

HOUSEHOLD AWARENESS AND PARTICIPATION IN E-WASTE MANAGEMENT IN NOVI SAD, SERBIA

Isidora Berežni *, Tijana Marinković, Aleksandar Kokanović, Marko Muhadinović, Nemanja Stanisavljevic and Bojan Batinić

Department of Environmental Engineering, Faculty of Technical Sciences, University of Novi Sad, Novi Sad, 21000, Serbia

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ABSTRACT

The rapid growth of waste electrical and electronic equipment (WEEE) poses a significant challenge for sustainable management, particularly in developing countries. Households play a key role in waste management as major consumers of electrical and electronic equipment and generators of e-waste. This study examines household awareness, practices, and willingness to participate in organized e-waste management in Serbia. An online questionnaire survey was conducted in Novi Sad. The results show that, although most respondents are aware of the hazardous nature of e-waste and the need for special treatment, regular participation in formal recycling remains limited. Storing old devices at home is a common practice, mainly due to insufficient information and a lack of accessible collection infrastructure. Despite this, a high willingness to participate in organized e-waste collection systems was identified. Household income significantly influences the willingness to financially support e-waste management, while age and education show no significant effect. The findings highlight the need for improved collection systems, strengthened awareness campaigns, and appropriate economic incentives to support e-waste management and circular economy objectives.

1. INTRODUCTION

Waste electrical and electronic equipment (WEEE) represents the fastest-growing waste stream worldwide, with an average annual growth rate of 6.5% between 2010 and 2019 (Bachér et al., 2017). The rapid spread of digital technologies has significantly changed the way people live, work, learn, communicate, and conduct business. With the growing use of electronic devices and improved connectivity in both urban and remote areas, the amount of electrical and electronic equipment (EEE) placed on the market has continued to rise (Baldé et al., 2024).

The rapid expansion has been accompanied by a significant increase in e-waste generation, which contains both hazardous substances and valuable secondary raw materials. In 2022, global e-waste generation reached a record of 62 billion kg, equivalent to an average of 7.8 kg per capita per year, while only 22.3% of this volume was formally collected and recycled in an environmentally sound manner. Over the same period, the amount of EEE placed on the market grew from 62 billion kg in 2010 to 96 billion kg in 2022, and it is projected to reach 120 billion kg by 2030 (Baldé et al., 2024). Although some progress has been made in improving formal collection and recycling

systems, the rapid growth of e-waste continues to exceed these efforts, underscoring the urgent need for more effective and sustainable WEEE management strategies.

E-waste is defined as electrical equipment that is no longer useful to the end-user and is discarded as waste. On the one hand, it can be considered a potential source of valuable base metals, such as iron, copper and aluminium and precious and rare earth elements (gold, silver, palladium and platinum) that can significantly contribute to material recovery and resource efficiency (Abdulaziz, 2022; Berežni, 2021). On the other hand, it also contains hazardous substances such as heavy metals, ozone-depleting substances, halogenated compounds and brominated flame retardants that pose a serious risk to human health and the environment if not properly managed (Banaszkiewicz et al., 2022). Therefore, e-waste management needs to be prioritized.

The issue represents a serious and growing challenge in many developing countries where insufficient policies and environmental management systems, as well as inadequate infrastructure, limit the effective regulation of this waste stream. In the absence of sustainable waste management systems, landfilling remains one of the most widely used disposal practices. Hence, the collection, uti-



* Corresponding author:
Isidora Berežni
email: isidoraberezni@uns.ac.rs



lization, disposal and recycling of e-waste require a coordinated, multilevel approach where all stakeholders need to be involved. In this context, households play a crucial role, as they are directly involved in both consumption of electronic products and the generation of e-waste, making their awareness and participation essential for effective management strategies (Wang et al., 2017; Lim-Wavde et al., 2017).

