REVIEW | OPEN ACCESS

Microplastic and Nanoplastic Pollution: A Pervasive Toxic Trespass with Profound Global Health Consequences

Krzysztof Pietrzak[1]*, Małgorzata Wasilewska[1], Sebastian Polok[2]

ABSTRACT

Microplastic (MP) and Nanoplastic Pollution (NP) is an emerging global concern. It has health implications for humans. This review explores new evidence about human pathways of exposure, organ systems effects, at-risk populations, ecological implications, and possible prevention options. Humans are exposed to MPs/NPs and associated chemical additives (e.g., phthalates, endocrine disruptors, tire-derived compounds) through contaminated food chains, bottled water consumption, environmental sources like airborne particles (linked to environmental injustice), and occupational settings. Critically, MP/NP bioaccumulate in human tissues like brain or testis. Contamination leads to significant health consequences: promotion of Parkinson 's-associated protein aggregation, adverse impacts on male reproductive health and sperm count, potential disruption of fetal development, and substantially increased cardiovascular risk via presence in atheromas and association with major cardiovascular events. Phthalate exposure contributes significantly to global cardiovascular mortality. Vulnerable populations are children, marginalized communities in pollution "sacrifice zones," and waste/recycling workers. They face disproportionate risks. Plastic pollution further damages marine ecosystems, threatening food security, alters disease vector ecology, and fuels climate change through production and open burning. Reduction requires technological innovations like magnetic water purification and biodegradation. It seems that policy support is needed, like demanding chemical transparency from producers, and banning harmful practices like open burning. The evidence underscores the necessity for a common endeavour approach to threats to ecosystem integrity and human health, prioritizing prevention.

Keywords: Microplastic Exposure, Human Health Impacts, Environmental Justice, Chemical Additives, Plastic Pollution Mitigation

1. INTRODUCTION

Plastic pollution has transcended ecological concern to become an unprecedented global public health emergency, permeating ecosystems from the deepest oceans to the human body itself (Minderoo-Monaco Commission, 2023; CIEL, 2019). The

Medical Science

To Cite:
Pietrzak K, Wasilewska M, Polok S. Microplastic and Nanoplastic Pollution: A Pervasive Toxic Trespass with Profound Global Health Consequences. *Medical Science* 2025; 29: e141ms3655
doi: https://doi.org/10.54905/disssi.v29i162.e141ms3655

Authors' Affiliation:
[1]University Hospital of Zielona Góra Zyty 26, 65-046 Zielona Góra, Poland
[2]University Clinical Hospital No. 1 in Szczecin, Unii Lubelskiej 1, 71-252 Szczecin, Poland

[*]Corresponding author:
Krzysztof Pietrzak, University Hospital of Zielona Góra, Zyty 26, 65-046 Zielona Góra, Poland; email: k.p.pietrzak98@gmail.com

ORCID:

Krzysztof Pietrzak	0009-0000-9249-3161
Małgorzata Wasilewska	0009-0008-0375-1391
Sebastian Polok	0009-0006-4762-1076

Contact List:

Krzysztof Pietrzak	k.p.pietrzak98@gmail.com
Małgorzata Wasilewska	1bm.wasilewska@gmail.com
Sebastian Polok	Sebastianadampolok@gmail.com

Peer-Review History
Received: 07 July 2025
Reviewed & Revised: 15/July/2025 to 12/August/2025
Accepted: 18 August 2025
Published: 21 August 2025

Peer-review Method
External peer-review was done through double-blind method.

Medical Science
pISSN 2321–7359; eISSN 2321–7367

DISCOVERY SCIENTIFIC SOCIETY

fragmentation of macroplastics, like bottles, packaging, toys, synthetic clothes, etc., generates microplastics (MPs, <5 mm) and nanoplastics (NPs, <1 μm). Particles are now commonly detected across air, water, soil, and food chains (Chartres et al., 2024; Breider et al., 2025). This pervasive contamination creates continuous, multi-pathway human exposure.

