



Knowledge, concerns and attitudes towards plastic pollution: An empirical study of public perceptions in Portugal

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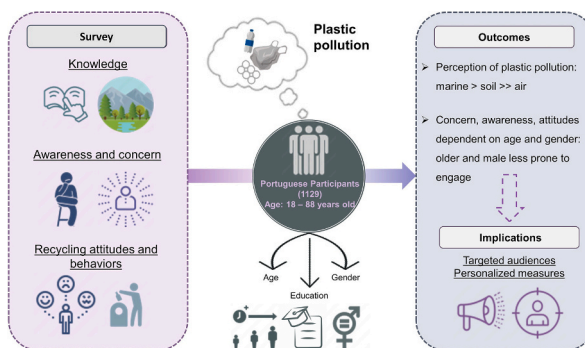
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HIGHLIGHTS

- Studies addressing public perceptions towards plastics are scarce.
- Knowledge, awareness, and attitudes about plastic pollution were studied.
- Education and age play a key role in public perceptions of plastic contamination.
- Sociodemographic-based education may promote sustainable behaviors.

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor: Damia Barcelo

Keywords:

Plastic pollution
Public perceptions
Environmental knowledge and awareness
Recycling attitudes and behaviors

ABSTRACT

While the harmful effects of different types of plastic particles have been increasingly reported, studies on public perceptions and behaviors related to plastic pollution may be considered limited. The present study aims to assess the general public's knowledge, awareness, and concern about plastic pollution in different environmental compartments (air, water, and soil) and assess recycling behaviors. For this, a large representative sample was considered (over 1000 participants), composed of members of different genders, levels of education, and age groups. Overall, the results showed that participants were aware of plastic pollution in many environmental compartments, although they reported being more concerned about the marine and land environments than the air. Participants' levels of concern about the plastic problem were influenced by age and level of education, with older participants and those with lower educational levels attributing less importance to recycling as a means of tackling the plastic problem. Women are more likely to adopt plastic alternatives and engage in recycling practices than men. Data allowed the identification of priority sociodemographic characteristics of communities that should be targeted in education and awareness-raising activities.

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<https://doi.org/10.1016/j.scitotenv.2023.167784>

Received 24 July 2023; Received in revised form 8 October 2023; Accepted 10 October 2023

Available online 14 October 2023

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1. Introduction

Over the years, anthropogenic activities have been associated with the accidental or deliberate release of large amounts of pollutants into different environmental compartments, which may have long-term effects on the environment and, ultimately, on human health (Oliveira et al., 2019). Among these pollutants are plastics, materials that emerged to satisfy the countless needs of growing population, that become essential for human well-being. Owing to their versatility, durability, and cost-effectiveness, plastics have applications in a wide range of industries and consumer products. However, this durability also implies that they can persist in the environment for a long time before gradually breaking down into smaller fragments, known as microplastics (<5 mm), which in turn can degrade into nanoplastics (<100 nm) (Oliveira and Almeida, 2019). Therefore, the accumulation of plastic waste has emerged as a pressing environmental and social challenge (Soares et al., 2020).

In line with the European Commission's plastic reduction strategies (Copello et al., 2022), the Portuguese government and various non-governmental organizations have taken measures to combat plastic pollution. Starting in 2018 and 2019, the Plastics Strategy and Single-Use Plastics Directive paved the way for a significant reduction of plastic pollution and investments in waste management infrastructures. For example, the Plastics Strategy has promoted the development of eco-friendly products aimed at increasing their recyclability and/or degradation, reducing plastic waste, and supporting research and innovation, while the Single-Use Plastics Directive promotes policies that include banning plastic bags, straws, or cotton swabs. At a more corporate level, the Circular Plastics Alliance (Watkins et al., 2020) brought together stakeholders to streamline and promote a circular economy for plastics. However, other equally pertinent solutions would remain largely unexplored, like for instance public awareness-raising campaigns. In this way, and in parallel with these measures, the focus on public awareness of plastic pollution began to take shape, having been recognized as fundamental as the aforementioned strategies for protecting the environment (Soares et al., 2020; Soares et al., 2021a). Public awareness and education campaigns are essential to inform, inspire, and empower individuals to make sustainable choices, make informed decisions, and even advocate for policy changes that address the problem at its root. By adopting sustainable practices in their daily lives, individuals can dramatically minimize their plastic footprint and help create a healthy environment. These campaigns need to deconstruct the "public," i.e., to understand how factors such as gender, age, and level of education, influence and condition the perception and adoption of measures to act against plastic pollution (e.g., Soares et al., 2020; Soares et al., 2021a). This is necessary to tailor the awareness and mobilization actions according to the priority interventions' target audience. Moreover, some knowledge gaps persist, which may hamper plastic pollution reduction goals. For instance, regarding soil pollution by plastics, it is important to highlight that the few existing studies focus on the agricultural group/sector and/or demonstrate that there is still a great deal of ignorance of the public about the potential environmental and health effects of soil's contamination by plastics (Deng et al., 2020; King et al., 2023). Moreover, a great deal of concern arises with respect to the threat to air quality caused by plastics (King et al., 2023). The latter has been considered less serious and deserves further attention, aimed at strengthening campaign actions. Therefore, it is crucial to understand social perceptions, attitudes, and behaviors, identify knowledge gaps and debunk misconceptions, and effectively design campaigns and programs to engage and encourage behavioral change towards plastic pollution mitigation.

