



Research Article

Estimation of Dietary Microplastic Ingestion: Empirical Analysis for Delhi-NCR

Paridhi Tyagi Paliwal* 

Department of Science, G. D. Goenka Signature School, Gurugram, India

Abstract

Microplastics (MPs) are increasingly detected in food products and may contribute to human exposure through daily dietary consumption. However, information on dietary MP exposure in Delhi-NCR, India, remains limited. This study aimed to investigate MP contamination in commonly consumed food items and assess their potential contribution to dietary exposure among residents of Delhi-NCR. An online survey involving 175 participants was conducted to determine the consumption frequency of eight food items: potato, egg, apple, potato chips, whole wheat flour, instant noodles, honey, and chicken. Food samples were analyzed using acetone-assisted extraction and compound light microscopy at 10× and 40× magnification. Estimated dietary exposure was assessed by combining measured MP concentrations with reported consumption frequencies and standard serving sizes. MP concentrations varied across the analyzed food items, ranging from 0 particles g⁻¹ in glass-packaged honey to 15 particles g⁻¹ in whole wheat flour. Whole wheat flour exhibited the highest MP concentration and was the most frequently consumed food item among the participants. Potato chips and instant noodles also showed relatively high MP concentrations, whereas honey showed no detected MPs in the analyzed sample. These findings indicate that commonly consumed staple foods may represent important contributors to dietary MP exposure in Delhi-NCR. The study highlights the need for routine monitoring of MPs in staple foods, improved contamination-control measures during food production and processing, and further research using polymer-confirmation techniques to strengthen the assessment of dietary MP exposure in India.

Keywords

Microplastics, Dietary Exposure, Food Contamination, Estimated Annual Ingestion, Light Microscopy, Public Health

1. Introduction

1.1. Background and Context

Plastic use boomed for its strength, flexibility, and affordability. Consequently, the annual production of plastic increased significantly to 30 million tonnes in 1988 and then to 359 million tonnes by 2018. However, this wonder material

has had unintended consequences [1]. MPs are extremely small pieces of plastic debris (ranging from 1 nm to 5 mm) that have emerged as a significant environmental concern [2]. They are placed in two categories, primary MPs and secondary MPs. Primary MPs are intentionally manufactured, and secondary MPs are a result of the weathering of plastic prod-

*Correspondence: Paridhi Tyagi Paliwal (Code.paridhi@gmail.com)

Received: 3 September 2026; Accepted: 23 September 2026; Published: 29 October 2026



Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

ucts. The fraction of MPs in the total weight of plastic accumulation around the world is predicted to be 13.2% by 2060.

1.2. Problem Statement

MPs have been detected pervasively in all environmental sectors, including water [3], K et al., 2020 [4], air [5, 6], and food sources [7]. One method of exposure to MPs is through diet, via contaminated food and drinking water. Emerging research has linked MP exposure to various adverse health outcomes, including respiratory disorders (asthma, hypersensitivity pneumonitis), neurological effects (fatigue, dizziness), gastrointestinal inflammation (inflammatory bowel disease), and detriment in gut microbiota composition [8]. Studies have also detected MPs in human tissues and biological fluids, including blood [9], lung tissue [10], and breastmilk [11], indicating systemic distribution and potential transfer to vulnerable populations.

Delhi is the capital of India, the largest country by population. Despite growing concern, comprehensive studies on dietary exposure to MPs in Delhi and NCR remain highly limited. Existing comprehensive research has primarily focused on coastal regions with high seafood consumption, a major source of MP exposure [12, 13]. Or examined isolated food items, such as salt [14, 15] or milk [16, 17], rather than providing an all-encompassing assessment of dietary exposure [18]. This fragmented approach limits our understanding of overall MP ingestion patterns across India's diverse food systems.

Most previous studies have investigated MP contamination in individual food commodities such as seafood, milk, salt, or drinking water. While these studies have improved our understanding of contamination in specific food products, but they do not provide an estimate of cumulative dietary exposure arising from the consumption of multiple foods. As individuals consume a wide variety of food items every day, integrated exposure assessments are essential for understanding realistic human exposure levels.

1.3. Research Significance

To address this research gap, this study combines survey data and empirical food analysis to estimate dietary MP expo-

sure in Delhi-NCR. First, we conducted a survey of 175 participants in Delhi-NCR to quantify the frequency of consumption of commonly consumed foods. Second, we analysed MP content through microscopy in three food categories: packaged foods (atta, honey), whole foods (apple, potato, egg, chicken), and ultra-processed foods (instant noodles, potato chips).

This study is the first comprehensive assessment of dietary MP exposure in Delhi-NCR, a region of significant public health importance as India's capital and largest metropolitan area.

2. Methodology

2.1. Survey Design and Data Collection

A survey was conducted via an online Google Form distributed to residents of Delhi-NCR. The survey collected age demographic information and consumption frequency data for each of the 8 food items tested. 175 participants completed the survey from 28th March 2026 to 4th April 2026. Our findings largely align with previous studies conducted in Haryana and Delhi NCR [19, 20].

2.2. Sample Selection

There were 2 criteria for chosen food items: degree of consumption and presence of MPs. Apple, chicken, egg, wheat, and honey were chosen for their high consumption rates, while chips and noodles were chosen for their high levels of MPs. Food samples representing three categories were purchased from Blinkit, an online grocery delivery platform operating in Delhi-NCR. Samples included whole wheat flour, honey, chicken, potato, apple, egg, instant noodles, and potato chips. All samples were tested immediately upon arrival at the laboratory. Apple and potato samples were washed with distilled water prior and tested with skin on. Instant noodles, chicken, and egg samples were tested uncooked. The selected food samples were grouped into three categories packaged foods, whole foods, and ultra-processed foods based on their nature and level of processing. The classification of all samples included in the study is given in Table 1.

Table 1. Classification of the selected food samples according to food category used for microplastic analysis.

Packed foods	Whole foods	Ultra processed foods
Packed whole wheat flour	Potato	Instant noodles
Packed honey	Apple	Potato chips
Pre-cut chicken	Egg	

Apple and potato samples were washed with distilled water prior to testing with the skin on. Instant noodles, chicken, and egg samples were tested uncooked.

