Microplastic Exposure in Everyday Life: An Awareness-Based KAP Study Among the Indian Population

Rahul Mulchandji Joshi[1], Sourav Debnath[2], Girish Chandra Sharma[3*], Bhumi Chaturvedi[2], Sandli Jain[2], Pradnya Bhaskar[1], Anupama Sharma[4, *], Mahaveer Singh[5]

[1]Department of Clinical Research, Nims College of Allied and Health Care sciences, Nims University Rajasthan, Jaipur, India

[2]Department of Pharmacy Practice, Nims Institute of Pharmacy, Nims University Rajasthan, Jaipur, India

[3]Department of Chemistry, Nims Institute of Engineering and Technology, Nims University Rajasthan, Jaipur, India

[4]Department of Biochemistry and Clinical Research, Research and Innovation Cell, Nims University Rajasthan, Jaipur, India

[5]Department of Endocrinology, National Institute of Medical Science & Research, Nims University Rajasthan, Jaipur, India

Authors: Rahul Mulchandji Joshi1, Sourav Debnath2, Girish Chandra Sharma3, Bhumi Chaturvedi2, Sandli Jain2, Pradnya Bhaskar1, Anupama Sharma4, *, Mahaveer Singh5,*

Affiliations:

****Corresponding author: Dr. Anupama Sharma, Dr. Girish Chandra Sharma** shanuanupama@gmail.com, Sharmagirish82@gmail.com*

Received: 04/06/2026; Revised: 29/06/2026; Accepted: 13/07/2026; Available Online: 17/07/2026

ABSTRACT

Background: Microplastics are emerging environmental contaminants that pose potential risks to human health and ecosystems. Public awareness and preventive behaviours regarding microplastic exposure remain poorly understood in India. Objective: To assess the knowledge, attitudes, and practices (KAP) related to microplastic exposure among the Indian population. Methods: A cross-sectional questionnaire-based study was conducted among 361 participants from 18 Indian states. Data were collected using a pre-tested KAP questionnaire and analyzed using SPSS version 31. Descriptive statistics and Chi-square tests were applied. Results: Most participants were male (59.8%), undergraduate students (62.05%), urban residents (71.2%), and unmarried (83.4%). Awareness of plastic pollution was high, with 93.1% recognizing its harmful effects and 97.2% identifying plastic pollution as a major environmental issue. Most respondents (85.3%) acknowledged that microplastics affect humans, animals, and the environment, while 76.7% correctly identified multiple exposure pathways. Positive attitudes toward reducing plastic use and strengthening regulations were common; however, preventive practices were limited. Overall, 53.5% of participants demonstrated moderate knowledge, 42.7% poor knowledge, and only 3.9% good knowledge. Positive attitudes were observed in 35.5% of respondents, while good practices were reported by only 10.0%. Residence and marital status were significantly associated with attitude scores, whereas marital status was significantly associated with practice scores ($p<0.05$). Conclusion: Despite relatively high awareness of microplastic pollution, preventive practices remain inadequate. Targeted educational programs, behavioral interventions, and stronger environmental policies are needed to improve public engagement in plastic reduction and exposure prevention.

Keywords: Microplastics, Plastic Pollution, Public Awareness, Environmental Health, Human Exposure

How to cite this article: Joshi RM, Debnath S, Sharma GC, Chaturvedi B, Jain S, Bhaskar P, Sharma A, Singh M. Microplastic exposure in everyday life: an awareness-based KAP study among the Indian population. Int J Drug Deliv Technol. 2026;16(74s): 2152-2160. DOI: 10.25258/ijddt.16.74s.178

1.0 Introduction

Plastic is widely used due to their durability, low cost, Versatility but these same properties have led to severe environmental pollution. Global plastic production exceeds 450 million tons annually and approximately 400 million tons of plastic waste is generated each year (1). Among the all plastic waste produced only an estimated 9 to 10 percent is recycled. Large amounts of plastic waste accumulate in terrestrial and aquatic environments because of excessive use and improper disposal (2). According to Geyer R et al., 2017 (3), billions of tons of plastic waste have been generated globally, which is poorly managed. As reported by Azeem et al., 2021 (4), global plastic production has reached nearly 6300

million metric tons, with about 79% ending up in landfills or the environment (5). Plastic exists in the land ocean far more than 400 years because of very slow degradation rate (6).