In light of the above, the aims of this study were outlined, taking into account that society can play a significant role in reducing the plastic problem: i) to clarify the factors underlying environmental consciousness, concerns, and behaviors; ii) to assess how participants' socio-demographic characteristics affect these perceptions, in order to tailor

more specific initiatives aimed at increasing environmental knowledge and encouraging pro-environmental behavior.

2. Method

2.1. Instrument of the study and data collection

A self-report questionnaire was developed that consisted of 13 questions, with responses collected on a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*). In addition to sociodemographic characteristics (age, gender, formal level of education), participants were asked about their knowledge of plastics pollution (4 items; e.g., "Plastic pollution can be found in agricultural soils"), awareness and concern about plastic pollution (5 items; e.g., "Plastic pollution is a serious problem nowadays"), and recycling attitudes and behaviors (4 items; e.g., "I recycle at home"). To ensure face validity, the questionnaire was previously submitted to a pilot study to identify potential weaknesses of the questionnaire and test if the questions were formulated in a clear and understandable way. The feedback from the 5 subjects participating in the pilot study was discussed and considered for the final version, to ensure the robustness of the questionnaire.

In the presentation of the questionnaire, the aims of the study were explained, and the confidentiality of the information collected was assured. The survey was delivered to the participants in a hard copy. All responses were anonymous. Participation was entirely voluntary, and participants did not receive any type of compensation. Ethical principles for research with human subjects from the Declaration of Helsinki were followed. All participants were aged 18 years or older. Informed consent was provided in a written form.

2.2. Participants characterization

A total of 1129 Portuguese individuals (53.6 % female) participated in this study. Participants' ages ranged from 18 to 88 years old (*Mean* (*M*) = 38.3; *Standard Deviation* (*SD*) = 17.1), with 33.7 % of participants being between 18 and 25 years old, 24.4 % between 26 and 40 years old, 26.7 % between 41 and 60 years old, and 15.2 % being 61 years or older. About a third of the participants (32.3 %) had a basic education level (1–9 years of education), 42.8 % finished high school (10–12 years of education), and 24.9 % held a high education degree (university education). Most participants were employed (52.1 %), with unemployed and retired participants representing 15.4 % and 12.4 % of answers, respectively. The rest of the participants indicated another professional situation (20.1 %). Only 5 participants (0.4 %) were members of environmental organizations. Most participants lived in the north region of Portugal (83.6 % in Porto district and 5.6 % in Braga district). Almost two thirds of participants (62.7 %) preferred not to report their income.

Overall, the sample of this study is a good representation of the Portuguese population in terms of gender and education level. Recent data (PORDATA, 2023) show that in 2021, 52.4 % of the Portuguese population was female. Regarding educational level, 46.6 % had a basic level of education, 25.4 % had a high-school education, and 24.1 % had a high-education degree. However, only 5.4 % of the Portuguese population is aged between 18 and 25 years old, while 30.7 % is aged 60 years old or older.

2.3. Data analyses

Descriptive statistics were used to detail the sample characteristics and summarize variables. Multivariate analyses of variance (MANOVA) were performed with items concerning knowledge, awareness and concern, and recycling attitudes and behaviors as dependent variables, and generational age cohorts (18–25 years of age, 26–40 years of age, 41–60 years of age, and 61 years of age and older), sex (men and women), and degree of formal education (basic education, high school education, and high education) as independent variables, to explore

group differences. MANOVA were used to decrease the chance of Type I error associated with multiple significance testing with correlated outcome variables. Identified differences were further explored with univariate tests. Tukey's HSD test was used for post-hoc comparisons. Pearson correlations were performed to study the associations between the study variables. Outliers were replaced by mean values. Analyses were performed using the statistical program SPSS 27.0 for Windows, and results with $p < .05$ were retained as statistically significant.

3. Results

3.1. Knowledge of plastic pollution

Participants were asked about their perceptions of plastic pollution in different environmental compartments. Many participants (55.0 %) acknowledged that plastic pollution is not exclusive to aquatic/marine environments, with many agreeing or completely agreeing that agricultural soils (77.8 %) or air (47.1 %) might be contaminated with plastics (Fig. 1). Approximately half of the participants (47.0 %) reported having previously heard of the term “microplastics” prior to taking the survey.

