was conducted among residents of Dezhou and Zibo City in Shandong Province from May to August 2014, focusing on the methods of battery disposal. The study involved 1,975 participants, revealing concerning trends in waste management. It was observed that the collection practices for waste batteries from households were inadequate, with respondents mostly disposing of batteries alongside municipal waste (Sun et al., 2015). In related research conducted in Sydney (Islam et al. 2022), 27 % of respondents dispose of waste batteries in bins along with municipal waste. Moreover, a study in Malaysia (Mathew et al. 2023), revealed that a significant proportion of respondents have never recycled spent lithium-ion batteries, often choosing to store them at home or throw them away instead of using recycling bins.

However, the lack of proper disposal practices suggests that it is essential not only to inform people about the dangers but also to actively engage them in recycling processes and proper disposal methods.

To better understand the profile of this group of respondents we provided deeper insights into their habits related to battery disposal (Figure. 6).

Comparative analysis showed that all respondents with a PhD education dispose of batteries at designated collection places. Additionally, those who have high number of battery-operated devices (5-6) in their households also showed good practice in battery disposal.

For **indicator of knowledge**, we selected question: "What is your opinion on whether cadmium, lead, and mercury are classified as hazardous materials?" Based on the research results, it can be concluded that 94 % of respondents believe they are aware that cadmium, lead, and mercury are classified as hazardous materials (Figure 7). However, their knowledge is questionable because there is a clear gap between what they say and their actual behavior when it comes to disposing of batteries in the trash with other waste. Based on the research conducted in Russia (Tarasova et al., 2012), a similar situation emerged where respondents who recognized the harmful environmental impact of spent batteries still opted to dispose of them in the trash.

Figure 5. Structure of the Answers to the Question: "I throw batteries in the waste bin with other household waste / I dispose of batteries in designated collection places"

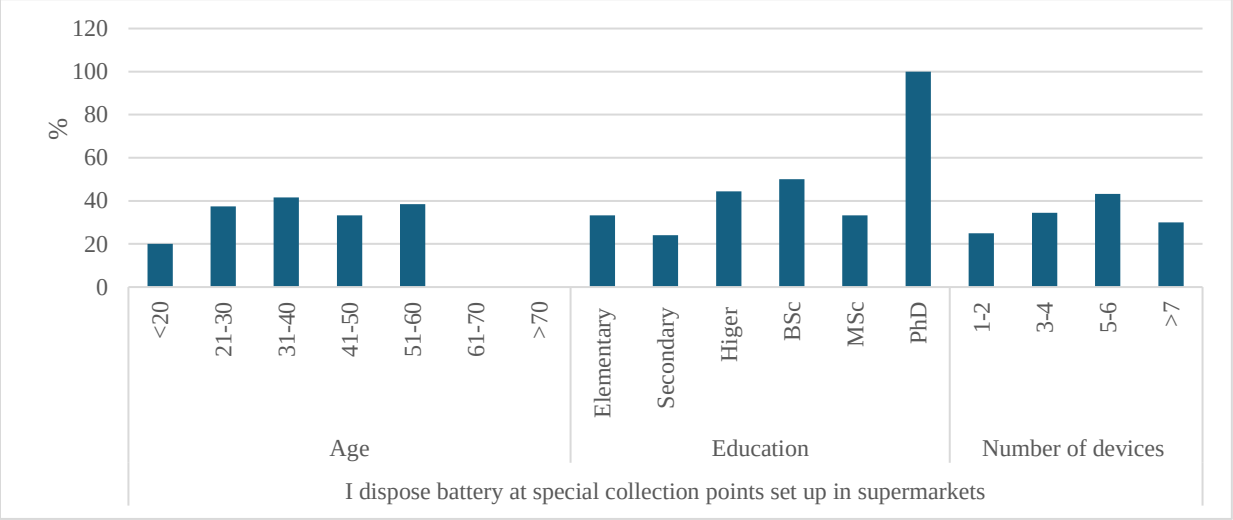


Figure 6. Indicator practice in correlation with the participants' variables

Based on the data presented in Figure 8, we can conclude that none of the examined groups across the three variables stand out in the category of the knowledge indicator. However, the question was formulated in such a way that respondents, even though they may not have been fully aware of the impact, hinted at the correct answer. It seems that all participants demonstrated same level of knowledge.