Over time, plastics break down into microplastics (1 µm–100 µm) and nanoplastics (100–1000 nm), collectively termed micro- and nanoplastics (MNPs), which are now recognized as emerging pollutants (7). Primarly MPs are intentionally added to personal care and cosmetic products such as toothpaste, facial cleansers, and makeup (8). Common polymers contributing to MNP pollution include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), and polyvinyl chloride (PVC) (9).

MNPs enter soils mainly through agricultural practices, including plastic mulch films, plastic-coated fertilizers, and irrigation systems, as well as through sewage sludge, atmospheric deposition, and improper waste disposal (10). Their small size allows them to persist in upper soil layers, altering soil structure, porosity, and water retention, which can affect plant growth and soil health (11). The presence of MNPs in fruits and vegetables indicates their entry into the food chain (12). Once ingested or inhaled, MNPs may accumulate in vital human organs and pose potential health risks (13). Accumulating evidence suggests that chronic exposure to such substances may be associated with hormonal disruption (14), reproductive and developmental impairment (15), metabolic disorders (16), immune dysfunction (17), neurological effects (18), and an elevated risk of certain cancers (19). Presence of micro and nanoplastics in human with detection reported in blood (20), placenta (21), lung tissue (22), aqueous humour (23), amniotic fluid and (24), feces (25), urine (26), stool (27), semen (28), Liver tissue (29) and menstrual blood (30)

The increasing prevalence of plastic pollution and the growing evidence of microplastic and nanoplastics contamination in the environment have raised significant concerns regarding their potential impacts on entire ecosystems (31,32). Despite these concerns, public awareness and understanding of the hazards associated with plastic waste and microplastic exposure remain largely unexplored.

Therefore, a cross-sectional Knowledge, Attitude, and Practice (KAP) study was undertaken to evaluate public awareness, perceptions, and behaviours regarding plastic pollution, health and environmental implications of microplastic exposure. The finding of this study will provide valuable insights into public knowledge gaps and attitudes toward plastic-related hazards. Furthermore, the results may serve as a foundation for developing targeted awareness programs, educational interventions, and future research initiatives aimed at reducing plastic pollution and decrease the potential health risks posed by microplastics and nanoplastics.

2.0 MATERIALS AND METHODS

2.1 Study settings and participants

This cross-sectional questionnaire-based observational study was conducted among the Indian population. Data were collected using both online and offline survey methods to ensure broad geographic representation and participant diversity. The online survey was administered through Google Forms and disseminated using various digital platforms, including WhatsApp, Facebook, Instagram, and email. Participants were encouraged to share the survey link within their social and professional networks, thereby facilitating wider participation through a snowball sampling approach. In addition, an offline survey was conducted at participating institutions in Jaipur, Rajasthan, India. A non-probability convenience sampling method combined with snowball sampling was employed for participant recruitment.

Participation in the study was voluntary. Individuals were eligible to participate if they were Indian citizens aged 15 years or older and provided informed consent and ascent both. As applicable Participants who declined consent or submitted incomplete questionnaires were excluded from the study.

2.2 Procedure

The e-questionnaire was developed after an intensive review of relevant literature and research articles. The e-questionnaire consisted of five modules: (i) socio-demographic characteristics; (ii) knowledge-related information; (iii) attitude-related information; (iv) practice-related information. Socio-demographic characteristics included Age, Gender, Education qualification, Occupation, Area (State and District) and Marital status living status, while the KAP modules contained 26 five-point Likert scale items regarding knowledge (8 Questions), attitude (7 Questions) and practice (5 Questions) towards Plastic and Microplastic. For knowledge and attitude-related items, possible responses ranged from ‘strongly disagree’ to ‘strongly agree’, whereas, for practice items, responses were ‘Yes’ and ‘No’ with an additional response of ‘sometimes’.

2.3 Questionnaire Development and Validation

The study questionnaire was developed following an extensive review of published literature related to plastic pollution, microplastic exposure, environmental health, and Knowledge–Attitude–

Practice (KAP) studies. The questionnaire comprised four sections, including socio-demographic characteristics, knowledge, attitude, and practice domains. Socio-demographic variables included age, gender, educational qualification, occupation, place of residence, state, district, and marital status.

The knowledge domain consisted of eight questions assessing awareness regarding plastic use, plastic-related environmental hazards, health impacts of plastics, microplastic exposure pathways, and the effects of microplastics on humans, animals, and the environment. The attitude domain included seven statements evaluating participants' perceptions regarding plastic pollution, health risks associated with microplastics, plastic reduction strategies, government regulations, educational interventions, and willingness to adopt environmentally sustainable practices. The practice domain comprised five questions assessing participants' day-to-day behaviours related to plastic use, waste disposal, use of reusable alternatives, and efforts to minimize plastic exposure.