A multivariate analysis of variance (MANOVA) was conducted, taking the four items assessing knowledge about plastic pollution as dependent variables and participants' age as the factor. Results showed a statistically significant difference in knowledge based on participants' age, $F(12, 2968) = 3.33, p < .001$; Wilk's $\Lambda = 0.96$, partial $\eta^2 = 0.01$. Subsequent univariate tests illustrated that age has a significant effect on both knowledge about plastic pollution in soils ($F(3, 1128) = 6.17; p < .001$; partial $\eta^2 = 0.01$) and the marine environment ($F(3, 1128) = 3.64; p = .012$; partial $\eta^2 = 0.01$). Tukey post-hoc tests revealed that, when compared to participants aged 26–40 years old ($M = 3.8$) and 61 years old or older ($M = 3.8$), participants aged 18–25 years old had a higher perception ($M = 4.2$) about soil contamination. In addition, participants aged 61 years or older agreed more ($M = 2.9$) that plastic pollution occurs solely in aquatic/marine environments, when compared to participants aged between 18 and 25 years old ($M = 2.4$) and those aged between 41 and 60 years old ($M = 2.5$). No multivariate effects of gender and education level were found in participants' knowledge about plastic pollution.

3.2. Awareness and concern about plastic pollution

As participants are aware of plastic pollution in several environments, this might influence their risk perception. Participants were

asked about the degree to which they noticed an increase in plastic use, and 36.3 % answered agreeing and 25.8 % answered completely agreeing (Fig. 2). However, the participants' perception of the presence of plastics in the environment is higher, with 71.0 % of participants recognizing that the presence of plastics in the environment is increasing, 38.0 % agreeing and 33.0 % agreeing completely. Also, most participants consider plastics to pose a threat: not only do they recognize plastic pollution as a serious problem nowadays (33.7 % agree and 51.1 % completely agree), but they also express being personally concerned with the impacts of plastic pollution (47.2 % agree and 30.0 % completely agree). However, such concern is not perceived as being widely shared, as only 37.4 % of participants report feeling people around them are concerned with the impacts of plastic pollution.

Another MANOVA was performed, now taking the five items concerning awareness and concern about plastic pollution as dependent variables. Results showed a statistically significant difference in awareness and concern based on participants' age ($F(15, 3086) = 2.81, p < .001$; Wilk's $\Lambda = 0.96$, partial $\eta^2 = 0.01$). More specifically, subsequent univariate tests illustrated that age has a significant effect on how plastic pollution is considered to be a serious problem nowadays ($F(3, 1128) = 6.01; p < .001$; partial $\eta^2 = 0.01$), on the perception that the amount of plastic in the environment is rising ($F(3, 1128) = 3.26; p = .021$; partial $\eta^2 = 0.01$), and in the perceived concern from others about plastic pollution ($F(3, 1128) = 3.31; p = .020$; partial $\eta^2 = 0.01$). Results of Tukey post-hoc tests show that participants aged 61 and older ($M = 3.9$) are the ones who least consider plastic pollution to be a serious problem nowadays (18–25 years old: $M = 4.3$; 26–40 years old: $M = 4.3$; 41–60 years old: $M = 4.3$), those who least consider ($M = 3.6$) that the amount of plastic in the environment is rising (18–25 years old: $M = 3.9$; 26–40 years old: $M = 3.7$; 41–60 years old: $M = 3.7$), and also those who most feel ($M = 3.2$) that people around them are concerned with the impacts of plastic pollution (18–25 years old: $M = 2.9$; 26–40 years old: $M = 2.9$; 41–60 years old: $M = 2.9$).

Education plays a significant multivariate effect in participants' awareness and concern about plastic pollution ($F(10, 2238) = 3.43, p < .001$; Wilk's $\Lambda = 0.97$, partial $\eta^2 = 0.01$), with univariate tests showing such an effect in the perception of plastic pollution as a serious problem nowadays ($F(2, 1128) = 5.50; p = .004$; partial $\eta^2 = 0.01$), and how participants' perceive people around them to be concerned with the impacts of plastic pollution ($F(2, 1128) = 6.51; p = .002$; partial $\eta^2 = 0.01$). Results of Tukey post-hoc tests show that, while participants with a lower level of education perceive people around them to be more concerned with plastic pollution ($M = 3.1$) when compared to other participants (high school education: $M = 2.9$; high education: $M = 2.8$),

