



Occupational Awareness of Airborne Microplastics in the Dry-Cleaning and Laundry Industry

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Abstract

Workers in dry-cleaning and laundry shops routinely handle large volumes of synthetic garments that shed airborne microplastics, potentially creating an underrecognized occupational exposure in this small-business sector. Despite growing concern about microplastics in environmental health research, little is known about their recognition as an occupational hazard among service-sector workers. This pilot study assessed awareness and knowledge of microplastics among dry-cleaning and laundry workers in Philadelphia and examined their associations with workplace protective practices. We collected information on workplace characteristics, microplastics awareness, knowledge, and personal protective equipment (PPE) use from 34 self-employed workers. Approximately one-third of participants had heard of microplastics, and those who were aware demonstrated higher knowledge scores (median: 71) than those who were unaware (median: 27). However, neither awareness nor knowledge was associated with PPE use. These findings suggest that microplastics remain an overlooked occupational hazard and underscore the need for enhanced occupational health education and worker protection efforts.

Keywords: synthetic garments; microplastics; personal protective equipment (PPE)

1. Introduction

Microplastics are plastic particles smaller than 5 mm that are generated from the breakdown or shedding of synthetic polymers, such as polyester, nylon, acrylics, and other man-made fibers [1–3]. These materials are now ubiquitous in textiles because they are inexpensive, durable, and easy to process. Modern “iron-free” and stain-resistant garments, which are often largely composed of synthetic fibers, can shed substantial amounts of microplastics during handling, washing, drying, ironing, and repair. Although prior studies have documented elevated levels of synthetic fibers in textile and garment manufacturing settings [4–6], workers in dry-cleaning and laundry shops remain an overlooked population at potential risk.

These workers (many of whom are self-employed with long work histories) spend long hours in confined spaces while processing hundreds of synthetic garments per day [7,8]. Daily tasks such as sorting, washing, drying, ironing, repairing, and packaging, often with vinyl or plastic wraps, may represent potential sources of elevated airborne microplastics. Prior studies have shown that tumble dryers can release cotton and polyester microfibers into air and that indoor particle resuspension can be influenced by relative humidity. Thus, hot and humid workplace conditions may affect airborne particle dynamics and worker comfort, potentially shaping inhalation exposure potential and protective practices,



Academic Editor: Jiming Zhang

Received: 11 April 2026

Revised: 9 June 2026

Accepted: 18 June 2026

Published: 2 July 2026

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although direct evidence specific to airborne microplastics in dry-cleaning workplaces remains limited [9]. Although the toxicity of inhaled microplastics remains uncertain due to variation in chemical composition, size, shape, and surface characteristics, airborne microplastics may plausibly pose cardiorespiratory risks based on existing evidence linking inhalable particulate matter to respiratory and cardiovascular effects [10,11].

Emerging toxicological studies further suggest that inhalable microplastics may deposit in the lower respiratory tract and induce inflammatory and oxidative responses in animal studies, although human evidence remains limited. Because of their small size, inhalable microplastics (e.g., <10 µm) can reach the lower airways, including the alveoli [12,13]. Several in vivo and in vitro studies have reported that inhaled microplastics may induce biological effects, including inflammation, oxidative stress, cytokine secretion, DNA and cellular damage, and neurotoxicity [14–17].

Although several studies have examined risk perception and awareness of microplastics among general populations and workers in other occupational fields, such as farmers and beauticians, to our knowledge, no studies have directly assessed microplastics risk perception among workers in dry-cleaning and laundry shops. A 2021 survey reported that lay respondents were highly aware of microplastic pollution in marine environments and food contamination, but awareness of airborne microplastics was low [18]. Despite growing concerns about potential health risks of microplastics exposure, little is known about how workers in small, self-employed dry-cleaning businesses perceive microplastics exposure risks or whether awareness translates into protective measures.