The questionnaire was developed in English it was translated in local language by subject matter expert of different languages and later reverse translation of questionnaire from regional languages to English was done. The questionnaire of all the versions were validated by group of experts. The questionnaire was later screened on 5 to 10 participants per item of the questionnaire for KAP assessment (33).

Questionnaire was reviewed by experts in environmental health, public health, and clinical research to assess content validity and relevance. A pilot study was conducted among 361 participants to evaluate the clarity, comprehensibility, and feasibility of the questionnaire. Necessary modifications were made based on participant feedback before final administration.

1.4 KAP Scoring

2.4.1 Knowledge Score

The knowledge domain consisted of eight questions assessing participants' awareness regarding plastic pollution, microplastic exposure pathways, and associated environmental and health risks. Each correct response was assigned a score of one, while incorrect or "Don't know" responses were assigned a score of zero. The total knowledge score ranged from 0 to 8, with higher scores indicating better knowledge regarding microplastic exposure and its potential consequences.

Knowledge levels were categorized according to Bloom's cut-off criteria. Participants scoring 80–100% of the total score (7–8 points) were classified as having good knowledge, those scoring 60–79% (5–6 points) as having moderate knowledge, and those scoring below 60% (<5 points) as having poor knowledge.

2.4.2 Attitude Score

The attitude domain consisted of seven statements measured using a five-point Likert scale. Responses were scored as follows: strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly agree = 5. The total attitude score ranged from 7 to 35, with higher scores indicating a more positive attitude toward plastic pollution prevention and microplastic exposure reduction.

Participants scoring ≥80% of the maximum attainable score (28–35 points) were classified as having a positive attitude, those scoring 21–27 points as having a neutral attitude, and those scoring <21 points as having a negative attitude.

2.4.3 Practice Score

The practice domain consisted of five questions evaluating behaviours related to plastic use and exposure prevention. For positive practice items, responses of "Yes," "Sometimes," and "No" were assigned scores of 2, 1, and 0, respectively. For negatively worded practice questions, reverse scoring was applied. The total practice score ranged from 0 to 10, with higher scores indicating better preventive practices. Practice scores were categorized as good (8–10 points), moderate (5–7 points), and poor (<5 points).

Statistical Analysis

Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 31.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize socio-demographic characteristics and KAP responses, and results were presented as frequencies and percentages.

Knowledge, Attitude, and Practice (KAP) scores were calculated based on participants' responses and categorized into predefined levels. Knowledge scores were classified as good, moderate, and poor knowledge, attitude scores as positive, neutral, and negative attitude, and practice scores as good, moderate, and poor practice.

Associations between socio-demographic variables and KAP categories were assessed using the Chi-square (χ^2) test. Statistical significance was considered at a p-value < 0.05 with a 95% confidence interval (CI).

3.0 RESULT

3.1 Socio-Demographic Characteristics

A total of 361 participants were included in the analysis. The socio-demographic characteristics of the study population are presented in Table 1.

Participants were recruited from 18 Indian states, providing broad geographic representation. Rajasthan contributed the highest proportion of participants (40.44%), followed by Maharashtra (19.67%), Bihar (9.14%), and Haryana (8.31%) (Figure 1). As this was a pilot study, the sample mainly comprised educated and urban participants, with limited representation from other population groups. A larger nationwide study involving a more diverse population is currently underway, and the findings may differ with broader representation.

3.2 Knowledge Regarding Microplastic Exposure

Nearly half of the participants (48.2%) reported daily use of plastic products. Awareness of plastic-related environmental and health hazards was high, with 93.1% recognizing harmful effects and 97.2% identifying plastic pollution as a major environmental issue. Most respondents correctly identified the impacts of microplastics on humans, animals, and the environment (85.3%) and recognized multiple exposure routes (76.7%) (Table 2).

3.3 Attitudes Toward Microplastic Pollution

Participants generally demonstrated favourable attitudes toward reducing plastic pollution. More than 90% supported reducing plastic consumption, increasing public awareness, and strengthening regulations on plastic use and waste management (Table 3).

3.4 Practices Related to Plastic Use and Microplastic Exposure

While 71.2% reported environmentally responsible behaviours, only 47.6% regularly practiced plastic-reduction measures. Most participants supported awareness initiatives (96.7%), and 78.1% expressed willingness to modify their behaviour to reduce microplastic exposure (Table 4).

