



Research article

Key factors to improve the management of household hazardous waste

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ABSTRACT

Household Hazardous Waste (HHW), although produced in small quantities, is often mixed with other municipal waste, disrupting treatment processes and contaminating products such as compost from organic recycling. In this context, as of January 2025 European Union Member States have been required to implement separate collection for HHW. This research aims to address gaps in the scientific literature by examining citizens' knowledge and perceptions, which are key to the success of such systems, regarding the hazardous products they acquire and store at home. The study also explores the factors influencing citizens' participation in separate collection systems for this waste. A questionnaire was administered to 215 citizens in a predominantly urban municipality in Portugal, which lacks a consistent separate collection system for HHW. The findings reveal that citizens have health-related concerns about HHW risks, but a limited recognition of labels and hazard symbols. The public is likely to use a future HHW separate collection service, favouring street containers over mobile units or kerbside collection. The system should provide clear disposal information, ensure accessibility, and be supported by awareness campaigns focusing on label interpretation and the risks of packaging, rather than just the products themselves. Municipal technicians from the region were also interviewed to gain insights into the current situation and future planning. These findings are crucial for practitioners and policymakers, as they will help shape decisions on the type of collection systems to implement and to improve strategies and practices, ultimately benefiting the effectiveness of municipal waste management.

1. Introduction

Population growth and the characteristics of consumption patterns lead to an increase in the number of goods and services available, which in turn results in the production and management of a greater quantity of Municipal Waste (MW) (Sharma et al., 2021; Das et al., 2019; Kaza et al., 2018). Specifically, Household Hazardous Waste (HHW) refers to waste originating from household products that possess characteristics which could make them hazardous and, when discarded, result in them entering into the MW stream (Saleh et al., 2019; Lim-Wavde et al., 2017). Examples of such waste include paints, varnishes and solvents, cleaning products, and garden pesticides (European Commission, 2020a).

The majority of this waste is disposed of incorrectly, commonly poured down household drains or onto the ground. An estimated 50% is discarded alongside mixed MW (Wang et al., 2021; Lim-Wavde et al., 2017). This also influences the resulting products of waste treatment (Liu et al., 2025). In response, all European Member States must

establish separate collection for HHW as of January 2025. This type of waste must be collected separately to prevent the contamination of MW, to ensure its sustainable management, and to avoid risks to human health and the environment (European Commission, 2020a).

This research aims to assess citizens' knowledge, practices, and perceptions concerning these products and the potentially hazardous waste associated with their disposal, as well as assessing their views on the implementation of specific separate collection systems, given the lack of information on this topic in the literature. The analysis also considers the practical context of more efficient waste management, ensuring that the findings can support both practitioners and policy-makers in developing effective systems for managing HHW.

2. Literature review

2.1. Household hazardous waste

Products that generate HHW are diverse, usually categorised by their

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hazardous properties (Inglezakis and Moustakas, 2015). The list of products varies between countries and regions depending on the chemical substances permitted in consumer goods, making cross-country data comparisons challenging (Mim et al., 2025; European Commission, 2020a). Nonetheless, the European Commission provides a list of examples of municipal and similar waste identified as hazardous in Chapter 20 of the European List of Waste, as defined in Commission Decision (2014)/955/EU of December 18, 2014 (Letcher and Slack, 2019). This includes: solvents; acids; alkalis; photochemicals; pesticides; fluorescent tubes and other mercury-containing waste; discarded equipment with chlorofluorocarbons; oil and fat contaminated with hazardous substances; paint, inks, adhesives and resins containing hazardous substances; hazardous detergents; cytotoxic and cytostatic medicines; certain batteries and accumulators; specific discarded electrical and electronic equipment with hazardous components; and wood treated with hazardous substances.

The risks associated with the potential hazardousness of these products and their respective waste must not be overlooked (Liu et al., 2025; Mim et al., 2025; Zhao and Huang, 2019; Inglezakis and Moustakas, 2015). The substances in these products may contain hazardous components harmful to human health, with children and pets being particularly vulnerable to poisoning (Chaiyarit and Intarasakrit, 2021; Decharat et al., 2020; Letcher and Slack, 2019). It is also important to note that the perception of a waste's hazardousness may vary depending on who is assessing it (Iurev et al., 2025).

2.2. European legal framework

Regarding waste, and at the European level, in which the Portuguese case study of this research project is framed, Directive (EU) 2018/851 of the European Parliament and of the Council of May 30, amending the Waste Framework Directive (WFD) (Directive, 2008/98/EC of November 19), established that by January 1, 2025, Member States shall have set up separate collection for HHW produced by households.

In the case of Portugal, this legislation has been transposed into the general waste management regime, as outlined in Annex I of Decree-Law 102-D/2020 of December 10, in its current version. This legislation transposes the obligation for the separate collection of HHW, making municipal systems responsible for providing this service. Non-compliance with this obligation constitutes a serious environmental offence.

In practice, the classification of hazardous waste in the European Union (EU) is primarily regulated by Commission Regulation (EU) 1357/2014 of December 18, which replaces Annex III of the WFD. This regulation defines the 15 hazardous properties (HP1 to HP15) that determine whether a type of waste is considered hazardous, based on its physical, chemical, or toxicological characteristics. These hazardous properties are: explosive, oxidising, flammable, irritant, harmful, toxic, carcinogenic, corrosive, infectious, toxic for reproduction, mutagenic, releases toxic gases, sensitising, ecotoxic, and waste that can exhibit hazardous characteristics. In addition, Council Regulation (EU) 2017/997 of June 8 provides further clarification regarding hazardous property HP14 (ecotoxic).

This also falls within the scope of the EU Regulation on the Classification, Labelling and Packaging (CLP) of substances and mixtures, Regulation (EC) 1272/2008 of December 16. The classification of hazards included are based on the type of hazard (which may be physical, health-related, environmental, or other), and are further divided into hazard categories (ECHA, 2022; Inglezakis and Moustakas, 2015).

Labelling requirements are also defined under the CLP Regulation and include the following elements: hazard pictograms, signal words, hazard statements, as well as guidance on prevention, response, storage, and disposal, according to each hazard class and category (ECHA, 2022). Nine hazard pictograms are used, each a label image featuring a warning symbol and designated colours, intended to inform users of the risks a substance or mixture may pose to health or the environment (ECHA,

2022; Da Silva et al., 2020; Vinceti et al., 2021).

2.3. Estimation of quantities

Due to the variety of HHW and its relatively small proportion within the total volume of MW, it is difficult to quantify accurately and, as a result, is not often distinguished in official waste statistics (Letcher and Slack, 2019; Inglezakis and Moustakas, 2015).

