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Dedicated to Prof. Ion Grosu
on the occasion of his 70th anniversary

ANALYSIS OF PUBLIC AWARENESS AND PERCEPTION OF MICROPLASTIC PARTICLES IN ROUMANIA

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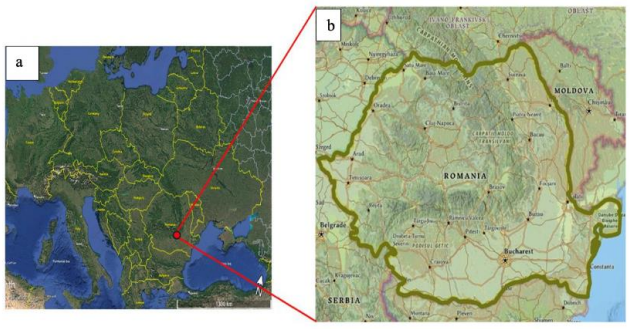
Microplastic particle (MPs) pollution is a growing global problem, affecting ecosystems, human health, and food chains worldwide. The study analyzes the level of awareness of the Roumanian population regarding MPs and their impact on the environment and health. Data were collected through a survey, using a scale from 1 to 7, to assess respondents' knowledge about the accumulation of MPs in the food chain, soil pollution by-products containing MPs, and general familiarity with the term. The results revealed that awareness is low regarding the concept of MPs (mean 1.33, median 1), moderate regarding the accumulation of MPs in the food chain (mean 4.1, median 4), and also moderate regarding the impact of products containing MPs on the soil (mean 4.3, median 5). These results highlight the need for educational campaigns to increase awareness and encourage adopting sustainable practices in daily life



INTRODUCTION

In recent years, MPs have become a topic of major interest both in the scientific field and among the general public.[1] These tiny plastic particles, resulting from the degradation of larger plastic products[2–4] or the direct use of products containing MPs, have been identified in various environments, from water and soil to air[5] and even in living organisms. MPs pollution represents a complex environmental problem[6] with potential implications for human health[7] and natural ecosystems.[8] In this context, it is essential to understand how the population[9] perceives and reacts to this emerging problem. The public's perception and attitude towards MPs are crucial in shaping environmental policies, promoting sustainable practices, and adopting effective measures[10,11] to reduce pollution.[12]

This type of pollution is widespread throughout the planet in all kinds of environments.[13] Leo

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Baekeland made the first synthetic plastic, Bakelite, in 1907 in New York. It was quickly discovered that it was a special material. Nowadays, plastics simplify our lives in many ways because they are lighter and cheaper than alternative materials. Light, affordable, practical, and last but not least, indestructible, in just a few years, the material has spread all over the world, from bottles to bags, packaging, etc. An important quality of plastic is its durability. Even a thin mesh can hold a few kilos and have a long lifespan. This is where the problem arises because it has increased resistance and durability. However, if they are not properly disposed of or recycled, they can end up in the environment, where they remain for centuries and degrade into smaller and smaller pieces.

Considering the latest research studies, exposure to pollutants has been associated with a series of negative eco-toxic and physical effects that act on the health of living organisms and the environment.[14] Sharma,[15] reports the hazardous nature and cancer risk of MPs originating from e-waste, while arriving at some calculated values for cancer risk in terms of lifetime MPs ingestion (1.13×10^{-5} for children and 1.28×10^{-5} for adults), these values being higher than the recommended value of 106. The abundance of MPs in aquatic and marine ecosystems contaminates seafood[16–19] and leads to the transfer of toxic pollutants to humans while increasing the risk of cancer. An assessment of human intake of MPs highlights the possible risks that seafood consumption poses to the human population, which is largely dependent on a seafood diet. Given the potential physical and chemical toxicity of MPs and their associated contaminants, routine consumption of high doses of the studied seafood should be controlled for vulnerable groups, such as pregnant/lactating women and their children, to ensure their safety.[20] The toxicity rate for MPs is on an upward slope when there is a rapid increase in particles over a certain period, according to Dong.[21]

Plastic pollution is a significant environmental problem[22] in Roumania, especially in urban areas and along waterways. Rivers and lakes are often affected by plastic waste,[23] which ends up in the sea and contributes to the pollution of the Black Sea. According to a report by the Ministry of Environment,[24] the amount of plastic waste generated in Roumania is increasing,[25] and inadequate management of this waste leads to its accumulation in the environment.[26] Although various initiatives have been implemented to reduce single-use plastics and improve recycling systems, challenges persist due to inadequate infrastructure and public awareness.

