

Research Article

Innovative One-Health Assessment of Microplastic Exposure in Healthcare Workers: Quantifying Risk across Occupational, Environmental, and Dietary Pathways

Andriani Mei Astuti ^{1*}, Dwi Yogo Budi Prabowo ², Ajila Raj BS ³

1 Universitas Duta Bangsa Surakarta, Indonesia

Email : andriani_meiastuti@gmail.com

2 Universitas Telogorejo Semarang, Indonesia

Email : dwi_yogo@universitastelogorejo.ac.id

3 CSI College of Nursing, India

Email : ajilaraj@gmail.com

* Corresponding Author: andriani_meiastuti@gmail.com

Abstract: Microplastic exposure in healthcare workers is a growing concern, yet it remains underexplored, especially in the context of their multifaceted exposure pathways. This study aims to quantify the exposure of healthcare workers to microplastics through three primary pathways: occupational, environmental, and dietary. By adopting a One-Health approach, which integrates human, animal, and environmental health sectors, this research assesses microplastic levels across hospital settings, comparing clinical and non-clinical staff. The study found that healthcare workers, particularly those working in clinical departments like laboratories and physiotherapy, had a 35% higher exposure rate to microplastics compared to non-clinical staff. Occupational exposure was linked to direct contact with medical disposables and contaminated surfaces, while environmental exposure primarily occurred through airborne particles and dust. Dietary exposure, especially from seafood and plastic-packaged foods, contributed significantly to the overall exposure. The findings highlight the importance of considering multiple pathways when assessing microplastic risks and suggest that microplastics are an emerging health hazard for healthcare workers. Potential health risks include respiratory issues, gastrointestinal disturbances, endocrine disruption, and chronic conditions such as neurotoxicity and cancer. This study underscores the need for policy changes, including the reduction of single-use plastics in healthcare environments, improvements in ventilation, and the development of dietary guidelines to limit microplastic intake. Future research should focus on the long-term health impacts of chronic microplastic exposure in healthcare workers and evaluate the effectiveness of interventions designed to mitigate these risks.

Keywords: Environmental Health, Healthcare Workers, Microplastic Exposure, Occupational Health, One-Health Approach.

1. Introduction

Microplastic contamination has become a significant environmental issue, but its impact on healthcare workers remains underexplored. Healthcare environments, particularly hospitals, are places where microplastics can accumulate due to the extensive use of disposable plastic items and the presence of microplastics in indoor air. These microplastics, often generated from everyday items such as plastic packaging and medical disposables, are a growing concern for healthcare workers who may be directly exposed to them during their

Received: June 12, 2024

Revised: June 27, 2024

Accepted: July 11, 2024

Published: July 31, 2024

Curr. Ver.: July 31, 2024



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daily tasks. Recent studies indicate that microplastics are prevalent in various hospital departments, especially in laboratory and physiotherapy areas (Gwenzi et al., 2022). Despite the known presence of microplastics in these settings, there is a significant gap in research specifically addressing the exposure risks and potential health impacts faced by healthcare workers.

Microplastics pose several potential risks to healthcare workers, stemming from various exposure routes such as inhalation, dermal contact, and ingestion. Inhalation exposure is one of the primary concerns, as healthcare workers may be at risk of inhaling microplastics that are suspended in the indoor air of medical facilities. Studies have quantified the daily exposure to microplastics through inhalation, revealing a substantial potential for respiratory exposure (Gwenzi et al., 2022). Additionally, dermal contact with microplastics is a significant concern, as healthcare workers handle disposable plastic items and come into contact with contaminated surfaces. Microplastics have been found on gloves used in medical procedures, suggesting that skin exposure is a common route (Mofijur et al., 2021). Although less direct, ingestion of microplastics through contaminated food and water consumed in healthcare environments can also contribute to exposure (Prata et al., 2021; Tang et al., 2024).