In Shanghai, Lin et al. (2023) estimated the average generation rate of HHW to be 0.1 g per person per day, with the most prominent categories being fluorescent lamps (30.6%), paint cans (26.1%), medicines (26.2%), and batteries (15.8%). It is estimated that an average household in Europe or the United States of America contains around 50 kg of materials containing hazardous substances (Letcher and Slack, 2019). In the EU specifically, HHW being a relatively minor fraction, is typically included under the "other" category of MW (Eurostat, 2022). Excluding Electrical and Electronic Equipment Waste (WEEE), which constitutes a significant share of HHW and is usually reported separately, it is estimated that HHW represents approximately 1 to 6 kg per capita annually (European Commission, 2020a).

In mainland Portugal, in 2022, HHW accounted for about 0.07% of total MW generated (APA, 2023). The value of 0.06% was recorded for mixed waste and 0.10% for HHW within separately collected MW. The physical characterisation of separately collected waste revealed the presence of HHW as contaminants within the glass, paper/cardboard, and packaging fractions, representing 0.01%, 0.04%, and 0.07%, respectively (APA, 2023).

2.4. Determinants of separate collection behaviours

Researchers have long sought to identify the factors that differentiate recyclers from non-recyclers. Among contextual factors, and in addition to the fact that waste collection may or may not be mandatory (Mühlenhoff et al., 2024), the most important elements to consider are: convenience; accessibility; proximity of collection points; frequency; recycling costs; and economic benefits (Islam et al., 2021; Botti et al., 2020; Martinho et al., 2017a; Wagner et al., 2013). In addition, the space available for storing recyclables at home can have an impact (Nainggolan et al., 2019), as can heterogeneous and complex territories, which pose significant challenges for efficient waste collection, namely for separate collection (Gadaleta et al., 2021; Bertanza et al., 2018; Martinho et al., 2017a,b).

The proximity-based waste collection systems may operate using fixed points but can also employ mobile units or specially adapted vehicles. While these systems do not allow for the identification of individual users, they offer the highest level of accessibility to householders, which can be a key motivator for public participation (Erkisi-Arici et al., 2021; Bertanza et al., 2018; Mwanza et al., 2018). Additionally, municipal drop-off centres are typically set up as general recycling stations that accept multiple types of waste, with staff monitoring for potential contamination (European Commission, 2015, 2020a, 2020b).

Furthermore, individuals' choices are influenced by their socio-demographic context (Corrado et al., 2022). Several studies highlight a positive relationship between age, education, employment, and recycling behaviour (Mim et al., 2025; Aprile and Fiorillo, 2019; Nainggolan et al., 2019). Also, residing in a particular location for a longer time and larger household sizes are associated with a higher likelihood of recycling (Nainggolan et al., 2019; J. Padilla and Trujillo, 2018). The presence of children in a household has also been identified as a significant factor, as they can encourage their families to adopt waste separation practices (Deng et al., 2022; Oliveira et al., 2018).

Numerous studies have demonstrated how psychosocial factors relate with correct environmental behaviours, these include knowledge, awareness, concern, risk perception, social pressure, and attitudes towards recycling (Kaplan Mintz et al., 2019; Meng et al., 2019). While socioeconomic factors influence individual behaviours, they are largely

beyond the control of waste management authorities, which is limited to the provision of information and awareness-raising initiatives (Zorpas, 2020).

In the specific case of HHW, Decharat et al. (2020) suggest that knowledge and risk perception significantly influence individuals' behaviour towards managing practices. Moreover, there appears to be a strong correlation between the appropriate use and storage of household hazardous products and their proper disposal when they become waste (Intarasaksit and Pitaksanurat, 2019; Saleh et al., 2019). The lack of information on managing these products and waste, such as the risks of household accidents, information on available collection points, or collection programmes, may impact consumers' behaviour when managing waste (Decharat et al., 2020).

2.5. Case studies of separate collection

The collection and management of HHW has historically relied on voluntary schemes, with citizens playing a key role in ensuring proper disposal (Inglezakis and Moustakas, 2015). Several countries, including the EU Member States, the United States of America, and Canada, have long-established separate collection schemes, with the primary aim of diverting it from the MW (Mim et al., 2025; EPA, 2022; Inglezakis and Moustakas, 2015; Wagner et al., 2013).

Proximity-based collection systems for HHW, either fixed or mobile, are widely used in various countries, cities or locations. Mobile systems may include compartmentalised containers, such as in Ljubljana (JP Voka Snaga, 2022; European Commission, 2015); specialised collection vehicles, as seen in Brussels (Bruxelles-Propreté, 2021), Luxembourg City (Super-DrecksKëscht, 2022), and Sofia (BalBok Engineering, 2022; R4R, 2014); or periodic collection events, like those organised in Ottawa (City of Ottawa, 2022) and Île-de-France (R4R, 2014). It is understood that the success of such specific initiatives depends on clear communication of collection schedules and locations through both traditional and digital media platforms (European Commission, 2020b).

Delivery of HHW to municipal drop-off centres is also a common practice. In places such as California (Central San, 2020) and Odense (R4R, 2014), there are dedicated facilities for hazardous waste disposal. In contrast, cities like Luxembourg, Tallinn (City of Tallinn, 2021; R4R, 2014) and Ljubljana (Voka Snaga, 2022; European Commission, 2015) do not operate dedicated centres specifically for hazardous waste. Instead, these materials are accepted at general drop-off centres handling multiple waste streams. In the United Kingdom, the collection scheme consists of decentralised drop-off points, often operated by non-municipal entities, typically accepting only specific waste types, as for instance paint collection (Community RePaint, 2022).

The least common method observed is kerbside collection, although present in Sofia (BalBok Engineering, 2022; R4R, 2014) and Luxembourg City (Super-DrecksKëscht, 2022; European Commission, 2020b), where collection is provided upon request.

In terms of incentives, various models have been identified. A common approach involves the inclusion of collection costs in a general MW fee. In Tallinn, however, a more detailed fee structure is applied, with charges varying depending on the collection method and waste fraction (City of Tallinn, 2021; R4R, 2014).

In mainland Portugal, the main disposal option for HHW is municipal drop-off centres managed by MW management systems. In addition to these fixed locations, mobile collection pilot projects are in operation since 2022 (e.g., Lipor, 2022; Gesamb, 2022; CMC, 2022). These projects, which run on predefined schedules, accept specific waste types, such as: small WEEE, electrical cables, batteries and accumulators, fluorescent lamps, packaging and cans with residual products (e.g., varnish, paint, solvents, cleaning products), and printer cartridges.

3. Methods

3.1. Research approach

The research approach to assess the key factors to optimise HHW management consists of a descriptive study, based on a questionnaire administered to the citizens of a Portuguese municipality located in a predominantly urban area, within the European context, where the legal framework establishes mandatory separate collection for this type of waste. This data was complemented by interviews with the technicians responsible for waste management, in the municipalities within the region studied. A clearer understanding of the relationship between the purpose, methods and criteria employed in the study is presented in Fig. 1 and the sections that follow.

