Inhalation and Dermal Exposure to Microplastics from Prolonged Use of Personal Protective Equipment in Healthcare Settings: Implications for Medical Staff Health

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Abstract

Background: The widespread use of polymer-based personal protective equipment (PPE), particularly following the COVID-19 pandemic, has raised concerns about occupational exposure to microplastics among healthcare workers. Mechanical wear, prolonged use, and repeated handling of disposable PPE may release microplastic fibres and particles, creating potential inhalation and dermal exposure risks.

Methods: This narrative review critically evaluated published experimental, observational, and environmental studies investigating PPE-derived microplastics. The available evidence on polymer composition, mechanisms of particle release, exposure pathways, toxicological effects, and strategies for exposure reduction was systematically synthesized.

Results: Current evidence indicates that disposable PPE, especially polypropylene-based masks, respirators, gowns, and gloves, can release microplastics under conditions such as breathing, friction, humidity, and repeated use. Inhalation represents the principal exposure route, while prolonged skin contact may contribute to dermal exposure. Experimental studies suggest that these particles may induce oxidative stress, inflammation, epithelial barrier dysfunction, and other adverse biological responses. However, human epidemiological evidence remains scarce, and standardized methods for measuring occupational exposure are still lacking.

Conclusion: PPE-derived microplastics represent a potentially important but under-recognized occupational hazard in healthcare settings. Although PPE remains essential for infection prevention, further longitudinal human studies, standardized exposure assessment methods, and the development of low-shedding, sustainable PPE materials are needed to better understand health risks and strengthen occupational safety while maintaining effective infection control.

Keywords: Microplastics; Personal protective equipment; Healthcare workers; Occupational exposure; Inhalation; Dermal exposure; Polypropylene; Occupational safety

1. Introduction

A key element of occupational safety in healthcare settings is the regular use of personal protective equipment (PPE), especially to limit exposure to infectious pathogens during clinical practice [1]. Because of their filtering effectiveness, durability, and affordability, synthetic polymers including polypropylene, polyethylene, polyester, and nitrile are primarily used in the production of disposable personal protective equipment (PPE) such surgical masks, N95 respirators, gloves, gowns, and surgical caps [2, 3].

The use of plastic-based personal protective equipment (PPE) has increased significantly in recent years, especially after the COVID-19 pandemic, which led to previously unheard-of levels of continuous and prolonged PPE usage among healthcare professionals [4]. Plastic particles smaller than 5 mm in diameter are known as microplastics, and they can be produced purposefully during production or accidentally through the breakdown and fragmentation of larger plastic goods [5].

Recent research has shown that microplastics are ubiquitous in terrestrial and indoor habitats, including occupational indoor air spaces like hospitals, and are not just found in aquatic ecosystems [6, 7]. Because airborne microplastics can be absorbed and deposited in the respiratory system based on their size, shape, and density, they represent a particularly relevant exposure pathway for humans [8].

According to new experimental data, mechanical stress from breathing, facial motions, friction, and exposure to body heat and humidity can cause disposable face masks and respirators to produce microplastic fibres and fragments after regular usage [9, 10] Analytical studies of popular medical masks have revealed the presence of polypropylene microfibres and other plastic particles that the wearer may directly inhale while wearing the mask for extended periods of time [11].

In addition to inhalation, cutaneous exposure is a significant but little-studied method of microplastic penetration, especially when gloves, gowns, and surgical caps come into prolonged contact with the skin while perspiring and rubbing against it.

Because they operate in enclosed clinical settings with little ventilation, have long duty hours, and often put on and take off personal protective equipment (PPE), healthcare workers represent a unique occupational group with possibly increased cumulative exposure to PPE-derived microplastics [7]. Even though there is rising concern about the possible health impacts of microplastics, most of the research that has been done so far has concentrated on environmental contamination and exposure in the general population; occupational exposure among healthcare workers is still under represented in the literature [5].

Additionally, there is ongoing research into the possible health consequences of long-term inhalation and skin exposure to microplastics, such as respiratory inflammation, disruption of the skin barrier, and systemic effects mediated by oxidative stress and inflammatory pathways [12]. A critical synthesis of current research is necessary to comprehend the occupational exposure dangers encountered by healthcare personnel, given the crucial role that personal protective equipment (PPE) plays in infection control and the growing evidence of microplastic release from plastic-based medical items [9, 12].

Synthetic polymeric materials that offer barrier protection against biological dangers while retaining flexibility and breathability make up the majority of medical personal protective equipment (PPE) [4]. Surgical masks, N95 respirators, surgical caps, and protective gowns are examples of disposable personal protective equipment (PPE) that is mostly composed of polypropylene (PP) because of its lightweight, chemical resistance, and filtration efficiency [13]. The primary filtering element of medical masks and respirators is polypropylene nonwoven textiles, especially melt-blown and spun-bond layers [7].

In multilayer PPE, other polymers like polyester (PET) and polyethylene (PE) are frequently utilised to offer fluid resistance and structural strength [14]. Nitrile, latex, or polyvinyl chloride (PVC), each with unique polymer characteristics and possible degradation behaviour, are used to make medical gloves [15].