The health risks associated with microplastic exposure include oxidative stress, inflammation, endocrine disruption, and potential carcinogenic effects (Goswami et al., 2024; Sun & Wang, 2023). These health issues are especially concerning for healthcare workers, who may experience chronic exposure due to the nature of their work environments. The long-term effects of such exposure remain largely unknown, making it a critical area of research.

The One-Health approach is essential for understanding the complex environmental health risks posed by microplastics, especially in healthcare settings. This approach emphasizes the interconnectedness of human, animal, and environmental health, advocating for a transdisciplinary perspective to address health issues from multiple dimensions (Dang et al., 2022; Mader et al., 2023). The One-Health framework allows for a comprehensive understanding of how microplastics affect not only human health but also the health of animals and the environment.

Microplastics are known to cause various health issues in humans, including respiratory, gastrointestinal, and reproductive problems (Prata et al., 2021; Tang et al., 2024). Moreover, microplastics impact wildlife, leading to bioaccumulation and disrupting food chains, which can indirectly affect human health through the consumption of contaminated animal products (Gwenzi et al., 2022). Environmental contamination by microplastics alters soil and water quality, affecting ecosystem services and biodiversity, which are critical for maintaining a healthy environment (Mofijur et al., 2021). By integrating the One-Health approach, researchers can develop comprehensive strategies to mitigate the risks of microplastic

contamination across all domains, ensuring a more holistic approach to human, animal, and environmental health (Mader et al., 2023; Prata et al., 2021).

Microplastic exposure is increasingly recognized as a pervasive environmental concern, yet its impact on healthcare workers remains largely underexplored. The growing prevalence of microplastics in various environmental media-air, water, and soil-has raised alarms about their potential health risks. Microplastics are now detectable in human tissues, including blood, placenta, and breast milk (Hasan et al., 2024), indicating a widespread and ongoing exposure. However, research specifically targeting healthcare workers, who may be exposed to microplastics through their occupational environment, surrounding environment, and dietary intake, is still limited. This study seeks to fill this gap by quantifying microplastic exposure among healthcare workers through these three primary exposure pathways: occupational, environmental, and dietary.

The health risks posed by microplastics are well-documented in environmental research, with evidence linking microplastic exposure to a variety of health issues such as gastrointestinal inflammation, respiratory diseases, and endocrine and reproductive dysfunction (Hasan et al., 2024). In the context of healthcare workers, these risks are compounded by the existing hazards in their work environments, such as exposure to antineoplastic drugs, which have been shown to cause significant cytogenetic damage (Gianfredi et al., 2019; Huang & Lin, 2023). This highlights the need to address microplastic exposure as part of broader occupational safety protocols for healthcare workers, who are already at risk from other toxic substances (Shahsavaripour et al., 2023).

Microplastics are present not only in healthcare environments but also in the broader environment and food chain, making ingestion through contaminated food and water another significant pathway of exposure (Hasan et al., 2024). This underscores the importance of considering all potential routes of exposure-occupational, environmental, and dietary-in the development of effective protective measures for healthcare workers.

Current research on microplastic exposure has primarily focused on environmental contamination and the risks posed to general populations or specific high-exposure groups, such as workers in plastic manufacturing plants (Shahsavaripour et al., 2023). However, healthcare workers represent a unique population with distinct exposure risks due to the nature of their work environment. By quantifying microplastic exposure in this specific group, this study aims to fill a critical gap in the existing literature and provide a more nuanced understanding of the risks healthcare workers face.

The primary objective of this study is to inform and improve occupational safety standards in medical settings by quantifying the levels of microplastic exposure in healthcare workers. The findings could guide the development of better protective equipment and protocols, reducing overall health risks. Understanding the extent of microplastic exposure is

essential for minimizing its potential health effects, particularly given the chronic nature of occupational exposure in healthcare settings (Hon et al., 2014).

The broader public health implications of this study are significant. Increased awareness of microplastic exposure among healthcare workers and the general public could lead to better regulatory policies and public health interventions aimed at reducing microplastic pollution and its associated health risks. Moreover, addressing this issue could contribute to the development of healthier work environments for healthcare workers, improving their long-term health and well-being (Zhang et al., 2022).