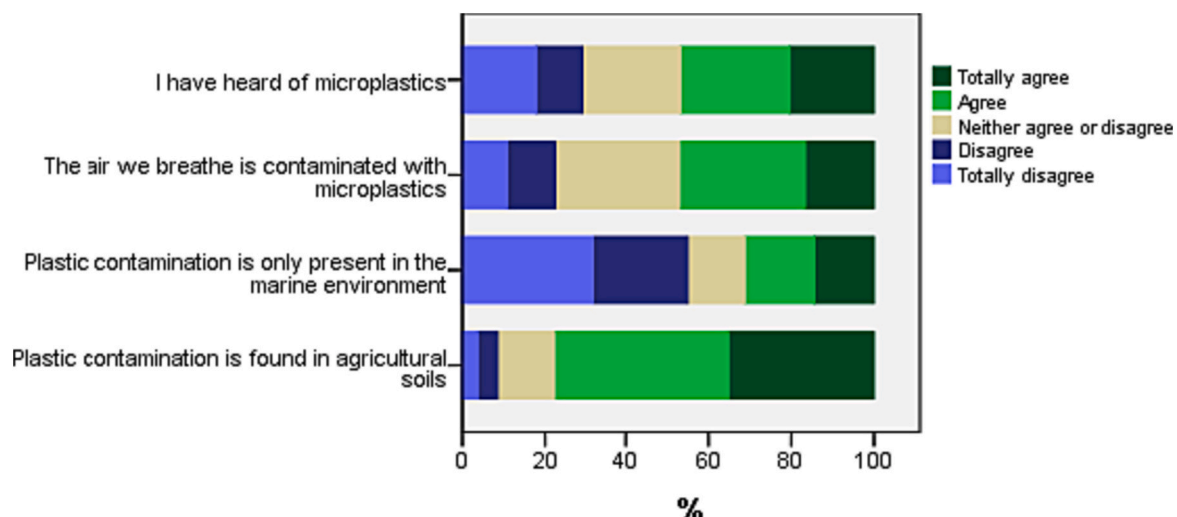


Fig. 1. Knowledge of plastic pollution.

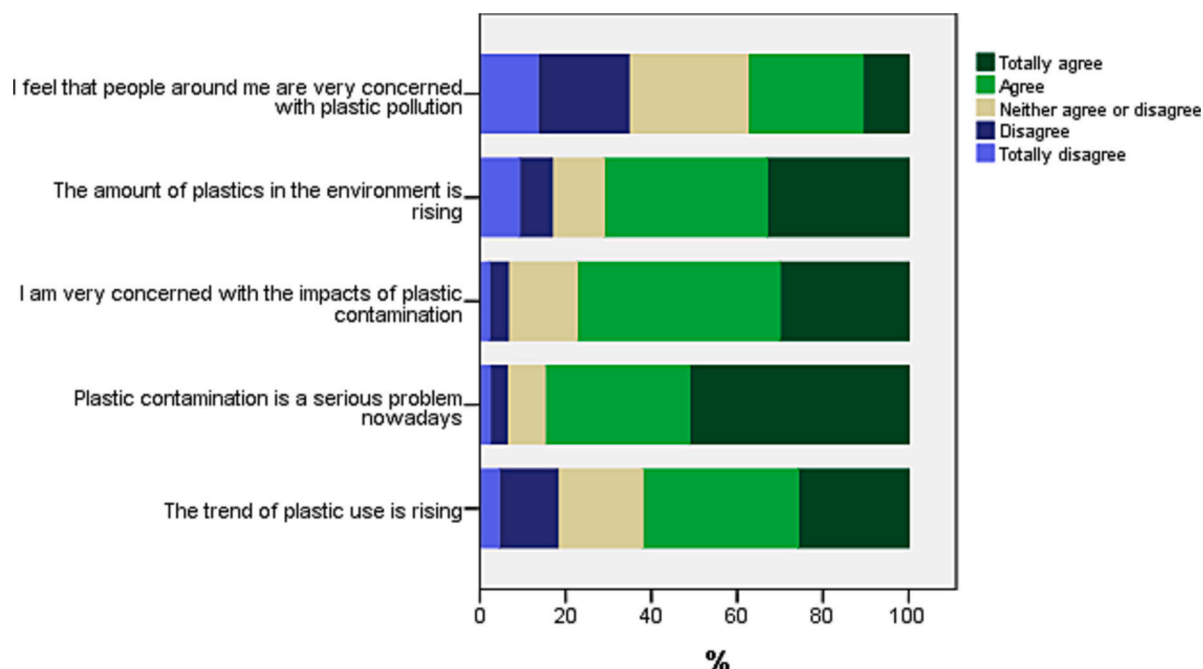


Fig. 2. Awareness and concern about plastic pollution.

they are the ones who least recognize plastic pollution as a serious problem nowadays ($M = 4.1$) when compared to participants with high school ($M = 4.3$) and high education ($M = 4.3$).

No effects of gender were found in participants' awareness and concern about plastic pollution.