MPs research is an emerging and very important field, but several drawbacks and challenges limit the understanding and management of this problem, both globally and in Roumania. Among the drawbacks at the global level, we can mention: (i) Lack of standardization of research methods[28] since there are no uniform methods for collecting, analyzing, and quantifying MPs. This makes it difficult to compare results[29] from different regions or studies. (ii) Limited access to data on long-term impacts. Although the effects of MPs on the environment and human health are intensely discussed, longitudinal studies investigating long-term impacts are few. (iii) Focus on certain types of ecosystems. Most research has focused on marine ecosystems,[30,31] while terrestrial and freshwater ecosystems[32] (where MPs frequently end up) are insufficiently studied. (iv) Difficulties in identifying and classifying MPs. Technologies for MPs analysis are expensive and require advanced knowledge, limiting access for researchers from many countries. (v) Underestimation of MPs sources. Much of the research focuses on major sources, such as plastic packaging, but less obvious sources, such as wear and tear from paints, tires, or synthetic textiles, are often ignored.

Disadvantages at the level of Roumania: (i) Lack of funding and infrastructure for research. MPs research in Roumania is underfunded, and laboratories are not properly equipped for detailed analyses, which limits the number and quality of studies. (ii) Limited data on MPs in national ecosystems. Although Roumania has a high ecological diversity (Danube Delta, Black Sea, mountain ranges),[33] there are few local studies on the presence and impact of MPs in these ecosystems. (iii) Lack of awareness and education. Among the public, but also among some institutional actors, awareness of the impact of MPs is low.[6,34] This limits the pressure on decision-makers to implement appropriate policies. (iv) Lack of strict regulations. National legislation on the reduction of MPs (*e.g.* from cosmetics or other products) is either absent or poorly implemented,[23] compared to Western European countries. (v) Isolated research. Studies on MPs are fragmented and there is no national research network or international cooperation well enough developed to understand the scale of the problem in Roumania.[35] (vi) Focus on other environmental priorities: Environmental problems in Roumania, such as deforestation, water, and air pollution, tend to

receive more attention, and MPs are not seen as an immediate priority.

The problem could be addressed by: (i) Developing research infrastructure with laboratories equipped for MPs analysis would encourage more national studies. (ii) Increasing funding for interdisciplinary research by investigating the interaction of MPs with human health, ecosystems, and the economy. (iii) Public education and awareness by informing consumers about the use of products that do not contain MPs and the correct recycling of plastic.[27] (iv) Legislation and public policies by implementing stricter regulations for the reduction and management of plastic waste.

The importance of our study can be highlighted from several perspectives, given the descriptive analysis of data related to MPs. As a scientific contribution, our study brings valuable data to the emerging scientific literature on MPs, especially since there is little similar research in Roumania. Through the applied methodology, we provide a solid basis for future research that can explore in more depth the impact of MPs on the environment and health. Last but not least, our study could develop a guideline for concrete actions by identifying trends (such as a higher average for certain questions), and the data could guide toward specific directions of action, such as creating information campaigns that respond to the identified needs and concerns and suggesting ecological alternatives for products containing MPs.

Hypotheses

The hypotheses formulated in this study reflect the key objectives of the research, focusing on the level of awareness and attitudes of the Roumanian population towards MPs and their impact on the environment and health. These hypotheses are essential to better understand the public's perceptions, their level of information, and how this influences daily behaviors.

H1: Most respondents are familiar with the concept of MPs and understand their impact on the environment and human health. This hypothesis explores the general level of awareness of the population towards MPs, a phenomenon increasingly discussed in a global context. The public's familiarity with this concept reflects the success of the education and information campaigns carried out to date.