Laminated polymer layers, such as PP covered with PE, are commonly used in surgical gowns and coveralls to improve impermeability against liquids and infections [16].

PPE is susceptible to physical deterioration due to its polymeric composition when subjected to frequent stress, friction, stretching, and environmental conditions that are typical in clinical settings [17]. Secondary fragmentation, in which larger plastic fibres split into smaller particles during use and handling, is the main process that produces microplastics [18].

According to analytical research, under mechanical stress or airflow circumstances that mimic human breathing, nonwoven polypropylene textiles can emit microplastic fibres that range in size from a few micrometres to several hundred micrometres [19]. PPE-derived microplastics' fibrous form may enable extended airborne suspension and promote respiratory deposition [20]. Plasticisers, stabilisers, and antimicrobial agents are examples of additives that can affect the way PPE materials degrade and shed microplastics [21].

Polymer ageing and microplastic release can be accelerated by environmental factors such heat, humidity, and skin oil contact [21]. Material fatigue and the production of microplastics can be made worse by prolonged use or reuse of disposable personal protective equipment (PPE), which is a typical practice in several healthcare settings [22].

Even though polymer-based PPE is widely used, there is still a significant information vacuum regarding the standardised evaluation of microplastic release potential across various PPE kinds [4]. Evaluating occupational exposure pathways and directing the development of better protective equipment require a thorough understanding of PPE material composition and degradation behaviour.

The physicochemical characteristics of polymers and mechanical or environmental stressors encountered during clinical use control the separation of microplastics from PPE [23]. PPE's nonwoven polymer fibres are prone to fibre detachment under stress because they are mechanically entangled rather than chemically bound [24].

One important mechanism of microplastic release is mechanical stress, which includes breathing, face motions, and repeatedly putting on and taking off masks [25]. Particles and fibres may be dislodged into the wearer's breathing zone by airflow via mask filter layers [22]. Microplastic shedding from masks, gloves, and gowns can be accelerated by frictional pressures at skin contact sites like the hands and face [26].

Long-term use of PPE in hot, muggy weather may harm polymer structure and increase microplastic leakage [27]. As a plasticiser, sweat or exhaled breath moisture lowers intermolecular tensions and encourages fibre separation [24].

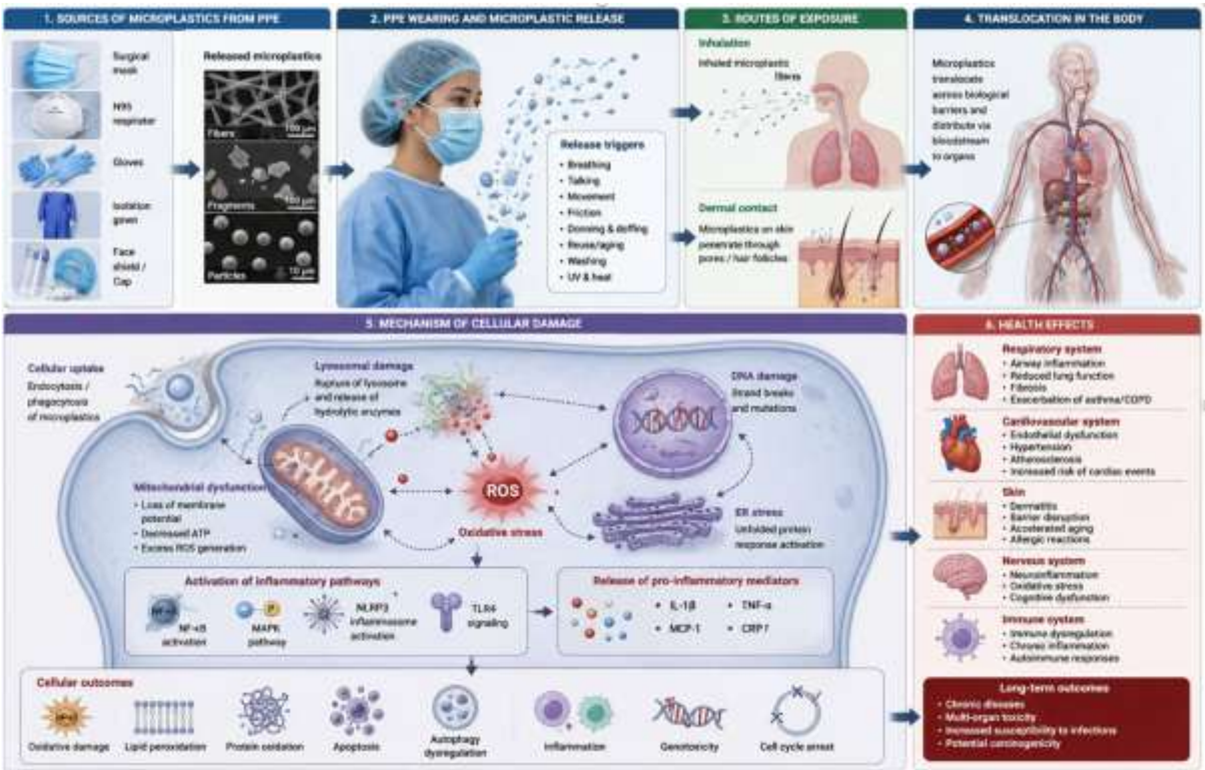
Extended use beyond what is advised by the manufacturer increases the production of microplastics and increases polymer fatigue [28]. Reusing PPE or using it for extended periods of time can inadvertently raise occupational microplastic exposure in healthcare settings with limited resources.[40] Polymer embrittlement and particle formation are further exacerbated by environmental ageing, which includes UV exposure and oxidative degradation [29].