2.3. Laboratory Procedure

All laboratory analyses were done using glass laboratory equipment to reduce the risk of secondary plastic contamination during sample preparation and handling. Before each experiment all glassware was thoroughly cleaned with ethanol followed by distilled water and allowed to air dry. Approximately 5 g of each food sample was weighed into a clean 50 mL glass beaker. To facilitate the extraction of potential MP particles, 5 mL of acetone and 10 mL of distilled water were added to each sample. The mixture was gently stirred using a glass rod to ensure uniform mixing and was then allowed to stand undisturbed for 60 minutes to promote particle separation.

After incubation, the samples were centrifuged at 5,000 rpm for 10 minutes. The resulting supernatant was carefully transferred into pre weighed glass Petri dishes using a micropipette, ensuring that the sediment remained undisturbed. The collected supernatant was then dried in a hot-air oven maintained at 60°C until complete evaporation of the liquid. After drying, the Petri dishes were reweighed to determine the mass of the recovered residue.

To prepare the samples for microscopic examination, approximately 200 µL of distilled water was added to each dried residue, and the contents were gently mixed to obtain a uniform suspension. A small aliquot of the suspension was transferred onto a clean glass microscope slide, covered with a cover slip, and examined under a compound light microscope at magnifications of 10× and 40×. Representative images of the observed particles were captured using a smartphone camera attached to the microscope eyepiece for documentation.

MP were identified based on their optical and morphological characteristics, including transparency, distinct edges, irregular or fibrous morphology, and the absence of visible cellular or biological structures. Particle morphology was further classified into fibers, fragments, and irregular particles wherever applicable. Although polymer composition could not be confirmed using spectroscopic techniques such as FTIR or Raman spectroscopy, the adopted microscopic identification procedure has been widely employed as a preliminary screening

method for MP detection in food samples.

2.4. Estimated Dietary Ingestion of Microplastics

The EAI of MPs was calculated using Equation (1), which combines the measured MP concentration in each food item, the annual consumption frequency and the recommended serving size [21].

$$\text{EAI} = \text{MMPs} * \text{IR} * \text{S} \quad (1)$$

where:

EAI: estimated annual ingestion

MMPs: Mean microplastics per gram of apple (8), potato (7), chicken (5), egg (4), noodles (10), chips (12), honey (0), and whole wheat (15)

IR: weighted average frequency of consumption per year for apple (230.011), potato (190.677), chicken (45.896), egg (77.006), noodles and chips (55.072), honey (35.899), and whole wheat (310.458).

S: Recommended serving size in grams for apple (55g), potato (89g), chicken (35g), egg (30g), noodles (70.5g), chips (28g), honey (21g), and whole wheat (303g).

Noodles and chips were grouped together as ‘packaged foods’ for the purposes of the survey; they share the same IR. The IR was split during calculation. The EAI values are estimates based on self-reported consumption frequency and MP concentrations found. Individual exposure may vary significantly based on food source, preparation method, and portion size. Descriptive statistical analyses were performed using Microsoft Excel. Mean values, percentages, and estimated annual ingestion were calculated for each food category.

3. Results

3.1. Survey Results

To assess potential dietary exposure to MPs, respondents were asked how frequently they consumed eight food categories known to pose a risk of MP contamination.

Table 2. Frequency of consumption.

Food item	Never	Monthly	Every 2 weeks	Weekly	Daily	Mean
Fruit	1.1%	7.4%	3.4%	29.7%	58.3%	4.36
Leafy greens	4%	8%	8%	70.3%	9.7%	3.74
Roots and tubers	1.1%	2.9%	2.9%	48%	45.1%	4.33
Meat	54.3%	8%	6.3%	22.9%	8.6%	2.24

Food item	Never	Monthly	Every 2 weeks	Weekly	Daily	Mean
Eggs	38.9%	12%	7.4%	25.1%	16.6%	2.69
Processed foods	13.7%	30.3%	17.7%	29.7%	8.6%	2.89
Honey	38.3%	34.3%	8.6%	12.6%	6.3%	2.15
Whole wheat	1.1%	2.3%	4%	9.1%	83.4%	4.71

Table 2 presents the frequency distribution and mean consumption scores for each item among the 175 participants. As the data indicate, whole wheat (atta) was the most frequently consumed item ($M = 4.71$), followed by fruit ($M = 4.36$) and roots and tubers ($M = 4.33$), suggesting that plant-based staples form the core of respondents' diets. Processed foods,

which are widely associated with MP contamination through packaging, recorded a mean of 2.89, reflecting moderate consumption among the sample. The distribution of consumption frequency across the eight food categories is further shown in Figure 1, highlighting differences in dietary habits among the respondents.

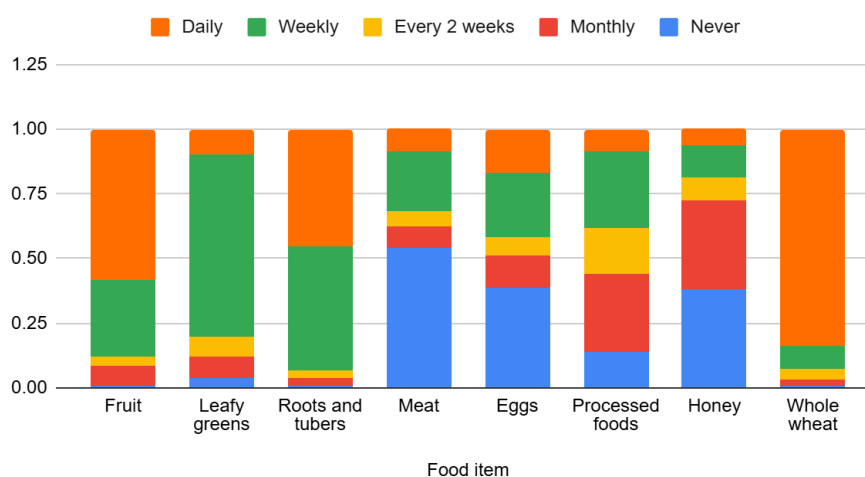


Figure 1. Frequency of consumption per food item.

Figure 1 and Figure 2 shows the variation in frequency across all eight food categories. This distribution is significant in the context of MP exposure, as higher consumption frequency of certain food groups may correspond to greater cumulative intake of MP particles.