H2: These results highlight the need for educational campaigns to increase awareness and encourage adopting sustainable practices in daily life.

H3: Awareness of soil pollution caused by products containing MPs (during production, use, or disposal) is significant in Roumania, influencing consumer decisions, such as choosing food, cosmetics, or clothing. The hypothesis examines the extent to which the Roumanian public recognizes the negative impact of MPs on soil, a crucial aspect of protecting natural resources. If this awareness is high, it can represent an important step towards changing consumer behavior towards more environmentally friendly choices. By testing these hypotheses, the study aims to highlight knowledge gaps and provide a starting point for future initiatives aimed at increasing public awareness and reducing the use of MPs.

EXPERIMENTAL

To better understand the perceptions and knowledge of the Roumanian population regarding the impact of MPs on the environment and human health, we conducted a questionnaire with a nationally representative sample (Fig 1). This research aimed to assess the level of awareness and concern of respondents regarding MPs in everyday life, especially in contexts such as the use of cosmetics, packaging, and clothing. The data were collected through an online survey developed using the Google Forms platform. The responses obtained were centralized and processed into an Excel database, which was subsequently used for statistical analysis using descriptive statistical indicators such as mean, median, minimum, maximum, and range. For descriptive statistical analysis, Microsoft Excel built-in functions were used, such as AVERAGE for the mean, MEDIAN for the median, and MAX/MIN for the range of variation. These measures helped us to gain a deep understanding of the responses and identify central trends and variability of responses among respondents. Thus, the results from Roumania provided an important basis for comparing the level of awareness and concern of the population with other European countries and for assessing the perceived impact of the use of MPs in everyday life. In this context, we identified areas where additional education is needed and proposed measures to raise awareness and promote more sustainable practices in Roumania.

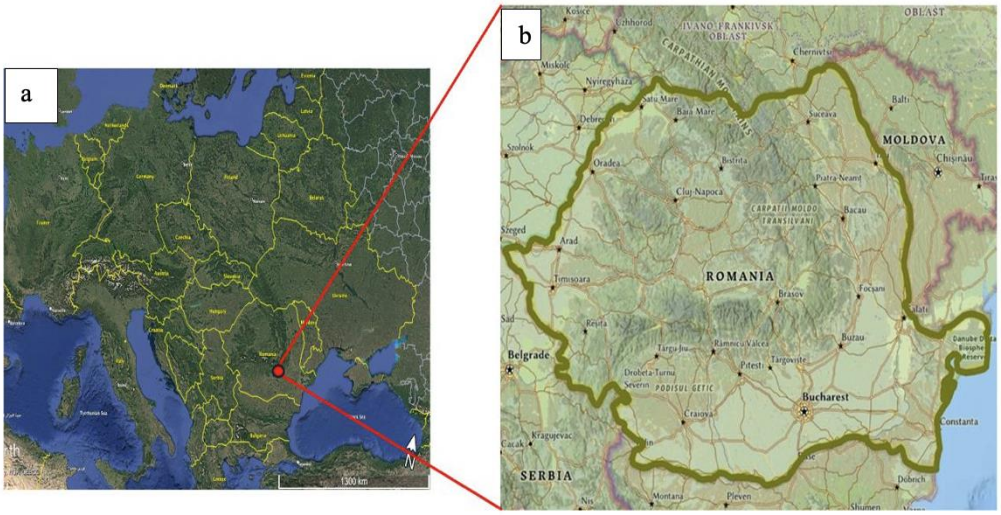

Fig. 1 – Map of the study area in Europe (a), specifically in Roumania (b).

