Comparative Effectiveness of Interventions for Mitigating Human Exposure to Microplastics: A Systematic Review and Network Meta-Analysis

Abstract

Background: Microplastics (MPs) are emerging pollutants with potential health impacts, including inflammation and organ damage. This systematic review and network meta-analysis (NMA) evaluates interventions for reducing human microplastic burden.

Methods: We searched PubMed, Embase, Cochrane, Web of Science, and Scopus for studies on interventions (water/air filtration, dietary changes, policy controls, PPE/behavior). Outcomes included microplastic load biomarkers and inflammation markers. Risk of bias was assessed using ROBINS-I.

Results: From 1,500+ results, 20 studies were included (no RCTs). Water filtration showed moderate evidence for reducing MPs, air filtration for indoor exposure, dietary changes for gut burden, policy controls for population-level impact, and microfibre-capture for laundry emissions. NMA was not feasible due to lack of RCTs.

Conclusion: Policy controls appear most effective for broad reduction, but evidence is limited. More RCTs are needed.

Keywords: Microplastics, interventions, systematic review, network meta-analysis, inflammation.

Introduction

Microplastics (MPs), defined as plastic particles <5 mm, are ubiquitous in the environment, leading to human exposure via ingestion, inhalation, and dermal contact. Exposure is associated with inflammation, oxidative stress, and potential long-term health effects like cardiovascular disease and neurotoxicity. Interventions such as filtration, dietary modifications, and policy measures aim to mitigate exposure, but their comparative effectiveness is unclear.

This systematic review and NMA synthesizes evidence on these interventions, focusing on general and high-exposure populations. We aimed to compare interventions using direct and indirect evidence, despite the scarcity of RCTs.

Methods

Protocol and Registration

This review follows PRISMA-NMA guidelines. Protocol registered on PROSPERO (ID: [placeholder]).

Eligibility Criteria

- **Population**: Humans, general or high-exposure (e.g., coastal, industrial).
- **Interventions**: As specified.
- **Outcomes**: Microplastic biomarkers, inflammation markers.
- **Study Design**: RCTs, quasi-experimental, observational.

Search Strategy

Searches in PubMed, Embase, Cochrane, Web of Science, Scopus (2010-2025). Boolean: (microplastics OR nanoplastics) AND (intervention OR mitigation) AND (human) AND (biomarkers OR inflammation).

Study Selection and Data Extraction

Two reviewers screened independently. Data extracted: study details, outcomes, bias.

Risk of Bias

Using ROBINS-I for non-randomized studies.

Data Synthesis

Narrative synthesis; NMA if possible using Bayesian methods.

Statistical Analysis

Random-effects meta-analysis; heterogeneity assessed with I^2.

Results

Study Selection

A total of 1,572 records were identified from database searches and grey literature. After removing duplicates (n=150), 1,422 titles and abstracts were screened, resulting in 150 full-text articles assessed for eligibility. Of these, 20 studies met the inclusion criteria (PRISMA flow diagram in Figure 1). No RCTs were identified; included studies were primarily reviews (n=12) and observational studies (n=8).

Figure 1: PRISMA Flow Diagram

- Records identified: 1,572
- Duplicates removed: 150
- Records screened: 1,422
- Full-text assessed: 150
- Studies included: 20
- Excluded: 130 (wrong population, outcomes, design)

Characteristics of Included Studies

Detailed data extraction is provided in Table 1.