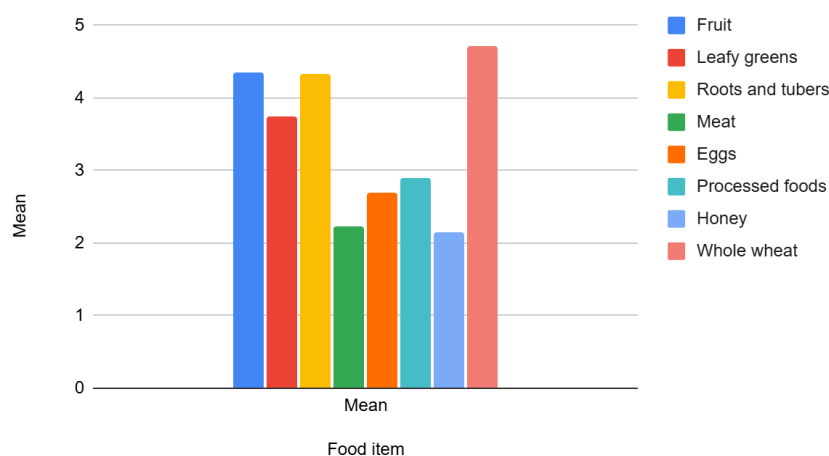


Figure 2. Mean score per food item.

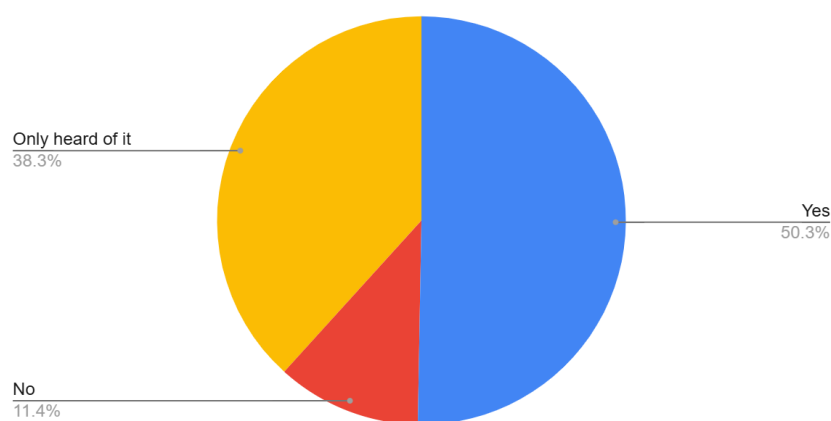


Figure 3. Answer to are you aware about microplastics in food.

In addition to dietary patterns, the survey examined respondents' awareness of MP presence in food. **Figure 3** presents the distribution of responses among the 175 participants. As illustrated, approximately half of the respondents (50.3%) reported being aware of MPs in food, while 38.3% had only heard of the issue without having detailed knowledge. A

smaller proportion (11.4%) was entirely unaware. These findings suggest that while general awareness exists within the sample, there is a significant (nearly half) lack of comprehensive knowledge in residents of Delhi NCR. **Figure 4** shows the sources of awareness, with participants asked to tick

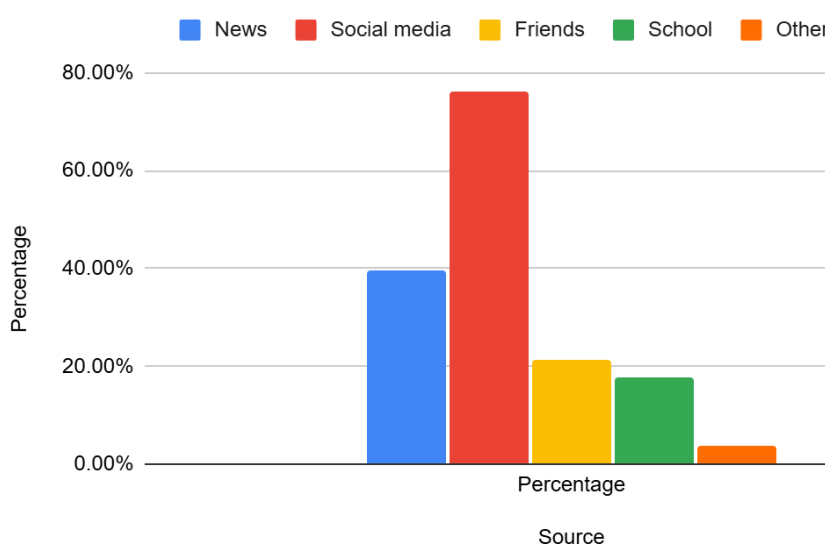


Figure 4. Sources of awareness.

All that apply. As shown, social media played a significant role in spreading awareness (76.3%), nearly double that of news channels (39.7%).

3.2. Microscopic Observation of Food Items

3.2.1. Potato

The MP content was found to be 7 per gram. Each was small and spherical, with a distinct dark outline. Potato contamination has been found to originate in the agricultural process, through the pollution of irrigation water, soil, and the atmos-

phere. MP levels also varied by site, and a connection was observed between MP abundance and low potato yield [22]. Samples were tested, washed and with the peel on to reflect typical consumption habits.

3.2.2. Egg

Egg had 4 MPs per gram. The shape was small and irregular, some having a thin black outline.

Previous studies validate our findings by detecting MP presence on both yolk and whites of the egg, with cooking not showing any significant change. The most common type found in these studies was PE [23]. The only channel for MPs

to enter eggs is through the hen, which can ingest them via feed, water, litter, and environment [24].

3.2.3. Apple

Apple contained 8 MPs per gram, each with a medium-sized, elongated, fiber like shape. Previous data have shown the presence of MPs in apples, most commonly in the form of PE, PP, and PET. Previous studies also suggest that MPs of this size would not be allowed to pass through the plant xylem transport system, suggesting that fresh vegetables and fruits could be contaminated during the production phase, during agricultural activities, and during transport [21]. However, despite thoroughly washing the sample with distilled water, significant levels of MPs were found. This suggests that simple washing alone cannot remove the MP content introduced by agricultural activity and transport. These findings shows that post-harvest washing alone may not be sufficient to eliminate MP contamination, highlighting the importance of reducing contamination during agricultural production and handling.