This knowledge gap is particularly important because workers in small businesses view airborne dust (potentially including microplastics) as a nuisance rather than a health hazard and may rarely use protective measures such as masks due to discomfort, limited information, or workplace constraints [19–21]. Hence, understanding workers' knowledge, awareness, and protective behaviors is essential for developing feasible occupational health interventions for small businesses in the service sector. The objective of this exploratory pilot study was to examine knowledge and awareness of microplastics among self-employed dry-cleaning shop owners and to assess whether knowledge and awareness were associated with protective measures, such as wearing masks during work hours.

2. Materials and Methods

2.1. Study Location

This exploratory pilot study was conducted in the Greater Philadelphia area, including Philadelphia, Delaware, Montgomery, and Chester Counties in Pennsylvania. Philadelphia, located in Philadelphia County, is one of the largest cities in the United States (U.S.), with a population of approximately 1.6 million and a land area of 134.3 square miles [22]. The population is racially and ethnically diverse, with 38% Black, 33% White, 16% Hispanic or Latino, and 8% Asian residents [23]. The median age is 35.6 years, and women slightly outnumber men, comprising 53% of the population [22]. Many residents face economic challenges. The median household income is \$60,521, which is below the Pennsylvania state average of \$77,545, and approximately 20% of residents live below the poverty line, including nearly one quarter of children [22]. Educational attainment is moderate, with 36.4% of adults holding a bachelor's degree or higher, and approximately one quarter of residents speak a language other than English at home [22].

The study location was selected because the Greater Philadelphia region has one of the highest concentrations of dry-cleaning and laundry workers in the U.S. [24]. Many dry-cleaning and laundry shops are small businesses primarily operated by immigrant workers, particularly Asian immigrants. Although this industry has relatively low barriers to entry,

such as short-term training requirements, limited need for English proficiency, and access to ethnic business networks, these same factors may contribute to occupational vulnerability.

2.2. Study Design and Participants

This exploratory pilot study was conducted as part of the Microplastics Exposure assessment of Laundry and Dry-cleaning industry (MELD) project, which aimed to examine how workplace and workforce characteristics may affect airborne microplastics exposure in dry-cleaning and laundry shops in the Greater Philadelphia area. In December 2023, we identified 180 dry-cleaning and laundry shops using Google Maps. These shops represented approximately 0.53% of all private-sector establishments in the area. Of the 180 listed dry-cleaning and laundry shops, 160 shops were contacted through in-person canvassing and phone outreach. Among these businesses, 34 shops (21.3%) participated in the study, while 69 declined participation. Of the remaining businesses, four initially agreed but did not complete the study, 32 could not be reached or were unavailable, and 21 were contacted but did not provide a final decision about participation. Language information was available for 122 businesses, of which 87 (71.3%) were Korean-speaking. Because this was an exploratory pilot study, the recruitment goal was 30 participants to support descriptive analyses, assess feasibility, and generate preliminary findings rather than provide definitive statistical inference. Ultimately, we recruited 34 self-employed workers from laundry and dry-cleaning shops between February and November 2024 (Figure 1). When a self-employed shop owner expressed interest in participating, a study team member scheduled a visit to the shop to obtain informed consent and administer the questionnaire. Only one self-employed owner from each shop participated in the study. Eligible participants were at least 18 years old, currently owned, operated, or worked in a laundry or dry-cleaning facility, and were able to complete the survey in English or Korean because Korean-speaking workers represent a substantial portion of the dry-cleaning and laundry workforce in the study area. Upon completing the survey, participants received a gift card as compensation for their participation. The study protocol was approved by Temple University's Institutional Review Board (IRB#31039).