3.2. Study area description

The Portuguese municipality of Almada, located in the Lisbon Metropolitan Area (NUTS II), was selected as a case study. It occupies an area of 70 km², is classified as predominantly urban territory, and has 177,238 residents, of whom 53.1% are women and 46.9% are men. It has a population density of 2,532 inhabitants/km², more densely populated than the greater metropolitan area, with 952 inhabitants/km² (INE, 2022). The largest age group in the municipality is between 25 and 64 years old, representing 52% of Almada's population, followed by the group aged 65 or older, which accounts for 24%, indicating an ageing population. Regarding the educational qualifications, the most common levels are secondary or post-secondary, and higher education, corresponding to 24% and 21%, respectively (INE, 2022).

The municipality of Almada is part of the Urban Waste Management System known as Amarsul, which operates across eight other municipalities (Alcochete, Barreiro, Moita, Montijo, Palmela, Seixal, Sesimbra, and Setúbal). The system serves approximately 800,000 inhabitants within a total area of around 1,625 km², and is responsible for managing waste treatment facilities. Specifically, the municipality is responsible for the mixed waste collection and Amarsul for the separate collection, sorting, and treatment of MW (both mixed waste and recyclables) (CMA, 2022).

In the municipality there are three methods of MW collection: street collection, kerbside, and on-demand. It is also possible to deliver recyclables and other waste at the municipal drop-off centres (CMA, 2022b). Street collection is the main method used in the municipality, characterised by the use of collective containers of various capacities, available on public streets and, desirably, within a maximum distance of 100 m from the user (Martinho et al., 2023; CMA, 2022b). Currently, this type collection is available for mixed MW, recyclable waste (paper and cardboard, plastic/metal/composite packaging, and glass), and, in specific areas, for organic waste (CMA, 2022b). On-demand waste collection is carried out by appointment and is available in the municipality for the following waste streams: bulky waste, green waste resulting from the maintenance of private gardens, and debris from do-it-yourself construction works (CMA, 2022b).

3.3. Interviews with municipal technicians involved in the waste management field

Semi-structured interviews were conducted with technicians from the services responsible for MW collection in the nine municipalities within Amarsul's operational area, using e-mail as the primary means of contact. The process of contacting the participants and submitting the form took place during the second half of July 2022. The interview guide was divided into two sections: one focusing on the current situation in each municipality, and the other on future perspectives regarding the obligation to collect HHW separately.

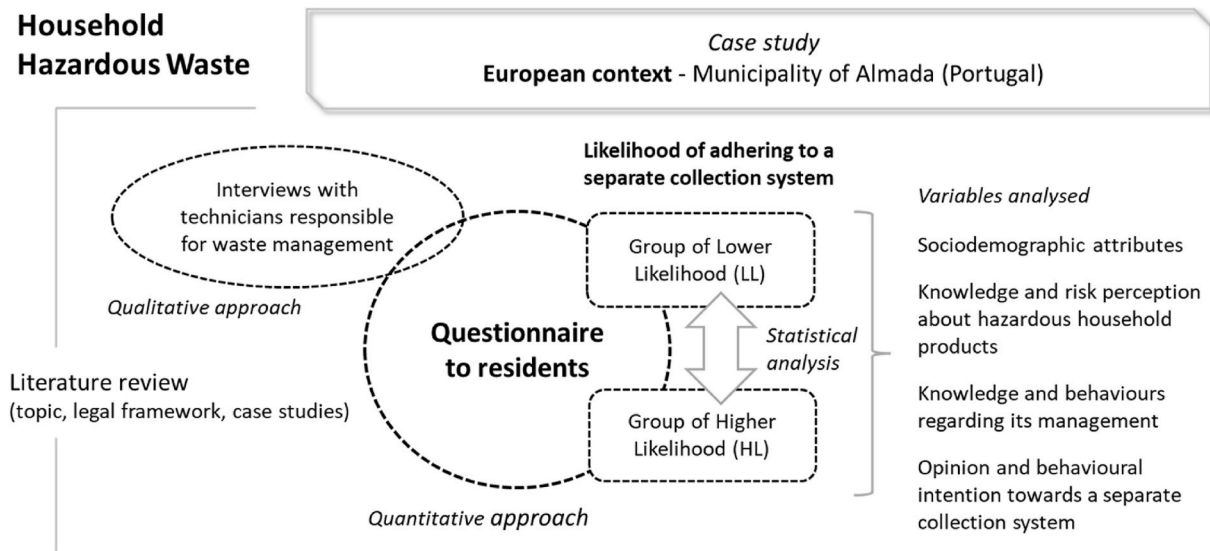


Fig. 1. Research approach.

3.4. Questionnaire to residents in the municipality

The main objective of the questionnaire administered to residents in the municipality of Almada was to assess their knowledge and perceptions regarding hazardous household products and their disposal methods. Given the available resources, it was not possible to obtain a representative and stratified sample of the population. Therefore, the sampling method used was convenience sampling, through contacts made via informal groups and social networks of people residing in the municipality of Almada. The questionnaire was open for submissions throughout the first half of May 2022. Participants were informed in advance that their responses would remain anonymous, and that all data collected would be used solely for research purposes. The study ensured strict confidentiality and full compliance with the Portuguese General Data Protection Regulations, in line with broader European obligations.

The questionnaire was divided into four sections (Annex I), with responses grouped into and analysed within the following variable categories: sociodemographic attributes; knowledge and risk perception related to hazardous household products; knowledge and practices concerning the management of these products and their associated waste; and opinions and behavioural intentions regarding a separate collection system.

An inferential statistical analysis was conducted using the question “What is the likelihood of you using a separate collection system to dispose of your HHW?”, which measures behavioural intention as the group (or independent) variable. This was used to assess the differences between two respondent groups: LL (“Lower Likelihood” of using a separate collection system to HHW), and HL (“Higher Likelihood” of using such a system).

For the statistical analysis of the data, a one-way ANOVA and Pearson’s chi-square test (χ^2) were employed to assess whether the differences in the means or distributions between the groups were statistically significant. The significance level was established at 5% ($p \leq 0.05$), and the analysis was conducted using IBM SPSS Statistics software.

4. Results and discussion

4.1. Interviews with the municipal technicians involved in waste management

After contacting the technicians responsible for MW management in the nine municipalities within the Amarsul area of operation, four

responses were received from the municipalities of Almada, Barreiro, Montijo, and Setúbal. A qualitative analysis of the responses follows, with a focus on HHW management.

Concerning the current situation, the Almada municipality offers the widest range of solutions for HHW disposal, as well as the largest variety of HHW collected. The technicians from Barreiro did not mention the provision of any solutions, while Setúbal’s technicians only referred to the collection, upon request, of construction and demolition waste containing asbestos (CDWA) resulting from do-it-yourself construction interventions. Technicians in Barreiro and Setúbal noted that hazardous waste collection is carried out by licensed waste management operators.

In terms of hazardous waste abandonment in public spaces, the most commonly found items in Almada are large WEEE (also observed in the municipality of Montijo), as well as CDWA and mineral oils and their contaminated packaging. In Almada, WEEE is sent to Amarsul, where it is either recycled or landfilled. Mineral oils are disposed of at the local drop-off centre, while CDWA is handled by a private licensed waste management operator.