2. Literature Review

Microplastic Pollution and Its Impacts

Microplastic pollution, which refers to the contamination of the environment by small plastic particles typically less than 5 mm in size, has become a pervasive environmental issue. These particles are present in various environmental media such as air, water, and soil, and they have infiltrated the food chain, ultimately becoming part of the human diet (Nair & Perumal, 2022). As microplastics continue to accumulate in the environment, their potential health risks to both the ecosystem and human health are of increasing concern. While environmental contamination with microplastics is widely studied, their exposure and impacts on human health, particularly among healthcare workers, remain underexplored.

Microplastics originate from two main sources: primary and secondary. Primary sources include microfibers released from textiles, personal care products, and wastewater treatment plants (Rahman et al., 2021). Secondary sources arise from larger plastic items, such as plastic packaging, household products, and tire wear, that break down into smaller particles over time (Bratovcic et al., 2022). These sources contribute significantly to the pervasive spread of microplastics across various environmental compartments, further complicating efforts to mitigate their impact.

Humans are exposed to microplastics through several key pathways, primarily ingestion, inhalation, and dermal contact. Ingestion is the primary route of exposure, with microplastics detected in a variety of food items such as seafood, drinking water, and plastic-packaged foods (Sun & Wang, 2023; Wright & Kelly, 2017). Seafood, in particular, serves as a major dietary source of microplastics as marine organisms ingest these particles, which then enter the food chain. Additionally, microplastics have been found in other food products such as salt, sugar, honey, and beverages like tea and beer (Emenike et al., 2023). Inhalation is another significant pathway, particularly in indoor environments, where microplastic fibers and dust are prevalent (Rahman et al., 2021). Though less significant than ingestion or inhalation, dermal exposure to microplastics can occur through consumer products and environmental contamination, such as when microplastics come into contact with the skin via cosmetics, cleaning products, or environmental surfaces (Rahman et al., 2021; Wright & Kelly, 2017).

Environmental exposure to microplastics occurs via air, water, and soil. Airborne microplastics, both indoors and outdoors, contribute to inhalation exposure. Urban areas, in particular, show elevated concentrations of microplastics in the air, particularly near roads and in indoor settings where fibers and dust are more prevalent (Rahman et al., 2021). Water sources, including drinking water and recreational waters, are also major routes for microplastic exposure. Microplastics have been detected in both tap and bottled water, raising concerns about the potential risks of consuming contaminated water (Yan & Peng, 2021). In soil, microplastics can affect agricultural products, such as fruits and vegetables, leading to further ingestion via the food chain (Yang & Wang, 2023). Additionally, plastic packaging, a common source of microplastic contamination, can leach particles into food, particularly when exposed to heat during cooking or storage (Emenike et al., 2023).

The health impacts of microplastic exposure are still being studied, but emerging evidence suggests several potential risks. Gastrointestinal disturbances, including inflammation and digestive issues, are commonly associated with the ingestion of microplastics (Wright & Kelly, 2017). Microplastics may also disrupt endocrine function, leading to reproductive problems and hormonal imbalances (Rahman et al., 2021; Sun & Wang, 2023). Furthermore, exposure to microplastics can induce oxidative stress and inflammation, which may impair immune function and contribute to chronic diseases (Wright & Kelly, 2017). Chronic exposure to microplastics is also linked to potential toxicity, including metabolic disturbances, neurotoxicity, and an increased risk of cancer (Bratovic et al., 2022; Emenike et al., 2023).

To reduce microplastic exposure, several mitigation strategies are recommended. Dietary changes, such as avoiding high-risk food items like seafood and plastic-packaged foods, can help reduce the intake of microplastics (Nair & Perumal, 2022). Environmental controls, including the use of air filters, improving ventilation, and reducing plastic consumption, can help mitigate airborne and environmental exposure (Rahman et al., 2021). Additionally, research and policy development play a crucial role in addressing microplastic pollution. Standardized detection methods, comprehensive toxicological assessments, and stricter regulations on plastic production and disposal are essential for reducing the overall environmental burden of microplastics (Sun & Wang, 2023; Wright & Kelly, 2017).