3.5 Overall Knowledge, Attitude, and Practice Scores

Overall, 53.5% of participants had moderate knowledge, 42.7% had poor knowledge, and 3.9% had good knowledge. Positive attitudes were observed in 35.5% of respondents, while 39.1% showed negative attitudes. Poor practices predominated (56.0%), with only 10.0% demonstrating good practices. These findings highlight a gap between awareness and the adoption of preventive behaviours related to microplastic exposure. (Figure 2).

3.6 Association of Socio-Demographic Characteristics with KAP Scores

No significant associations were observed between demographic variables and knowledge scores (all $p > 0.05$). Positive attitude was significantly associated with place of residence ($p = 0.002$), with urban participants demonstrating more positive attitudes than rural participants. No significant associations were found between gender or educational status and any KAP domain. (Table 5)

4.0 Discussion

Microplastics and nanoplastics have emerged as contaminants of global environmental and public health concern due to their widespread occurrence in ecosystems, food chains, drinking water, and human biological samples (34). Although literature has documented the presence of microplastics in blood (20), placenta (21), lung tissue (22), aqueous humour (23), amniotic fluid and (24), feces (25), urine (26), stool (27), semen (28), Liver tissue (29) and menstrual blood (30). Lack of information available regarding public awareness, perceptions, and preventive behaviours related to microplastic exposure, particularly in developing countries such as India. Therefore, the present study aimed to assess the knowledge, attitudes, and practices (KAP) regarding microplastic exposure among a geographically diverse Indian population and identify socio-demographic factors associated with KAP outcomes.

The present study generated three important findings. First, awareness regarding plastic pollution and its harmful effects on human health and the environment was relatively high among educated participants. Second, despite this awareness, only a small proportion of respondents demonstrated good knowledge regarding microplastic exposure and associated risks. Third, preventive practices remained inadequate, indicating a substantial gap between awareness and behavioural adoption. Collectively, these findings suggest that although concerns regarding plastic pollution are increasingly recognized, translation of knowledge into sustainable behavioural practices remains minimal

A notable observation was the high level of awareness regarding the adverse effects of plastic pollution. More than 90% of participants recognized that plastics can be harmful, and a large majority acknowledged that microplastics may affect humans, animals, and the environment. Furthermore, over three-quarters correctly identified multiple routes of exposure, including contaminated food, drinking water, inhalation, and cosmetic products. These findings are consistent with those reported by Enyoh et al.,2020 (35), who observed increasing public awareness of plastic pollution among community

populations following extensive media coverage and environmental campaigns. Similarly, de Sousa et al.,2023 (36) reported that concerns regarding plastic waste and environmental contamination have increased substantially over the past decade, particularly among younger and urban populations. The growing visibility of plastic pollution in public discourse, combined with increasing scientific attention, may explain the relatively high awareness observed in the present study.

Despite this encouraging level of awareness, only 3.9% of participants achieved good knowledge scores, whereas more than half demonstrated moderate knowledge and approximately 43% exhibited poor knowledge. These findings suggest that awareness of plastic pollution does not necessarily equate to an understanding of microplastic exposure pathways, biological accumulation, and potential health consequences. Similar findings were reported by Suman et al.2026., (37) who found that while participants were familiar with the term "microplastics," detailed knowledge regarding sources of exposure and associated health risks remained limited. The difference in our study may be because information about microplastics is still developing, and there is limited simple and reliable public health information available for people to understand the risks. As scientific research continues to identify microplastics in various human tissues and biological fluids, effective communication of these findings to the public becomes increasingly important.

Participants generally demonstrated favorable attitudes toward environmental protection and plastic reduction strategies. Most respondents agreed that plastic pollution is a serious environmental issue, supported stronger governmental regulations, and endorsed educational initiatives aimed at reducing plastic consumption. These findings are consistent with those reported by Hasan et al 2026., (38), who observed strong public support for policy interventions targeting plastic waste reduction and environmental sustainability. Likewise, Dowarah et al., 2022 (39), found that individuals with greater awareness of environmental pollution were more likely to support regulatory actions and community-based environmental programs. The positive attitudes observed in the present study suggest a growing societal recognition of the environmental burden posed by plastic pollution and indicate public readiness to support preventive interventions.