The total number of respondents was 457, with most questions being closed and using a Likert scale from 1 to 7 (where 1 indicates the minimum degree of agreement or knowledge, and 7 indicates the maximum degree). There was also an open question, which allowed respondents to express their opinions and perspectives in their own words. The questionnaire included questions related to familiarity with MPs and their impact on health and the environment, awareness of the accumulation of MPs in the food chain, information about products containing MPs and their effects on soil, and information related to income, age, education, etc. All collected data were processed following the General Data Protection Regulation (GDPR) requirements. The questionnaire was anonymous, and participants were provided with clear information regarding the purpose of data collection, their rights, and the confidentiality of the information provided. Our study was carried out in two stages: The first data collection period took place between May and July 2022, with 417 respondents,[34] and the second data collection period took place between September and October 2024, reaching the number mentioned above of 457 respondents. In both stages, the questionnaire questions were the same, using the same set of questions for all survey participants. Regarding the territorial distribution of respondents, Cluj County recorded the highest participation, with a percentage of over 50% of the total responses. Two other counties with a significant response rate were Arad, with just over 17%, and Maramureș, with approximately 9%. The remaining 27 counties included in the survey, out of a total of 41 existing in Roumania, recorded a lower response rate. However, their contribution remains essential for ensuring a representative analysis of the regional distribution of responses. The predominant level of education among respondents was university, representing just over 65% of the total. Also, 31% of participants had completed 12 grades, and approximately 4% stated that they had completed only primary education, having completed 8 grades at most. The predominant age group among respondents was between 18 and 35 years old, representing over 28% of the total. This prevalence could be influenced by the increased familiarity of people in this age group with the online environment, which facilitated their access and participation in the questionnaire.

We extracted three questions from our survey: Q1) Have you heard of MPs? (Yes, No); Q2) Do MPs accumulate in the food chain, and can they ultimately be found in different foods we eat? (1–7); Q3) Do you think that many products containing MPs (*e.g.*, glitter, cosmetics, clothing, ornaments, packaging) can pollute the soil during production, use, or when they become waste? (1–7). On the scale of Likert, response 1 means “I have never heard” and 7 means “I have heard very often”. Descriptive Analysis was used to summarize and present the data obtained from the questionnaire in a simple and accessible way. The purpose of this analysis was to highlight the general characteristics of the distribution of respondents’ answers regarding MPs and their impact on the environment and human health. For this analysis, we used several descriptive statistical measures: (i) The mean provides a general picture of the central tendency of the responses, showing where most of the data lies and how close they are to the mean value; (ii) The

median represents the central value in the data set, dividing the responses in half and giving an idea of where the distribution of responses is most frequently found; (iii) The minimum and maximum provide the range of variability of the responses, showing the lowest and highest values found in the collected data; (iv) The range measures the difference between the maximum and minimum values, giving an idea of how dispersed the responses are. These measures helped us to better understand the perceptions and knowledge of respondents regarding the awareness and impact of MPs. The results of these descriptive analyses provided us with a solid basis for interpreting the responses obtained and for formulating conclusions regarding the perceived impact of MPs on the environment and human health in Roumania.

RESULTS

For Q1, the results of our study are as follows: (i) The mean has a value of 1.337. This value indicates that most respondents answered "Yes" (1), but there is also a significant percentage that answered "No" (2). Since the mean is closer to 1 than 2, we can conclude that "Yes" answers are predominant. (ii) Median with the value 1, shows that if we arrange all the answers in order, the central answer is "Yes" (1). This confirms that most respondents are familiar with the term MPs. (iii) Minimum and Maximum: The values 1 and 2 reflect the available answer options. There are no other values because the question was binary (Yes/No). (iv) Range: It is 1, showing that the question is narrow, with only two answer options. This is expected for a question with binary answers. To interpret the results in terms of awareness, most respondents have heard of MPs, as evidenced by the mean of 1.3337 and the median of 1. However, given that approximately 33% of respondents (153 people) answered "No" (2), this may indicate a relatively low level of public awareness of the issue of MPs. Over 66% of respondents have heard of MPs, answering "Yes" (304 people); thus, the mean of 1.337 reflects a positive trend but not necessarily a high level of awareness.