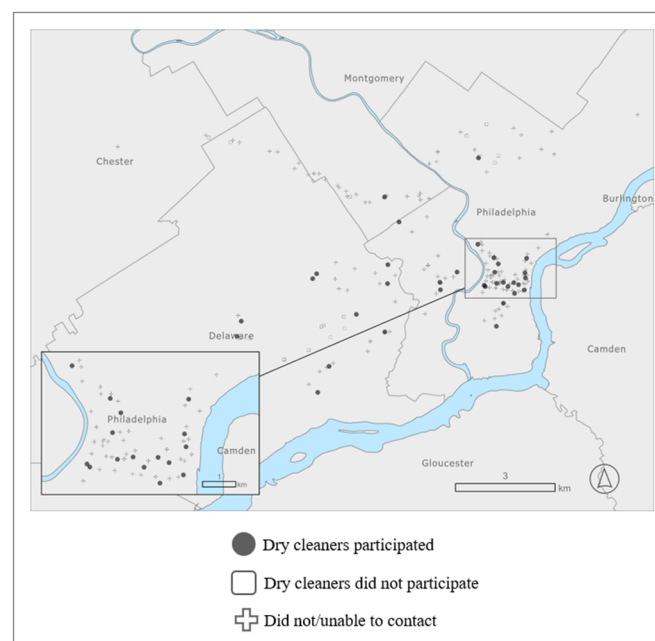


Figure 1. Locations of dry cleaners and study participants in the Greater Philadelphia region.

2.3. Survey Instrument and Data Collection

The survey instrument was developed based on prior microplastics awareness surveys [25–27] and reviewed by study investigators. The draft survey was pilot tested with five respondents who were not included in the final study sample. Based on feedback from this pilot testing, we revised and finalized the survey. The final version was then administered to the 34 study participants. The questionnaire included 27 items and was administered in either English or Korean, according to each participant's preferred language. The survey included a combination of open-ended, binary (yes/no), multiple-choice, check-all-that-apply, and frequency-based questions. Items were organized into four domains: (a) participant demographics, (b) workplace characteristics, (c) work practices and protective behaviors, and (d) knowledge and awareness of microplastics.

Participant demographic information included age, gender, race/ethnicity, education, income, and language spoken at home. Workplace characteristics included shop location (urban or suburban), building age, number of workers, shop floor size, number of business days per week, hours worked per day, number of customers served per day, and number of garments handled daily. Work practices included workloads, job duties, cleaning and maintenance activities, and personal protective behaviors. These items assessed the types of fabrics processed, specific job duties, and the frequency of cleaning tasks such as dusting, vacuuming, mopping, and machine maintenance. PPE use was assessed by asking participants about the frequency and types of protective equipment used during work (e.g., surgical masks, N95 masks, gloves, gowns, and hats/helmets). The fourth domain assessed participants' knowledge and awareness of microplastics. Participants were asked about their awareness of microplastics, knowledge of environmental sources and presence of microplastics in air, water, soil, food, and the human body, and perception of whether microplastics may be present in their workplace.

2.4. Data Analysis

Survey data were entered into Microsoft Excel and validated by two independent investigators. Statistical data analysis was performed using RStudio (version 2023.06.1). Descriptive statistics, including means, standard deviations (SDs), ranges, frequencies and percentages, were used to summarize participant demographics, workplace characteristics, work practices, and protective practices. Continuous variables, such as shop size, were examined for outliers, and results were reported both with and without outliers. Given the small sample size and exploratory nature of this pilot study, statistical analyses were intended to identify preliminary patterns of workers' demographics, workplace characteristics, work practices, and workers' knowledge and awareness, rather than to assess causal associations.

To quantitatively assess participants' understanding of microplastics, we developed a knowledge scoring system using 12 scored items derived from four survey questions in the questionnaire (Questions 14–17, see Supplementary Materials). The scoring system included one item assessing knowledge of the definition of microplastics (Q14); five items assessing knowledge of microplastics sources (Q15), including cosmetic products, breakdown of larger plastic waste, washing synthetic clothing, natural sources, and automobile tires; five items assessing knowledge of the presence of microplastics in environmental media (Q16), including air, water, soil, food, and the human body; and one item assessing perceived workplace exposure to microplastics (Q17). Each item was coded as correct (1) or incorrect (0) based on a predefined answer key. Individual item scores were summed to produce a composite knowledge score ranging from 0 to 12, which was then normalized to a 0–100 scale for ease of interpretation (e.g., 9 correct answers were converted to 75 (9/12)).