However, despite favorable attitudes and relatively high awareness, preventive practices remained poor. Only 10% of participants demonstrated good practice scores, while more than half exhibited poor practices related to plastic use and exposure prevention. This finding highlights a significant knowledge–practice gap and represents one of the most important observations of the present study. Similar discrepancies between awareness and behaviour have been documented by Raheel et al 2026 (40)., who reported that environmental knowledge alone was insufficient to drive sustained behavioural change. Likewise, Khorsandi et al., 2025 (41) found that although individuals expressed concern regarding environmental pollution, adoption of environmentally responsible practices remained limited. Several factors may explain this phenomenon. Plastic products remain inexpensive, convenient, and widely accessible, making behavioural modification challenging while awareness of associated risks. In addition, inadequate recycling infrastructure, limited availability of affordable alternatives, and deeply ingrained consumption habits may Challenge the adoption of environmentally sustainable practices.

The socio-demographic analysis revealed that place of residence and marital status significantly influenced attitude scores, whereas marital status was also associated with practice scores. Urban participants demonstrated more positive attitudes toward microplastic pollution awareness and practice than rural participants. This finding is consistent with reports by Sheasby et al 2023., (42), who observed higher environmental awareness and stronger pro-environmental attitudes among urban populations due to greater access to educational resources, media exposure, and environmental campaigns. Urban residents may also experience more visible consequences of plastic pollution, thereby increasing environmental concern. Conversely, no significant association was identified between place of residence and knowledge scores, suggesting that awareness of plastic pollution may be widely disseminated across both urban and rural communities.

No significant associations were observed between educational status, gender, and knowledge scores. This finding differs from the observations of Prawiroharjo et al., (44) who reported higher environmental knowledge among individuals with advanced educational attainment. The absence of such an association in our study may reflect the increasing influence of social media, digital communication platforms, and public awareness campaigns, which facilitate widespread dissemination of environmental information regardless of formal educational background.

The findings of this study have important public health implications. Emerging evidence suggests that chronic exposure to microplastics may contribute to several health issues. Public awareness programs

should move beyond general environmental messaging and focus on practical strategies for reducing personal exposure, including minimizing single-use plastic consumption, promoting reusable alternatives, avoiding heating food in plastic containers, and improving household waste segregation practices. Simultaneously, policymakers should strengthen regulations governing plastic production, disposal, and recycling while investing in sustainable alternatives and waste management infrastructure.

Limitation of the study

First, because it was a cross-sectional study, it cannot determine cause-and-effect relationships. Second, the data were self-reported, which may have resulted in recall bias. As this was a pilot study, most participants were educated and lived in urban areas, so the findings may not represent the entire Indian population. Although participants were recruited from 18 Indian states, rural communities and less educated groups were underrepresented. Therefore, the findings should be interpreted with caution. A larger nationwide study including more diverse populations is currently underway, and the results may differ with broader representation.

Future research should employ nationally representative sampling frameworks to better characterize public awareness and behavioural patterns regarding microplastic exposure in India. Longitudinal studies are needed to evaluate changes in knowledge and behaviour over time, while intervention-based studies should assess the effectiveness of educational and behavioural modification programs. Furthermore, large sized assessment of the KAP questionnaire is recommended to understand the importance of need of strict plastic ban policy.

6.0 Conclusion

Although awareness regarding plastic pollution and microplastic exposure was relatively high among participants, substantial deficiencies remained in detailed knowledge and preventive practices. The significant gap between awareness and behavioural implementation underscores the need for targeted educational interventions, public health campaigns, improved waste management systems, and stronger environmental policies. Addressing these challenges will be critical for reducing microplastic exposure, promoting sustainable environmental practices, and protecting both human and ecosystem health in India.

DECLARATIONS

Ethics Approval and Consent to Participate

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of NIMS University Rajasthan, Jaipur, India (Approval No.: IEC/P-1431/2026). Written informed consent was obtained from all participants prior to enrollment.

Consent for Publication

Not applicable.

Availability of Data and Materials

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

Competing Interests

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.

FUNDING

The authors received no specific funding for this work from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' Contributions

RMJ: Conceptualization, Methodology, Data Collection, Formal Analysis, Writing – Original Draft; **SD:** Study Design, Statistical Analysis, Data Interpretation, Writing – Review & Editing; **GCS:** Methodology, Supervision, Writing – Review & Editing; **BC:** Data Collection, Literature Review, Manuscript Preparation; **SJ**: Data Collection, Literature Review, Manuscript Preparation **AS:** Conceptualization, Project Administration, Critical Revision of Manuscript; **MS:** Conceptualization, Supervision, Critical Revision and Final Approval of Manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

The authors sincerely thank all participants who voluntarily participated in this study. The authors also acknowledge the support provided by NIMS University Rajasthan, Jaipur, India, during the conduct of this research.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely to improve language, grammar, readability, and manuscript organization. The authors carefully reviewed and edited the generated content and take full responsibility for the content of this publication.