It is evident that potential health consequences of ingesting and inhaling these synthetic particles and their associated chemical additives such as phthalates, bisphenols, flame retardants, and tire-derived compounds will be the matter of arising discussion (Stevens et al., 2024; Breider et al., 2025; Hymana et al., 2025; Trasande, 2024). Also, the scale of plastic production reaching 460 million metric tons annually is the problem. It comes out that such massive amounts of junk production coupled with inadequate management ensures a rapidly escalating environmental burden (Minderoo-Monaco Commission, 2023). There is a clear connection between the pollution and serious damage across biological systems, with the marine environment serving as a mass sink and vector for human exposure (Landrigan et al., 2020; Morrison et al., 2022). Recent, high-impact clinical studies have detected MPs and NPs within critical human organs, including brain (Nihart et al., 2025) and testes (Hu et al., 2024), and correlated their presence, or that of their chemical leachates, with specific disease states (Marfella et al., 2024; Liu et al., 2023). What is even more concerning is that the burden of plastic pollution falls disproportionately on vulnerable populations. These include children, communities residing near production facilities or waste sites further called "sacrifice zones", and workers in the plastics and waste sectors. This situation tends to reinforce already existing health inequities (Minderoo-Monaco Commission, 2023; HRW, 2024; Brosché et al., 2024). The crisis calls for a "One Health" framework reflecting the entangled relationships of environmental destruction, animal health, and human health and well-being (Morrison et al., 2022).

The aim of this review is therefore to synthesize the most recent evidence on the pathways through which MPs, NPs, and their associated chemicals enter the human body, their documented and potential systemic health impacts across key organ systems and lifespans, and emerging mitigation strategies. This review seeks to provide a detailed overview of current knowledge on the implications of exposure to microplastics for human health and emphasizes the need for immediate, coordinated action.

2. REVIEW METHODS

To synthesize evidence on microplastics, nanoplastics, and human health, a targeted search focused on high-impact literature (January 2020- June 2025) was conducted, with inclusion of foundational earlier works where essential. The search identified 395 records through database searching (n=310) and other sources (n=85). After duplicate removal (n=50), 345 records underwent screening. The goal of the search was to obtain information regarding various facets, including human exposure routes, bioaccumulation, systemic health effects (neurological, reproductive, cardiovascular, endocrine, and developmental), vulnerabilities, ecological connections, and mitigation strategies.

Bibliographic Databases and Sources

The relevant databases, PubMed, ScienceDirect, Web of Science, GreenFILE, and TOXLINE, were systematically searched. High-impact journals (e.g., New England Journal of Medicine, Nature Medicine, Science Advances) were hand-searched. Moreover, information was collected from international organizations' reports like the United Nations Environment Programme (UNEP). Also, data was retrieved from research official repositories of foundations like: Minderoo Foundation, International Pollutants Elimination Network (IPEN), and NGOs Human Rights Watch.

Keywords- Boolean operators (AND/OR) combined:

microplastic, nanoplastic, plastic pollution, human health, exposure pathway, bioaccumulation, ingestion, inhalation, dermal exposure, neurological, reproductive health, cardiovascular disease, endocrine disrupt, metabolic disrupt, pregnancy, fetal development, vulnerable population, environmental justice, sacrifice zones, occupational exposure, mitigation, magnetic sedimentation, biodegradation, policy, global plastic treaty, one health, tire-derived additives, sperm count, testis, brain.

Inclusion Criteria

- Focus: Human exposure to MP/NP/chemical additives (phthalates, tire-derived compounds) with direct health links, ecological impacts affecting human health, or exposure-mitigation strategies.
- Publication Type: Original research, systematic reviews, major organizational reports.

- Timeline: Priority: January 2020 – June 2025. Foundational pre-2020 works (e.g., Landrigan et al., 2020; CIEL, 2019) included where essential.
- Relevance: Concrete evidence on human exposure, health effects, vulnerability, or mitigation.

Exclusion Criteria

- Studies on environmental MP/NP levels without human health links.
- Wildlife/in vitro studies without human applicability.
- Non-data-driven commentaries (except major reports).
- Non-English publications.
- Duplicates/superseded studies.