Residents do not frequently contact the municipal services for information on the correct disposal of HHW. However, when contacted, they provide a list of licensed waste management operators in the area or nearby and advise residents to deliver their waste to specific collection points. In the case of Almada, they offer the option of receiving small quantities of HHW at their own facilities.

Regarding the measures that municipalities plan to implement in response to their responsibility for providing separate HHW collection from January 2025, in Almada there are plans to implement a mobile ecocentre that will rotate across all parishes, accepting six categories of HHW. Additionally, kerbside collection and collection at schools will be organised specifically for WEEE. Setúbal plans to install five HHW collection points throughout the municipality, alongside two fixed ecocenters, where various categories of HHW will be accepted. The selection of HHW types for the initial phase of the collection systems was based on the production of HHW for which disposal and proper handling options are either limited or non-existent. The municipalities of Barreiro and Montijo stated that no specific measures have yet been defined.

In relation to communication strategies for HHW separate collection, Almada plans to promote the mobile ecocentre through its website, social media, local magazines, and other as yet undefined communication channels. Setúbal’s outreach efforts will include meetings with residents, informational and awareness-raising materials, as well as advertisements through billboards, local press, and municipal communication channels.

The main challenges identified include, in general, the low level of public awareness and sensitivity regarding the importance of HHW management, resulting in poor participation or the contamination of MW, motivating residents to engage with the collection system, ensuring complete coverage of the territory, and effective communication with the population.

4.2. Perceptions and behaviour of residents

4.2.1. Characterisation of respondents to the questionnaire

Regarding the sociodemographic characteristics of the 275 respondents to the questionnaire, the average age was 44.4 years, being the only variable showing a statistically significant difference between groups: Group LL (“Lower Likelihood” of using a separate collection system for HHW; N = 127) had a mean age of 41.7 years, while Group HL (“Higher Likelihood” of using such a system; N = 148) had a mean age of 46.3 years ($F(1, 273) = 8.402; p \leq 0.004$). Of the total respondents, 75.6% identified as female and 24.4% as male ($p \leq 0.228$). The average household size was 2.9 individuals ($p \leq 0.439$). A total of 23.6% of respondents reported having children in the household ($p \leq 0.228$). On average, respondents have lived in the municipality for 24.5 years ($p \leq 0.097$), and 82.5% are employed ($p \leq 0.513$). In terms of education, 61.5% reported having completed higher education, followed by 25.1% completing up to upper secondary education (12th year), 5.8% lower secondary education (9th year), and 5.5% vocational education ($p \leq 0.191$). Furthermore, 65.8% of respondents stated that

their households have space for storing separated waste ($p \leq 0.554$).

4.2.2. Knowledge and perceptions of risk about household hazardous products

With regard to residents’ perceptions of the hazardousness of products stored in the household, Fig. 2 presents the results and compares Group LL (“Lower Likelihood” of using a separate collection system for HHW; N = 127) and Group HL (“Higher Likelihood” of using such a system; N = 148). Overall, among all the products considered by respondents, plant and garden herbicides and pesticides are perceived as the most hazardous (average rating of 3.9 on a 5-point Likert-type scale ranging from “Not hazardous” to “Highly hazardous”), although several other products follow closely behind. It is worth noting that, five of the 13 products pre-selected have a score equal or lower than 3.0 (i.e., cleaning products for sanitary use, varnish, disinfectant sprays, oil-based paints, and wood and floor treatment products).

Group HL respondents consistently perceive products as more hazardous than Group LL, except in the case of bleach or products containing bleach, where both groups assigned an equal level of hazard (3.5). Nevertheless, statistically significant differences between the two groups were observed for oil-based paints, varnish, car maintenance products, and paint solvents/thinners, respectively: $F(1, 273) = 8.393; p \leq 0.04$; $F(1, 273) = 7.569; p \leq 0.006$; $F(1, 273) = 7.060; p \leq 0.008$; and $F(1, 273) = 5.758; p \leq 0.017$.

This level of understanding regarding the hazardous nature of waste is important to consider, as Iurev et al. (2025) state that waste

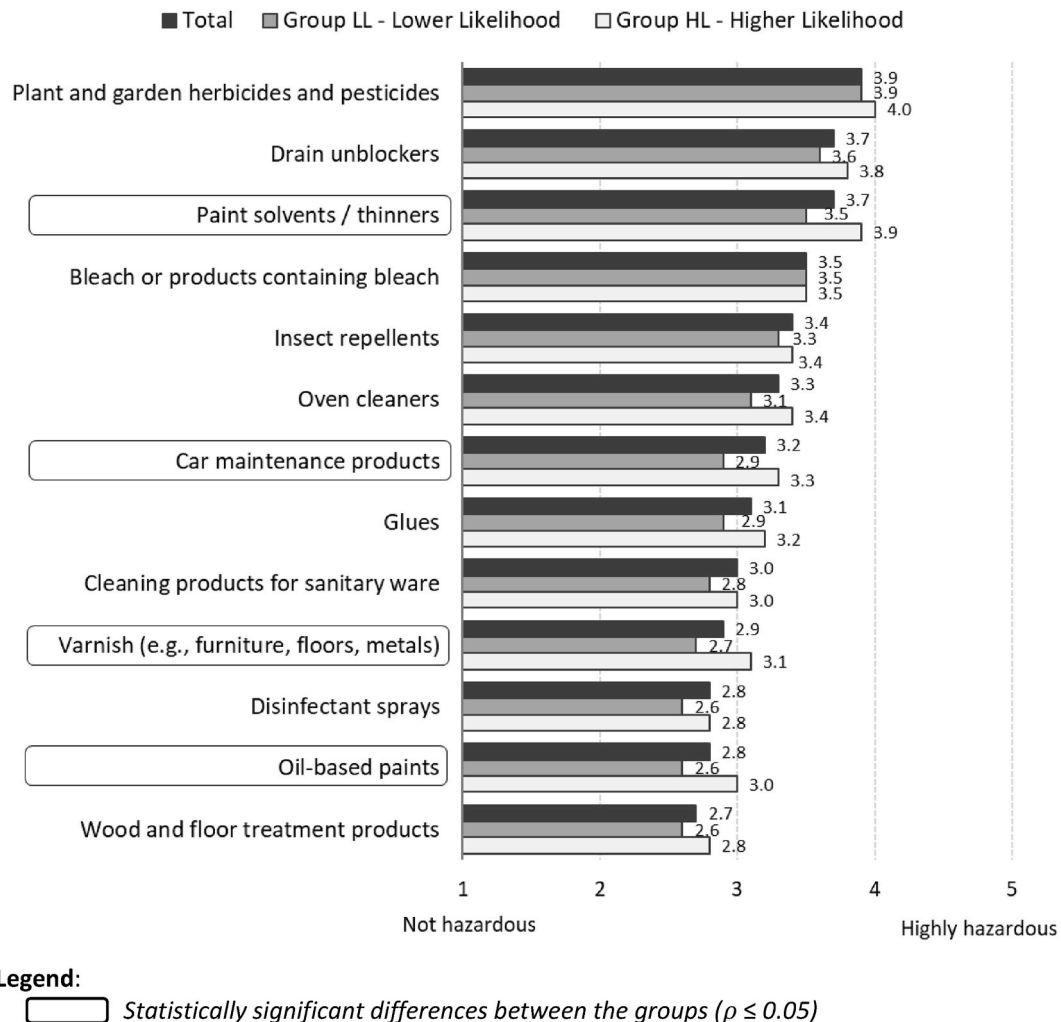


Fig. 2. Respondents’ perceptions of the hazardousness of products stored in the household.