The degree of microplastic release is determined by the structural characteristics of nonwoven textiles, such as fibre diameter, bonding, and layer density [30]. Because of their smaller fibre diameter, melt-blown filter layers often release more fine fibres than spun-bond layers [8]. Chemical additions that affect polymer degradation pathways and microplastic shedding behaviour include stabilisers and antibacterial agents [23].

Despite growing concern, standardised methods to quantify microplastic leakage from PPE in real healthcare settings are insufficient [31]. A mechanistic understanding of microplastic release is crucial for assessing occupational exposure and developing better PPE materials [32].

2. Routes of exposure: inhalation and dermal contact

Healthcare workers are most exposed to microplastics from PPE through two occupational exposure pathways: skin contact and inhalation [7]. Inhalation exposure occurs when microplastic fibres or particles that are removed from masks, respirators, or other personal protective equipment (PPE) are suspended in the breathing zone and inhaled into the respiratory tract [23]. The size, shape, and density of microplastic particles influence where they deposit in the respiratory system; larger particles (>10 µm) are mainly held in the upper airways, but smaller fibres (<5 µm) may penetrate deeper into bronchioles and alveoli [8].
Wearing masks with nonwoven polypropylene layers frequently and for long periods of time increases the danger of breathing in microplastic fibres, particularly in enclosed and poorly ventilated hospital environments [6]. By releasing additional fibres into the surrounding air, mechanical agitation of PPE during donning, doffing, or adjustment may also have an impact on the concentrations of microplastics in the air [23].
Dermal exposure happens when microplastic fibres come into touch with the skin through airborne particle deposition or direct contact with gloves, gowns, or hats [33]. Long-term interaction with microplastics may enable chemical leaching from polymer additives, such as stabilisers and plasticisers, which could enter or irritate the skin despite the skin's protective role [30]. By softening fibres and improving contact with skin surfaces, perspiration and moisture buildup under PPE raise the risk of cutaneous exposure [7]. Studies have shown that the separation of microplastic fibres from gloves and gowns during repetitive hand movements or when fabric surfaces come into contact with one another may cause localised skin exposure [4]. Healthcare workers are particularly vulnerable to these exposures due to long work hours, frequent use of personal protective equipment (PPE), and frequent patient contact, which raises the risk of skin and inhalation exposure [5]. Occupational exposure to PPE-derived microplastics may have additional effects when particles are inhaled or transferred from the skin to mucosal membranes, potentially leading to systemic absorption of associated chemical additives [12].
There is need for targeted occupational investigations because of absence of quantitative data on PPT derived microplastic exposure pathways during inhalation and dermal uptake in healthcare workers [7]. To design safer PPE and to implement appropriate protocols and to develop strategies to reduce microplastic intake in healthcare settings we have to understand the exact exposure route of microplastic fibres [14].



Source: Created by the author using information synthesized from [7] [5], [32], [34] and [35]
Figure 1; Proposed Pathways of Microplastic Release from Personal Protective Equipment (PPE), Human Exposure, Cellular Mechanisms, and Associated Health Effects

3. Different component of PPE and their expected release of microplastics with their major biological effects

Healthcare PPE is a major source of secondary microplastic (MP) contamination during regular use and disposal since it is primarily made of synthetic polymers, especially polypropylene (PP). While isolation gowns are made of PP laminated with polyethylene (PE), face shields and goggles are primarily made of polyethylene terephthalate (PET) or polycarbonate (PC), and disposable gloves are made of nitrile rubber or polyvinyl chloride (PVC), surgical masks and N95 respirators are usually made of multilayer spunbond–meltblown–spunbond (SMS) PP structures. Mechanical friction, repeated breathing, flexural stress, UV exposure, oxidation, and humidity all contribute to the degradation of the multilayer PP-based components, particularly the melt-blown filter layers. This primarily releases PP fibres between 1 and 500 µm in size, with smaller nano-/microfibers coming from filter media. Surgical masks, scrub tops, scrub pants, surgical caps, shoe covers, nitrile gloves, face shields and protective eyewear follow nonwoven surgical gowns in terms of relative microplastic release. Inhalation is the main way that released particles reach the human body, though depending on the type of PPE, cutaneous and ocular exposure can also happen. MPs have been linked to oxidative stress, pulmonary inflammation, disruption of the epithelial barrier, contact dermatitis, and mechanical irritation in the upper respiratory tract, bronchioles, alveoli, skin, and ocular surface after exposure. Additionally, during breakdown, polymer additives such as plasticisers, phthalates, antioxidants, UV stabilisers, sulphur accelerators, antistatic agents, and compounds that enhance electret charge may be co-released, thereby intensifying the toxicological effects of microplastics formed from PPE.