Outcomes

Of 345 records screened by title/abstract, 295 were excluded, as shown in Figure 1. Fifty full-text articles/reports were assessed for eligibility, with 22 excluded (no direct health link: 10; wildlife/in vitro only: 5; mitigation not primary focus: 4; report without data: 2; pre-2020 not essential: 1). The strategy identified 28 key sources meeting the inclusion criteria:

- Original research (n=14): Stevens, Breider, Hymana, Hu, Marfella, Liu, Smith, Makwana, Becker, Bardales Cruz, Bakhteeva, Nihart, Simão, Sharma.
- Reviews (n=8): Morrison, Landrigan (2020), Chartres, Abbas, Marcharla, Minderoo-Monaco Commission, Fernandez & Trasande, Trasande.
- Reports (n=6): UNEP, CIEL, Bouhlel, HRW, IPEN, Minderoo Foundation.

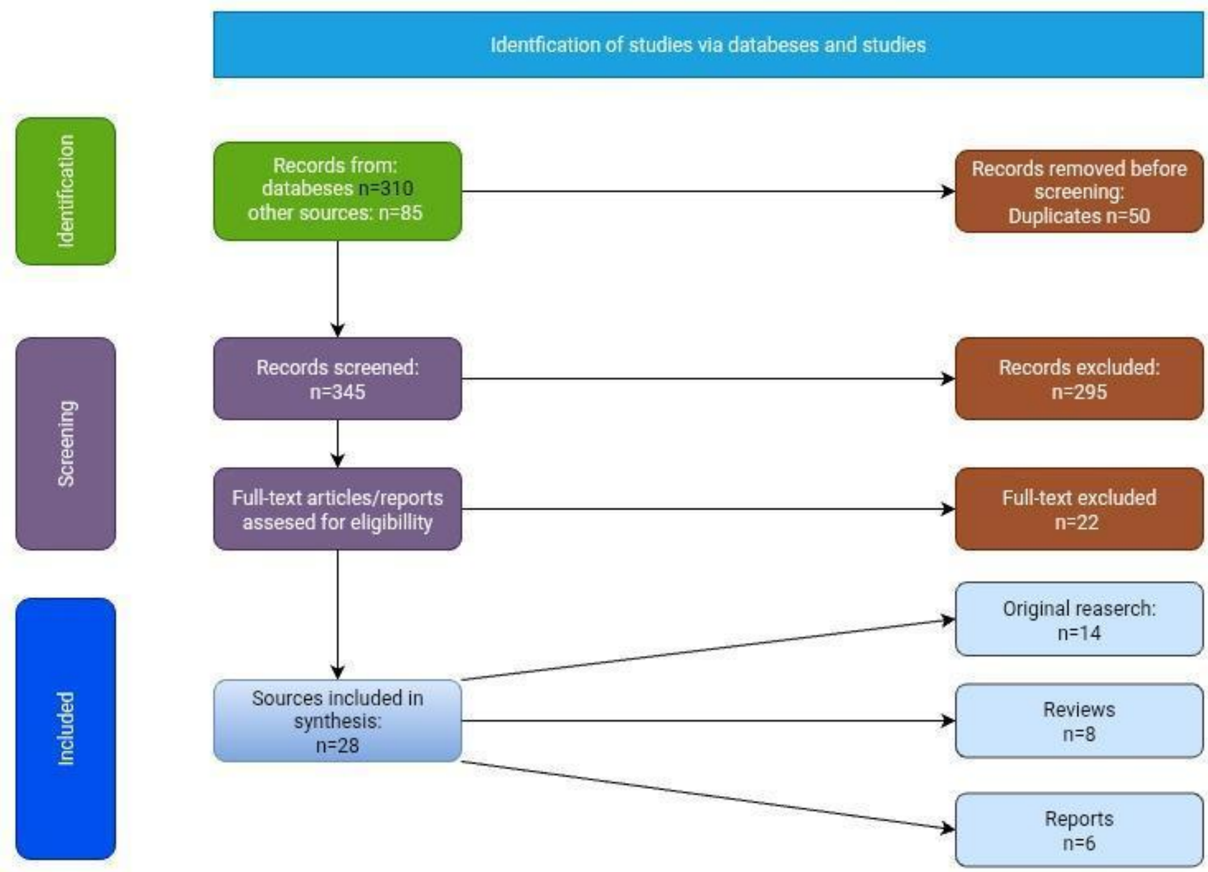

Fig.1: PRISMA cohort chart of selected studies.