3.3. Recycling attitudes and behaviors

When asked about solutions to reduce environmental problems (Fig. 3), a large majority of participants consider waste reduction and recycling as means to mitigate those problems (33.4 % of participants agreed and 59.2 % agreed completely). Most participants report recycling at home (32.4 % agree and 29.1 % completely agree), buying reusable products instead of disposable ones (32.4 % agree and 29.1 % completely agree), buying reusable products instead of disposable ones (32.2 % agree and 18.6 %

completely agree), and agreeing with financial incentives to promote consumers' recycling behaviors (36.0 % agree and 23.6 % completely agree).

To analyze how participants' recycling attitudes and behaviors are influenced by their sociodemographic characteristics, another MANOVA was conducted, now taking the four items of recycling attitudes and behaviors as dependent variables. The results showed statistically significant multivariate effects of the level of education on participants' recycling attitudes and behaviors ($F(8, 2234) = 3.71, p < .001$; Wilk's $\Lambda = 0.97$, partial $\eta^2 = 0.01$). Education had a statistically significant effect on how participants perceive waste reduction and recycling as important ways to tackle the plastic problem ($F(2, 1128) = 5.67; p = .004$; partial $\eta^2 = 0.01$), with participants with a high education level ($M = 4.6$) considering waste reduction and recycling as more important solutions

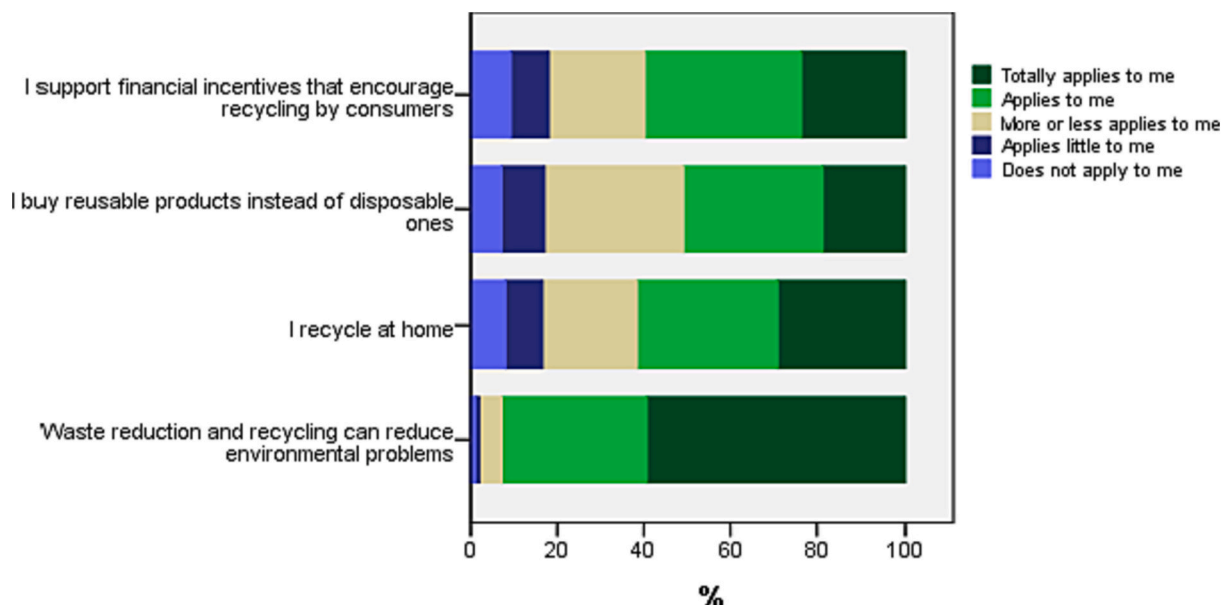


Fig. 3. Recycling attitudes and behaviors.

to environmental problems when compared with participants with a basic level of education ($M = 4.4$). Also, a univariate significant effect of the level of education was found in the reported recycling behavior at home ($F_{(2, 1128)} = 10.47$; $p < .001$; partial $\eta^2 = 0.01$). A deeper analysis of such pro-environmental behavior shows that less-educated participants ($M = 3.4$) report significantly lower levels of recycling behavior than participants with high school ($M = 3.7$) or high education ($M = 3.8$).

A multivariate effect of gender was found in participants' recycling attitudes and behaviors ($F_{(4, 1188)} = 3.31$, $p = .010$; Wilk's $\Lambda = 0.98$, partial $\eta^2 = 0.01$). More specifically, women ($M = 3.5$) report buying significantly more re-usable products when compared to men ($M = 3.3$) ($F_{(1, 1128)} = 7.69$; $p = .006$; partial $\eta^2 = 0.01$), while also recycling more at home ($M = 3.74$) than men ($M = 3.57$) ($F_{(1, 1128)} = 5.97$; $p = .015$; partial $\eta^2 = 0.01$).