Despite their critical role, household awareness and knowledge regarding proper e-waste handling remain limited in many developing countries. Accurate data on the quantities of e-waste generated are often unavailable and professional e-waste operators face significant challenges due to low public participation and unreliable collection systems. Household involvement is therefore a key factor in improving both the volume of e-waste collected and the overall efficiency of recycling programs. Understanding consumers' behaviour and attitudes toward e-waste disposal can provide valuable insights for enhancing recycling rates and optimizing the performance of e-waste recycling centres. Studies indicate that increasing consumer awareness has a direct positive effect on willingness to participate in recycling programs. Moreover, even in contexts where awareness is low, households in developing countries have demonstrated a willingness to pay for effective and environmentally sound e-waste disposal (Kitila et al., 2020; Borthakur & Govind, 2017).

The Waste Management Program of the Republic of Serbia for 2022-2031, as published in the Official Gazette of the Republic of Serbia (No.30/18), aims to reduce environmental pollution by minimizing waste generation and promoting the development of the circular economy. Managing e-waste remains a significant challenge and a key barrier to achieving circular objectives in Serbia (Waste Management Program of the Republic of Serbia 2022–2031). Improper e-waste disposal by consumers is still common and e-waste often ends up mixed with municipal waste. According to data from the Serbian Environmental Protection Agency from 2021 to 2023, the total amount of e-waste generated was 68,000 t, 81,000 t and 84,200 t, respectively. Of this, e-waste collected formally and recycled or reused amounted to 30,316 t, 34,532 t and 35,373 t for the corresponding years (SEPA, 2024), while the amount of informally collected e-waste is estimated at around 15,000 t per year (NALED, 2018). These figures suggest that a large portion of e-waste remains outside the formal system, potentially being disposed of improperly or untracked.

E-waste generated by households, businesses and public entities is collected by both formal and informal channels and transported to treatment facilities. While collection from businesses and public institutions is generally well-organized, there is no established system for household e-waste collection, leading to uncontrolled disposal and underscoring the importance of household participation in proper e-waste handling. Households' knowledge and awareness, as well as their behaviours in using, storing, disposing, repairing, and recycling electronic products play a key role in the effectiveness of e-waste management systems. Despite extensive research, significant gaps remain

in understanding household practices and their impact on circular economy outcomes. Raising public awareness and promoting responsible e-waste management at the household level can significantly improve recycling rates, increase material recovery, and mitigate the environmental impact of e-waste (Ofori & Mensah, 2022; ILO, 2025).

In this regard, this study focuses on analysing household behaviour, knowledge, and awareness regarding e-waste in Serbia. It examines the patterns of use of electronic devices, and the level of household understanding regarding the proper disposal and recycling of e-waste. In addition, the study explores the willingness of households to participate in e-waste collection and management initiatives, with the aim of identifying opportunities to improve recycling rates, enhance material recovery, and strengthen the overall efficiency of the e-waste management system.

2. STUDY AREA, MATERIALS, AND METHODS

This survey was conducted among households in Novi Sad. The city of Novi Sad is the second-largest city in Serbia with a population of over 300,000 inhabitants, and after Belgrade it represents the centre of economic development in the country. The structure of the economy is shaped by the existing industries mainly including trade, transport, and the processing industry. Although municipal waste collection coverage in Novi Sad is relatively high, the management of specific waste streams such as electrical and electronic waste remains underdeveloped. Increasing consumption of EEE, population growth and the absence of a proper collection system, combined with limited research on household awareness and practices regarding WEEE disposal in Europe make Novi Sad a relevant case for investigation.

This survey aimed to investigate knowledge and awareness levels related to e-waste and related issues among households in Novi Sad. Considering various survey methods and techniques, the authors decided to conduct the questionnaire online, due to the prevailing political circumstances and public protests in Novi Sad during that period. The questionnaire was administered online during the summer of 2025, and out of 209 received responses, 159 were complete and included in the analysis, resulting in a response rate of 76%. To ensure clarity and comprehension, the survey was carried out in Serbian, and the collected data were subsequently translated into English for analysis.

The questionnaire was developed based on previously published studies investigating household behaviour and awareness related to e-waste management and adapted to local conditions in Novi Sad (Borthakur & Govind, 2017; Banaszkiewicz et al., 2022).