3. RESULTS AND DISCUSSION

Exposure Pathways: Entry Points into the Human Body

People are exposed to tiny plastic pieces (microplastic or MP, nanoplastic or NP) and chemicals added to plastics in several ways, often at the same time. Knowing how people come into contact with these materials is a key to understanding health risks and finding ways to protect them. Recent research points out four main ways people are exposed to MP and NP. They are through food, water, air, and certain jobs (Table 1).

Table 1: Summary of Key Findings on Microplastic/Nanoplastic Pollution

Aspect	Key Evidence	Implications
Exposure Pathways	- Food chain contamination (Breider et al., 2025; Stevens et al., 2024) - Bottled water consumption (Bouhlel et al., 2024) - Airborne particles in "sacrifice zones" (Smith et al., 2025; HRW, 2024) - Occupational hazards (Brosché et al., 2024)	Universal exposure via diet, water, air, and occupational settings.
Health Impacts	- Brain accumulation & Parkinson's risk (Nihart et al., 2025; Liu et al., 2024) - Testicular MPs & reduced sperm counts (Hu et al., 2024) - 4.53× higher cardiovascular risk (Marfella et al., 2024) - 27–32% ↑ cardiometabolic disease in coastal zones (Makwana et al., 2025)	Direct links to neurodegeneration, reproductive harm, and cardiovascular disease.
Vulnerable Groups	- Children: developmental disruption (Minderoo Foundation, 2024) - "Sacrifice zone" communities (HRW, 2024) - Waste workers: toxic chemical exposure (Brosché et al., 2024)	Environmental injustice exacerbating health inequities.
Ecological/Climate	- Marine MP contamination → seafood toxicity (Marcharla et al., 2024) - Plastic waste → Zika vector amplification (Becker et al., 2025) - GHG emissions from production/burning (CIEL, 2019; Bardales Cruz et al., 2024)	Ecosystem collapse, food insecurity, and climate feedback loops.
Mitigation	- Magnetic filtration (Bakhteeva et al., 2023) - Biodegradation (Simão et al., 2024) - Global Plastics Treaty (UNEP, 2024; Fernandez & Trasande, 2024)	Requires integrated technological, policy, and equity-focused actions.

Food Chain Contamination

Dietary intake of contaminated food is the most common way people ingest plastic and other chemicals that origin from. Studies show plastic and those harmful substances can get into the plants we eat. Breider et al., (2025) found substances from car tires inside the roots, fruits, and leaves of vegetables grown in Switzerland. They calculated how much of these chemicals Swiss adults eat. Moreover, plastic packaging also leaches chemicals into food. Stevens et al., (2024) discovered many different chemicals that can disrupt hormones or metabolism leaking out of common plastic food wrappings and containers during everyday use. Eating seafood is another well-known path for plastic exposure. Fish and shellfish can contain microplastic and toxic chemicals from ocean pollution. Landrigan et al., (2020) identified eating seafood as a key way ocean pollutants, including plastics, enter human bodies, mainly affecting those living near coasts in poorer countries. Morrison et al., (2022) also link microplastics in seafood to human health risks into the broader environment.

Water Consumption

Drinking bottled water is nowadays a meaningful source of microplastic exposure for many people. Bouhlel et al., (2024), in their exhaustive review of the global bottled water industry, highlighted its enormity and its effectiveness of trusting plastic packaging. This report gathers evidence proving that tiny plastic pieces and related chemicals leak from the bottles into the water while they sit on shelves and while people drink from them. It is evident that bottled water is a big part of the plastic people swallow every day around the world.