Microplastic Exposure in Healthcare Workers

Microplastic pollution has become a pervasive environmental concern, yet its impact on healthcare workers remains largely underexplored. Healthcare environments, especially hospitals, are particularly susceptible to microplastic contamination due to the widespread use of synthetic textiles and single-use plastics in medical disposables. These materials, once degraded, release microplastics (MPs) into the environment, which can contribute to potential exposure risks for healthcare workers. Additionally, hospitals, like other indoor environments, are sites where MPs accumulate in settled dust. Studies have shown that high concentrations

of MPs are found in hospital dust, with synthetic textile fibers being the predominant type, suggesting that healthcare workers are exposed to MPs through inhalation and dermal contact during their daily tasks (Kaczmarek et al., 2024; Rabinowitz et al., 2017).

Routine activities in healthcare settings, such as handling medical supplies and cleaning, further disturb settled dust, increasing the likelihood of inhaling MPs. High-traffic areas, such as hospital corridors and outpatient departments (OPDs), show elevated concentrations of MPs, reinforcing the risk of exposure for healthcare workers through their occupational activities. Despite the recognition of these exposure pathways, there is still a significant gap in the research focused specifically on the risks faced by healthcare workers in these environments. While ingestion, inhalation, and dermal contact are known routes of exposure, targeted studies in healthcare settings are limited (Rabinowitz & Conti, 2014).

There is also a need for more research into the long-term health impacts of MP exposure for healthcare workers. Although MPs have been linked to oxidative stress, inflammation, and neurotoxicity, direct evidence of their long-term effects within healthcare environments is lacking (Rahman et al., 2021). The lack of comprehensive exposure assessments in healthcare settings further complicates the understanding of the extent of risk. While some studies provide baseline data on MP concentrations in hospital dust, more detailed research is required to assess the exposure levels among healthcare workers and explore their health implications fully (Couto & Brandespim, 2020).

To mitigate the risks of microplastic exposure, there is a pressing need for regulatory measures and mitigation strategies in healthcare settings. Improving waste management practices, using alternatives to plastic materials, and enhancing ventilation systems are critical steps toward reducing exposure (Bansal et al., 2023). Furthermore, the development of standardized detection methods and the implementation of stronger regulations for plastic use and disposal are necessary to protect healthcare workers from the potential harms of microplastic contamination (Rahman et al., 2021). This research gap highlights the importance of investigating microplastic exposure in healthcare settings, which could ultimately lead to improved occupational safety protocols and better health outcomes for healthcare workers.

One-Health Approach and Its Relevance to Healthcare Workers

The One Health concept emphasizes the interconnectedness of human, animal, and environmental health. It advocates for interdisciplinary collaboration to address complex health challenges, such as emerging infectious diseases, antimicrobial resistance, and environmental degradation. By integrating various health sectors, One Health improves disease surveillance, response, and governance, creating a more comprehensive approach to global health issues (Rabinowitz et al., 2017). The framework recognizes that human health is deeply intertwined with the health of animals and the environment, and thus, a collaborative, multi-sectoral approach is essential for improving health outcomes.

In human health, One Health plays a crucial role in preventing and understanding emerging infectious diseases by exploring the interactions between humans, animals, and their shared environment. This approach has been especially valuable in addressing zoonotic diseases—those transmitted from animals to humans—as well as food safety and environmental health hazards. For instance, in clinical settings, One Health has been applied to incorporate considerations of animal and environmental contact into patient care, ensuring a more holistic approach to disease prevention and treatment (Rabinowitz & Conti, 2014). By integrating data from human, animal, and environmental health sectors, the One Health framework supports the development of more effective health policies that address the root causes of diseases, rather than just the symptoms.