The questions that made up the questionnaire were grouped into sections related to (a) demographic and socio-economic characteristics of respondents, (b) practices related to e-waste, (c) knowledge and awareness of e-waste and related environmental and health issues, and (d) willingness to participate in organized recycling models. The questionnaire consisted of 15 questions covering the four thematic areas described above. The questions

included closed-ended formats, such as yes/no and a multiple-choice questions, as well as multiple-response questions where respondents could select more than one option. The average time required to complete the questionnaire was approximately 10 minutes.

The collected data were stored and processed using Microsoft Excel. Descriptive statistical analysis was applied to summarize the demographic and socio-economic characteristics of the respondents, as well as their practices, knowledge and awareness related to electrical and electronic waste management. In addition, inferential statistical analysis was performed using the chi-square (χ^2) test to examine potential associations between selected categorical variables. The chi-square test was used to assess relationships between socio-demographic characteristics (such as age group and educational level) and household practices related to e-waste disposal, as well as respondents' willingness to participate in organized e-waste management. A significance level of $p < 0.05$ was used when analysing the data, and the results are presented in tables.

3. RESULTS AND DISCUSSION

3.1 Demographic and socio-economic features of study participants

Table 1 provides a summary of the demographic data of respondents. Of 159 respondents, 59% ($n=94$) were men while 41% ($n=65$) were women. The largest group in

terms of age was between 41-50 (31%), followed by those between 31-40 (28%). Participants aged 51-60 years accounted for 16%, while the youngest (21-30) and the oldest (above 60) were least represented, each comprising 13%. Most of the respondents were educated at the university level (79%, $n=126$), while 17% ($n=27$) had completed secondary education. Only a few study participants had primary education (4%, $n=6$).

As illustrated in Table 2, the majority of respondents were employed (91%, $n=144$), while smaller proportions were pensioners, students and unemployed. Regarding income, the largest share of respondents reported monthly incomes above €2,000 (34%, $n=54$), followed by those earning between €1,500 and €2,000 (28%, $n=45$) and between €1,000 and €1,500 (19%, $n=31$). Lower income categories were less represented, with 6% ($n=9$) reporting monthly incomes between €800 and €1,000 and 4% ($n=6$) reporting incomes below €800. Additionally, 9% of respondents ($n=14$) did not want to report their income.

The socio-demographic structure of the sample should be considered when interpreting the subsequent findings. In particular, the high proportion of respondents with university education may have influenced the observed levels of knowledge and awareness regarding e-waste. At the same time, the predominance of highly educated respondents indicates that the sample may not fully reflect the educational structure of the wider population of Novi Sad. Therefore, the socio-demographic characteristics of the re-

TABLE 1: Demographic profile of respondents ($n=159$).

Variable	Category	Frequency	Percentage (%)
Gender	Male	94	59%
	Female	65	41%
Age	Less than or equal to 30 years	20	13%
	31-40 years	44	28%
	41-50 years	49	31%
	51-60 years	26	16%
	Above 60 years	20	13%
Educational level	Primary	6	4%
	Secondary	27	17%
	University or above	126	79%

TABLE 2: Socio-economic profile of respondents ($n=159$).

Aspects	Components	Frequency	Percentage (%)
Employment status	Employed	144	91%
	Unemployed	3	2%
	Student	5	3%
	Retired	7	4%
Income	Below €800	6	4%
	€800 - €1,000	9	6%
	€1,000 - €1,500	31	19%
	€1,500 - €2,000	45	28%
	Above €2,000	54	34%
	Didn't want to answer	14	9%

spondents should be taken into account when interpreting the findings presented in the following sections.

3.2 Knowledge and awareness regarding e-waste

Figure 1 shows the results regarding the different sources of information about the collection and recycling of e-waste at the household level in Novi Sad. Respondents were allowed to select multiple sources. Among the various sources of information, internet was the most frequently mentioned (58%, $n=93$), followed by social media and friends (19% each, $n=31$ and $n=30$). The predominance of the internet and social media as sources of information suggests that digital communication channels may represent an effective tool for increasing public awareness regarding e-waste management. A notable proportion of respondents (33%, $n=52$) reported that they do not receive any information about e-waste.