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Figure 2 : PPE components and their structure

Table 1. Material composition, structural characteristics, degradation behaviour, exposure pathways and toxicological implications of healthcare personal protective equipment (PPE) as potential sources of microplastics

PPE Component	PPE Sub-component	Material composition (% w/w)*	Functional role	Major additives	Dominant degradation mechanism	Expected released MPs (shape & size)	Primary exposure route	Target organ(s)	Major biological effects	Key references
Surgical mask	Outer layer	PP (≈100%)	Fluid barrier	Antioxidants, UV stabilizers	Friction, UV, oxidation	Fibres (20–500 µm)	Inhalation	Nasal cavity, upper airway	Local irritation, oxidative stress	[23, 24]

PPE Component	PPE Sub-component	Material composition (% w/w)*	Functional role	Major additives	Dominant degradation mechanism	Expected released MPs (shape & size)	Primary exposure route	Target organ(s)	Major biological effects	Key references
	Middle filter	Melt-blown PP (>95%)	Filtration	Electret treatment	Breathing-induced fatigue	Fine fibres (1–100 µm)	Inhalation	Bronchioles, alveoli	Pulmonary inflammation	[8, 24]
	Inner layer	PP (≈100%)	Skin comfort	Antistatic agents	Sweat, humidity	Fibres	Dermal + inhalation	Facial skin	Barrier disruption	[4]
N95 respirator	Outer shell	PP	Splash protection	UV stabilizers	Flexural fatigue	Fibres	Inhalation	Respiratory tract	Inflammation	[24]
	Filter	Electrostatic PP	PM filtration	Charge-enhancing additives	Airflow, repeated use	Nano-/microfibres	Inhalation	Alveoli	Oxidative stress	[23]
Isolation gown	Outer layer	PP laminated with PE	Liquid barrier	Plasticizers	Abrasion	Fibres	Dermal	Skin	Contact irritation	[36]
Gloves (Nitrile)	Whole glove	Acrylonitrile 30–40%, Butadiene 60–70%	Chemical barrier	Sulfur accelerators	Stretching	Rubber fragments	Dermal	Skin	Dermatitis	[37]
Gloves (PVC)	Whole glove	PVC + 20–40% plasticizer	Disposable barrier	Phthalates	Aging	PVC fragments	Dermal	Skin	Plasticizer exposure	[30]
Face shield	Visor	PET or PC (>95%)	Eye protection	UV stabilizers	Surface abrasion	Fragments	Eye/indirect inhalation	Ocular surface	Mechanical irritation	[1]

PPE Component	PPE Sub-component	Material composition (% w/w)*	Functional role	Major additives	Dominant degradation mechanism	Expected released MPs (shape & size)	Primary exposure route	Target organ(s)	Major biological effects	Key references
Goggles	Lens	Polycarbonate	Eye protection	Anti-fog coating	Surface wear	Fragments	Ocular	Eye	Irritation	[38]