Differences in normalized knowledge scores between participants who had and had not heard of microplastics (Q12) were evaluated using the Wilcoxon rank-sum test. The correlation between prior awareness and normalized knowledge score was further examined using Spearman's rank correlation coefficient. Associations of knowledge and awareness with protective practices (use of any PPE, surgical masks, or N95 masks) were evaluated using Fisher's exact tests at $\alpha = 0.05$, and corresponding odds ratios (ORs) and 95% confidence intervals (CIs) were reported.

3. Results

3.1. Participant Characteristics

Table 1 summarizes participants' demographic and workplace characteristics. The study population mainly consisted of older adults, with a mean age of 64.3 ± 7.9 years (range 51–85). Most participants self-identified as Asian (94 percent, $n = 32$); among them, 94 percent (30/32) identified as Korean, while one participant identified as White. More than 70 percent of participants reported having some college education or higher ($n = 25$). Most shops were located in older buildings, with 73 percent built more than 30 years ago. Shop size varied greatly, with a mean of 1574 ± 1533 sq ft (range: 160–8500 sq ft). After excluding one outlier, the mean shop size was 1343 ± 849 sq ft (range: 160–3200 sq ft). The average number of workers per shop was 2.8 ± 2.6 .

Table 1. Participant demographics and shop characteristics.

Baseline Information		Mean $\pm$ SD	Range
Age (years old)		64.3 ± 7.9	51–85
Gender	Female	Count 18	Percent 53
	Male	16	47
Race	White	1	3
	Asian	32	94
	N/A	1	3
Education	Less than or high school	7	21
	Some college	11	32
	College degree or higher	14	41
	Prefer Not to Answer	2	6
Built years	6–15 years	2	6
	Over 30 years	25	73
	Do not know	7	21

Participants reported long working hours, with a mean of 9.3 ± 1.6 h per day (range: 4–11.5 h). Participants handled an average of 145 ± 216 clothing items per day, ranging between 3 and 1000 (Table 2). Synthetic, natural, and heavy fabrics were processed at most shops (97%, 94%, and 85%, respectively). Garment repair and alteration tasks were the most commonly reported job responsibility (88%), followed by folding and packing (74%) and dry-cleaning-related tasks (65%), which included both in-house cleaning and sending garments to external dry-cleaning facilities.

Table 2. Summary of reported work characteristics and PPE use.

Work Practice Questions	Mean $\pm$ SD	Range
Number of work hours per day	9.3 $\pm$ 1.6	4–11.5
Number of clothing handled per day	144.5 $\pm$ 215.6	3–1000
	Count	Percent
Types of clothing processed ($n = 33$) *		
Synthetic fabrics	32	97
Natural fabrics	31	94
Heavy linens	28	85
Other	6	19
Types of job task ($n = 34$) *		
Garment repair and alteration	30	88
Folding, pressing, wrapping, and packing	25	74
Dry cleaning	22	65
Reception/Processing Payment	19	56
Washing	15	44
Delivery and pickup	13	38
Usage of PPE ($n = 33$) **		
Yes	12	36
No	21	64
Usage of PPE Mask ($n = 33$) **		
Surgical mask		
Yes	14	42
No	19	56
N95 mask		
Yes	11	32
No	22	65

* Participants could select multiple responses for Types of clothing processed. ** One participant did not respond to Types of clothing processed, usage of PPE and PPE mask.