Although no multivariate effect of age was found in participants' recycling attitudes and behaviors ($F_{(12, 2952)} = 1.31$, $p = .202$; Wilk's $\Lambda = 0.98$, partial $\eta^2 = 0.01$), subsequent tests show that the recognized importance of waste reduction and recycling is influenced by age ($F_{(1, 1128)} = 2.86$; $p = .035$; partial $\eta^2 = 0.01$): the youngest participants aged 18–25 years old ($M = 4.5$) score significantly higher than the oldest participants aged 61 and older ($M = 4.3$) in recognizing waste reduction and recycling as important strategies to mitigate environmental problems.

Overall, participants' acknowledgment of waste reduction and recycling as means to mitigate environmental problems seems to have implications for their pro-environmental behaviors. More specifically, the more participants report recycling at home, the more they report buying re-usable products instead of disposable ones ($r = 0.364$, $p < .001$), and supporting financial incentives that promote consumers' recycling ($r = 0.127$, $p < .001$).

4. Discussion

The excessive production and consumption of plastic is a major challenge of our time due to the associated environmental release and reported presence in different environmental matrices and biota, including humans. Therefore, there are major concerns regarding the effects that these particles may have. Several studies have reported the ability of plastics, either alone or in combination with other environmental contaminants, to induce lethality, altered reproduction, altered feeding and swimming behavior, and altered immune function and stress in aquatic organisms (Brandts et al., 2021; Ferreira et al., 2019; Oliveira and Almeida, 2019; Sendra et al., 2021; Silva et al., 2020; Venâncio et al., 2021; Yu et al., 2020). There are currently major concerns regarding the potential effects on humans, with increasing reports of detection in human samples (feces; Schwabl et al., 2019; blood; Leslie et al., 2022). Therefore, the reduction of plastic has become a major global challenge. Different approaches have been studied, ranging from the limitations of single-use materials to the use of alternative materials with higher biocompatibility and/or degradability (e.g., biopolymers). However, several challenges remain. It is recognized that part of the solution involves alteration of human behavior, from consumption patterns to the use of materials during their use life and end of life. Thus, understanding how the public perceives the plastic problem is a key aspect in dealing with the situation (Soares et al., 2021b), providing relevant information for didactic strategies for promoting better use of plastics, for industries to adopt more pro-environmental strategies that do not compromise their economic strategy, and for decision-makers to promote strategies to better handle the problem (e.g., more restrictive legislation, tax incentives). Portugal, having a historical connection with the sea and with a large maritime area under its jurisdiction (one of the largest in Europe) (e.g., fishing activities and high consumption of fish and shellfish, and tourism), can be considered a major target of aquatic plastic pollution effects. Furthermore, its agricultural activities (e.g., as one of the largest exporters of tomatoes and wine) may also be

compromised by plastic contamination in the soil. Thus, it may be a potential target of plastic pollution, both in terms of potential biological effects and social and economic impacts. Although a highly relevant topic, how the public understands plastic contamination is poorly understood. The present study aimed to contribute to this gap by investigating the public's knowledge, awareness, and concern about plastic pollution and recycling behaviors, exploring sociodemographic variations. Thus, a large representative Portuguese sample was used.

Overall, the present study showed that participants acknowledge plastic pollution in several environmental compartments. However, the participants reported being more aware of plastic pollution issues in marine and terrestrial environments than in the air. These results agree with other reports of the highest level of public awareness of plastic pollution in oceans (King et al., 2023), and the public believes that microplastics mostly accumulate in oceans, followed by animals and plants, air, rivers, lakes, and soils (Deng et al., 2020). In their European-wide study, Filho et al. (2021) also found that most of their survey respondents considered the problems associated with plastics in the oceans to be extremely serious, with fewer participants considering the serious effects of plastics on soils and air. Besides the fact that plastic pollution in aquatic environments and soils is "visible", while air pollution by (micro)plastics is "invisible", such a belief may also be associated with a considerably higher number of scientific studies focusing on aquatic environments, with marine and estuarine environments being the most frequently sampled systems in plastic pollution research (Jenkins et al., 2022), and thus having more information released to the public.

The production of plastic has markedly increased over the last decades, currently reaching about 390 million tonnes per year (PlasticsEurope, 2022). Such an increase is indeed recognized by almost two-thirds of the participants in the present study. Furthermore, a large majority of participants also recognize that the presence of plastics in the environment is increasing and consider it a serious problem nowadays. Recent and large-scale surveys conducted on citizens in several countries (e.g., Portugal, UK, Germany, Canada, Kenya) also showed that pollution in general and plastic waste in particular are perceived as major environmental problems and a threat to marine ecosystems (Hartley et al., 2018; Lotze et al., 2018). Also, Potts et al. (2016) have shown that when presented with a list of global environmental concerns, the issue of pollution was scored across seven countries (UK, France, Germany, Italy, Poland, Portugal, and Spain) as the issue of most concern, with pollution from industry and litter being considered the most severe threats to the marine environment.