Although 33% of respondents reported that they do not receive any information regarding e-waste, a majority demonstrated awareness of its management and associated risks. Specifically, 129 participants indicated that they are aware that it is prohibited to dispose of e-waste with other types of household waste, while 30 stated that they were not. Furthermore, 92% ($n=146$) reported that they are aware that e-waste contains toxic substances, while 88% ($n=140$) recognized the potential health and environmental risks arising from improper handling and disposal of e-waste. Finally, when asked whether e-waste requires special treatment before disposal, 125 agreed, while 34 disagreed. These findings suggest that despite gaps in information access, many participants demonstrate a reasonable level of knowledge regarding the safe management of e-waste (Table 3).

Overall, these findings indicate a relatively high level of general awareness of the potential risks associated with e-waste among the surveyed households. However,

awareness was somewhat lower regarding the need for special treatment and the prohibition of disposal together with household waste than regarding the presence of hazardous substances and associated environmental and health risks. This difference suggests that general knowledge about the harmful characteristics of e-waste does not necessarily imply equally strong knowledge of appropriate disposal requirements. Therefore, future awareness-raising activities should not focus only on communicating the hazardous nature of e-waste, but should also provide clear and practical information on appropriate disposal methods and available collection options.

3.3 Current practices and storage of electronic devices

The results indicate varying levels of engagement in e-waste recycling among participants (Table 4). Only 16% of participants reported that they always recycle electronic devices, while the majority (51%) stated that they do it occasionally. Moreover, the fact that 33% of the participants reported never handling electronic devices for recycling suggests that regular participation in formal recycling programs remains limited.

Figure 2 shows various alternatives that participants selected for handling and disposing of electrical and electronic devices. The same percentage of respondents reported storing their e-waste at home and/or repairing their devices (40%). It is important to note that respondents could select multiple options, indicating that individuals often use a combination of disposal methods. Donation of e-waste to others was also common (34%), with 30% giving it to informal collectors and 21% to authorized collectors. Discarding e-waste together with household waste was reported by 27% of respondents, while the least common practice was returning devices in retail stores (7%).

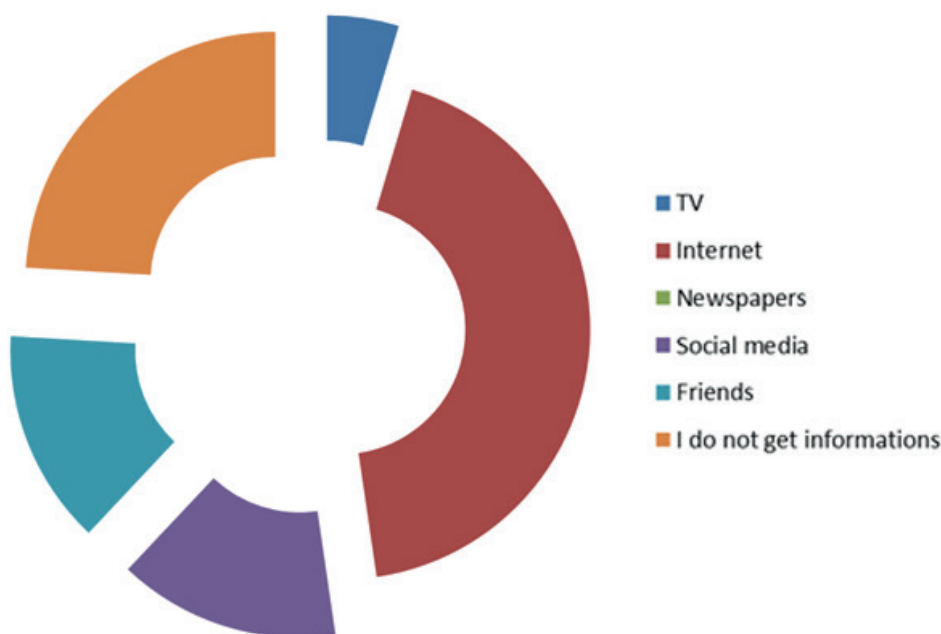


FIGURE 1: Sources used by respondents for information about e-waste.