REFERENCES

- Ritchie, H., & Roser, M. (2018). Plastic pollution. *Our world in data*.
- Kibria MG, Masuk NI, Safayet R, Nguyen HQ, Mourshed M. Plastic Waste: Challenges and Opportunities to Mitigate Pollution and Effective Management. Int J Environ Res. 2023;17(1):20. doi: 10.1007/s41742-023-00507-z. Epub 2023 Jan 20. PMID: 36711426; PMCID: PMC9857911.
- Geyer R, Jambeck JR, Law KL. Production, use, and fate of all plastics ever made. Sci Adv. 2017 Jul 19;3(7):e1700782. doi: 10.1126/sciadv.1700782. PMID: 28776036; PMCID: PMC5517107
- Azeem, I.; Adeel, M.Ahmad, M.A.; Shakoor, N.;Jiangcuo, G.D.; Azeem, K.; Ishfaq, M.;Shakoor, A.; Ayaz, M.; Xu, M.; et al.Uptake and Accumulation ofNano/Microplastics in Plants: ACritical Review. Nanomaterials 2021,11, 2935. https://doi.org/10.3390/nano11112935
- Soares, S., Serralha, F., Paz, M. C., Carriço, N., & Galatanu, S. V. (2024). Unveiling the data: An analysis of plastic waste with emphasis on the countries of the E³UDRES2 alliance. *Heliyon*, *10*(7).
- Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J. H., ... & Suh, S. (2020). Degradation rates of plastics in the environment. *ACS Sustainable Chemistry & Engineering*, *8*(9), 3494-3511.
- Dube, E., & Okuthe, G. E. (2023). Plastics and micro/nano-plastics (MNPs) in the environment: occurrence, impact, and toxicity. *International journal of environmental research and public health*, *20*(17), 6667.
- Li Y, Tao L, Wang Q, Wang F, Li G, Song M. Potential Health Impact of Microplastics: A Review of Environmental Distribution, Human Exposure, and Toxic Effects. Environ Health (Wash). 2023 Aug 10;1(4):249-257. doi: 10.1021/envhealth.3c00052. PMID: 39474495; PMCID: PMC11504192
- Nath S, Enerijiofi KE, Astapati AD, Guha A. Microplastics and nanoplastics in soil: Sources, impacts, and solutions for soil health and environmental sustainability. J Environ Qual. 2024 Nov-Dec;53(6):1048-1072. doi: 10.1002/jeq2.20625. Epub 2024 Sep 8. PMID: 39246015.
- Farooq, M. A., Hannan, F., Zou, H. X., Zhou, W., Zhao, D. S., Ayyaz, A., ... & Yan, X. (2025). Microplastics in soil–plant systems: impacts on soil health, plant toxicity, and multiomics insights. *Plant Cell Reports*, *44*(12), 283.
- Oliveri Conti G, Ferrante M, Banni M, Favara C, Nicolosi I, Cristaldi A, Fiore M, Zuccarello P. Micro- and nano-plastics in edible fruit and vegetables. The first diet risks assessment for the general population. Environ Res. 2020 Aug;187:109677. doi: 10.1016/j.envres.2020.109677. Epub 2020 May 20. PMID: 32454310.
- Duda, A., & Petka, K. (2025). The presence of micro-and nanoplastics in food and the estimation of the amount consumed depending on dietary patterns. *Molecules*, *30*(18), 3666.
- Ali N, Katsouli J, Marczylo EL, Gant TW, Wright S, Bernardino de la Serna J. The potential impacts of micro-and-nano plastics on various organ systems in humans. EBioMedicine. 2024 Jan;99:104901. doi: 10.1016/j.ebiom.2023.104901. Epub 2023 Dec 6. PMID: 38061242; PMCID: PMC10749881.
- Tyc, H. J., Kłodnicka, K., Teresińska, B., Karpiński, R., Flieger, J., & Baj, J. (2025). Micro-and nanoplastics as disruptors of the endocrine system—a review of the threats and consequences associated with plastic exposure. *International journal of molecular sciences*, *26*(13), 6156.
- Zurub, R. E., Cariaco, Y., Wade, M. G., & Bainbridge, S. A. (2024). Microplastics exposure: implications for human fertility, pregnancy and child health. *Frontiers in Endocrinology*, *14*, 1330396.
- Bossio, S., Ruffolo, S. A., Lofaro, D., Perri, A., & La Russa, M. F. (2025). Endocrine toxicity of micro-and nanoplastics, and advances in detection techniques for human tissues: a comprehensive review. *Endocrines*, *6*(2), 23.
- Fan, J., & Ha, Y. (2025). Micro-and nanoplastics and the immune system: mechanistic insights and future directions. *Immuno*, *5*(4), 52.
- Ma, Q., Lei, J., Pang, Y., Shen, Y., & Zhang, T. (2025). Neurotoxicity of Micro-and Nanoplastics: A Comprehensive Review of Central Nervous System Impacts. *Environment & Health*.
- Nabi, G., Aziz, T., & Lin, L. (2026). The bioaccumulation and carcinogenic potential of micro-and nanoplastics in humans. *Toxicological Research*, 1-15.
- Brits M, van Velzen MJM, Sefiloglu FO, et al. Quantitation of micro and nanoplastics in human blood by pyrolysis-gas chromatography–mass spectrometry. Microplast Nanoplast. 2024;4:12.
- Garcia MA, Liu R, Nihart A, El Hayek E, Castillo E, Barrozo ER, Suter MA, Bleske B, Scott J, Forsythe K, Gonzalez-Estrella J, Aagaard KM, Campen MJ. Quantitation and identification of