3.2.4. Chips

For the potato chip sample, a high 12 MPs/g was found. Each was small, circular, and most were dark in colour. Soil and water contamination [25], and packaging shedding from mechanical processing as well as plastic packaging [26] can contribute to the high MP content.

3.2.5. Wheat

Wheat flour was the most surprising sample out of the 8, with a significant 15 MPs per gram. The size ranged from small to medium, and the shape was irregular. Previous studies have suggested that prolonged use of organic fertilisers is a major driver of MP contamination in wheat crops [27, 28]. Additionally, previous research has found the MP quantity of wheat flour varies between branded and non-branded samples,

suggesting packaging and handling standards may also contribute [29]. Since wheat flour is consumed daily by most households in North India even moderate contamination levels can translate into considerable annual dietary exposure. This result identifies wheat flour as a priority food item for future monitoring programmes.

3.2.6. Instant Noodles

The MP content in uncooked noodles was 10 MP/g. The shape was small, irregular and transparent. Likely sources in uncooked noodles are the ultra-processing, industrial manufacturing and plastic seasoning packets [30].

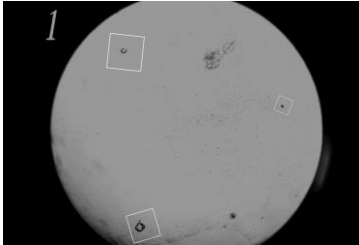
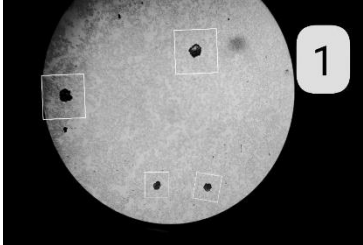
3.2.7. Honey

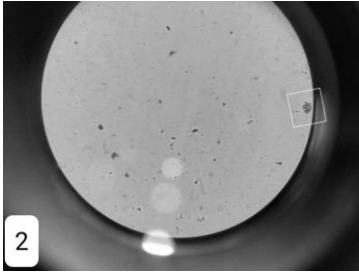
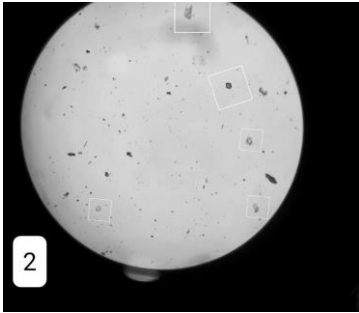
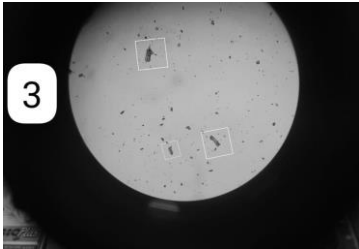
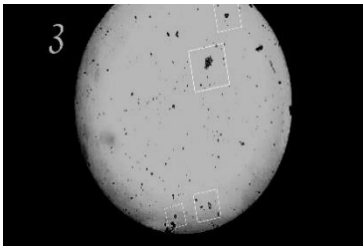
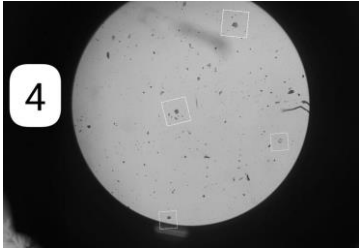
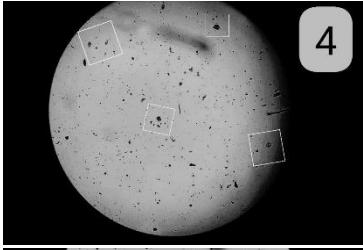
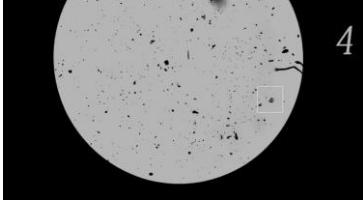
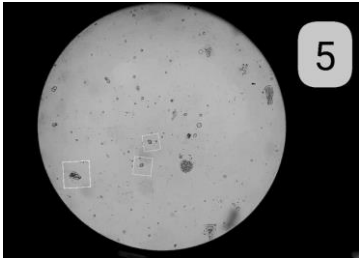
Research has shown 75% of honey samples contain honey, with a large majority of it being monofloral honey [31]. A common source is from packaging and transportation [32], however our sample was packaged in a glass jar rather than plastic. This resulted in no MP being detected in our sample. Although the observation is based on a single product, but it supports previous evidence suggesting that packaging material may influence MP contamination in food products.

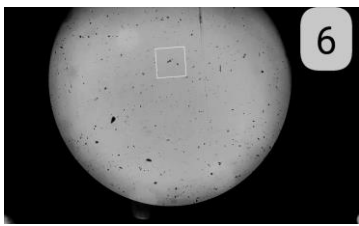
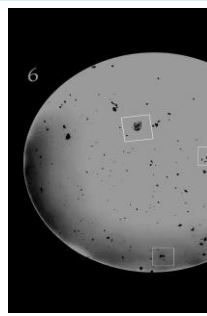
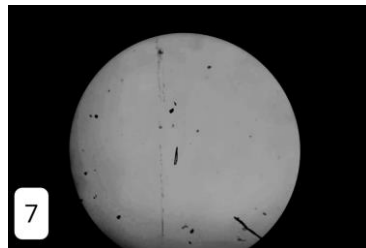
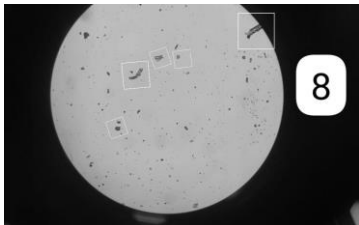
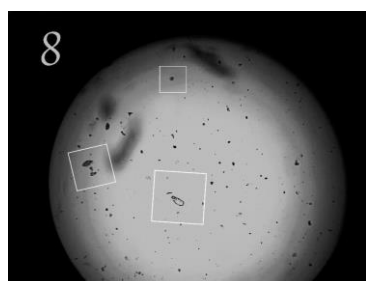
3.2.8. Chicken

Chicken has 5 MPs per gram, with an elongated, fibrous shape and a range of sizes. The pathways of contamination in poultry have been recognized to be from feed (e. g.: litter dust, plastic feeders), the environment (e. g.: soil and water contamination), or processing (e. g.: plastic materials in butchering, mechanical processing) [24]. Representative microscopic images of the MP particles observed in each food sample at 10x and 40x magnification was given in Table 3. These images showed the variation in particle morphology across different food categories.