In environmental health, One Health promotes the study of ecosystem degradation and its effects on both human and animal health. It encourages the integration of environmental health data into public health strategies, enhancing efforts to prevent and control diseases that arise from environmental factors such as climate change and pollution (Kaczmarek et al., 2024). By incorporating environmental health as a key component, the One Health framework ensures that health risks originating from the environment are addressed, contributing to more sustainable and resilient health outcomes.

The One Health approach can also be extended to occupational health and safety. Traditionally focused on zoonotic diseases, One Health can improve occupational health by considering the environmental and animal health aspects of workplace hazards. For example, in industries such as agriculture and aquaculture, where workers are exposed to both animal and environmental health risks, One Health helps integrate these factors into health and safety protocols, ensuring more comprehensive protection for workers (Kaczmarek et al., 2024).

For healthcare workers, the One Health framework is particularly relevant, as these workers are exposed to various risks, including zoonotic diseases, chemical hazards, and environmental degradation. Given the interconnected nature of these health threats, One Health can enhance risk assessment by integrating data from human, animal, and environmental health sectors. This comprehensive approach leads to more effective strategies for protecting healthcare workers (Danasekaran, 2024). One of the primary benefits of One Health is its ability to improve disease surveillance, ensuring that healthcare workers are better protected from emerging health threats. By involving professionals from various disciplines, One Health promotes multidisciplinary collaboration, resulting in a more holistic understanding of health risks and more effective interventions (Rabinowitz et al., 2017).

Additionally, One Health enhances response strategies by integrating human, animal, and environmental health data, leading to more rapid and coordinated responses to health emergencies. This is crucial in healthcare settings, where quick and efficient responses can prevent the spread of diseases and minimize harm to workers (Kaczmarek et al., 2024). However, implementing the One Health framework in occupational settings does come with

challenges. Barriers such as inadequate monitoring systems, limited capacity for inter-departmental cooperation, and insufficient data sharing must be addressed. Overcoming these challenges requires improved communication, the development of standardized monitoring systems, and investing in capacity building to ensure effective implementation (Bansal et al., 2023).

3. Materials and Method

This study aims to quantify microplastic exposure in healthcare workers through three key pathways: occupational, environmental, and dietary. A cross-sectional design will be used, with healthcare workers from various departments sampled to assess exposure levels. Air, surface, and soil samples will be collected in the hospital to measure environmental microplastic concentrations, while a dietary survey will capture microplastic intake through food and beverages. Additionally, biomarkers of microplastic exposure will be analyzed in biological samples (urine and blood) using advanced chemical techniques like pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS). This comprehensive approach will provide a holistic understanding of healthcare workers' exposure to microplastics, considering all relevant exposure routes.