TABLE 3: Statements on e-waste awareness among the study respondents (n=159).

Statements	No	Yes
Are you aware that it is prohibited to dispose of e-waste with other types of household waste?	30 (19%)	129 (81%)
Do electrical and electronic products contain hazardous substances?	13 (8%)	146 (92%)
Are you aware that e-waste requires special treatment before disposal?	34 (21%)	125 (79%)
Are there health and environmental risks associated with improper handling and disposal of e-waste?	19 (12%)	140 (88%)

TABLE 4: Statement on e-waste recycling.

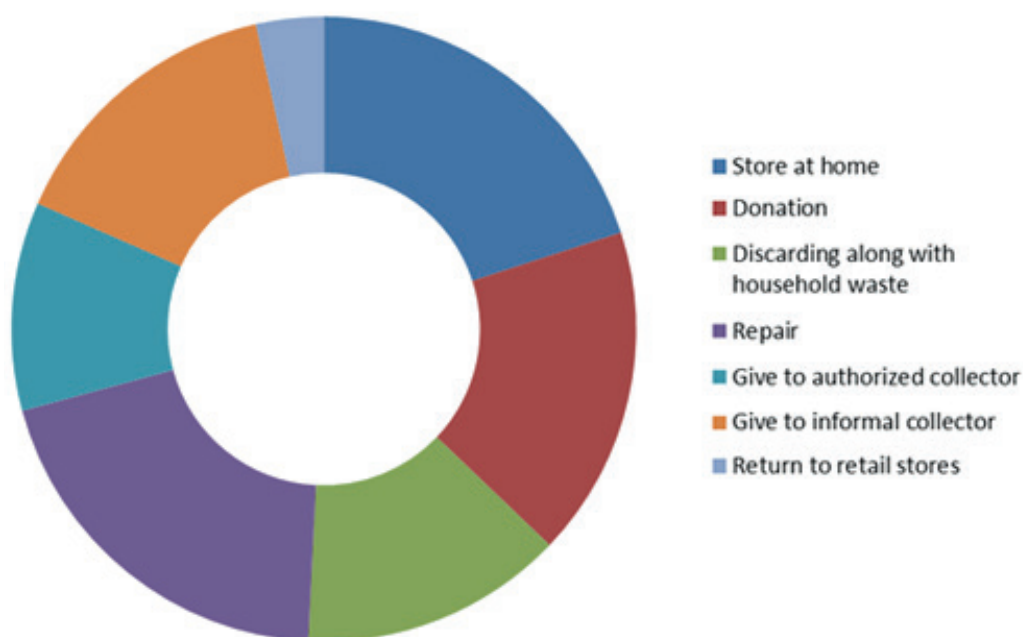
Statement	Always	Sometimes	Never
Do you recycle your electronic devices?	25 (16%)	81 (51%)	53 (33%)

The relatively high proportion of respondents reporting device repair and giving devices to others highlights the importance of life-extension strategies in household e-waste management. Repair can extend the useful lifetime of electrical and electronic equipment and delay its transition to the waste stream, while handing functional devices down to family members, friends or other users can support reuse. From a circular economy perspective, repair and reuse are important alternatives to immediate disposal and recycling because they preserve the functional value of products for a longer period and may reduce the demand for new electrical and electronic equipment. Therefore, recycling should not be considered the only desirable management option, as repair and reuse may represent preferable pathways when devices remain functional or can be restored.

However, storing unused devices at home may represent different underlying behaviours. Temporary storage may be associated with intentions to repair a device, use it

again in the future, or pass it on to another user. In contrast, prolonged storage may delay the recovery of valuable materials and keep devices outside formal reuse and recycling pathways. In the present study, the main reported barriers to disposal were insufficient information about where to take e-waste and the lack of nearby disposal points, suggesting that home storage may often result from limited access to convenient collection options rather than representing an intentional long-term management strategy.