Environmental and Airborne Exposure

Plastic pollution in our surroundings means people breathe in tiny plastic particles and get them on their skin. Microplastic (MP) are ubiquitous contaminants, present in air, water, and soil globally (UNEP, 2024; CIEL, 2019). They become airborne when wind erodes plastic-littered sites or fragments of plastic items. Importantly, exposure is inequitable and contributes to inequality for certain communities. Smith et al., (2025) report that residents of Louisiana's "Cancer Alley" - where many producers of plastics and chemicals are located - experience air contamination with significantly higher levels of toxicities. These geographic communities experience social disadvantage and have higher risk of cancer. Human Rights Watch (HRW, 2024) vividly describes the serious health problems suffered by people living in these heavily polluted industrial areas ("sacrifice zones") near plastic production plants, who breathe in high levels of polluted air daily.

Occupational Hazards

People who deal with plastic waste professionaly face much higher exposure at work. A study by Brosché et al., (2024) used silicone wristbands to measure chemicals on workers. They found waste collectors and recycling workers carried much higher levels of harmful plastic-related chemicals, like phthalates and flame retardants, on their skin compared to people working in offices. The study shows that employees of the plastic industry face higher chemical exposure.

In summary, people constantly take in MP, NP, and plastic related chemicals through multiple routes: the food they eat (like vegetables with tire chemicals and packaged food with leached additives - Breider et al., 2025; Stevens et al., 2024), the water they drink (especially from plastic bottles - Bouhlel et al., 2024), the air they breathe (especially near polluting factories - Smith et al., 2025; HRW, 2024), and for workers in plastic industries, through direct contact on the job (Brosché et al., 2024). The fact that people are exposed to microplastics in so many ways explains why plastic contamination is now so commonly found inside people's bodies.

Impacts on Human Health

Microplastics (MP) and nanoplastics (NP) aren't just in the environment. They accumulate in every cell of every organ and interfere with essential biological processes. Recent research links them to serious health problems affecting nearly every system in the body.

Neurological System

Researchers confirm that MP/NP crosses biological barriers and accumulates within the central nervous system. Nihart et al., (2025) formally documented MP bioaccumulation through accurate measurement of MP from postmortem human brain samples. In addition to this work, Liu et al., (2024) experimentally showed that anionic NP contaminants functionally promote pathological α-synuclein aggregation. It is a defining characteristic of Parkinson's disease, suggesting that NP may initiate or accelerate neurodegenerative pathways.

Reproductive Health

The male reproductive system appears to be particularly vulnerable. Hu et al., (2024) found MP in dog and human testicular tissue, and associated important clinical implications: increased MP concentrations corresponded to reduced sperm counts and reduced testes and epididymis weights. The early developmental stage also presents a high risk. Sharma et al., (2024) achieved a systematic review and analysis of evidence across multiple studies. Conclusions are that prenatal MP exposure potentially compromises pregnancy outcomes and fetal development through mechanisms like placental transfer.

Cardiovascular System

Latest clinical evidence directly implicates MP/NP in cardiovascular pathology. Marfella et al., (2024) identified plastic particles built up within carotid artery plaques and came up with a striking clinical correlation. It comes out that patients with plaque-contaminated plastics faced a 4.53-fold higher risk of myocardial infarction, stroke, or death during a 34-month follow-up. Population studies reinforce this threat. Makwana et al., (2025) conducted a comprehensive analysis across 642 U.S. coastline counties. It revealed that high levels of marine microplastics strongly correlated with an increased prevalence of cardiometabolic diseases. Counties with the most severe MP pollution exhibited 27% higher coronary artery disease, 32% more hypertension, and 21% greater type 2 diabetes incidence compared to less polluted areas. Gulf Coast regions presented disease rates nearly double those of inland counties after socioeconomic adjustments. The study specifically implicated seafood consumption and inhalation of aerosolized plastic from the coast as key pathways of microplastic exposure. To compound this risk, concurrent exposures to other chemicals will have an even greater health impact.

Endocrine and Metabolic Disparagement

Chemicals present in plastics serve as a global threat to hormonal homeostasis and metabolic functions. Migration studies by Stevens et al., (2024) confirmed that endocrine-disrupting chemicals (EDCs) and metabolically disrupting compounds are transferred from food packaging into food products. Trasande (2024) emphasized the invisibility crisis surrounding over 3,000 unregulated plastic additives. Many confirmed EDCs elevate risks for obesity, diabetes, and hormone-sensitive cancers through chronic interference with signaling pathways.