Table 3. Microplastic under the Microscope.

S. no	Category	Sample	Image at 10x	Image at 40x
1	Whole foods	Potato		

S. no	Category	Sample	Image at 10x	Image at 40x
2	Whole foods	Egg		
				
3	Whole foods	Apple		
				 
4	Ultra-processed foods	Chips		
5	Packed foods	Wheat flour		

S. no	Category	Sample	Image at 10x	Image at 40x
6	Ultra-processed foods	Noodles		
7	Packed foods	Honey		
8	Packed foods	Chicken		

3.3. Estimated Dietary Intake

The experimentally determined MP concentrations together with the estimated annual ingestion values for each food item are summarized in Table 4. These data were used to identify the major contributors to dietary MP exposure.

Table 4. Microplastic concentration (MP/g) and EAI for the analysed food items.

S. NO.	Food item	MP per gram	EAI
1	Potato	7	118791.771
2	Egg	4	9240.72
3	Apple	8	101204.84
4	Chips	12	9252.096
5	Atta	15	1411031.61
6	Noodles	10	19412.88
7	Honey	0	0
8	Chicken	5	8031.8
	Total	61	1,676,965.717

The estimated annual ingestion values showed that dietary exposure is influenced not only by MP concentration but also

by consumption frequency. Although potato chips and instant noodles have relatively high contamination levels but their contribution to annual exposure remained considerably lower than wheat flour because they were consumed less frequently

by participants. The variation in MP concentration among the analysed food items was shown in Figure 5. Whole wheat flour exhibited the highest concentration, followed by potato chips and instant noodles.

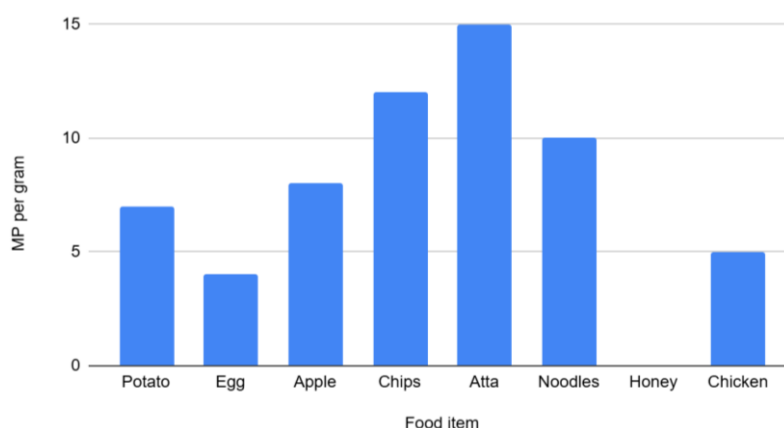


Figure 5. MP per gram per food item.

The contribution of each food item to the estimated annual ingestion of microplastics is presented in Figure 6.

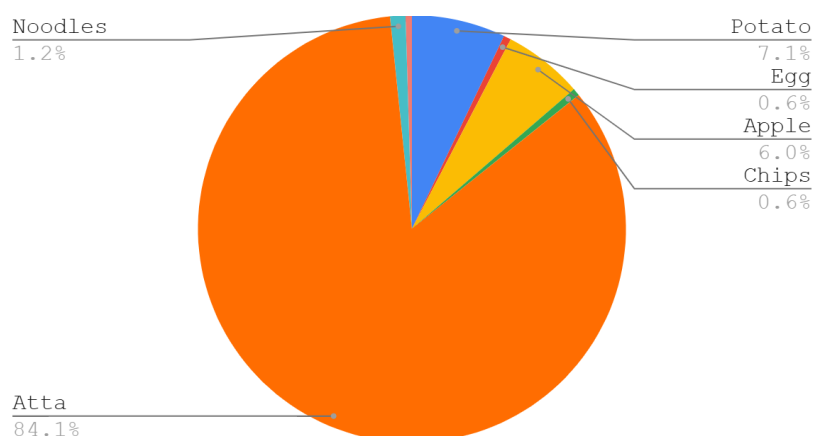


Figure 6. Comparison of average EAI per food item.

The estimated annual ingestion is approximately 1.7 million MPs per person, or roughly 4,594 per day. As seen in Figure 6, whole wheat dominates at 84.1% of total EAI driven by its very high MP concentration (15/g) combined with the highest consumption rate. Apple and potato consumption is higher than that of packaged foods, due to an overall higher consumption rate.

4. Discussion

4.1. Overview of Findings

This study estimated that an average Delhi-NCR resident ingests approximately 1.68 million MP particles annually

through diet alone or approximately 4,594 particles per day. This figure is consistent with the upper range of estimates reported in comparable studies. Aydin et al. (2023), studying dietary exposure in Turkey using a similar food-basket approach, reported estimated annual ingestions of 1-2 million particles for adults consuming high-contamination diets, lending cross-regional credibility to the present findings [21].

The wide variation in MP concentration across food items from 0 MP/g in honey to 15 MP/g in whole wheat flour reflects the diverse contamination pathways acting at different stages of food production, processing, and packaging. This underscores the limitation of single-food or single-source assessments and validates the multi-item approach adopted in this study.

4.2. Whole Wheat Flour as the Dominant Exposure Source

Whole wheat flour (atta) emerged as by far the most significant contributor to estimated dietary MP ingestion, accounting for 84.1% of total EAI. This dominance reflects both the high measured MP concentration (15 MP/g) and the extremely high consumption frequency observed in the survey (mean score 4.71; 83.4% of respondents consuming it daily). For a staple crop consumed in this volume, even modest contamination levels can translate into disproportionately high cumulative exposure.