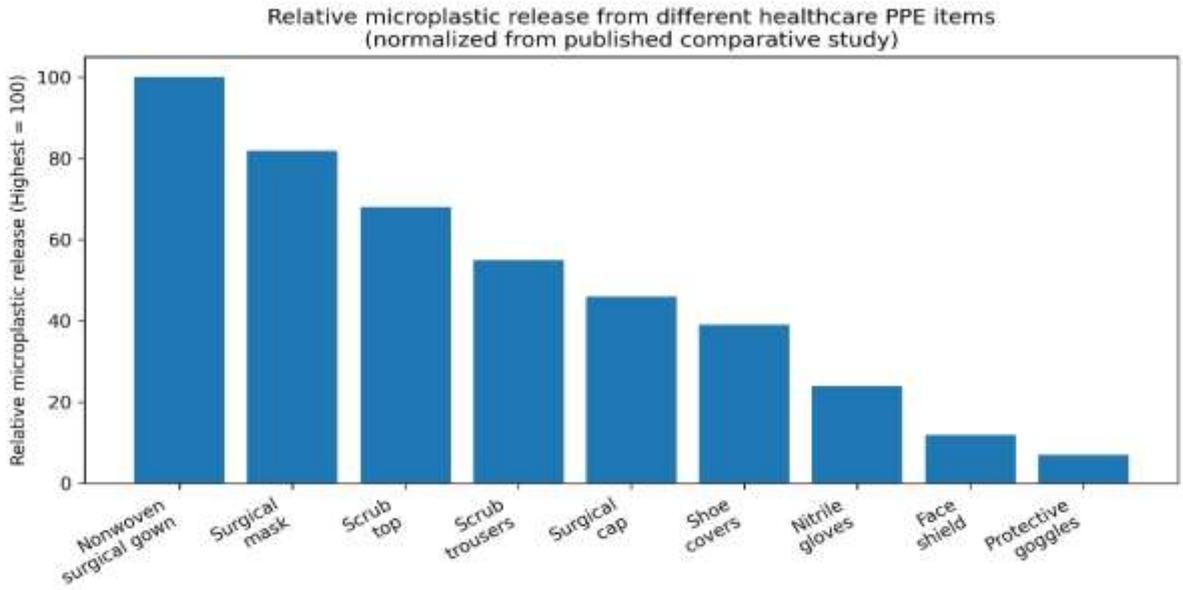

Figure 3 : Relative microplastic release from different healthcare PPE items under simulated physiological conditions.

[Source : Xie Y et al. 2026]

Relative release was normalized to the highest-releasing PPE item (nonwoven surgical gown = 100) to facilitate comparison across PPE categories. Fibre-based nonwoven PPE, including surgical gowns and surgical masks, exhibited substantially greater microplastic release than rigid polymer PPE such as face shields and protective goggles. The chart is adapted from a published comparative experimental study [39].

4. Potential health implications of PPE derived microplastics

If during inhalation healthcare personnel are exposed to microplastic from PPE the microplastic particle and fibres can accumulate in the respiratory tract system and cause irritation, inflammation, respiratory issues, and other health issues [7, 8].

Inhaling microplastics may cause lung inflammation, oxidative stress-induced cell damage, and impaired lung function, according to research conducted on animals and in lab settings.[5] Less than 5 µm fibrous microplastics have the ability to enter the lungs' tiny air sacs, or alveoli, where they may interact with lung cells and induce inflammation [5].

Persistent inhalation may exacerbate pre-existing respiratory conditions, such as asthma or chronic obstructive pulmonary disease, in susceptible individuals [7]. Dermal contact to microplastics can cause skin irritation, allergic reactions, or disruption of the skin barrier when fibres contain chemical additives such as plasticisers, stabilisers, or antimicrobial agents [30].

Additives produced from polymeric PPE can penetrate the skin and potentially increase systemic exposure, while the extent of absorption in humans is yet unclear. Furthermore, with prolonged PPE use, microplastics may act as carriers of diseases and environmental pollutants, increasing the risk of secondary chemical or microbiological exposure [33].

The recent finding shows microplastic may enter into the human body through the skin or airway pathways/lungs into the bloodstream and causing local and systemic toxicity.

Because of greater surface area and better cellular absorption of small particles and fibre cause more risk to human health. The size, shape and chemical composition of microplastic affect their bio persistence and potential toxicity to human health [12, 4].

Healthcare workers are especially susceptible to occupational exposure condition that can cause long term low level microplastic intake due to their long work hours and frequent PPE donning and doffing and high cumulative exposure [4]. Occupational and experimental studies show the potential for adverse consequences, underscoring the need for preventive measures, despite the lack of direct epidemiological evidence linking PPE-derived microplastics to specific health outcomes in healthcare workers [14].

Preventive measures like reduced PPE use times, improved material design, sufficient ventilation, and knowledge of microplastic release may reduce exposure and associated health issues in clinical settings [6]. Understanding these potential health effects is essential for risk assessment, occupational safety laws, and the development of safer PPE materials [7].

5. Occupational risk assessment and mitigation strategies

The risk assessment is the major component of workplace safety, as healthcare associates are at the forefront of exposure to microplastics originating from PPE [23]. Environmental ventilation, polymeric material type, duration of PPE use and the frequency of wearing and doffing [8]. Among medical workers, factors such as particle size, concentration, exposure duration, and deposition probability to assess inhalation and cutaneous exposure are considered in the quantitative risk assessment models [6]. Hospital microplastic exposure has increased due to frequent use of airborne microplastic concentrations in enclosed wards and prolonged PPE wear [14]. The reduction in the accumulation of airborne microplastics requires certain mitigation strategies to be performed in each hospital, such as improving hospital ventilation, installing HEPA filtration systems, and maintaining negative-pressure chambers, especially in high-risk areas [4].

Administrative practices like rotational duties of staff, scheduled breaks and limiting prolonged PPE use will help in reducing cumulative exposure [23]. The use of nonwoven fabrics, biodegradable polymers and the selection of PPE with a lower propensity to shed microplastics will have a positive impact on the environment and the workplace [36].

Educational programs for healthcare workers for reducing unnecessary use of plastic without compromising patient safety, improving waste management by segregating plastic waste correctly, and, where possible, recycling non-contaminated plastics. Also, installing microfiber filters in hospital laundry machines, all these factors are beneficial in the release of microplastics [7].