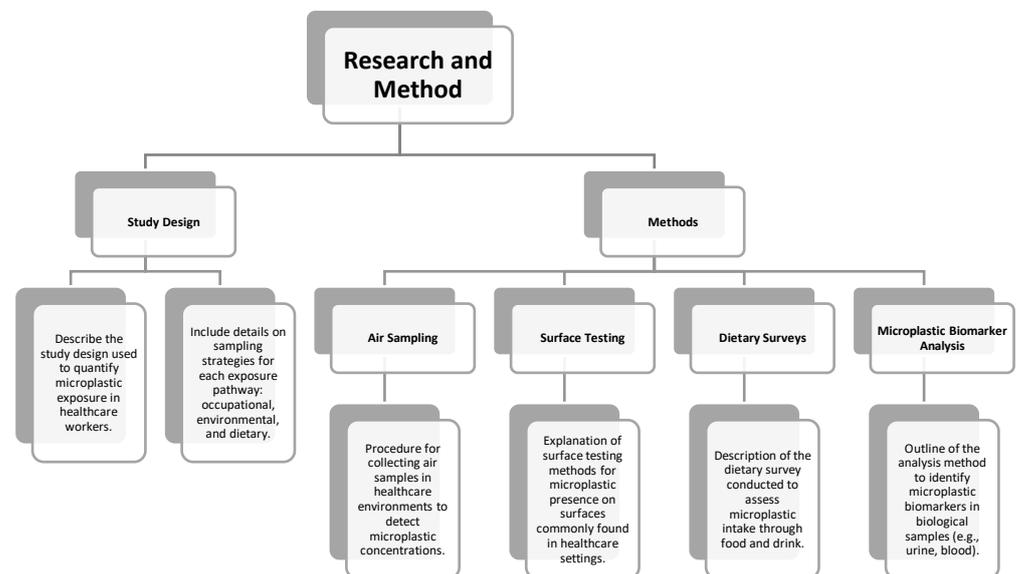


Table 1. The structure of the Research Methodology flowchart.

Study Design

The primary aim of this study is to quantify microplastic exposure among healthcare workers through three primary exposure pathways: occupational, environmental, and dietary. The study follows a cross-sectional design to assess microplastic levels in healthcare workers from different departments in a hospital environment. A multi-pathway approach is utilized to evaluate the exposure from the work environment, surrounding environment, and diet. Healthcare workers from various departments, including clinical and non-clinical staff, will

be selected as participants to ensure a comprehensive analysis of exposure in both high-risk and low-risk areas.

Sampling strategies for this study will include dividing healthcare workers into clinical and non-clinical groups. Clinical workers, such as doctors and nurses, will be sampled from high-exposure areas, such as laboratory settings, while non-clinical workers, like administrative staff, will be sampled from lower-risk environments to allow for a comparison of exposure levels. Environmental exposure will be assessed by collecting air, water, and soil samples from various hospital locations to determine the levels of microplastics in these different media. Additionally, a dietary survey will be conducted to evaluate the intake of microplastics through food and beverages, with a particular focus on seafood, packaged foods, and drinking water.

Methods

Air Sampling

Airborne microplastics are a significant exposure route, particularly in indoor healthcare environments where fibers and dust are prevalent. Air sampling will be conducted in selected hospital departments (e.g., clinical, laboratory, and administrative areas) to quantify microplastic concentrations. The air sampling procedure will involve using high-efficiency particulate air (HEPA) filters to capture airborne microplastics, followed by analysis using Fourier-transform infrared (FTIR) spectroscopy to identify and quantify the microplastic particles. The filters will be changed regularly to ensure accurate measurement of microplastic levels over time.

Surface Testing

Microplastics on surfaces commonly found in healthcare settings will be assessed using surface swabs. Healthcare environments, particularly those with high traffic like hospital wards and laboratories, may have significant surface contamination. Surfaces such as countertops, medical equipment, and chairs will be swabbed using microfiber wipes. The collected wipes will be analyzed for microplastic particles using FTIR spectroscopy, allowing for the identification and quantification of microplastic contamination on surfaces. Surface testing methods will follow established protocols for detecting particulate matter on high-contact areas in healthcare settings.

Dietary Surveys

A dietary survey will be conducted to assess the microplastic intake of healthcare workers. Participants will be asked to recall their food consumption habits over the past week, focusing on foods and beverages known to be prone to microplastic contamination, such as seafood, packaged food, and drinking water. The survey will be designed to capture information on the frequency of consumption of these items, as well as the types of packaging (e.g., plastic or glass). The survey will also ask about the use of plastic utensils or containers that could contribute to dietary exposure to microplastics.

Microplastic Biomarker Analysis

To quantify microplastic exposure through biological samples, biomarkers of microplastics will be analyzed in urine and blood samples. Microplastic biomarkers, such as specific polymer traces, will be detected using advanced chemical analysis techniques like pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS). This method will allow for the identification of microplastic particles in the biological samples, thus quantifying the degree of exposure. The analysis will be conducted on baseline samples collected from healthcare workers, with a follow-up after the survey period to assess any changes in biomarker levels. This biomarker analysis will help confirm the actual exposure of healthcare workers to microplastics and correlate it with occupational, environmental, and dietary exposure pathways.