Table 1

Descriptive analyses of awareness (Q1), accumulation in the food chain (Q2), and impacts on health and environment (Q3) of MPs

Statistical indicators	Q1 Values	Q2 Values	Q3 Values
Mean	1,337	4,1008	4,3311
Median	1	4	5
Minimum	1	1	1
Maximum	2	7	7
Range	1	6	6

For Q2, the results obtained have the following values: (i) The mean on a scale from 1-7, where 1 represents "never heard of," 7 represents "very often heard," has a value of 4.1008. This suggests that, on average, respondents have heard about MPs in the food chain occasionally but not very often. The mean is closer to 4, indicating a moderate familiarity with this issue among the population. (ii) The median is equal to 4, which is a central value in the distribution of responses, confirming that half of the respondents have heard about MPs in the food chain occasionally, and the other half have heard very rarely or not at all. (iii) A Minimum of 1, shows that there are respondents who have never heard of MPs. The Maximum of 7, being the highest response, suggests that some respondents are very familiar with the risks of MPs, hearing about them very often. (iv) The range with the value of 6 shows a wide dispersion in the answers, suggesting that there is a wide variety of perceptions and knowledge related to MPs among the population.

As an interpretation, it can be said that we obtained a varied awareness. The mean close to 4 suggests that most people have heard about MPs in the food chain to a moderate extent. This indicates a general familiarity, but not necessarily a deep awareness of the associated risks. The median is at the same level 4, indicating that half of the population is in this category of average knowledge. The minimum of 1 shows that there is a group of respondents who have never heard of this topic, which is worrying for public awareness. The maximum of 7 shows that there is a small but

important group of respondents who are very aware of the risks of MPs.

As implications for Public Policy and Education, this variability in responses may suggest the need for more active public education and outreach campaigns to raise awareness[26] and inform the population about the risks of MPs. It is important to communicate effectively with the general public so that knowledge about this issue becomes more common and better understood. Our data indicate a clear need for educational initiatives to increase awareness and understanding of the risks associated with MPs in the food chain and our diet. This information can be used to argue for the need for prevention and protection measures and stimulate public and political dialogue in this area.

Considering our data for the question "Do you think that many products containing MPs (*e.g.*, glitter, cosmetics, clothing, ornaments, packaging, etc.) can pollute the soil during production, use, or when they become waste?" we obtained the following results: (i) Mean = 4.3311, indicates that, on average, respondents in Roumania have heard about the impact of MPs on the soil occasionally. This is an interesting starting point, suggesting moderate familiarity with this issue among the population. (ii) Median = 5 shows that half of the respondents have heard about this topic frequently ("sometimes" to "quite often"), and the other half have heard less often or not at all. This suggests a somewhat deeper knowledge and a growing awareness of the impact of MPs on the soil. (iii) Minimum = 1: This suggests that there is a part of the population (1 answer) that has never heard about the risks of MPs in products during production, use or disposal. Max = 7: The highest response (7) shows that there are respondents who are very aware of these risks and have heard about them very often. (iv) The range of 6 shows a wide dispersion of the responses, indicating a wide variety of perceptions among the population.

In interpretation, we can say that we have a relatively moderate awareness with a Mean of 4.3311 which suggests that most people have heard about the impact of MPs on soil occasionally, but not frequently. This reflects a moderate familiarity and somewhat limited understanding of this topic among the population. The median of 5 suggests that half of the population is already familiar with this concept "sometimes" or "quite often." This shows a relatively good knowledge among these respondents. We also encountered difficulties in awareness related to the Minimum with a value of 1, which suggests that a significant number of respondents are not aware of the impact of MPs on the soil. This may prove the need to raise public awareness in this area. A maximum of 7 shows that a part of the population is highly aware of the issues related to MPs and their impact on the environment. Communicating information about these risks effectively is important to raise awareness and encourage more environmentally responsible behaviors. The media, NGOs, etc can help this communication. We do not exclude the need for a broad dialogue because the data reflect a clear need to promote public and political dialogue on using MPs and their impact on the environment. This information can be used to argue for stricter regulatory measures and to support stronger awareness campaigns. Campaigns developed through schools, starting from primary grades, are very important.

In conclusion, our results related to the public perception of the risk of products containing MPs *(e.g.*, glitter, cosmetics, clothing, ornaments, packaging, etc.), which can pollute the soil during production, use, or when they become waste, show a relatively moderate knowledge of this type of risk, more specifically the impact on the soil. It is essential to continue education and awareness efforts to expand this understanding and to make the population more responsible and informed about their daily choices.