An important finding is that 27% of respondents reported disposing of electronic devices together with household waste. This practice represents an incorrect disposal pathway and is particularly relevant given that the majority of respondents were aware that e-waste contains hazardous substances and may pose environmental and health risks. The results therefore suggest a potential gap between knowledge and actual disposal behaviour. Environmental awareness alone may not be sufficient to ensure appropriate e-waste management when households lack convenient collection options or clear information about available services. The improper disposal of e-waste through the municipal waste stream may result in hazardous components entering inappropriate waste treatment or disposal pathways, potentially contributing to environmental contamination and human exposure. This finding highlights

**FIGURE 2:** Methods used by households in handling and disposing of e-waste.

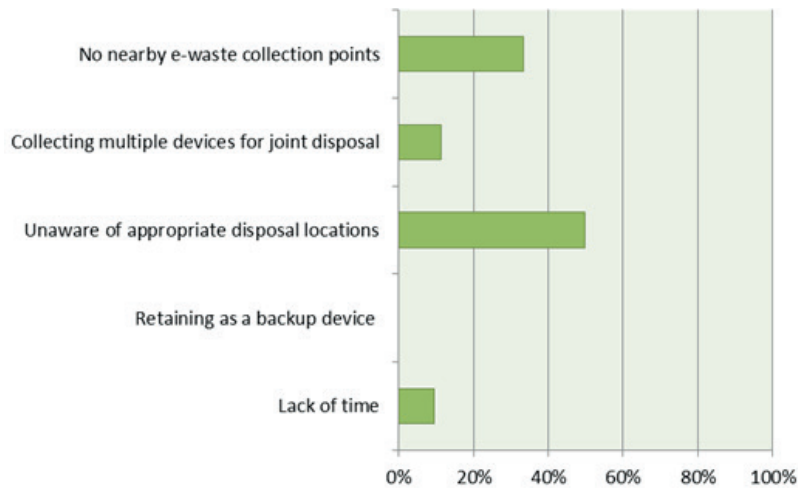


FIGURE 3: Reasons for not disposing of old devices.

the importance of combining awareness-raising activities with accessible and convenient household collection systems.

Storing e-waste at home may be driven by limited access to information and disposal infrastructure, according to the reasons respondents gave for not disposing of their e-waste (Figure 3). With the option to select multiple answers, 50% of respondents reported a lack of information on where to take e-waste as the main barrier to disposal. A significant proportion (33%) indicated that there are no nearby disposal points, while 11% reported that they are collecting devices to dispose of them together. Only 9% mentioned lack of time as a reason, and none of the respondents reported keeping devices as backups. These findings suggest that storing e-waste at home may be largely driven by limited awareness and inadequate access to formal disposal options.

Taken together, these findings suggest that household e-waste management practices are influenced not only by environmental awareness, but also by the accessibility and convenience of disposal options. The reported lack of information on where to dispose of e-waste and the absence of nearby collection points may help explain why some households continue to store obsolete devices or dispose of them through inappropriate channels. Improving access to clear information and convenient collection infrastructure could therefore facilitate the transition from temporary storage and informal disposal practices toward formal collection, reuse and recycling.

3.4 Households' willingness to participate in e-waste management

In addition to existing knowledge and current household practices related to e-waste, the survey also explored respondents' willingness to participate in and financially support organized e-waste management systems. Table 5 presents the willingness of study participants to hand over electrical and electronic devices for recycling if an appropriate system were established. The survey results indicate a high level of willingness among the respondents (94%), although the motivation for participation varied. While 66% stated they would participate free of charge, 16% indicated they would participate if offered a voucher or discount for a new device, and 12% if financial compensation were provided, suggesting that economic incentives could further encourage participation.

Respondents were also asked to evaluate different potential e-waste collection models. The results indicate that the most preferred option among households was scheduled monthly collection at the household address, suggesting that regular and convenient services may significantly improve participation. Recycling yards located at a moderate distance from households were also considered an acceptable option by many respondents. Collection on request by contacting an operator was similarly evaluated, indicating that flexible but slightly more demanding systems could still achieve moderate participation. The least preferred option was the placement of containers for small devices near residential buildings, which may reflect con-

TABLE 5: Willingness of study participants to participate in e-waste recycling if a collection system is established (n = 159).