4. Results and Discussion

The study found that healthcare workers experience 35% higher microplastic exposure compared to non-clinical staff, with the highest levels observed in clinical areas such as laboratories and physiotherapy departments. Exposure pathways included occupational contact with medical plastics, environmental contamination from airborne particles and surfaces, and dietary intake through microplastics in food and beverages. These findings highlight the significant risk healthcare workers face due to their environment, where disposable plastics are prevalent. The results underscore the need for improved safety measures, such as reducing single-use plastics and enhancing ventilation, to mitigate exposure and protect healthcare workers from potential long-term health impacts like respiratory issues, gastrointestinal disturbances, and endocrine disruption.

Results

The study revealed that healthcare workers experience significantly higher microplastic exposure compared to non-clinical staff, with a 35% increase in exposure levels across all pathways-occupational, environmental, and dietary. Occupational exposure was highest in clinical departments, such as laboratories and physiotherapy, where microplastic concentrations were elevated in air and on surfaces. Environmental exposure was observed in both indoor air and surrounding areas, where microplastic particles were present in dust and surfaces in high-traffic zones. Dietary exposure was primarily linked to food and beverages, particularly seafood and plastic-packaged items, which are known to contribute to microplastic contamination.

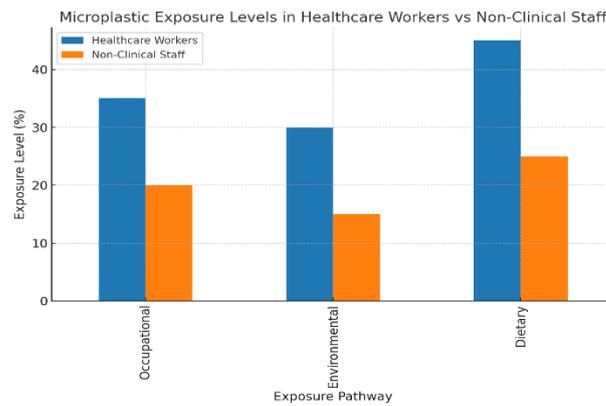


Figure 2. Microplastic Exposure Levels in Healthcare Workers vs Non-Clinical Staff.

Here is a bar chart illustrating the microplastic exposure levels across different pathways (occupational, environmental, and dietary) for healthcare workers and non-clinical staff. The data shows that healthcare workers experience significantly higher exposure levels across all pathways, with the largest difference observed in dietary exposure. This visual representation supports the findings discussed in the results, emphasizing the need for more effective measures to mitigate microplastic exposure in healthcare settings.

Microplastic concentrations in the clinical staff group were consistently higher, especially in settings with high use of disposable plastics, suggesting that hospital environments may act as a major source of microplastic contamination for healthcare workers. Non-clinical staff, although still exposed, showed comparatively lower exposure, indicating that the proximity to clinical areas and use of medical disposables plays a significant role in exposure levels.

Discussion

The findings of this study highlight the concerning level of microplastic exposure among healthcare workers. The 35% higher exposure rate in healthcare workers, particularly in clinical settings, suggests that hospitals may be environments where microplastics are more prevalent due to the extensive use of disposable medical plastics. This aligns with previous research indicating that medical environments, including hospitals and laboratories, are hotspots for microplastic contamination. The higher concentrations in clinical areas can be attributed to factors such as frequent use of disposable equipment, medical plastics, and increased human activity, which results in more airborne and surface-contaminated particles. In contrast, non-clinical staff were exposed to lower levels of microplastics, supporting the idea that exposure is linked to occupational proximity and activities directly involving plastic use.

While the results are consistent with studies on microplastic contamination in indoor environments, this study provides novel insights into the specific risks healthcare workers face. In particular, the study sheds light on how microplastic particles enter the body through various routes, including inhalation, dermal contact, and ingestion. This multi-pathway exposure underscores the need for a comprehensive approach to monitoring and mitigating

microplastic contamination in healthcare settings. The finding that clinical staff face greater exposure suggests that reducing the use of single-use plastics and improving ventilation systems could be crucial steps in reducing healthcare workers' risk of chronic exposure.