management strategies and policies must consider both waste valorisation and hazardousness in order to be effective, but also, since familiarity with and knowledge of particular waste types strongly influence how their risks are perceived. Raising awareness about products that are perceived as less risky is important for making the correct management of these products more effective (Lim-Wavde et al., 2017), particularly in terms of reducing the contamination of MW.

Regarding the types of risk to be associated with hazardous products (Fig. 3), concern about accidents involving children or pets is predominant (76.4% of respondents, in relation to the total). However, statistically significant differences were found between Group LL and Group HL with respect to the options related to soil and water contamination if sent to landfill ($\chi^2(1) = 7.908; p \leq 0.005$) and the contamination of other non-hazardous waste, rendering it no longer recyclable ($\chi^2(1) = 8.041; p \leq 0.005$). Of these two options, Group HL places greater emphasis on the associated risks, highlighting them more frequently than Group LL.

The message here appears to be that individuals who are less likely to engage with a system of separate collection for HHW tend to focus more on factors related to safety and the immediate consequences for health (Deng et al., 2022; Chaiyarit and Intarasaksit, 2021; Decharat et al., 2020; Oliveira et al., 2018), whereas the HL group has a broader perception of risk. It is important to highlight that risk perception can vary, as noted by Iurev et al. (2025), and this should be considered when designing separate collection systems.

With regard to precautionary behaviours in the storage of hazardous household products (Fig. 4), both groups are primarily concerned with having a designated area for storing them and with avoiding their storage alongside food (66.9% and 66.2% of the total, respectively). The first option aligns with the 65.8% of respondents who indicated that their households have space to store separated waste (section 4.1), which is a determinant according to Nainggolan et al. (2019). Group LL

appears to be more sensitive to issues related to keeping these products away from food and out of children’s reach. However, statistically significant differences between groups were found only in relation to practices involving ventilation and protective surfaces, where Group HL demonstrated a higher level of adherence ($\chi^2(1) = 4.164; p \leq 0.041$).

Respondents were also asked about their habit of checking labels on household products to determine whether they contain hazardous substances. The average score was 2.7, slightly above the midpoint of the scale, measured on a 5-point Likert-type scale ranging from 1 (“Never”) to 5 (“Always”), with statistically significant differences between groups: 2.4 for Group LL and 2.9 for Group HL ($F(1, 273) = 10.671; p \leq 0.010$). Additionally, to assess the respondents’ level of knowledge, they were shown an image of one of the most common pictograms, that warns of health hazards. It was found that respondents were almost equally divided between the responses (i.e., correct, incorrect, and do not know), with no statistically significant differences between the groups (37.5%, 33.8%, and 28.7% of the total, respectively) ($p \leq 0.117$). In such cases, raising awareness about the importance of reading and understanding labels is crucial in awareness and communication campaigns, in line with the general ideas presented by Zorpas (2020), Kaplan Mintz et al. (2019), and Meng et al. (2019).

Participants were asked about the characteristics of a household product that classify it as hazardous and lead to precautions regarding its handling, allowing a maximum of three responses per participant (Fig. 5).

It was found that there were no statistically significant differences between groups, with the most frequently selected responses related to the following characteristics: toxic, flammable, and explosive (69.5%, 49.1%, and 46.9%, respectively). These results may indicate that a more detailed approach to raising awareness about the characteristics that make household products hazardous is necessary.

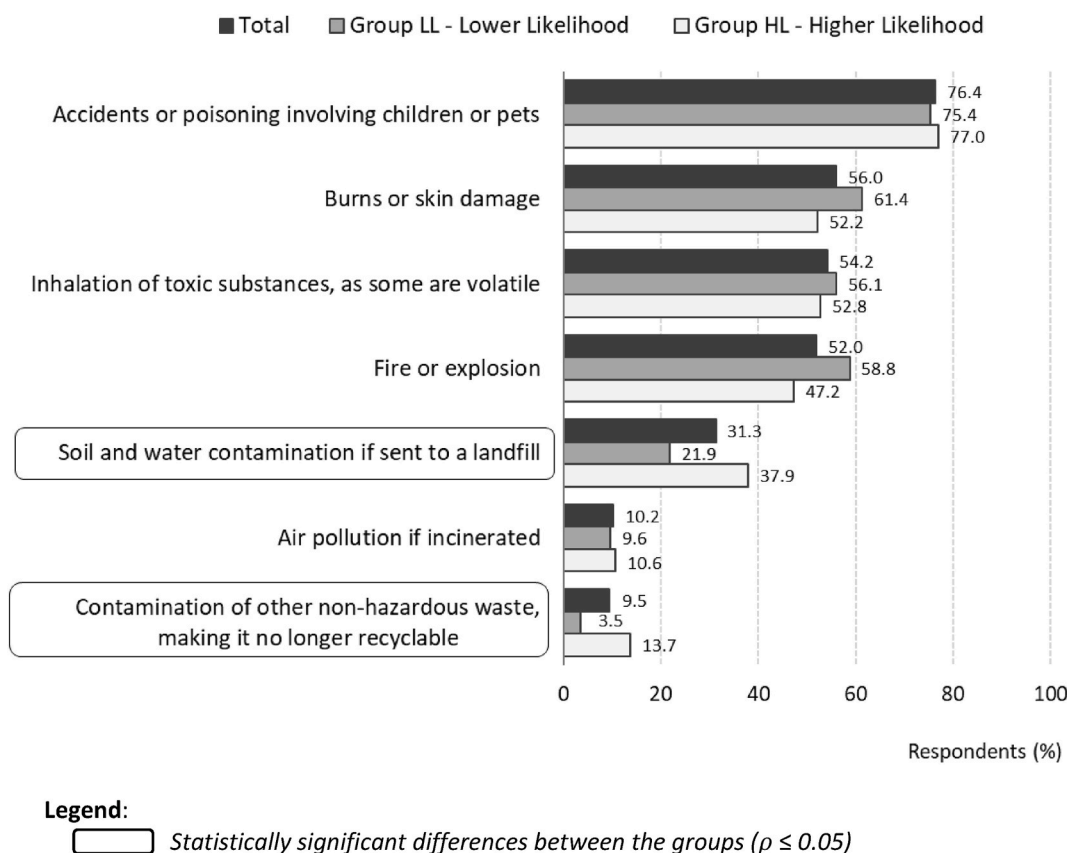


Fig. 3. Respondents’ perceptions of the types of risks associated with household hazardous products.