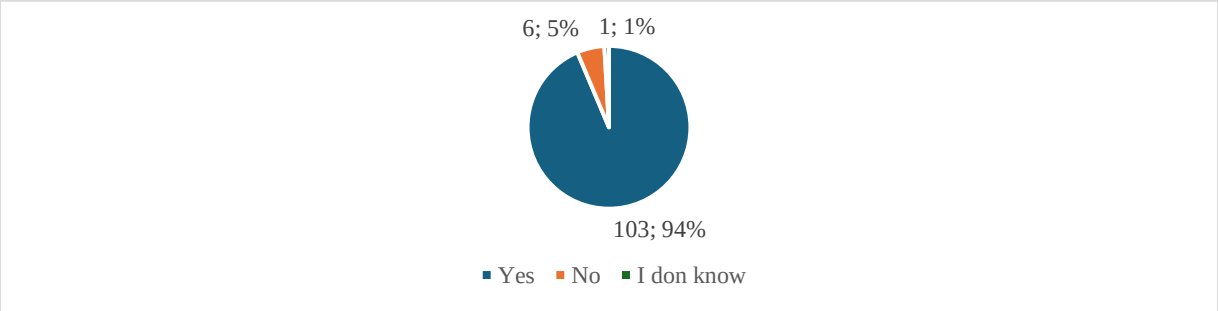
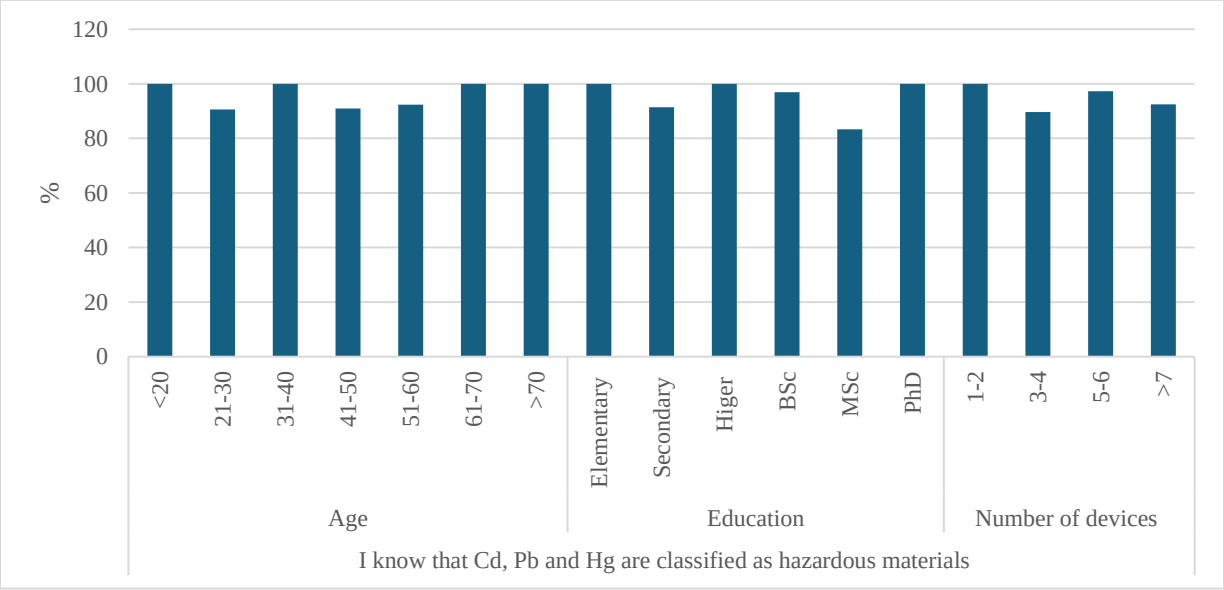


Figure 7. Structure of the answers on question "Are the cadmium, lead, and mercury classified as hazardous materials?"