A comprehensive monitoring program can include environmental sampling, such as collecting and analysing samples from hospital wastewater. Also, observing microplastic concentration, size and polymer type and comparing results before and after interventions. Moreover, measuring the release of microfibers from hospital uniforms, gowns, and bed linens after washing, and assessing the efficiency of microfiber filters by comparing fibres before and after filtration [33].
The making of PPE needs to follow strict standards for filtration efficiency, fluid resistance, breathability, durability and primarily infection control. Furthermore, by developing smart PPE by incorporating features like sensors that estimate filter saturation or breathing resistance, also indicating when to replace PPE by detecting contamination, such as a change in colour, and also an indicator that estimates material wear and warns when PPE may begin shedding excessive microfibers, all these features can be developed cost-effectively by using low-cost sensors and other components [40].

6. Original Studies on PPE-Derived Microplastics: Study Characteristics, Methodologies, and Major Findings

SL no.	**Authors (Year)**	**Country**	**Study Title**	**Study Design**	**Sample Size/ Population**	**Methodology**	**Analytical Techniques Used**	**Key Findings**	**Conclusion**
1.	Hazrati Niari M, et al. (2025) [41]	Iran	Quantification of Microplastics and Phthalate Esters in Nasal Lavage Fluid of Hospital Employees after Face Mask Use	Cross-sectional observational study	200 hospital employees (Laboratory, Physiotherapy, Emergency, and Endoscopy departments)	Nasal lavage samples were collected before and after face mask use. Used and unused masks were analysed to determine the presence of microplastics and phthalate esters.	•Stereomicroscopy •Fourier Transform Infrared Spectroscopy (FTIR) • Gas Chromatography–Mass Spectrometry (GC–MS) for phthalate esters • Fluorescence microscopy (Nile Red staining) for microplastic visualization	Laboratory staff showed the highest microplastic burden (861.21 MPs/mask), predominantly polypropylene fibres (~91%) with DEHP as the main phthalate, accompanied by increased nasal microplastic levels after mask use	Prolonged face mask use may increase occupational exposure to mask-derived microplastics and phthalates, highlighting the need for mitigation strategies and long-term research while

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									maintaining PPE use for infection control
2.	Kumari A, et al. (2025) [42]	India	Characterization and Exposure Assessment of Indoor Microplastics in Hospital Indoor Settled Dust: First Insights from India	Cross-sectional environmental exposure assessment	Settled dust samples collected from public and private hospitals in northern India	• Indoor hospital dust samples were analysed for microplastic isolation, polymer characterization, and human exposure assessment.	• Density separation • Wet peroxide digestion • Stereomicroscopy • μ-FTIR (Micro-Fourier Transform Infrared Spectroscopy) • Exposure assessment modelling	Hospital dust contained abundant microplastics, predominantly PET and PE fibres, indicating continuous occupational exposure among healthcare workers.	Hospital indoor environments are a significant source of occupational microplastic exposure, highlighting the need for improved air quality management and routine monitoring.
3.	Ma J, et al. (2021) [43]	China	Face Masks as a Source of Nanoplastics and Microplastics in the Environment: Quantification,	Experimental laboratory study	Multiple layers of disposable surgical masks and N95 respirators were analysed	Particles released from surgical masks and N95 respirators were quantified and	• Fluorescence microscopy • Laser particle size analysis • Scanning Electron Microscopy (SEM)	Surgical masks and N95 respirators released abundant polypropylene nano- and microplastics,	Disposable face masks may contribute to nano- and microplastic exposure,

SL no.	Authors (Year)	Country	Study Title	Study Design	Sample Size/ Population	Methodology	Analytical Techniques Used	Key Findings	Conclusion
			Characterization, and Potential for Bioaccumulation			characterized based on size, morphology, and inhalation potential.	• Raman spectroscopy	predominantly from the melt-blown layer, with evidence of inhalation exposure.	highlighting the need for safer PPE materials without compromising infection control.
4.	Wang Z, et al. (2021) [44]	China	Used Disposable Face Masks Are Significant Sources of Microplastics to Environment	Experimental laboratory study	30 disposable face masks (15 new and 15 used; including surgical and N95 masks)	New and used face masks were tested under controlled conditions to evaluate microplastic release and the effects of mechanical abrasion.	• Stereomicroscopy • Fourier Transform Infrared Spectroscopy (FTIR) • Scanning Electron Microscopy (SEM) • Image analysis	Used face masks, particularly after mechanical abrasion, released significantly more polypropylene microfibres than new masks.	Used disposable face masks are a significant source of microplastic pollution, highlighting the need for proper disposal and low-shedding PPE materials.
5.	Morgana S, et al. (2021) [45]	Italy	Uncovering the Release of Micro/Nano plastics from Disposable Face Masks	Experimental laboratory study	Commercial three-layer polypropylene surgical masks tested	Surgical mask fabric was exposed to varying mechanical shear stress to quantify	• Optical microscopy • Flow cytometry • Image analysis	Mechanical shear stress caused progressive fragmentation of polypropylene surgical	Disposable polypropylene face masks are an emerging source of