The results obtained from means, medians, minimum, maximum, and ranges provide a solid basis for understanding the level of awareness and attitudes of the Roumanian population towards the issue of MPs (Table 1). These data allow the identification of general trends, highlighting both the level of information of the respondents and possible gaps in knowledge. In addition, the analysis (Fig. 2) provides a starting point for future educational campaigns and strategies to reduce the use of MPs, thus contributing to efforts to protect the environment and public health.

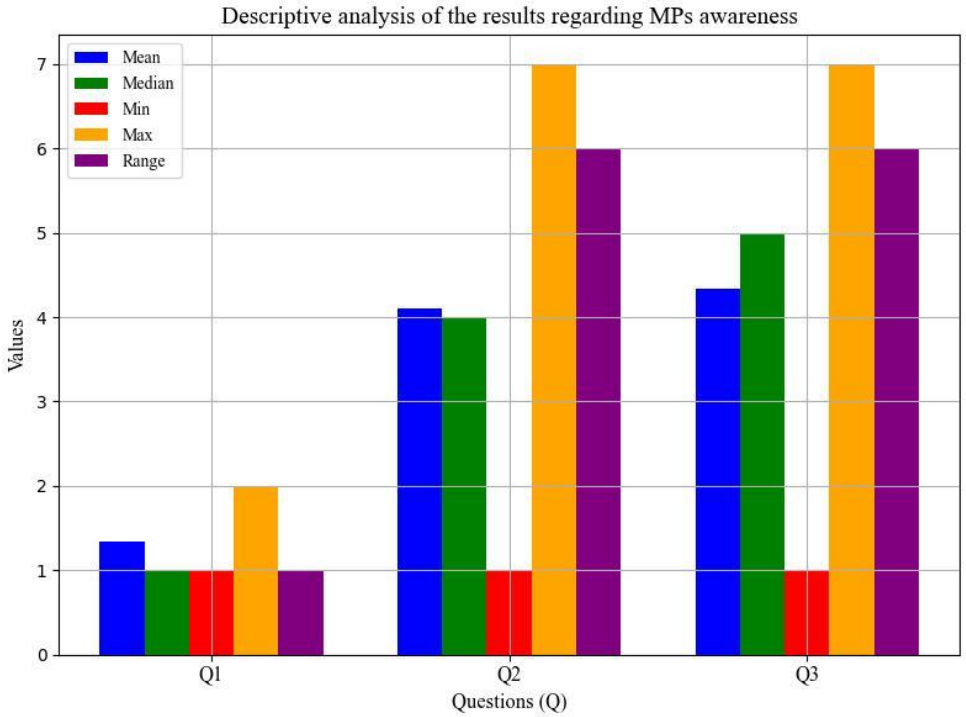

Fig. 2 – Summary of survey results on MPs awareness, food chain accumulation, and soil pollution perceptions.

DISCUSSION

Hypothesis H1 assumes that most respondents are familiar with the concept of MPs and understand their impact on the environment and human health. According to the results obtained from the answers to the question "Have you heard of MPs?", the low mean (approximately 1.3337) and median value of 1 indicate that most respondents are not familiar with this concept. Although a good proportion of participants indicated that they had heard of MPs, these results suggest a low level of awareness of MPs among the population. Thus, hypothesis H1 is not confirmed in this context. Hypothesis H2 suggested that the population has a high level of information regarding the accumulation of MPs in the food chain and shows a high concern for reducing the use of products containing MPs. The results for the question regarding the accumulation of MPs in the food chain (mean of approximately 4.1 and median 4) indicate a moderate level of information. The values obtained suggest that respondents have some knowledge of this phenomenon, but not at a high level. This observation can be interpreted as a sign of partial awareness, which highlights the need for additional educational campaigns to increase the level of information. Thus, H2 is partially confirmed. Through the last hypothesis of our study, namely H3, we proposed that there is a moderate awareness of soil pollution caused by products containing MPs, influencing consumers' purchasing decisions. In the case of the question about soil pollution caused by products containing MPs (*e.g.*, glitter, cosmetics, clothing, etc.), the results (mean ~4.3, median 5) show a relatively positive perception and a moderate, slightly higher awareness compared to the other questions. This suggests that respondents are aware of the impact of products containing MPs on the environment. Also, the higher median value indicates that many respondents expressed increased concern about this issue. Therefore, H3 is confirmed.