Statement	Response	Percentage
Would you hand over electrical and electronic devices for recycling if an appropriate collection system were available?	Yes, free of charge	105 (66%)
	Yes, with financial compensation	19 (12%)
	Yes, with a voucher or discount for a new device	25 (16%)
	No	10 (6%)

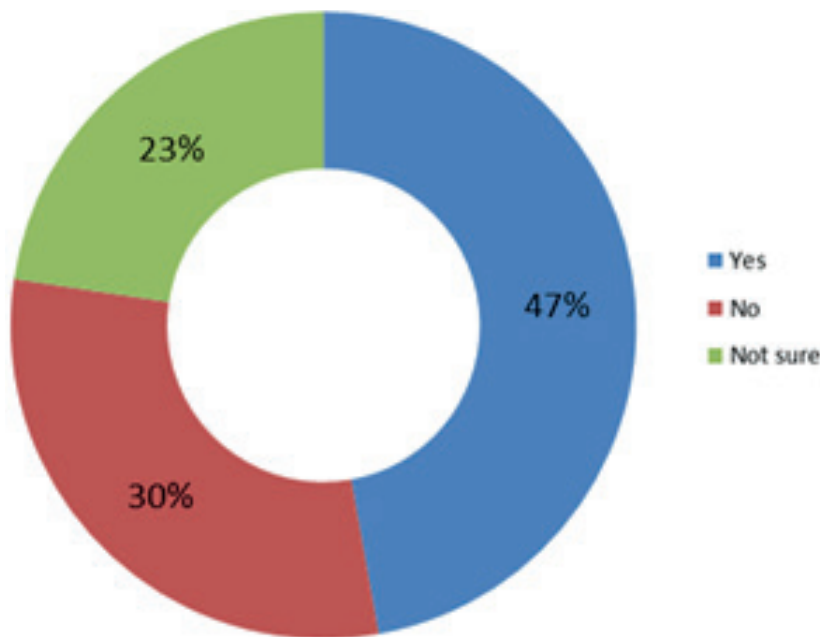


FIGURE 4: Participants' willingness to pay for e-waste management services.

cerns related to accessibility, safety, or limited capacity for handling different types of e-waste.

Regarding financial support for e-waste management, the survey revealed a moderate willingness to pay for such services. Specifically, 47% of respondents expressed readiness to pay a fee for an e-waste management system, while 30% were unwilling to pay, and 23% were uncertain (Figure 4).

Transparent communication regarding the allocation and use of collection fees is essential to build public trust and enhance participation. Providing clear information on how the funds will support the operation and maintenance of e-waste management programs can reassure households that their contributions are effectively utilized. Additionally, implementing flexible payment options or incentives such as discounts on new appliances or integration with existing municipal waste fees may increase overall engagement and support for long-term, sustainable e-waste management.

More broadly, the high willingness to hand over e-waste indicates considerable potential for increasing household

participation if an appropriate collection system is available. The fact that most respondents would participate without financial compensation suggests that convenience and accessibility may be more important incentives than direct economic benefits for many households. The interpretation is also supported by the preference for monthly household collection, which requires minimal additional effort from residents. These findings highlight the importance of designing collection systems that are simple, accessible, and adapted to household needs, as willingness to participate may not necessarily translate into actual behaviour if collection options are inconvenient or difficult to access.

3.5 Statistical analysis of socio-demographic factors and e-waste practices

Table 6 shows the results from chi-square tests performed to examine the relationship between sociodemographic characteristics and behaviours related to e-waste management. The significance level was set at $\alpha = 0.05$.

TABLE 6: Chi-square tests on the willingness to participate in e-waste management.