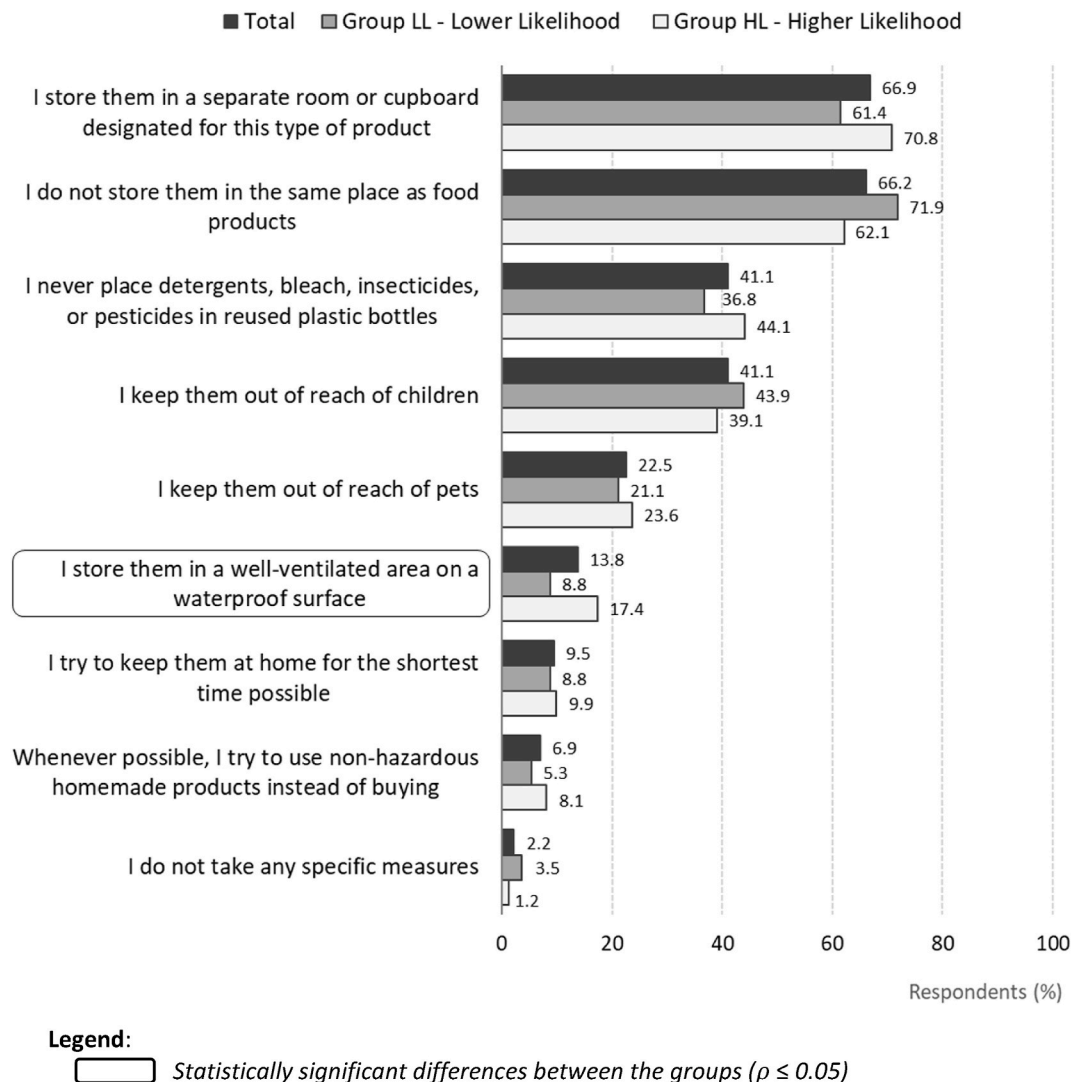


Fig. 4. Respondents' perceptions of precautionary behaviours in the storage of household hazardous products.

4.2.3. Behaviour concerning household hazardous waste management

Regarding the disposal of packaging with potentially household hazardous products, the responses were grouped into three categories: a) more appropriate disposal options, which included "I keep it at home as I may need to use it again", "I take it to a facility that accepts this type of waste", "I take it to the municipal drop-off centre", "I give it to someone who needs it", and "I use it until the product is finished"; b) less appropriate disposal options, including "I keep it at home as I do not know where to dispose of it", "I put everything in the mixed waste bin", "I put everything in the recycling bin without emptying the contents", and "I pour the leftover product down the drain or into the mixed waste bin and place the empty containers in the recycling bin"; and c) "Do not know".

Group LL ("Lower Likelihood" of using a separate collection system for HHW; $N = 127$) and Group HL ("Higher Likelihood" of using such a system; $N = 148$) did not show statistically significant differences in their responses (relative to the total): 77.5% for the more appropriate disposal options ($p \leq 0.837$); 50.5% for the less appropriate disposal options ($p \leq 0.691$); and 5.1% for the "Do not know" option ($p \leq 0.913$).