The results of this study highlight several relevant conclusions concerning the hypotheses formulated. H1 was not confirmed, suggesting a significant lack of familiarity of the Roumanian population with the concept of MPs and their impact on the environment and human health. This finding is in contrast to studies conducted in other European countries, such as Germany. For example, Kramm [12] showed that the German public shows a high level of awareness and concern about the issue of MPs, which reflects a better integration of this topic in educational programs and public debate. H2 was partially confirmed, showing that although there is a moderate awareness of the accumulation of MPs in the food chain, this is not extensive enough to generate a generalized concern among the population. In comparison, the aforementioned

study highlighted that the German public is not only aware of the risks associated with MPs in the food chain but also motivated to take individual measures to reduce their use, such as avoiding products with plastic packaging. H3 was confirmed, indicating a significant awareness in Roumania regarding the impact of products containing MPs on the soil and a potential effect on consumer behavior, such as shopping choices or the use of cosmetics and clothing. This suggests a possibility to mobilize the population for behavioral changes through targeted campaigns. However, this level of awareness seems to be specific to certain aspects of the problem rather than a holistic understanding. Regarding the discrepancies between questions Q1, Q2, and Q3, it is important to note that even though some respondents were not familiar with the term MPs (as reflected in the answers in Q1), this does not preclude their ability to form opinions about their presence in food or their impact on the environment. Questions Q2 and Q3 refer to general effects and hazards related to environmental and food pollution, and many respondents may have a general understanding of the impact of pollutants (including MPs) on soil and food, even if they are not fully familiar with the term or their specific sources. For example, in Q2 and Q3, respondents may associate pollution with MPs at a general level based on their knowledge of environmental pollution, even if they are not aware of all their sources.

Comparing the results from Roumania with those from Germany highlights the need for more effective educational and awareness initiatives in Roumania. While in Germany, the public seems to be well informed, in Roumania, there are significant gaps in the level of understanding of the MPs issue, especially regarding the general health and environmental risks. Adapting information campaigns to the cultural and social specificities of the Roumanian population could significantly contribute to improving awareness and reducing the impact of MPs on the environment. However, comparing our results with the results obtained in Bangladesh, where only 22% of respondents had previous knowledge about MPs, and 66% were not informed about this type of pollution,[36] we can conclude that in Roumania, a country with an emerging economy, the level of awareness of MPs as being average reflects a good result. In contrast, as mentioned above, in Germany, a country with a developed economy, public perception of the risks associated with MPs is much higher,[12] Germany being at the same time a state with a developed economy, with much more consistent policies for prevention and environmental education. Thus, this comparison highlights the significant variations in awareness and concern about MPs depending on the economic and educational context of each country.

CONCLUSIONS

Some points that underline the relevance and impact of our research are: (i) Understanding the level of public awareness. The results regarding the question “Have you heard of MPs?” show that a part of the population is unfamiliar with the term, as indicated by the descriptive values. This aspect highlights a clear need for educational and awareness campaigns, suggesting that the public needs to be informed about the presence of MPs and their impact on health and the environment. The study highlights a gap between the level of knowledge and the need to educate citizens better. (ii) Identifying gaps in education and information. Questions about the accumulation of MPs in the food chain or soil pollution suggest that the level of information is variable, and the medians and means obtained may indicate an increased interest in these issues. Importantly, these results can be used to adapt environmental education programs, both in schools and at the level of public campaigns. (iii) Relevance in public policies and regulations. (iv) Global context and international comparability. The values obtained in Roumania (mean, median, etc.) are compared with results from other countries to assess where the level of awareness and involvement lies. Such comparisons can contribute to understanding the role that Roumania plays in managing the problem of MPs globally. In conclusion, our study is important because it highlights the current level of awareness in Roumania regarding MPs, urges educational and political actions, and contributes to a better global understanding of the issue of MPs, in the Roumanian context.

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