Variable	Groups	χ^2 calculated	df	p-value	Significance
Education vs. Willingness to recycle	Primary, Secondary, University ¹	0.46	2	0.79	Not significant ($p > 0.05$)
Age group vs. Giving devices for recycling	≤ 30 , 31-40, 41-50, 51-60, above 60 ²	0.21	8	1.00	Not significant ($p > 0.05$)
Income vs. Willingness to pay	Low, Middle, High ^{3,4}	9.91	2	0.007	Significant ($p < 0.05$)

Notes: ¹ Response categories: Yes, No - ² Response categories: Always, Sometimes, Never - ³ Response categories: Willing, Not willing/Uncertain - ⁴ Income categories were grouped for statistical analysis as follows: Low = below €1,000; Middle = €1,000 - €2,000; High = above €2,000. Significance level $\alpha = 0.05$

The analysis revealed no statistically significant differences in willingness to recycle electronic devices across different education levels or between age groups and the practice of giving devices for recycling.

In contrast, a statistically significant association was observed between household income and willingness to pay for organized e-waste management. Middle-income households (€1,000 - €2,000) showed the highest willingness to pay, whereas respondents from the high-income group (> €2,000) more frequently reported unwillingness or uncertainty. These findings suggest that income level influences households' readiness to financially support the e-waste management system, but does not necessarily increase with higher income.

Overall, these findings suggest that socio-demographic characteristics may not influence all aspects of household e-waste behaviour in the same way. The absence of statistically significant associations between education and willingness to recycle, as well as between age and device disposal practices, indicates that these behaviours may be shaped by factors beyond basic demographic characteristics, such as the accessibility of collection services, available information, and convenience. In contrast, the significant association between household income and willingness to pay suggests that economic considerations may play a more important role when participation involves a direct financial contribution. This distinction is relevant for the design of e-waste management policies, as measures aimed at increasing general participation may require different approaches from those involving household payment for collection services.

4. CONCLUSIONS

In this survey, the authors investigated household awareness, knowledge and behaviours regarding the management of electrical and electronic waste in Novi Sad, Serbia. The results showed that, while most respondents demonstrated awareness that e-waste contains toxic substances and requires special treatment, regular participation in formal recycling programs remained limited. Only 16% of households reported always recycling their electronic devices, while 51% recycled them occasionally, and 33% never participated in formal recycling programs. Storage of e-waste at home and repair of old devices were common, highlighting both limited access to convenient disposal options and the influence of behavioural habits. While repair and reuse can extend the useful lifetime of electrical and electronic equipment and support circular economy objectives, prolonged home storage may delay the recovery of valuable materials when devices are no longer functional. These findings highlight the need to distinguish between life-extension practices and the accumulation of unwanted devices resulting from limited access to convenient collection and recycling options.

Regarding the socioeconomic factors, household income was found to be a significant determinant of financial support for organized e-waste management, with middle-income households exhibiting the highest willingness to pay. In contrast, demographic factors, such as age and

education level showed no statistically significant effect on willingness to participate in e-waste collection and recycling, suggesting that economic factors play a more decisive role.

This study has several limitations that should be considered when interpreting the results. The survey was conducted online, which may have influenced the demographic structure of respondents, particularly the high share of participants with university education. As a result, the sample may not fully represent the educational structure of the general population of Novi Sad, which may limit the generalizability of the findings. In particular, the high level of education within the sample may have influenced the observed levels of awareness and knowledge regarding e-waste and its environmental and health impacts. Therefore, these findings should be interpreted with caution when extrapolating them to the wider population. Nevertheless, education level was not significantly associated with willingness to recycle in the present study. Although the survey included questions on incorrect disposal practices, it did not specifically investigate illegal dumping or littering of e-waste in public spaces. Therefore, the extent and environmental and health implications of these specific forms of improper disposal cannot be assessed based on the present data. Future research could include larger and more diverse samples, as well as longitudinal studies to better understand behavioural changes over time.

Given the limited current infrastructure for household e-waste collection, the study emphasizes the need for a coordinated approach involving local authorities, private operators, and community stakeholders. Implementing adequate collection systems may help reduce informal disposal and home storage of e-waste. Public awareness campaigns should be strengthened to improve knowledge of proper e-waste handling, including collection points and disposal methods. Additionally, offering flexible incentives, such as vouchers, discounts, or integration of e-waste fees into municipal services, may further improve participation. Ensuring transparency regarding the allocation and use of collected funds is crucial to building public trust and long-term engagement.

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