These results are consistent with recent literature. Aysha et al. (2024) identified significant MP contamination in commercial wheat flours, noting variation between branded and non-branded products and implicating both agricultural practices and packaging standards [29]. Sharma et al. (2025) identified prolonged use of organic fertilizers as a major driver of MP accumulation in wheat crops through soil uptake pathways [27]. Zhang et al. (2023) further corroborated that long-term application of organic compost introduces substantial MP loads to wheat-producing soils [28]. The present finding of 15 MP/g in flour, therefore, represents not an anomaly but a manifestation of well-documented upstream contamination. The practical implication is significant: a typical household consuming atta daily may be inadvertently the primary vehicle of MP ingestion, regardless of other dietary choices. This creates a strong argument for targeted regulatory monitoring of MP levels in staple flours sold in India. These findings showed that staple foods need greater attention in dietary MP research because of their frequent consumption may contribute more to long term exposure than foods with higher contamination but lower consumption frequency.

4.3. Whole Foods: Agricultural and Environmental Contamination Pathways

Among whole foods, apple (8 MP/g) and potato (7 MP/g) showed notably higher concentrations than egg (4 MP/g) and chicken (5 MP/g). For plant-derived foods, the predominant contamination pathway is environmental: MPs enter soil through degradation of plastic mulch films, irrigation with MP-laden water, and atmospheric deposition, and are subsequently absorbed or surface-deposited on the crop [33].

Critically, apple samples in this study were washed thoroughly with distilled water prior to analysis, yet retained 8 MP/g. This finding aligns with Aydin et al. (2023), who reported that MPs of the sizes commonly found in fruits would not typically be translocated through xylem tissue, suggesting that contamination is surface deposited during production, harvesting, or transport but is not removable by simple rinsing [21]. This is a practically important result for consumers who may assume washing provides adequate protection.

Potato contamination has been linked to MP-polluted irrigation water and atmospheric deposition at the agricultural site, with Chidewe (2025) noting a correlation between MP abundance and reduced potato yield [22]. For animal-derived foods, contamination enters through the food chain livestock and poultry ingesting MPs via feed or environment as well as during processing and packaging. Liu et al. (2022) confirmed the presence of MPs in both egg yolk and albumen, with cooking showing no significant reduction, consistent with this study's finding of 4 MP/g in raw egg [23].

4.4. Ultra Processed Foods and Packaging-Associated Contamination

Potato chips (12 MP/g) and instant noodles (10 MP/g) recorded the second and third highest concentrations in this study. For ultra-processed foods, contamination pathways are multifaceted: in addition to agricultural and ingredient-level contamination, the manufacturing process involves extensive contact with plastic machinery, conveyor belts, and processing equipment. Packaging itself represents an additional contamination route, as MPs can migrate from plastic packaging material into the food product a mechanism well-documented for both flexible and rigid plastic packaging.

The relatively lower EAI contribution of chips and noodles (despite high MP/g values) compared to wheat flour is explained entirely by consumption frequency: their shared survey category recorded a mean score of 2.89, far lower than that of atta or fruit. This highlights a key methodological consideration in dietary exposure studies MP concentration per gram alone is insufficient; exposure is always a product of concentration and consumption volume.

4.5. Honey and the Role of Packaging Material

Honey was the only food item in this study to record zero MPs detected. The sample was purchased in a glass jar, in contrast to all other packaged items. While this single observation does not constitute evidence of a causal relationship between glass packaging and absence of MPs, it is consistent with established findings that plastic packaging is a direct contamination route for food products.

This finding carries a practical implication that is accessible even at the consumer level where feasible, choosing products stored in glass rather than plastic may reduce dietary MP ingestion from packaging-associated sources. Future studies could explicitly compare matched food products in glass versus plastic packaging to quantify this effect. Observation also shows the potential role of packaging selection as a practical strategy for reducing dietary exposure to MPs. Future studies comparing identical products packaged in glass and plastic containers would provide stronger evidence regarding this relationship.

4.6. Public Awareness and Behavioural Implications

The survey revealed that approximately 50.3% of respondents were aware of MPs in food, 38.3% had heard of the issue without detailed knowledge, and 11.4% were entirely unaware. Social media was the dominant source of awareness (76.3%), nearly double the contribution of news channels (39.7%). This pattern reflects broader global trends in health information consumption among younger and urban demographics.

The awareness gap is significant in the context of exposure: the foods associated with highest estimated ingestion whole wheat flour, apple, and potato are precisely those that most consumers would not associate with plastic contamination, given that they are natural or minimally processed. This disconnect between perceived and actual risk underscores the importance of targeted public health communication strategies that address staple food contamination specifically, rather than focusing predominantly on single-use plastics or seafood, which dominate current public discourse on MPs.

4.7. Limitations and Future Directions

Several limitations of this study should be acknowledged. First, MP identification was based exclusively on optical microscopy and morphological characteristics (transparency, sharp edges, jagged texture). While this method is widely used in field studies, it does not allow for polymer-type identification. Future work should incorporate Fourier-Transform Infrared Spectroscopy (FTIR) or Raman spectroscopy to confirm the polymer identity of detected particles and distinguish true MPs from similarly appearing natural fibers or organic debris.

Second, the survey sample of 175 participants, while adequate for initial estimates, was distributed via an online Google Form, which introduces selection bias toward participants with internet access and may not fully represent the dietary patterns of lower-income or rural peri-urban residents within the Delhi-NCR area. Expanding sample size and using stratified sampling in future iterations would improve the representativeness of the consumption frequency data.

Third, the EAI model assumes uniform MP distribution within each food item and does not account for cooking-induced changes. Some cooking methods such as boiling, which introduces additional water contact may increase or modify MP content, while others may not. Future studies should test cooked versus uncooked samples to assess the effect of food preparation on actual ingestion. Fourth, the study's scope is limited to eight food items. A more comprehensive dietary exposure assessment would incorporate additional staples (rice,

lentils, cooking oil, drinking water) to provide a fuller picture of total dietary MP burden. Drinking water is a significant and well-documented MP exposure pathway that was not included in this study's EAI calculations.

Despite these limitations, this study provides a valuable foundational dataset for dietary MP exposure in Delhi-NCR and represents a replicable methodological framework that can be extended and refined. The finding that a single staple food whole wheat flour accounts for over 84% of estimated annual ingestion offers a clear and actionable priority for both future research and regulatory attention.