3.2. Use of Personal Protective Equipment and Cleaning Practices

Use of PPE was generally low. More than half reported that they did not wear any masks at all during work. Surgical masks were used by 41% of participants and N95 masks by 32%. Other PPE such as hats, gloves, and gowns was infrequently used. Most participants reported never using these items, including 68% for hats, 50% for gloves, and 86% for gowns. Cleaning activities varied by task. When asked how often they performed cleaning activities during the week preceding the survey, dusting or sweeping was the most frequently reported activity (31%), followed by cleaning windows or mirrors (30%).

3.3. Awareness of Microplastics and Knowledge of Sources

Figure 2 shows the relationship between awareness of microplastics and knowledge of their definition and sources. Among participants who reported that they had heard of microplastics, 69% correctly identified microplastics as tiny plastic fragments smaller than 5 mm, compared with only 20% of those who had not heard of microplastics.

Participants who reported prior awareness of microplastics demonstrated substantially greater knowledge of environmental sources and exposure pathways. For example, 92% of participants with prior awareness correctly identified the breakdown of larger plastic waste as a source of microplastics, and 85% identified washing synthetic clothing as a source, compared with 30% and 40%, respectively, among participants without prior awareness. Similar differences were observed for exposure pathways. Participants with prior awareness identified air (92%) and water (77%) as potential routes of exposure, whereas recognition was lower among participants without prior awareness (air: 35%; water: 15%). This pattern was generally consistent across the environmental source and exposure pathway items between the two groups. Prior awareness was also associated with greater recognition of microplastics in occupational settings. Sixty-nine percent of

participants with prior awareness reported that microplastics could be present in their workplace, compared with 35% of participants without prior awareness. Overall, participants who had previously heard of microplastics were more likely to correctly identify common environmental sources and exposure pathways of microplastics.

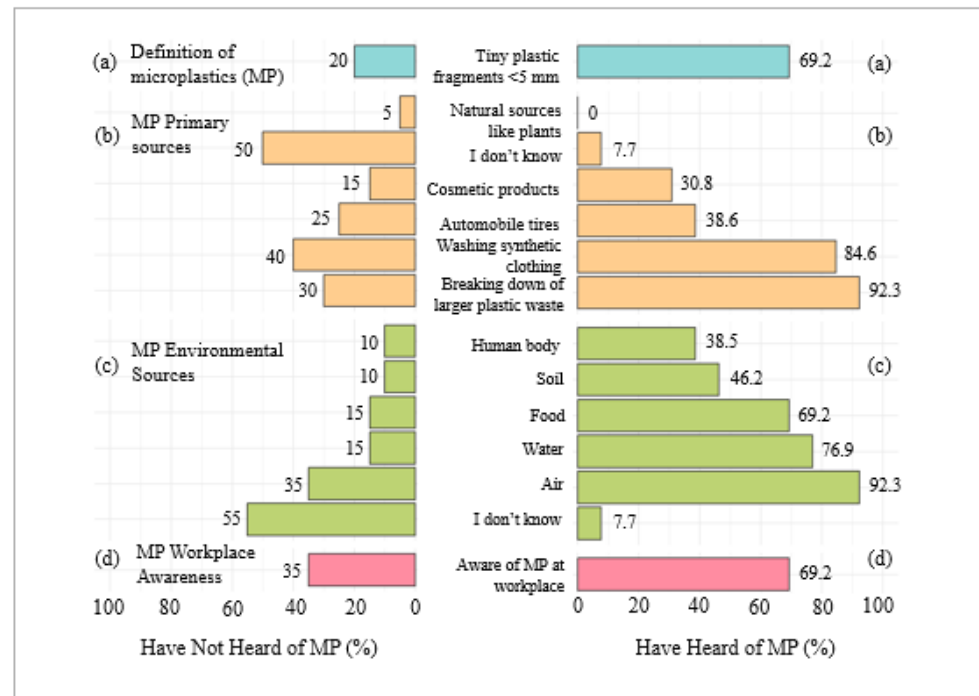


Figure 2. Survey responses on microplastics knowledge: (a) definition of microplastics, (b) primary sources, (c) environmental sources, and (d) workplace awareness.