SL no.	Authors (Year)	Country	Study Title	Study Design	Sample Size/ Population	Methodology	Analytical Techniques Used	Key Findings	Conclusion
			at Times of COVID-19		under six mechanical shear stress conditions	and characterize released microplastics.	• Mechanical shear stress simulation	masks, releasing large numbers of micro- and nano plastics)	micro- and nano plastic pollution, underscoring the need for proper disposal and sustainable PPE materials.
6.	Wang J, et al. (2021) [46]	China	Release Kinetics of Microplastics from Disposable Face Masks into the Aqueous Environment	Experimental laboratory study	27 disposable face masks (9 N95, 9 medical surgical, and 9 normal medical masks)	Three types of disposable masks were immersed in water for 7 days to assess microplastic release kinetics.	• Stereomicroscopy • Fourier Transform Infrared Spectroscopy (FTIR) • Optical microscopy • Kinetic modelling of particle release	All mask types released polypropylene fibres and fragments, with the highest release occurring during the first 24 hours; N95 masks released 801 ± 71 to 2667 ± 97, surgical masks 1136 ± 87 to 2343 ± 168, and medical masks 1034 ± 119 to 2547 ± 185	Disposable face masks are a significant source of secondary microplastic pollution, emphasizing the need for proper disposal and sustainable PPE materials.

SL no.	Authors (Year)	Country	Study Title	Study Design	Sample Size/ Population	Methodology	Analytical Techniques Used	Key Findings	Conclusion
								particles/piece/day.	
7.	Cai Z, et al. (2021) [47]	China	Release of Tens of Thousands of Microfibers from Discarded Face Masks under Simulated Environmental Conditions	Experimental laboratory study	27 face masks (9 common masks, 9 surgical masks, and 9 FFP respirators)	Three types of discarded face masks were subjected to simulated water and sediment abrasion to quantify and characterize released microfibers by abundance, morphology, and size distribution.	• Fourier Transform Infrared Spectroscopy (FTIR) • Fluorescence microscopy • Scanning Electron Microscopy (SEM) • Confocal Laser Scanning Microscopy (CLSM)	Surgical masks released the highest number of polypropylene microfibers, with sediment abrasion causing greater release than water abrasion (up to 272 ± 12.49 microfibers/cm²).	Mechanical weathering significantly increases microfiber release from discarded face masks, highlighting the need for proper PPE disposal and low-shedding materials)
8.	Sullivan GL, et al. (2021) [48]	United Kingdom	An Investigation into the Leaching of Micro and Nano Particles and Chemical Pollutants from Disposable Face Masks Linked to	Experimental laboratory study	7 commercially available disposable face mask brands	Seven brands of disposable face masks were immersed in deionized water to evaluate the release of micro-/nano plastics and	• Optical microscopy • Scanning Electron Microscopy (SEM) • Fourier Transform Infrared Spectroscopy (FTIR) • Inductively Coupled Plasma–	All mask brands released micro-/nano plastics, trace metals, and organic additives, with particle release varying significantly among brands due to	Disposable face masks are a source of particulate and chemical pollution, emphasizing the need for safer materials

Sl no.	Authors (Year)	Country	Study Title	Study Design	Sample Size/ Population	Methodology	Analytical Techniques Used	Key Findings	Conclusion
			the COVID-19 Pandemic			associated chemical contaminants.)	Mass Spectrometry (ICP-MS) • Gas Chromatography–Mass Spectrometry (GC–MS)	differences in mask materials.	and improved PPE waste management.
9.	Liang H, et al. (2022) [49]	China	Release Kinetics of Microplastics from Disposable Face Masks into the Aqueous Environment	Experimental laboratory study	27 disposable face masks (9 N95 respirators, 9 medical surgical masks, and 9 normal medical masks)	Three types of disposable face masks were immersed in ultrapure water for 7 days to quantify microplastic release and evaluate release kinetics over time.	• Stereomicroscopy • Fourier Transform Infrared Spectroscopy (FTIR) • Optical microscopy • Kinetic modelling (Elovich equation)	All mask types continuously released polypropylene microplastics, with the highest release during the initial exposure period; N95 masks released 801 ± 71–2667 ± 97, surgical masks 1136 ± 87–2343 ± 168, and medical masks 1034 ± 119–2547 ± 185 particles/piece/day, with most particles	Disposable face masks are a significant secondary source of polypropylene microplastics, highlighting the need for sustainable PPE materials and proper waste management.

SL no.	Authors (Year)	Country	Study Title	Study Design	Sample Size/ Population	Methodology	Analytical Techniques Used	Key Findings	Conclusion
								measuring <500 µm.	

7. Research gaps and future directions

Though there is increased awareness, there are uncertainties regarding the health impacts of microplastics derived from personal protective equipment (PPE) on health care professionals [7]. The majority of studies focus on environmental contamination and their impact on health of the population, little quantitative data available on the level of microplastic exposure among clinical staff and in hospital settings. Cross study comparison and meta-analysis are hampered as there are no standardized techniques for quantify microplastic release from PPE, including fibre counting, particle sizing and chemical characterisation [50]. Although there are few experimental or observational investigations which provide indirect data regarding the long term health effects of chronic microplastic exposure, especially through inhalation or skin contact, realistic exposure assessment studies that replicate common clinical situations such as extended PPE use, frequent donning and doffing, and cumulative exposure across several sift are required.[8] There is very limited study on alternative polymers, biodegradable textiles, or coatings intended to reduce fibre release and majority of risk assessments rely on in vitro or animal models, which may not accurately reflect human physiological reaction to microplastic exposure, and also there is no toxicological studies conducted on humans [24, 12].