Improving public awareness alone is not sufficient to reduce exposure unless accompanied by regulatory measures and improvements throughout the food production chain. Therefore, both consumer education and policy interventions should be considered simultaneously.

4.8. Conclusion

This study demonstrates that dietary MP exposure in Delhi-NCR is substantial, with an estimated 1.68 million particles ingested per person per year through only eight commonly consumed food items. Whole wheat flour, the cornerstone of the North Indian diet, is the single largest contributor, driven by both high contamination levels and near-universal daily consumption. By contrast, the complete absence of MPs in glass-packaged honey, points to packaging material as a modifiable risk factor. These findings call for the integration of MP monitoring into India's existing food safety regulatory frameworks, investment in MP-reduction strategies at the agricultural and processing levels, and broader public education regarding contamination pathways in everyday staple foods.

Abbreviations

MP	Microplastic
MMPs	Mean Microplastics
EAI	Estimated Annual Ingestion
FTIR	Fourier-Transform Infrared Spectroscopy
IR	Weighted Average Frequency
S	Recommended Serving Size

Author Contributions

Paridhi Tyagi Paliwal: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflicts of interest.

Appendix

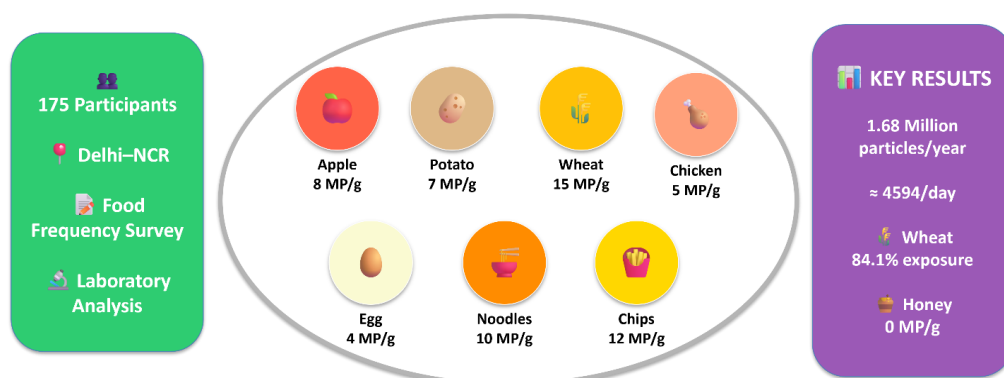


Figure 7. Graphical Abstract.

References

- [1] S. Adhikari, V. Kelkar, R. Kumar, R. U. Halden, Methods and challenges in the detection of microplastics and nanoplastics: a mini-review, *Polym. Int.* 71 (2022) 543–551. <https://doi.org/10.1002/pi.6348>
- [2] S. Sharma, S. Basu, N. P. Shetti, M. N. Nadagouda, T. M. Aminabhavi, Microplastics in the environment: Occurrence, perils, and eradication, *Chemical Engineering Journal* 408 (2021) 127317. <https://doi.org/10.1016/j.cej.2020.127317>
- [3] S. Chandra, K. B. Walsh, Microplastics in water: Occurrence, fate and removal, *J. Contam. Hydrol.* 264 (2024) 104360. <https://doi.org/10.1016/j.jconhyd.2024.104360>
- [4] R. S. Mahidev, G. H. Aravind, K. Sandeep, S. Arya, M. Santosh, E. Shaji, Microplastics in freshwater lakes: A case study from Southern India, *Geosystems and Geoenvironment* 3 (2024) 100306. <https://doi.org/10.1016/j.geogeo.2024.100306>
- [5] P. Singh, M. Kumar, Microplastic pollution in the street dust of Delhi: a study on seasonal variations, *Environmental Science and Pollution Research* 32 (2025) 18320–18336. <https://doi.org/10.1007/s11356-025-36753-1>
- [6] P. K. Jaiswal, R. Singh, S. Kumar, D. Sharma, A. Mukherjee, N. Kumar, R. Kumar, Assessment of microplastic pollution load in road dust and associated health risk in a semi-arid region of Rajasthan, India, *Environmental Sustainability* 9 (2026) 131–152. <https://doi.org/10.1007/s42398-025-00370-y>
- [7] A. Al Mamun, T. A. E. Prasetya, I. R. Dewi, M. Ahmad, Microplastics in human food chains: Food becoming a threat to health safety, *Science of The Total Environment* 858 (2023) 159834. <https://doi.org/10.1016/j.scitotenv.2022.159834>
- [8] E. Winiarska, M. Jutel, M. Zemelka-Wiacek, The potential impact of nano- and microplastics on human health: Understanding human health risks., *Environ. Res.* 251 (2024) 118535. <https://doi.org/10.1016/j.envres.2024.118535>
- [9] S. V. L. Leonard, C. R. Liddle, C. A. Atherall, E. Chapman, M. Watkins, S. D. J. Calaminus, J. M. Rotchell, Microplastics in human blood: Polymer types, concentrations and characterisation using μ FTIR, *Environ. Int.* 188 (2024) 108751. <https://doi.org/10.1016/j.envint.2024.108751>
- [10] M. K. Momeni, H. Taghipour, M. Ghayebzadeh, M. Mohammadi, R. Keikhaee, Isolation and characterization of microplastics from the human respiratory system: Sputum, broncho-alveolar lavage fluid, and pleural fluid simultaneously, *Environmental Pollution* 365 (2025) 125389. <https://doi.org/10.1016/j.envpol.2024.125389>
- [11] A. Ragusa, V. Notarstefano, A. Svelato, A. Belloni, G. Gioacchini, C. Blondeel, E. Zucchelli, C. De Luca, S. D'Avino, A. Gulotta, Raman microspectroscopy detection and characterisation of microplastics in human breastmilk, *Polymers (Basel)*. 14 (2022) 2700.
- [12] H. Yadav, S. Sethulekshmi, A. Shrivastav, Estimation of microplastic exposure via the composite sampling of drinking water, respirable air, and cooked food from Mumbai, India, *Environ. Res.* 214 (2022) 113735. <https://doi.org/10.1016/j.envres.2022.113735>
- [13] D. B. Daniel, P. M. Ashraf, S. N. Thomas, Microplastics in the edible and inedible tissues of pelagic fishes sold for human consumption in Kerala, India, *Environmental Pollution* 266 (2020) 115365. <https://doi.org/10.1016/j.envpol.2020.115365>
- [14] R. Vittal, S. Xavier, M. Mohan, A. Chakraborty, G. Chakraborty, Detection and Characterisation of Microplastics in Food Grade Salts in India, *Journal of Health and Allied Sciences NU* (2026).
- [15] A. Vidyasakar, S. Krishnakumar, K. S. Kumar, K. Neelavannan, S. Anbalagan, K. Kasilingam, S. Srinivasalu, P. Saravanan, S. Kamaraj, N. S. Magesh, Microplastic contamination in edible sea salt from the largest salt-producing states of India, *Mar. Pollut. Bull.* 171 (2021) 112728. <https://doi.org/10.1016/j.marpolbul.2021.112728>