3.4. Association Between Awareness and Knowledge Score

Figure 3 shows the distribution of normalized knowledge scores by participants' prior awareness of microplastics. Participants who had previously heard of microplastics had higher knowledge scores than those who had not. The median knowledge score was 71 among participants with prior awareness of microplastics, compared with 27 among those without prior awareness. The difference was statistically significant based on the Wilcoxon rank-sum test ($W = 193$, $p < 0.001$). Spearman's rank correlation analysis showed a strong positive association between prior awareness and knowledge score ($\rho = 0.72$, $p < 0.001$). These findings suggest that prior awareness of microplastics was positively associated with greater knowledge of microplastics sources and exposure pathways.

3.5. Association Between Awareness, Knowledge, and PPE Use

We examined whether prior awareness and knowledge of microplastics were associated with protective measures such as the use of PPE (e.g., wearing masks). However, neither prior awareness nor knowledge score was associated with PPE use (Figure 4). For prior awareness, the ORs were 0.76 for any PPE (95% CI: 0.12–4.14), 0.65 for surgical masks (95% CI: 0.11–3.54), and 0.63 for N95 masks (95% CI: 0.08–3.77). Similarly, knowledge scores were not associated with PPE use. The ORs were 0.76 for any PPE (95% CI: 0.13–4.22), 0.58 for surgical masks (95% CI: 0.10–3.24), and 0.75 for N95 masks (95% CI: 0.12–4.33).

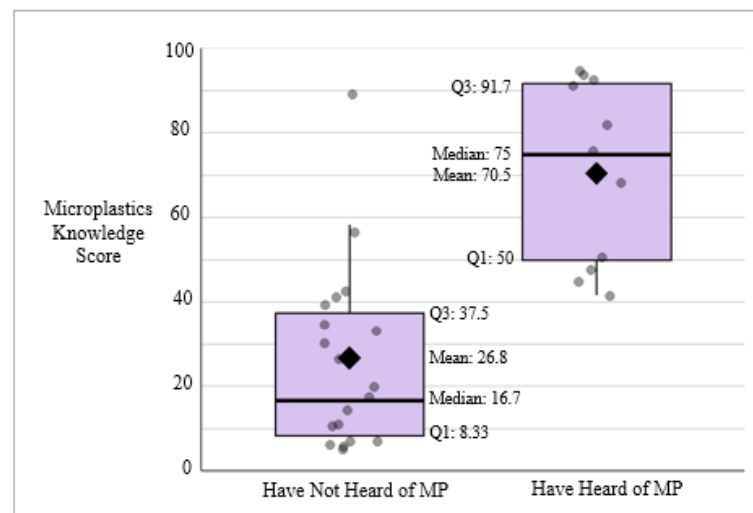


Figure 3. Box plot of normalized knowledge scores (y axis) by prior awareness status among participants who had and had not heard of microplastics (MP). Each gray dot represents the microplastics knowledge score of an individual participant.

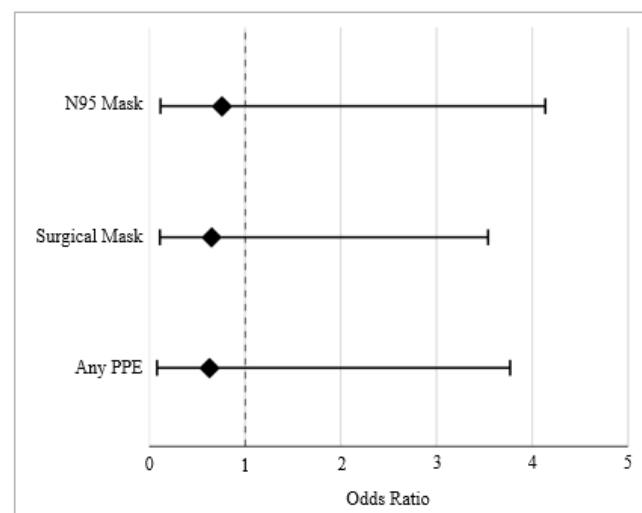


Figure 4. Odds ratios (ORs) with 95% CIs showing the association between microplastic awareness and PPE use. The estimates were OR = 0.76 [0.12–4.14] for any PPE use, OR = 0.65 [0.11–3.54] for surgical mask, and OR = 0.63 [0.08–3.77] for N95 mask use.