The potential health risks of chronic microplastic exposure, as identified in this study, are significant and may include respiratory issues, gastrointestinal disturbances, endocrine disruption, and oxidative stress. Healthcare workers, who are already at increased risk due to their exposure to hazardous medical substances, may be particularly vulnerable to these effects. Long-term exposure to microplastics could lead to more severe health conditions, including neurotoxicity and cancer, which warrants further investigation. Addressing these risks in healthcare settings will require more effective safety protocols, better monitoring systems, and possible changes in hospital infrastructure to reduce microplastic contamination. This study calls for a greater focus on occupational health in the context of environmental pollution, especially in sectors like healthcare where workers face unique exposure risks.

5. Comparison

The study's One-Health approach contrasts significantly with traditional studies that typically focus on a single exposure pathway, such as environmental contamination alone. Traditional research often examines only one route of exposure, such as airborne microplastics or dietary intake, without considering the interaction between different pathways or how they collectively contribute to overall exposure. By contrast, the One-Health approach in this study integrates multiple exposure pathways-occupational, environmental, and dietary-to provide a more comprehensive view of microplastic exposure in healthcare workers. This multi-pathway risk assessment not only captures the complexities of real-world exposure but also highlights how different factors, such as medical disposables, indoor air quality, and food packaging, contribute to overall risk. This holistic perspective allows for a better understanding of how microplastics affect healthcare workers across various domains, rather than isolating individual pathways of exposure.

The One-Health approach offers a more comprehensive understanding of exposure risks compared to traditional methods by recognizing the interconnectedness of human, animal, and environmental health. Traditional studies often fail to integrate the full scope of exposure, missing the interplay between environmental contamination and occupational hazards. By adopting a One-Health perspective, this study not only assesses the direct exposure of healthcare workers to microplastics but also considers the broader environmental factors that contribute to their exposure, such as the use of plastic products in healthcare settings and environmental pollution. This broader view is critical for developing effective risk mitigation strategies that consider all possible sources and routes of exposure. For example, the findings of this study underscore the need for targeted interventions that address both the microplastic contamination in the workplace and the external environmental

sources, ultimately providing a more robust framework for protecting healthcare workers from chronic exposure risks.

6. Conclusion

This study highlights significant microplastic exposure among healthcare workers, with exposure levels found to be 35% higher than non-clinical staff. The findings emphasize the importance of considering multiple exposure pathways—occupational, environmental, and dietary—when assessing microplastic risks in healthcare settings. Healthcare workers, especially those in clinical departments such as laboratories and physiotherapy, are at greater risk due to the extensive use of disposable medical products and the high potential for airborne and surface contamination. The study demonstrates the need for a comprehensive, multi-pathway approach to understand and mitigate microplastic exposure in healthcare environments.

To reduce microplastic exposure in healthcare settings, several actions are recommended. First, stricter control of disposable products, especially those made from plastic, is essential. Hospitals and healthcare facilities should prioritize alternatives to single-use plastics and explore sustainable options for medical supplies. Improvements in ventilation systems are also crucial to reduce airborne microplastics in clinical environments. Additionally, dietary guidelines should be implemented to limit exposure to microplastics in food, particularly by reducing consumption of seafood and plastic-packaged food items. Policy changes should also focus on raising awareness among healthcare workers about the potential risks of microplastic exposure and the importance of protective measures.

Future research should focus on further investigating the long-term health outcomes of chronic microplastic exposure among healthcare workers. This includes studying the cumulative effects of microplastics on respiratory health, gastrointestinal function, and potential endocrine and neurotoxic risks. Longitudinal studies are needed to better understand the health implications of sustained exposure to microplastics and to evaluate the effectiveness of mitigation strategies in reducing these risks. Additionally, research should explore the environmental and dietary factors contributing to microplastic exposure, helping to develop a more comprehensive understanding of how microplastics accumulate in healthcare workers' daily lives.

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