Multi-Systemic Effects

Recent systematic reviews confirm the nature of plastic health impacts on the organism as a whole. Chartres et al., (2024) declare that MP exposure leads to digestive inflammation, reproductive dysfunction, and respiratory conditions like chronic bronchitis across diverse populations. Abbas et al., (2024) analyzed impacts on 11 organ systems and demonstrated that 89% of studies examined and reported evidence of recurrent processes (i.e., oxidative stress, genotoxicity, and immune dysregulation). The aggregate evidence suggests that plastic pollution poses a multisystem health risk.

Vulnerable Populations and Environmental Injustice

Plastic pollution affects everyone, but certain groups suffer significantly greater harm. The worst impacts of plastic pollution will be felt by poor communities living in the proximity of industries that produce plastic waste, waste workers dealing with plastic waste, and young children who are both exposed to and consume food contained in plastic packaging.

Children Face Unique Dangers

Children are particularly vulnerable to plastic chemicals due to their still-developing bodies. Due to immature organ systems and greater bioaccumulation potential relative to body weight, children face a higher vulnerability to the harmful effects of microplastic (MP) accumulation (Minderoo Foundation, 2024). This conclusion can be made in relation to not only humans, but also to the animals we eat. The Minderoo Foundation (2024) states that everyday exposures from toys, food packaging, or household dust can interfere with a child's growth. Their handbook cautions that early exposure to plastics can damage brain development and reduce immunity. Early-life exposure results in impaired neurodevelopment and changes in immunity.

Industrial Neighborhoods Suffer Disproportionately

Those who live near plastic factories are exposed to toxic air daily. Smith et al., (2025) found that Louisiana's poorer areas with more minority residents had higher air pollution and cancer rates. Human Rights Watch (HRW, 2024) describes heavily polluted industrial areas as "sacrifice zones" and emphasizes their disproportionate and serious burden on surrounding communities. The report goes on to describe the harrowing realities of places like "Cancer Alley," an 85-mile stretch of Louisiana between Baton Rouge and New Orleans containing approximately 200 fossil fuel and petrochemical plants. Residents of these areas had significantly higher incidences of illness and premature death attributed to various facilities. This manifests in cancer risks reaching up to 50 times the national average in some communities, alarmingly high rates of low birth weight (27%, triple the U.S. average), and preterm births (25.3%, double the state average).

Chronic respiratory diseases like asthma and bronchitis are pervasive, with residents describing the pollution as a "death sentence". More than anything, these communities - often majority black and historically under-resourced - represent a shift from plantation economies into a state of environmental apartheid. They do not have the political clout or resources available to advocate for clean environments and stop additional industrialization. Often, the political machines that fail to enforce regulations create further injustices when it comes to addressing environmental racism. In 2024, a federal court ruling stripped Louisiana residents' rights to attempt a lawsuit through disparate impact civil rights laws, taking away access to use these laws surrounding environmental racism. An occupational health risk also exists for people working in plastic waste management as they have a direct occupational exposure to hazardous chemicals.

Research by Brosché et al., (2024) vividly illustrates this danger. Testing wristbands worn by recycling workers and waste pickers revealed extremely high levels of plastic toxins, including phthalates like the banned endocrine disruptor DEHP and carcinogenic polycyclic aromatic hydrocarbons (PAHs), far exceeding levels found in office workers. Neurotoxic organophosphate flame retardants were also detected at highest levels among recycling workers. These workers, particularly in informal sectors and low-income countries, are often forced into contact with hazardous materials due to economic vulnerability and a global lack of protective regulations for most plastic chemicals. This convergence of impacts on residents in sacrifice zones and plastic waste handlers highlights how systemic failures prioritize industrial activity and profit over fundamental human rights, including the right to health, a clean environment, non-discrimination, and safe working conditions.