Graph 8. Indicator knowledge in correlation with the participants' variables

For **Indicator of familiarity**, we selected question: "I am familiar with the locations (in my place of residence or the nearest city) where waste batteries are collected." As depicted in Graph 9.42 % of respondents reported familiarity with these designated locations.

Conversely, 51 % of participants indicated that they are unaware of where to dispose of waste batteries properly.

This lack of familiarity and insufficient infrastructure not only hinders effective recycling practices but also underscores the urgent need for a more robust waste battery management system in Serbia.

For analysis correlation of indicator with the participants' variables, group of respondents that stated that they are familiar with the battery disposal locations were selected.

The data indicates that respondents aged under 20 and those between 21 and 30 years are significantly less familiar with battery disposal sites. In contrast, respondents with a PhD education emerge as the most familiar group in this category.

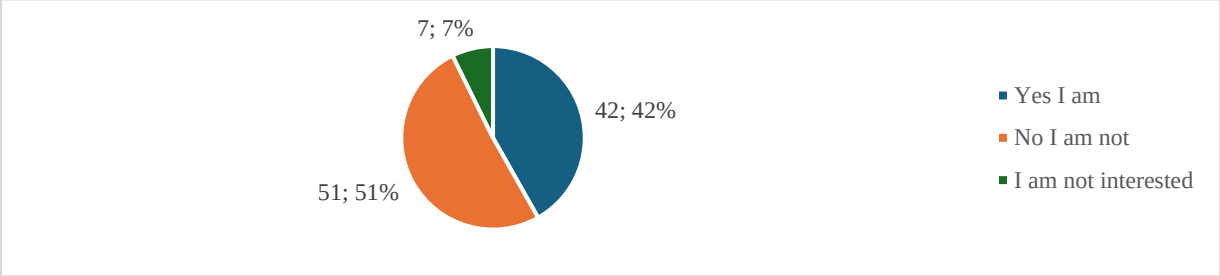


Figure 9. Structure of the answers on question: I am familiar with the locations (in my place of residence or the nearest city) where waste batteries are collected