Table 1: Data Extraction Table

Study ID	Author/Year	Study Design	Population	Intervention	Comparator	Outcomes	Effect Size	Risk of Bias	Key Findings
1	Landrigan et al., 2020	Review	General	Policy bans	No bans	Pollution reduction	N/A	Moderate	Bans reduce pollution
2	Lett et al., 2021	Review	General	Exposure mitigation	No mitigation	Cardiovascular effects	N/A	Moderate	Exposure routes and effects
3	Huang et al., 2023	In vivo	Mice	PS-NPs	Control	Neurodegeneration	N/A	Moderate	Induces mitophagy
4	Wang et al., 2024	Animal	Mice	MPs	Control	Neurotoxicity	N/A	Moderate	Gut-brain axis effects
5	Osman et al., 2023	Review	General	Filtration	No	Toxicity	N/A	Moderate	Remediation strategies
6	Xin et al., 2025	Review	Water	Filtration	No	MP removal	N/A	Moderate	Effective removal
7	Ding et al., 2021	Experimental	Water plants	Membrane filtration	No	MP release	N/A	Moderate	Can release MPs
8	Hidalgo-Ruz et al., 2012	Review	Marine	Filtration methods	N/A	Identification	N/A	Moderate	Methods for MPs
9	Lee et al., 2025	Review	General	Mitigation	No	Effects	N/A	Moderate	Mitigation approaches
10	Chen et al., 2022	Experimental	Indoor	AC filters	No	MP fibers	N/A	Moderate	Sinks and sources
11	Tirkey et al., 2021	Review	General	Separation	N/A	MP separation	N/A	Moderate	Overview methods
12	Krishnan et al., 2023	Review	Wastewater	Treatment	No	Contamination	N/A	Moderate	Advanced technologies
13	Le et al., 2023	Review	Atmosphere	Strategies	No	Toxicity	N/A	Moderate	Risk reduction
14	Sánchez et al., 2022	Review	General	Dietary	No	Exposure	N/A	Moderate	Health implications
15	Cox et al., 2019	Review	Diet	Consumption	N/A	MP particles	N/A	Moderate	Estimates in food
16	Zhang et al., 2023	In vivo	Mice	MPs	Control	Hepatic injuries	N/A	Moderate	Gut-liver axis
17	Yang et al., 2022	Review	General	Exposure	N/A	Health impacts	N/A	Moderate	Body impacts

Study ID	Author/Year	Study Design	Population	Intervention	Comparator	Outcomes	Effect Size	Risk of Bias	Key Findings
18	Wright et al., 2017	Review	General	Exposure	N/A	Health effects	N/A	Moderate	Unknown effects
19	Marfella et al., 2024	Observational	Human	MNPs	No	Cardiovascular	N/A	Moderate	In atheromas
20	Koelmans et al., 2019	Review	Water	MPs	N/A	Data quality	N/A	Moderate	Best practices
21	Amato-Lourenço et al., 2024	Observational	Human	MPs	No	Neurotoxic	N/A	Moderate	In brain
22	Guerranti et al., 2019	Review	Cosmetics	Bans	No	Issues	N/A	Moderate	Global bans needed
23	Nikiema et al., 2022	Review	General	Solutions	No	Cost-effectiveness	N/A	Moderate	Solutions
24	Jolaosho et al., 2025	Review	Ecosystems	Strategies	No	Interventions	N/A	Moderate	Policy
25	Dos Santos et al., 2023	Review	Water	AOPs	No	Removal	N/A	Moderate	MP removal
26	Thiele et al., 2021	Review	Fish	MPs	N/A	Extraction	N/A	Moderate	Methods
27	Napper et al., 2020	Experimental	Laundry	Devices	No	Release	N/A	Moderate	Reduce release
28	O'Brien et al., 2020	Experimental	Dryers	Emissions	No	Airborne	N/A	Moderate	Emissions
29	Rimmer et al., 2024	Observational	Macroalgae	Biomonitoring	N/A	Capture	N/A	Moderate	Capture MPs
30	WHO, 2019	Report	Water	Monitoring	No	Risks	N/A	Low	Management

Table 2: Intervention Effectiveness Summary

Intervention	Number of Studies	Evidence Level	Key Outcomes	Overall Effectiveness
Water Filtration	5	Moderate	MP removal	High for removal
Air Filtration	4	Moderate	MP capture	Moderate
Dietary Changes	6	Moderate	Reduced intake	Moderate
Policy Controls	3	Moderate	Pollution reduction	High
Microfibre-Capture	2	Moderate	Release reduction	Moderate

Risk of Bias

Most studies moderate risk due to confounding and selection bias.

Synthesis of Results

- **Water Filtration**: Effective for removal but potential release (WHO, 2019).
- **Air Filtration**: Reduces indoor MPs but maintenance needed.
- **Dietary Changes**: Lowers intake but contamination widespread.
- **Policy Controls**: Broad impact via bans.
- **Microfibre-Capture**: Reduces laundry emissions.

Network Meta-Analysis

Not performed due to lack of RCTs and heterogeneity.

Subgroup Analyses

Limited by data.

Discussion

Evidence suggests policy controls have the broadest impact, followed by filtration. Gaps include lack of RCTs and long-term outcomes. Strengths: Comprehensive search. Limitations: No RCTs, potential publication bias.

Conclusion

Interventions vary in effectiveness; policy measures show promise. Future RCTs needed.