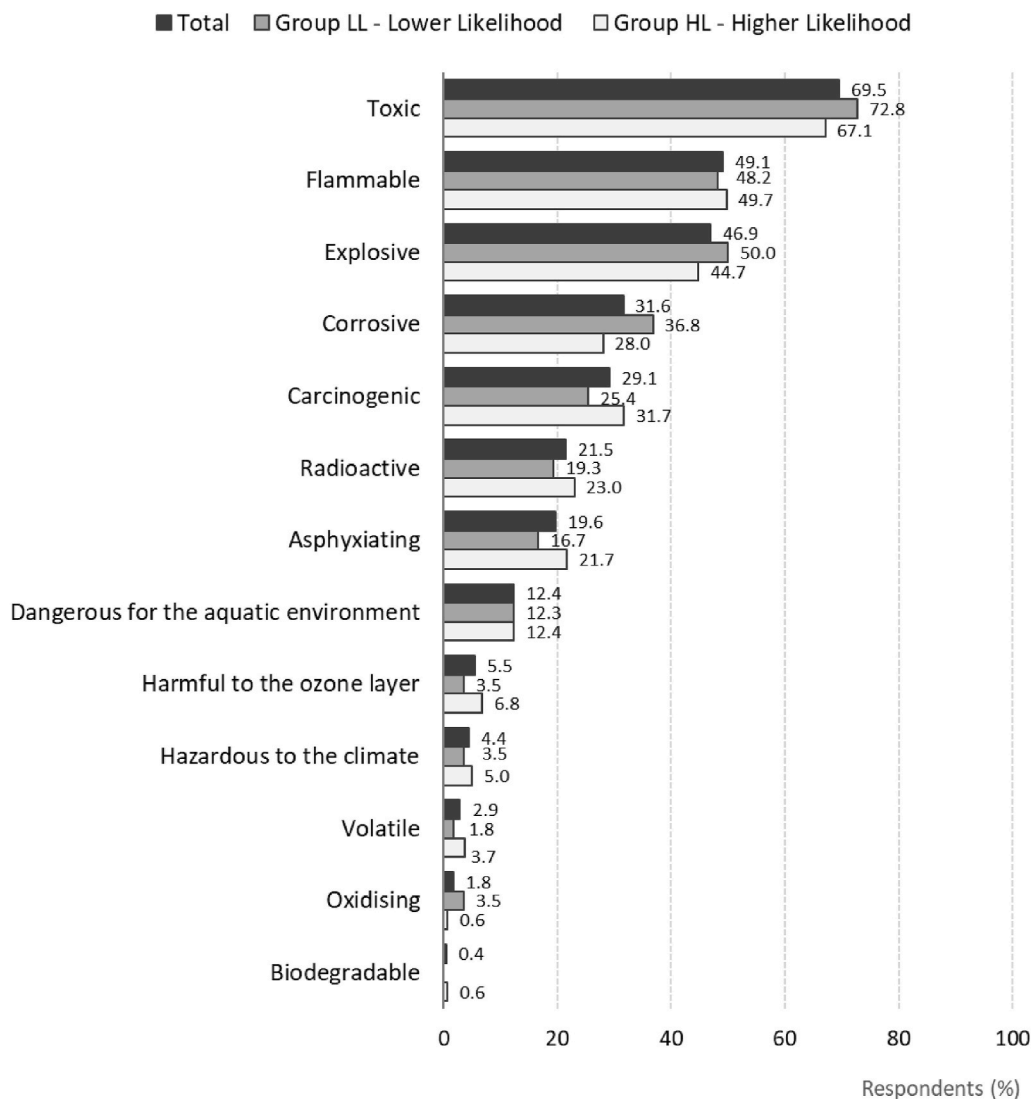
In a complementary way, regarding the disposal of empty packaging from potentially hazardous household products, the responses were grouped into two categories: a) more appropriate disposal options, which included "I take it to a facility that accepts this type of waste", "I follow the instructions on the labels", and "I take it to the municipal

drop-off centre"; and b) less appropriate disposal options, which included "I keep it at home as I do not know what to do with it", "I put it in the mixed waste bin", and "I put it always in the yellow recycling bin". The results showed that the differences between the two groups of respondents were statistically significant regarding the disposal of the empty packaging.

Overall, 44.0% of respondents selected the most appropriate disposal options, with a higher percentage in Group HL, demonstrating a statistically significant difference between groups (49.1% for Group HL compared to 36.8% for Group LL; $\chi^2(1) = 4.049$; $p \leq 0.044$). The less appropriate disposal options were selected by 80.4% of all respondents, with an even higher percentage in Group LL, once again showing statistically significant differences between these groups (86.0% for Group LL compared to 76.4% for Group HL; $\chi^2(1) = 4.480$; $p \leq 0.044$). Reinforcing information regarding the hazardousness of packaging, rather than focusing solely on household hazardous products, is necessary, as these findings demonstrate that this aspect has been lacking in awareness-raising efforts so far. In this context, Decharat et al. (2020) suggest that knowledge and risk perception are key factors influencing individual behaviour toward waste management practices.

4.2.4. Behavioural intention towards a separate collection system

When asked about the level of importance attributed to the implementation of a separate system for collecting HHW, measured on a 5-



Note: No statistically significant differences between the groups ($\rho > 0.05$)

Fig. 5. Respondents' perceptions of the characteristics that make household products hazardous.

point Likert scale, from 1 (“Not important”) to 5 (“Very important”), the average score obtained across all respondents was 4.4, demonstrating that the public understands this component of the waste management system as important. Nonetheless, Group LL (“Lower Likelihood” of using a separate collection system for HHW; N = 127) showed an average score of 4.0, which was lower than the 4.6 average obtained by Group HL (“Higher Likelihood” of using such a system N = 148) ($F(1, 273) = 40.984; p \leq 0.001$).

With regard to respondents' opinions on the most practical system for citizens to dispose of their HHW (Fig. 6), the responses from Groups LL and HL were similar, with the most relevant option being the disposal in specific containers located on the street. This highlights that people prefer to use this equipment without restrictions (Islam et al., 2021; Botti et al., 2020; Martinho et al., 2017). A statistically significant difference was met only for the option related to disposal at service stations, supermarkets, and other easily accessible establishments, which received more support from Group HL (51.6% versus 39.5% from Group LL; $\chi^2(1) = 3.914; p \leq 0.048$).

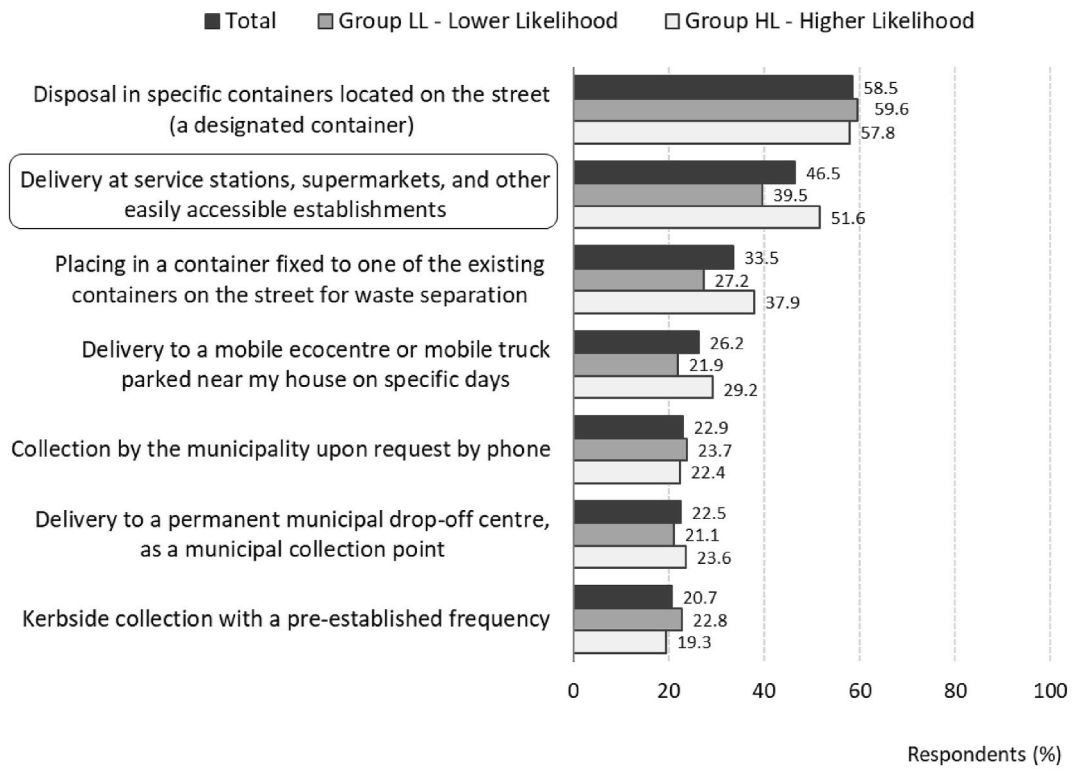
The option for collection via mobile units appears to receive limited support, with only 26.2% of respondents overall selecting this option. This reflects the preference for fixed rather than mobile equipment. The

kerbside collection was also rarely chosen (20.7% in total), likely due to concerns about user compliance with specific schedules. This topic deserves reflection, as Mim et al. (2025) concluded that higher collection rates do not always correspond to greater recycling efficiency, emphasising the need for strategies tailored to specific locations.