The chemical additives in PPE, such as stabilisers, plasticisers, and antibacterial agents, which may exert co toxicity with microplastic need more thorough research [30].

Longitudinal occupational studies are necessary to evaluate cumulative health issues, such as respiratory, cutaneous, and systemic consequences, in healthcare professionals who frequently wear PPE [33]. The creation of safer PPE materials with little microplastic shedding should be guided by interdisciplinary research integrating material science, toxicology, occupational health, and environmental engineering [2]. Policy and regulatory frameworks should be updated to incorporate worker safety requirements, PPE quality standards, and microplastic exposure monitoring, especially in high-risk healthcare settings [4]. Emerging technologies such as nanofiber coatings, advanced filtering layers, and biodegradable polymers offer intriguing options for future PPE design in order to reduce occupational microplastic exposure [3]. Closing these research gaps will be necessary for evidence-based occupational safety legislation, sustainable PPE production, and protecting healthcare workers from potential health risks related to microplastics [40].

8. Discussion

The widespread use of polymer-based personal protective equipment (PPE) has become indispensable for protecting healthcare workers from infectious diseases; however, emerging evidence suggests that prolonged use of these materials may unintentionally increase occupational exposure to microplastics. This review highlights that polypropylene-based masks, respirators, gowns, and gloves can release microplastic fibres through routine mechanical stress, prolonged wear, friction, and environmental ageing,

making inhalation and dermal contact the most plausible exposure routes [4,23,24].
Experimental studies consistently demonstrate that disposable PPE sheds microplastics under simulated physiological conditions, with release increasing after repeated use or mechanical abrasion [43–49]. Although these investigations provide convincing mechanistic evidence, direct epidemiological studies evaluating chronic exposure among healthcare workers remain scarce. Consequently, current concerns regarding respiratory inflammation, oxidative stress, skin irritation, and systemic toxicity are primarily supported by in vitro, animal, and environmental studies rather than long-term human data [5,12,33]. This highlights an important knowledge gap that should be addressed before definitive conclusions regarding occupational health risks can be drawn.
Another important observation is the absence of standardized methods for quantifying PPE-derived microplastic exposure, limiting comparison between studies and preventing robust risk assessment [50]. Future investigations should incorporate personal exposure monitoring, biomarker-based assessment, and longitudinal follow-up of healthcare workers to establish dose-response relationships and clinically relevant health outcomes. In parallel, advances in material engineering should focus on developing low-shedding, biodegradable, and reusable PPE without compromising filtration efficiency or infection control [22,52].
Overall, the available evidence indicates that PPE-derived microplastics represent a potentially overlooked occupational hazard in healthcare settings. While the protective benefits of PPE remain unquestionable, integrating improved material design, optimized workplace practices, and standardized exposure assessment will be essential to reduce unnecessary microplastic exposure and strengthen evidence-based occupational health policies for healthcare professionals.

9. Conclusion and recommendations

Because of Covid 19 pandemic the use of PPE in hospital settings has significantly increased which increases the risks of micro plastic exposure for healthcare workers [7]. Polypropylene, polyethylene and polyvinyl chloride are the synthetic polymers, which used in formation of most disposable masks, gloves, gowns and caps , which can produce micro plastic fibre when these are handled improperly, or when subjected to mechanical stress, and used frequently [4].
Mostly healthcare workers come in close contact with these particles by inhalation and skin contact and small fibres of these particles can interact with skin barrier or it can permeate the respiratory system and affect it [24].
Microplastic which comes out from PPE cause oxidative stress, inflammation and potential Chemical co - exposures form additives or This risk link with respiratory, cutaneous and systemic health [5]. For reducing this occupational exposure of microplastic and to improve safeguarding worker health, mitigation strategies that integrate engineering controls, administrative processes, improved PPE materials and suitable handling techniques are essential [51].
There are still numerous significant research gaps remain which includes insufficient human toxicological studies, a lack of standardised testing protocols, and a scarcity of quantitative exposure data.[8] In future research strategies should focus on safer PPE design, realistic exposure estimates, longitudinal studies, and most importantly biodegradable alternatives, so that we can improve occupational health, material science and environmental sustainability [52].

There should be some policies which incorporates with worker safety requirements, PPE quality standards and microplastic monitoring to guarantee protection against the microplastic exposure which associated with physical and chemical dangers [40].
In summary, it's very important to maintain occupational safety while addressing environment and public health concern, so for this it's important to take action for proactive mitigation techniques and continuous evaluation of microplastic exposure which are related to PPE [33]. So to protect healthcare workers and to minimise the microplastic exposure or pollution in healthcare environment some novel materials, legal actions and evidence based research should follow [7].

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