microplastics accumulation in human placental specimens using pyrolysis gas chromatography mass spectrometry. Toxicol Sci. 2024 Apr 29;199(1):81-88. doi: 10.1093/toxsci/kfae021. PMID: 38366932; PMCID: PMC11057519.

- Ragusa A, Svelato A, Santacroce C, Catalano P, Notarstefano V, Carnevali O, Papa F, Rongioletti MCA, Baiocco F, Draghi S, D'Amore E, Rinaldo D, Matta M, Giorgini E. Plasticenta: First evidence of microplastics in human placenta. Environ Int. 2021 Jan;146:106274. doi: 10.1016/j.envint.2020.106274. Epub 2020 Dec 2. PMID: 33395930.
- Chen Q, Gao J, Yu H, et al. An emerging role of microplastics in the etiology of lung ground glass nodules. Environ Sci Eur. 2022; 34:25.
- Zhu C, Cheng Y, Tang Y, Wu H, Liu Z. Changes of aqueous humor cytokine profiles of patients with high intraocular pressure after PPV for retinal detachment. Sci Rep. 2024 Jun 6;14(1):13044. doi: 10.1038/s41598-024-61913-7. PMID: 38844441; PMCID: PMC11156964.
- Zhang J, Wang L, Tsande L, et al. Occurrence of polyethylene terephthalate and polycarbonate microplastics in infant and adult feces. Environ Sci Technol Lett. 2021;8(11):989–994.
- Pironti C, Notarstefano V, Ricciardi M, Motta O, Giorgini E, Montano L. First evidence of microplastics in human urine, a preliminary study of intake in the human body. Toxics[Internet]. 2022 Dec 30;11(1):40. Available from: https://doi.org/10.3390/toxics11010040.
- Schwabl, P., Koeppel, S., Koenigshofer, P., Bucsics, T., Trauner, M., Reiberger, T., et al., 2019. Detection of various microplastics in human stool: a prospective case series. C9
- Montano L, Giorgini E, Notarstefano V, Notari T, Ricciardi M, Piscopo M, et al. Raman Microspectroscopy evidence of microplastics in human semen. The Science of the TotalEnvironment [Internet]. 2023 Jul 31;901:165922. https://doi.org/10.1016/j.scitotenv.2023.165922
- Horvatits, T., Tamminga, M., Liu, B., Sebode, M., Carambia, A., Fischer, L., et al., 2022. Microplastics detected in cirrhotic liver tissue. E Bio Medicine 82, 104147. https:// doi.org/10.1016/j.ebiom.2022.104147.
- Sharma GC, Kumar N, Devrukhkar D, Joshi RM, Debnath S, Chaturvedi B, Rajotiya S, Mishra S, Sharma A, Singh M, Nathiya D, Tomar BS. Human reproductive exposure to microplastics: A multi-technique analytical study of menstrual and amniotic fluids. NanoImpact. 2026 Mar 10;42:100617. doi: 10.1016/j.impact.2026.100617. Epub ahead of print. PMID: 41819283
- Amobonye, A., Bhagwat, P., Raveendran, S., Singh, S., & Pillai, S. (2021). Environmental impacts of microplastics and nanoplastics: a current overview. *Frontiers in microbiology*, *12*, 768297.
- Jiang, B., Kauffman, A. E., Li, L., McFee, W., Cai, B., Weinstein, J., ... & Xiao, S. (2020). Health impacts of environmental contamination of micro-and nanoplastics: a review. *Environmental health and preventive medicine*, *25*(1), 29.
- Sharma, A., Debnath, S., Chaturvedi, B., Singh, A. K., Rajotiya, S., Mishra, S., ... & Singh, M. (2026). Development and psychometric validation of the diet and physical activity questionnaire for patients with diabetes (DPQD). *Discover Public Health*, *23*(1), 332.