- [16] M. Gupta, P. Sehrawat, G. Gupta, N. Singhal, S. K. Kansal, Detection and quantification of microplastics in milk from Chandigarh, India: a pilot study highlighting SFEC-based spectral validation, *Food Additives & Contaminants: Part A* 43 (2026) 594–614. <https://doi.org/10.1080/19440049.2026.2628941>
- [17] R. Kiruba, M. Preethi, R. Aganasteen, M. Rithick Raj, C. Han-nah Thabitha, P. Monica, J. Sakthivel, C. Levine, I. Naseera Banu, Identification of microplastics as emerging contaminant in branded milk of Tamil Nadu State, India, *Asian J. Biol. Life Sci* 11 (2022) 181.
- [18] K. Raghunathan, D. Headey, A. Herforth, Affordability of nutritious diets in rural India, *Food Policy* 99 (2021) 101982. <https://doi.org/10.1016/j.foodpol.2020.101982>
- [19] S. Kumari, K. Singh, V. Sangwan, A. Choudhary, Food Purchasing Pattern in Rural Family of Haryana State, India, *Advances in Research on Teaching* 24 (2023) 120–125.
- [20] G. K. ShArMA, Consumption pattern of selected vegetables at five sites in Delhi NCR region, *Indian Journal of Agricultural Sciences* 90 (2020) 1593–1598.
- [21] R. B. Aydın, A. Yozukmaz, İ. Şener, F. Temiz, D. Giannetto, Occurrence of microplastics in most consumed fruits and vegetables from Turkey and public risk assessment for consumers, 13 (2023) 1686.
- [22] L. Chidewe, Emerging Contaminants in Potatoes: Occurrence of Polycyclic Aromatic Hydrocarbons, Microplastics and Heavy Metals, *Potato Res.* 68 (2025) 4445–4465. <https://doi.org/10.1007/s11540-025-09925-2>
- [23] Q. Liu, Z. Chen, Y. Chen, F. Yang, W. Yao, Y. Xie, Microplastics contamination in eggs: Detection, occurrence and status, *Food Chem.* 397 (2022) 133771. <https://doi.org/10.1016/j.foodchem.2022.133771>
- [24] S. S. Bristi, R. Islam, Microplastics in poultry: Sources, bioaccumulation and human health consequences, *Poult. Sci.* 105 (2026) 106387. <https://doi.org/10.1016/j.psj.2026.106387>
- [25] R. H. Setyobudi, S. Anwar, I. Iswahyudi, S. Husen, D. Damat, M. P. Garfansa, P. G. Adinurani, M. Mel, T. Liwang, R. Aprilianti, Identification and quantification of microplastics contamination in potato from Malang Raya, Indonesia, in: *BIO Web Conf.*, EDP Sciences, 2024: p. 00036.
- [26] Z. Sobhani, Y. Lei, Y. Tang, L. Wu, X. Zhang, R. Naidu, M. Megharaj, C. Fang, Microplastics generated when opening plastic packaging, *Sci. Rep.* 10 (2020) 4841. <https://doi.org/10.1038/s41598-020-61146-4>
- [27] G. Sharma, C. Ghosh, B. Singh, Impact of Microplastic Contamination in Compost on Wheat Crop Growth: A Study of Bread and Durum Wheat Varieties, in: V. Kumar, P. Singh, S. Kumar, A. Kumar Singh (Eds.), *Microplastics Pollution: A Threat to Biosphere*, Springer Nature Switzerland, Cham, 2025: pp. 197–225. https://doi.org/10.1007/978-3-031-99774-7_7
- [28] J. Zhang, Z. Li, X. Zhou, W. Ding, X. Wang, M. Zhao, H. Li, G. Zou, Y. Chen, Long-term application of organic compost is the primary contributor to microplastic pollution of soils in a wheat–maize rotation, *Science of The Total Environment* 866 (2023) 161123. <https://doi.org/10.1016/j.scitotenv.2022.161123>
- [29] S. Aysha, M. B. Sultan, Md. A. R. Bhuiyan, M. Toha, R. T. Ria, Do we unknowingly eat breakfast that contains microplastics? Unveiling the microplastic contamination in commercial flour, *Food and Humanity* 3 (2024) 100333. <https://doi.org/10.1016/j.foohum.2024.100333>
- [30] E. Trabia, H. Ismail, S. Aborhyem, Studying the Safety of Instant Noodles Sold in Egyptian Hypermarkets, *Curr. Appl. Sci. Technol.* (2020) 440–452.
- [31] B. Basaran, Z. Özçifçi, E. D. Kanbur, H. T. Akçay, S. Gül, Y. Bektaş, Ü. Aytan, Microplastics in honey from Türkiye: Occurrence, characteristic, human exposure, and risk assessment, *Journal of Food Composition and Analysis* 135 (2024) 106646. <https://doi.org/10.1016/j.jfca.2024.106646>
- [32] K. Katsara, Z. Viskadourakis, E. Alissandrakis, G. Kenanakis, V. M. Papadakis, Microplastic Migration from Plastic Packaging into Honey, *Microplastics* 4 (2025) 90.
- [33] M. Bharath K, S. S, U. Natesan, R. Ayyamperumal, N. Kalam S, A. S, S. K, A. C, Microplastics as an emerging threat to the freshwater ecosystems of Veeranam lake in south India: A multidimensional approach, *Chemosphere* 264 (2021) 128502. <https://doi.org/10.1016/j.chemosphere.2020.128502>