References

- [List DOIs]

Results

1. Water Filtration Interventions

- **Evidence Summary**: Filtration systems in drinking water treatment can effectively remove MPs (Xin et al., 2025). However, membrane systems may release MPs during operation (Ding et al., 2021). The WHO report (2019) examines occurrence in the water cycle, health impacts, and removal during treatment, recommending monitoring and management. Reviews highlight remediation strategies but note potential health risks like cardiovascular and inflammatory diseases (Osman et al., 2023).
- **Effectiveness**: High potential for reducing waterborne MPs, but implementation must address secondary release.
- **Outcomes**: Reduced microplastic load in drinking water; limited data on systemic inflammation.
- **Moderators**: Effective in urban areas with high water pollution; baseline burden influences efficacy.

2. Air Filtration Interventions

- **Evidence Summary**: Air conditioner filters act as both sinks and sources of microplastic fibers (MPFs) (Chen et al., 2022). Comprehensive reviews discuss atmospheric MPs and strategies for risk reduction, including indoor air management (Le et al., 2023).
- **Effectiveness**: HVAC/HEPA systems can capture MPs but may release them if not maintained. Mitigation approaches show promise in reducing exposure.
- **Outcomes**: Potential reduction in airway microplastic load; associated with respiratory and cardiovascular effects (Lee et al., 2025).
- **Moderators**: More effective in indoor environments; urban vs. coastal differences in air quality.

3. Dietary Interventions

- **Evidence Summary**: MPs are prevalent in dietary sources, leading to health implications such as hepatic injuries and microbial dysbiosis (Sánchez et al., 2022; Zhang et al., 2023). Human consumption studies estimate exposure from food and water (Cox et al., 2019).
- **Effectiveness**: Reducing seafood and processed foods may lower intake, but widespread contamination limits impact. Dietary changes could mitigate gut-related inflammation.
- **Outcomes**: Biomarkers in stool indicate high load; linked to systemic inflammation and neurotoxicity (Wang et al., 2024).
- **Moderators**: Exposure route (diet) dominant; higher in coastal populations due to seafood.

4. Policy Controls

- **Evidence Summary**: Bans on single-use plastics and microplastics in cosmetics are effective in reducing pollution (Landrigan et al., 2020; Guerranti et al., 2019). Reviews emphasize cost-effective solutions and policy interventions based on the 3Rs (reduce, reuse, recycle) (Nikiema et al., 2022; Jolaosho et al., 2025).
- **Effectiveness**: High impact at population level; global bans needed for significant reduction.
- **Outcomes**: Reduced environmental MPs leading to lower human exposure; health outcomes like cardiovascular events (Marfella et al., 2024).
- **Moderators**: Effective across urban and coastal areas; baseline burden reduced through upstream controls.

5. PPE/Behavior and Microfibre-Capture Devices

- **Evidence Summary**: Devices for capturing microfibres during clothes washing show varying efficiency (Napper et al., 2020). Advanced oxidation processes can remove MPs and MFs in water treatment (Dos Santos et al., 2023). Airborne emissions from laundry dryers highlight the need for capture technologies (O'Brien et al., 2020).
- **Effectiveness**: Microfibre-capture devices can reduce release during washing; PPE and behavioral changes like proper laundry practices offer personal protection.
- **Outcomes**: Reduced microfibre load in wastewater and air; potential decrease in personal exposure and associated inflammation.
- **Moderators**: Effective for high-exposure workers and households with synthetic clothing; adherence to usage is key.

Discussion

Comparison of Interventions

- **Water Filtration**: Strong evidence for removal but risks of release; suitable for point-of-use.
- **Air Filtration**: Effective for indoor exposure but maintenance required; complements dietary changes.
- **Dietary Changes**: Addresses a major exposure route but challenging due to ubiquitous contamination.
- **Policy Controls**: Broadest impact, cost-effective, but requires international cooperation.
- **PPE/Behavior**: Limited evidence; best as adjunct to other interventions.

Gaps and Limitations

- No RCTs found; evidence from reviews and observational studies.
- Limited data on long-term health outcomes and inflammation biomarkers.
- Need for studies on combined interventions and moderators like urban vs. coastal.

Recommendations

- Prioritize policy bans for upstream reduction.
- Implement filtration systems with monitoring for release.
- Promote dietary awareness and behavioral changes.
- Conduct RCTs to evaluate efficacy.

Conclusion

Interventions show varying levels of evidence for reducing microplastic burden. Policy controls offer the most comprehensive approach, while filtration and dietary changes provide targeted mitigation. Further research, including RCTs, is essential to quantify impacts on inflammation and health outcomes.

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