4. Discussion

In this pilot study of 34 self-employed dry-cleaning and laundry workers in the Greater Philadelphia area, prior awareness of microplastics was strongly associated with higher knowledge scores. However, neither awareness nor knowledge was associated with PPE use. These findings suggest that awareness and knowledge alone may be insufficient to change protective practices in this occupational setting. Instead, PPE use may be shaped by broader factors, including long-standing work routines, perceived risk, comfort, workload, limited workplace guidance, and the practical constraints of small-business environments.

The demographic and occupational profile of participants may partly help contextualize our findings. Most participants were older Korean immigrant workers with long occupational histories (several decades) in the dry-cleaning and laundry industry. Korean participants had a mean age of 65.2 ± 7.6 years, and both Korean and non-Korean participants reported more than 20 years of occupational tenure. These extended work histories suggest that self-employed workers in this sector may have experienced pro-

longed occupational exposure to airborne contaminants over many years. Although the specific contaminants differ, previous studies of textile and dry-cleaning workers have raised exposure concerns related to cotton dust, cleaning solvents, and other workplace contaminants [7,8]. Similarly, workers who handle large volumes of clothing and linens daily may experience repeated opportunities for exposure to airborne particles generated from textile handling, including synthetic fibers and microplastics.

The demographic characteristics of our study population also reflect the historical role of Korean immigrant workers and business owners in the U.S. dry-cleaning and laundry industry. Since the late twentieth century, many first-generation Korean immigrants have established small businesses in this sector, supported by ethnic community networks, family lending, and co-ethnic labor [28,29]. As a result, Korean immigrants have remained highly concentrated in this sector, with prior research estimating that Korean immigrants are about 30 times more likely than other immigrant groups to operate dry-cleaning businesses [29,30].

Compared with previous studies of Korean dry-cleaning workers in the U.S., participants in our study appeared older and had longer occupational histories. Prior studies conducted in the 2010s reported mean ages ranging from 49 to 56 years and business ownership durations of approximately 10 to 16 years [31–34]. In contrast, participants in our study had a mean age of 65 years among Korean workers and an average occupational tenure of 22 years. This difference may reflect the aging of an established workforce, as many self-employed dry-cleaning and laundry shop owners continue operating their businesses until retirement. Consequently, the participants in this study represent a long-standing segment of the workforce with extended occupational histories in this sector.

It is also important to distinguish between awareness and knowledge when interpreting these findings. In the microplastics literature, awareness is typically measured as familiarity with or recognition of the term “microplastics,” whereas knowledge reflects a deeper understanding of the definition, sources, exposure pathways, and environmental or health implications [35,36]. Previous studies have reported relatively high awareness of microplastics across different populations. For example, approximately 80% of Malaysian health sciences students reported familiarity with microplastics, and about 75% of Italian university students indicated that they had heard of microplastics [35,36]. In contrast, the depth of knowledge has varied considerably across studies. Malaysian students reported a mean knowledge score of 4.7 on an –8 to +8 scale [35], while a separate study of community residents found that only half of respondents rated their knowledge of microplastics as high [37]. Italian university students also reported relatively low self-rated knowledge, with average scores less than 3.6 on a 10-point scale [36].