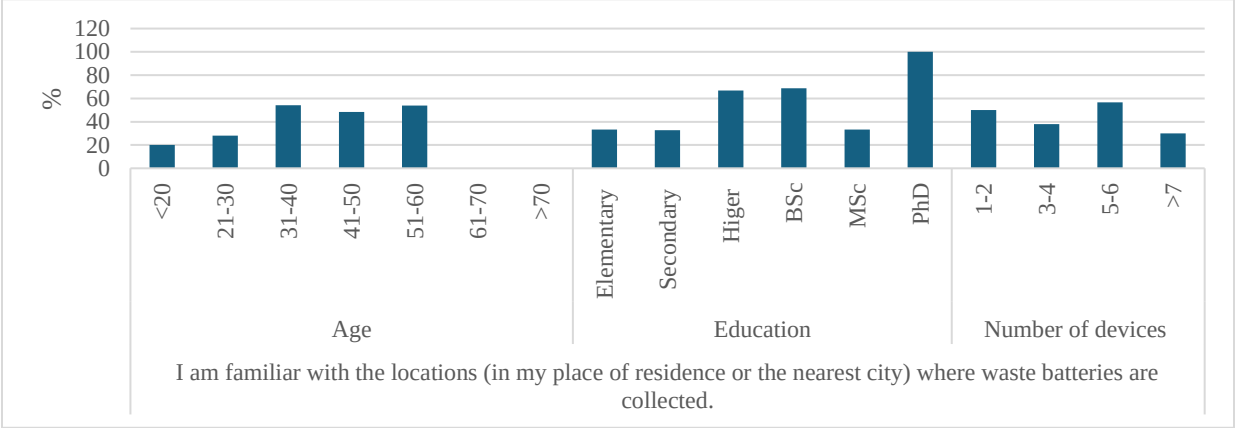


Figure 10. Indicator familiarity in correlation with the participants variables

For **Indicator of willingness** following question was selected: “Since rechargeable batteries significantly reduce potential environmental pollution caused by improper disposal, would you be willing to change your lifestyle habits and invest more money in purchasing rechargeable batteries and chargers to help reduce the generation of this type of waste?” The results indicate that an impressive 78 % of respondents express a willingness to modify their habits and invest in rechargeable options to help reduce the generation of this type of waste (Figure 11).

This result provides a foundation for developing strategies that could further encourage the transition to more sustainable options while simultaneously reducing the negative impact of battery waste on the environment.

The following graph (Figure 12) provides a detailed profile of respondents who expressed full willingness to change their lifestyle habits.

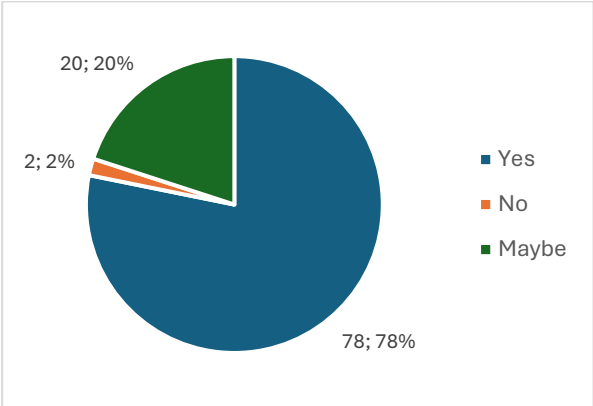


Figure 11. Structure of the answers on question: Since rechargeable batteries significantly reduce potential environmental pollution caused by improper disposal, would you be willing to change your lifestyle habits and invest more money in purchasing rechargeable batteries and chargers to help reduce the generation of this type of waste?