The participants of the present study recognize waste reduction and recycling as important means to mitigate the plastic problem and report recycling at home. These data are consistent with previous findings depicting environmentally friendly behaviors manifested through a high frequency of recycling and a reduction in plastic use (Soares et al., 2021a). In recent literature reviews, recycling behavior has been identified as one of the solutions to tackle the plastic problem (Heidbreder et al., 2019; Oliveira et al., 2019). Furthermore, in the present study, participants' attitudes towards recycling were positively related to their recycling behavior at home. Significant attention has been devoted in the past few decades to identifying and describing major socio-psychological and situational determinants and barriers to recycling behavior. Tonglet et al. (2004), for example, reported that recycling attitudes are the main determinants of recycling behavior and that opportunities, knowledge, and not feeling deterred by behavior costs are antecedents of pro-recycling attitudes. However, many other factors seem to influence recycling behavior. For example, availability and shorter distances to recycling bins (Madigale et al., 2017; McCoy et al., 2018), waste bins being overloaded (Vogt and Nunes, 2014), convenience or cost of recycling (Ahmad et al., 2016), or incentives (Struk, 2017) have been shown to influence the overall recycling rate of plastics. A meta-analysis (Varotto and Spagnolli, 2017) identified 29 determinants of household recycling, consisting of three categories:

sociodemographic (e.g., age, education level, income), psychological (e.g., information and knowledge, convenience, general environmental attitudes, perception of recycling consequences), and contextual (e.g., monetary incentives, location, and characteristics of bins, and product characteristics) factors. The present study showed how sociodemographic determinants such as education level influence participants reported recycling behavior at home, with less-educated participants reporting lower levels of recycling behavior.

In general, the results of the present study show that participants hold a high level of concern about the plastic problem. These results relate to previous findings showing that, when compared to the other six countries, the Portuguese expressed relatively higher levels of concern across issues such as pollution, food safety, and climate change (Potts et al., 2016). Soares et al. (2021b) had also shown a high general knowledge of plastic pollution, highlighting awareness and knowledge about the environmental threats of plastics. In the present study, education level seemed to influence participants' level of concern about the plastic problem; when compared to individuals with a higher level of education, individuals with a lower education level were significantly less likely to recognize plastic problems as a serious issue nowadays, less likely to acknowledge recycling as a means to tackle the plastic problem, those least personally concerned with the problem and those who reported less recycling at home. This finding agrees with the study of Hartley et al. (2018), which analyzed the perception of 16 European countries (participants aged 16–89 years) about marine litter and contributing factors. As observed in the present study, education level significantly predicted concern, with people with a higher level of education reporting more concern about marine litter than people with a lower level of education. Given its central role in predicting environmental concern and behavior, inferences have been raised about participants' socioeconomic situation based on their level of education. For example, other studies, also facing the lack of cooperation in income reporting, found that the education parameter could be considered a reliable predictor of environmental behaviors, since individuals with higher levels of education invested more in recycling efforts or equipment (Fiorillo, 2013; Corrado et al., 2022). Also, the education-income binomial has been suggested as an indication of the capital situation or level of development of the region where the respondents live. For example, a study that included the representative population of two macro-regions of Italy (north and south) revealed a lower willingness or involvement in recycling associated with lower educational levels in the south, contrasting with a higher educational level and pro-environmental behavior highest in the northern region (Fiorillo, 2013). Therefore, although the present study did not report on participants' socioeconomic status and region, their level of education might be taken as a reliable predictor of participants' knowledge, concern and behaviors about plastic pollution.

In the present study, age was also related to concern, as older individuals were significantly less likely to recognize plastic problems as a serious issue nowadays and less likely to acknowledge recycling to tackle plastic problems. These results are consistent with those of Hartley et al. (2018), who showed that older participants had lower levels of concern about marine litter. However, contradicting findings emerge from the literature. For example, Potts et al. (2016) observed statistically significant differences between generations over the health of the marine environments, with concern increasing with age, while King et al. (2023) have also observed a decline in concern in younger cohorts in their levels of concern about the amount of plastic used for farming activities. Recent prediction models have also pointed that, whether at the individual or social level, older individuals (older than 64 years-old) may be more engaged and active in plastic pollution subjects and may be promoters or encouragers for other age groups (Wang et al., 2021). Also, although greater engagement on the part of younger age groups regarding plastic-related environmental issues has been identified, responses might later be shaped in terms of convenience and costs, forming a barrier between the transition from what is

expressed by them (verbally/written) to the behaviors themselves (physical actions) (Kollmuss and Agyeman, 2002). Therefore, although not straightforward, this study can provide insight on how campaigns on plastic pollution can be streamlined and focused on different groups, to integrate them into effective actions (e.g., cleaning campaigns).