- Yee MS, Hii LW, Looi CK, Lim WM, Wong SF, Kok YY, Tan BK, Wong CY, Leong CO. Impact of Microplastics and Nanoplastics on Human Health. Nanomaterials (Basel). 2021 Feb 16;11(2):496. doi: 10.3390/nano11020496. PMID: 33669327; PMCID: PMC7920297.
- Enyoh CE, Shafea L, Verla AW, Verla EN, Qingyue W, Chowdhury T, Paredes M. Microplastics Exposure Routes and Toxicity Studies to Ecosystems: An Overview. Environ Anal Health Toxicol. 2020 Mar;35(1):e2020004. doi: 10.5620/eaht.e2020004. Epub 2020 Mar 25. PMID: 32570999; PMCID: PMC7308665.
- de Sousa FDB. Consumer Awareness of Plastic: an Overview of Different Research Areas. Circ Econ Sustain. 2023 Mar 25:1-25. doi: 10.1007/s43615-023-00263-4. Epub ahead of print. PMID: 37360378; PMCID: PMC10039692.
- Suman, Thodhal Yoganandham, Keerthiga Rajendiran, and Ihn-Sil Kwak. "Microplastics and nanoplastics in human health: a comprehensive review of exposure pathways, cellular mechanisms, and toxicological implications." *Archives of Toxicology* 100, no. 3 (2026): 811-836.
- Hasan MR, Saha A, Chowdhury MSA, Chakraborty S, Hossain I. Determinants of Plastic Waste Awareness, Preventive Practices, and Health Symptoms: An Urban-Rural Comparative Cross-Sectional Study in Bangladesh. Health Sci Rep. 2026 Apr 19;9(4):e72363. doi: 10.1002/hsr2.72363. PMID: 42011269; PMCID: PMC13092224.
- Dowarah, K., Duarah, H., & Devipriya, S. P. (2022). A preliminary survey to assess the

awareness, attitudes/behaviours, and opinions pertaining to plastic and microplastic pollution among students in India. *Marine Policy*, *144*, 105220.

- Raheel, H., Ferguson, A., Leslie, S. L., Guardado-Menjivar, V., Chen, K., Merceron, A., ... & Thompson, L. M. (2026). Behavioral interventions related to plastic waste management in low-and middle-income countries: a systematic review using the behavior change wheel and the theoretical domains framework. *Environmental Research Letters*, *21*(5), 053003..
- Khorsandi, J., Blank, L., Momchilov, K., Dagovetz, M., & Batra, K. (2025). From ocean to table: how public awareness shapes the fight against microplastic pollution. *Urban Science*, *9*(10), 418.
- Sheasby, J., & Smith, A. (2023). Examining the factors that contribute to pro-environmental behaviour between rural and urban populations. *Sustainability*, *15*(7), 6179.
- Harvey, N. E., Ringer, L. C., Stapleton, D., Simmons, J., Jobst, K. J., & Cahill, L. S. (2025). Opinions of parents and parents-to-be on micro-and nanoplastics: knowledge and willingness to implement change in Canada. *Microplastics and Nanoplastics*, *5*(1), 10.
- Prawiroharjo, P., Putri, A. N. M., Ikhromi, N., Fakhri, A., Divina, E., Permata, R., ... & Zulys, A. (2026). Frequent Plastic Usage Behavior and Lack of Microplastic Awareness Correlates with Cognitive Decline: A Cross-Sectional Survey. *International Journal of Environmental Research and Public Health*, *23*(1), 67.