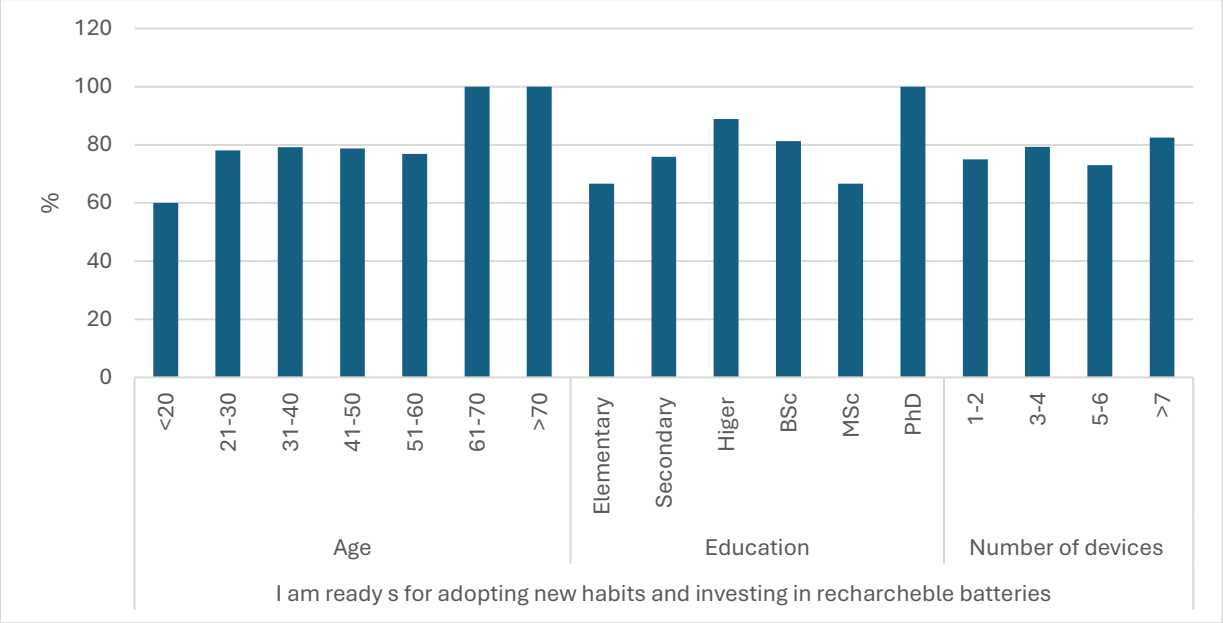


Figure 12. Indicator willingness in correlation with the participants variables

Based on the research findings, it can be concluded that older respondents, particularly those in the age groups of 61-70 and over 70 years, are the most willing to change their lifestyles regarding the purchase of rechargeable batteries.

4. Conclusion

The research on the issue of battery waste highlights the serious ecological challenges posed by the improper disposal of this specific type of waste. The results indicate that only 32 % of respondents feel adequately informed about the impact of battery waste on the environment. While the majority, 67 % of respondents, express concern about the ecological consequences of old waste, as many as 69.63 % still dispose of batteries in regular waste instead of designated disposal sites. These data clearly demonstrate the need for several actions.

First, educational campaigns are necessary to raise awareness about the environmental risks of improper battery disposal and inform citizens about best practices. Infrastructure development is also required, especially to provide accessible and well-marked battery collection points in the community to encourage proper disposal. Another important action is the promotion of rechargeable batteries, emphasizing their longevity and lower environmental impact. Finally, collaboration with local authorities is essential to ensure the effective implementation of waste management regulations.

In line with European Union regulations and local laws, it is essential to improve the infrastructure for the collection and recycling of used batteries to ensure the proper management of this hazardous waste. By implementing educational initiatives and building an efficient collection system, it is possible to significantly reduce the impact of battery waste on the environment.

This approach not only aligns with sustainable waste management practices but also contributes to the circular economy by maximizing resource recovery and minimizing waste.

This study provides valuable insights into the level of awareness among citizens of Vojvodina and identifies key areas for improvement in public education and waste management systems.

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Studija preseka o shvatanju uticaja otpada od baterija u zajednici u Vojvodini

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INFORMACIJE O RADU

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Prihvaćen 07 novembar 2024

Naučni rad

Ključne reči:
Istrošene Baterije
Stavovi Lokalnog Stanovništva
Svest Zajednice
Upravljanje Otpadom

I Z V O D

Problem istrošenih baterija kao specifične vrste otpada predstavlja veliki izazov za životnu sredinu, pre svega zbog nepravilnih praksi odlaganja među lokalnim stanovništvom. Cilj ove studije je da istraži svest lokalnog stanovništva o ekološkom uticaju istrošenih baterija, koje se često odbacuju zajedno sa komunalnim otpadom umesto da se pravilno odlažu. Iako 67 % ispitanika izražava zabrinutost zbog ekoloških posledica, 69,63 % njih i dalje nepravilno odlaže iskorišćene baterije, a samo 32 % se oseća dovoljno informisano o ekološkim rizicima. Nalazi ukazuju na hitnu potrebu za ciljanom edukacijom radi podizanja svesti javnosti o pravilnim metodama odlaganja i štetnim efektima lošeg upravljanja otpadom na životnu sredinu. Studija takođe naglašava značaj promovisanja punjivih baterija i razvoja dostupnih punktova za prikupljanje, kako bi se podstaklo pravilno odlaganje. Saradnja sa lokalnim vlastima i usklađivanje sa regulativama EU su ključni za uvođenje održivih praksi upravljanja otpadom.