Regarding the factors identified by respondents as most relevant for the success of HHW collection systems (Fig. 7), the following stand out, in relation to the total respondents: information about where to dispose of HHW (75.3%); the convenience and accessibility of locations to dispose of this waste (64.0%); information about the products themselves, whether they are considered hazardous and how to identify them (56.7%); and awareness campaigns about health risks (43.6%).

It is important to note that health risks are considered more relevant than environmental risks (20.0%, in total), although there are statistical differences between groups for this variable: 24.8% for Group HL versus 13.2% for Group LL ($\chi^2(1) = 5.697; p \leq 0.017$). Again, the perception of risk may vary depending on people's background, experiences or expectations (supported, for instance, by Iurev et al., 2025, Mim et al., 2025; Corrado et al., 2022), which should be considered when designing future separate collection services.

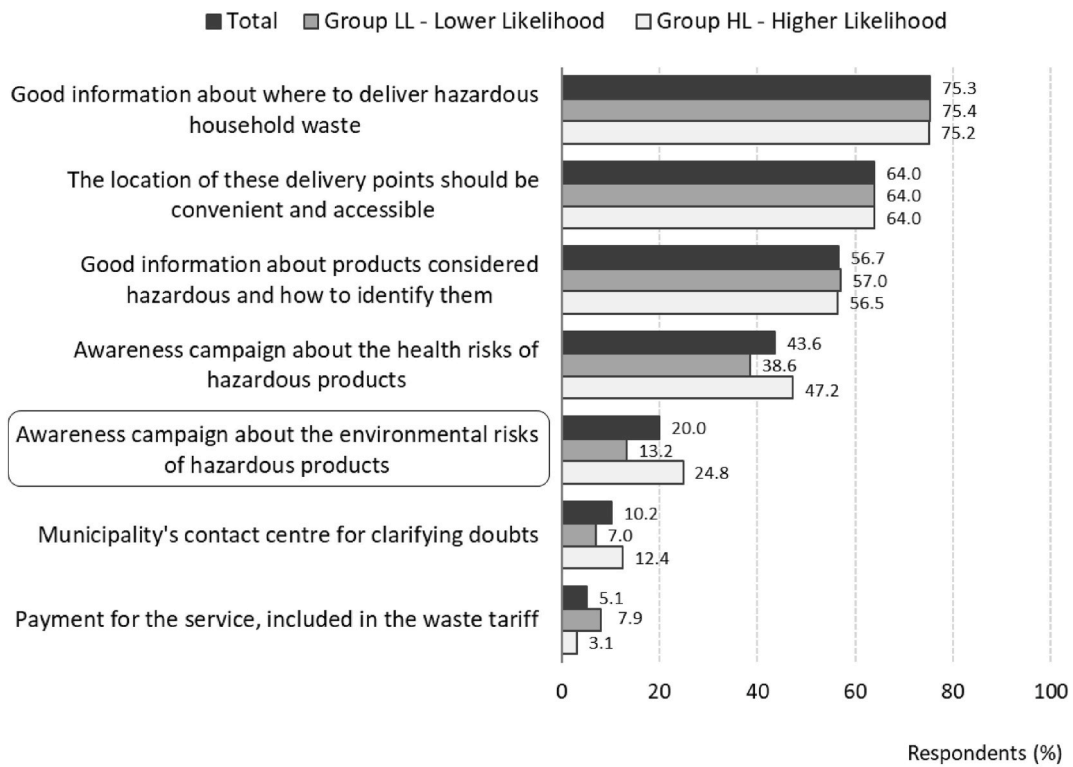
Information and communication campaigns are important, but as



Legend:

 Statistically significant differences between the groups ($p \leq 0.05$)

Fig. 6. Respondents' opinions on the most practical system for citizens to dispose of their household hazardous waste.



Legend:

 Statistically significant differences between the groups ($p \leq 0.05$)

Fig. 7. Respondents' opinions on the factors for the success of household hazardous waste collection system.

Mühlenhoff et al. (2024) point out, in mandatory schemes, households are required to participate regardless of their intrinsic motivation. This often results in a small number of households being responsible for the majority of contamination. In such cases, choosing the proper collection scheme, but also redesigning or adapting separate collection systems, alongside targeted awareness and training initiatives, is particularly important.

5. Conclusions

The findings from the questionnaire conducted with residents of Almada, a predominantly urban Portuguese municipality, in the Lisbon Metropolitan Area, reveal several key insights: overall, there is low awareness of household hazardous products, limited recognition of labels and hazard symbols, and the concerns held about HHW risks primarily relate to health, particularly for vulnerable groups (children and pets). Residents take precautions in storing hazardous products in designated areas within their homes. The public shows a strong likelihood of using a future HHW collection system, with a preference for fixed equipment over mobile units or kerbside collection.

Statistical analysis indicates that those most likely to participate in a separate HHW collection system tend to be older, more concerned about hazardous products and check labels for information about the hazards a product may have more frequently. They also show a broader understanding of risks, including environmental concerns, and take greater care when storing HHW, using ventilated spaces and impermeable surfaces. This group is also more likely to dispose of empty hazardous product containers properly. Awareness campaigns focused on environmental risks are seen as a key success factor by this group. In contrast, those least likely to use a separate collection system are less aware of the wider hazards posed by household products, tend to dispose of hazardous product packaging incorrectly, and assign less importance to awareness campaigns.

Based on these findings, a HHW separate collection service should focus on fixed disposal solutions, such as specific containers located on the street, rather than mobile equipment or kerbside collection. The system should offer clear information on where to dispose of HHW, ensuring convenience and accessibility. It should also be accompanied by awareness campaigns about health and environmental risks, addressing the different perceptions of hazardousness based on individual experiences with specific products. Information campaigns should emphasise hazard labels, how to interpret them, and the risks associated with packaging, not just the products themselves. These insights will help practitioners and decision-makers design or improve HHW collection systems, aligning solutions with the needs of citizens.

CRedit authorship contribution statement

Catarina Pereira: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mário Ramos:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Graça Martinho:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2025.126940>.

Data availability

Data will be made available on request.

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