However, greater awareness and knowledge did not translate into greater PPE use. This pattern is consistent with findings from other occupational settings showing that awareness of workplace hazards does not always lead to protective behavior. For example, welders in Nepal had higher awareness of occupational hazards and the benefits of wearing PPE, yet fewer than half of workers reported using PPE, indicating a gap between awareness and adoption of protective measures [38]. Other factors may contribute to this finding. In our study, participants reported long work schedules (an average of 5.6 days per week for 9.3 h per day). This may contribute to fatigue and reduced adherence to protective practices. Repeated exposure to familiar workplace conditions may also lead to normalization of risks, reducing the perceived need for PPE use even among workers who are aware of potential hazards [39,40]. For instance, studies of Korean firefighters suggest that fatigue and heavy workloads may reduce perceived susceptibility to occupational risks and contribute to lower PPE adherence, despite substantial occupational risks [41]. Similarly, workers in small-business sectors such as construction, textile manufacturing, and carpentry

have reported that discomfort, fatigue, and workflow disruptions reduce consistent PPE use [42–44]. These findings suggest that awareness alone may not be sufficient to promote protective behaviors.

This study has several strengths. First, it provides preliminary evidence on microplastics awareness, knowledge, and protective practices among dry-cleaning and laundry workers, an occupational group that has received limited attention in research on emerging contaminants. Second, the study focused on self-employed workers with long occupational histories in a small-business service sector, a population that may face distinct barriers to occupational health protection. Third, the use of a quantitative knowledge score allowed us to examine the relationship between microplastics awareness, knowledge, and PPE use, providing an initial framework for future occupational health studies of emerging contaminants.

Several limitations should be considered. First, the sample size was small ($n = 34$), limiting statistical power and generalizability. Our results cannot establish causal relationships between awareness, knowledge, and protective practices. Because of the small sample size, estimates of the associations between awareness or knowledge and protective practices, including PPE use, were imprecise, with wide confidence intervals and no statistically significant findings. Larger studies are needed to evaluate these associations more robustly. Second, the study relied on self-reported protective measures and may be subject to recall or reporting bias. Lastly, this pilot study did not include objective measurements of airborne microplastics or other workplace contaminants.

5. Conclusions

Overall, this study contributes to the limited literature on microplastics awareness in occupational environments. While workers with prior awareness of microplastics demonstrated greater knowledge of sources and exposure pathways, prior awareness did not translate into greater PPE use. These findings highlight a potential knowledge–action gap in small-business occupational settings and suggest that education alone may be insufficient to promote protective practices. Future research should include larger and more diverse worker populations to better understand how microplastics awareness, knowledge, risk perception, and workplace constraints influence protective practices in textile-handling workplaces. Strengthening risk communication and developing practical workplace guidance may help translate emerging scientific knowledge into feasible and acceptable protective strategies for workers and small-business owners.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/occuphealth1030028/s1>, File S1: survey questionnaire.

Author Contributions: Conceptualization, I.H.; methodology, I.H. and C.L.; software, I.H. and C.L.; validation, I.H. and C.L.; formal analysis, C.L.; data curation, C.L. and G.L.K.; writing—original draft preparation, I.H. and C.L.; writing—review and editing, I.H., C.L. and G.L.K.; visualization, C.L.; supervision, I.H.; project administration, I.H., C.L. and G.L.K.; funding acquisition, I.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded, in part, by the Centers for Disease Control and Prevention (CDC) and National Institute of Occupational Safety and Health (NIOSH) through grant R21OH012595.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Temple University (protocol code 31039 and date of approval: 24 October 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: De-identified data supporting the findings of this study are available from the corresponding author upon reasonable written request, subject to institutional and ethical approval.

Acknowledgments: We express our gratitude to the study subjects for their participation in the study.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

MELD	Microplastics Exposure assessment of Laundry and Dry-cleaning industry
PPE	Personal Protective Equipment
MP	Microplastics
OR	Odds Ratio
CI	Confidence Interval
SD	Standard Deviation

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