The findings of this study contribute to the theoretical and empirical literature on the perceptions of plastic pollution. In a field where there is still little empirical research on individuals' perceptions of plastic pollution and the means to tackle the problem, this paper presents the results of a survey that explores the knowledge, concern, and recycling behavior regarding the plastic problem from a wide national representative sample of participants, offering insights into how the Portuguese public understands and responds to the issue of plastic pollution. It provides an innovative contribution to the literature by refining our knowledge of how public perceptions of the plastic problem vary significantly by sociodemographic variables, such as age and level of education. At a practical level, the results reinforce the importance of emphasizing messages and interventions towards enhancing people's views on the overarching occurrence and impacts of plastic pollution, entailing its consequences not only to soil and aquatic environments but also to air. Additionally, it calls attention to the need to tailor messages and interventions to specific audiences and communities, especially targeting individuals who are older and have lower levels of education, as they seem less knowledgeable and concerned about the widespread problem of plastic pollution. Also, as results of the present study are in line with previous research, showing that women are more willing than men to accept alternatives to plastics and show more reusing practices (Kurusu and Bortoleto, 2011; Madigele et al., 2017), male individuals could also be specially targeted. Therefore, it reinforces previous suggestions that dissemination strategies should be planned according to specific variables (Soares et al., 2021b).

Notwithstanding its important contributions, the methodology used in this study presents some limitations. First, the study relied solely on participants' self-reported measures. Despite the anonymous nature of the study, this methodology can lead participants to selectively disclosure or withhold socially undesirable information (e.g., some participants could acknowledge they recycle at home without actually doing it), possibly leading to reporting bias. It would be worthwhile if future studies were built on observational or qualitative methods. Second, as it is a young sample (more than half of the participants are under forty years old), sampling bias might be occurring. Caution is recommended when generalizing results to the larger population. Future studies should provide a more balanced sample. Third, as five-point scales were used to assess the study variables, participants were given the opportunity to rate items towards the middle of the scale, probably creating a central tendency bias. Therefore, future studies should consider scales with a different Likert-point amplitude. Future research should also consider developing validated instruments for the assessment of knowledge, attitudes and concerns about plastic pollution in the general population, reporting on face, content and construct validity. Finally, future research should also explore how socioeconomic status and area of residence (e.g., living close to the ocean) might influence participants' knowledge, concerns, and attitudes towards plastic pollution.

5. Final considerations

It is important to carry out this type of study with different populations and methods. Individuals' perceptions may change over time in response to new information, targeted campaigns, or through informal influences from peers or groups. Therefore, future studies should invest in longitudinal approaches, exploring changes in perceptions over time. Furthermore, as attitudes and behavior are influenced by many factors, such as socio-demographic (e.g., education level, age, gender), economic (e.g., income level), psychological (e.g., living near the coast and having personal experience with plastic pollution) and social factors (e.g., traditional or cultural), it is important to have this approach in detail

as presented here in future research. This study highlighted the importance of considering sociodemographic factors in understanding the social perception and environmental awareness linked to plastic pollution. The findings of this study provide crucial information for policy-makers, educators and environmental activists seeking to successfully combat plastic pollution, providing a foundation for developing specialized interventions that target communities with varying degrees of awareness and overcome specific knowledge gaps, in order to encourage long-term behavior change. In view of this, environmental education must be implemented in society, with a special focus on reaching older individuals with less education, with the aim of reducing consumption and avoiding the inappropriate disposal of plastic waste. However, it remains crucial to continue funding environmental education as a useful tool to mitigate the issue of plastic pollution.

CRediT authorship contribution statement

IM: conceptualization, formal analysis, writing - original draft, funding acquisition; AS: writing - review and editing; CV: writing - review and editing; MO: conceptualization, funding acquisition, writing - original draft. All authors read and approved the final manuscript.

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.

Data availability

Data will be made available on request.

Acknowledgements

This work was developed within the project NanoPlanet (DOI [10.54499/2022.02340.PTDC](https://doi.org/10.54499/2022.02340.PTDC)), financially supported by national funds (OE), through FCT/MCTES. Thanks are also due for the financial support to CESAM financed by national funds through FCT/MCTES (UIDB/50017/2020, UIDP/50017/2020, LA/P/0094/2020) through strategic programs. Cátia Venâncio is a contracted researcher under the scope of the NanoPlanet project (Ref.: CDL-CTTRI-141-SGRH/2023).

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