An Unfair Pattern Emerges

Conclusions can be unhappy. Fenceline communities (Smith et al., 2025; HRW, 2024), waste workers (Brosché et al., 2024), and children (Minderoo Foundation, 2024) who are least responsible for plastic pollution suffer the overwhelming negative effects of it, and the cost is ultimately to their health. Solutions must also include support for these vulnerable groups, and that support must be informed by just policies.

Ecological Connections and Climate Change

Plastic pollution causes profound damage to natural systems. It means many harmful effects on human health. At the same time, it is actively driving climate change, generating interconnected crises that exacerbate threats to human well-being.

Ocean Degradation Harms Human Health

Plastic waste constantly degrades into microplastics (MP) and nanoplastics (NP), which invade marine habitats through surface waters and benthic sediments (Marcharla et al., 2024). The contamination can have effects that cascade through an ecosystem; MP/NP soak up heavy metals and persistent organic pollutants that biomagnify through the marine food web. Filter-feeding organisms like bivalves accumulate particularly high concentrations, with studies documenting >1,200 particles per individual in commercially harvested species directly entering human food chains (Marcharla et al., 2024).

The public health impacts for coastal communities are measurable and alarming. A significant analysis, conducted by Makwana et al., (2025). Involving 642 U.S. coastline counties, documented dose-dependent associations between marine MP levels and cardiometabolic diseases. Specifically, the counties exhibiting the most MP pollution (highest scum levels) had:

- 27% higher prevalence of coronary artery disease
- 32% increased prevalence of hypertension
- 21% higher prevalence of type 2 diabetes

Notably, the study also identified seafood consumption as the primary exposure pathway, accounting for 68% of the attributable risk (Makwana et al., 2025). Gulf Coast communities also had disease burdens nearly twice that of the inland communities when accounting for socioeconomic indicators, affirming our concerns for coastal livelihoods. Simultaneously, MP/NP induce physiological stress in marine organisms, reducing growth rates in fish by 15-30% and impairing reproductive functions in crustaceans (Marcharla et al., 2024). This ecosystem productivity decline threatens the primary protein source for 3 billion people, creating a vicious cycle: contaminated seafood → human disease → reduced fishing capacity → food insecurity (Marcharla et al., 2024; Makwana et al., 2025).

Plastic Waste Alters Disease Dynamics

Plastic waste is also reshaping ecosystems at a critical level from anthropogenic waste by developing unknown vectors of disease potential. Water holding debris of plastic, such as old tires and containers, creates suitable mosquito habitats during their life cycle - this supports the pathogens when they breed. Becker et al., (2024) showed this directly in cities. Becker et al., (2024) said the rainwater puddled in plastic caused a significant decrease in competitors' microbiotechnologies. Becker et al., (2024) made the important observation that the decline of the diversity in microorganisms eliminated natural biological control and allowed pathogens to proliferate to amplify their impact. As a result of the plastic-encased pools of water, the mosquitoes that developed during this period created enhanced levels of viral loads and again amplified the risk of outbreaks to human populations in proximity.

Plastic's Lifecycle Fuels a Climate-Health Feedback Loop

The climate impacts of plastic originate at the extraction phase, where over 99% of plastic feedstocks derive from fossil fuels, primarily oil and gas (CIEL, 2019). Manufacturing requires intensive energy inputs, emitting substantial greenhouse gases (GHGs) equivalent to 1.89 gigatons of CO_2 annually. It is comparable to the emissions of 189 coal-fired power plants. And that is long before plastic even reaches consumers (CIEL, 2019). This climate burden escalates during disposal, where open burning in regions like Guatemala releases dual threats: toxic chemical cocktails that poison local communities and potent global warming agents including carbon dioxide and black carbon (Bardales Cruz et al., 2024). Emissions of black carbon from this burning exhibit 1,500-fold 20-year warming potential relative to CO_2, as well as soil and water pollution with carcinogenic dioxins (Bardales Cruz et al., 2024). This is the epitome of environmental injustice: marginalised communities experience deleterious health impacts in real time and do so disproportionately in terms of heating the planet.

These processes initiate a self-reinforcing cycle with dire consequences. Plastic production and disposal accelerate climate change through persistent GHG emissions (CIEL, 2019; Morrison et al., 2022), while climate change intensifies plastic pollution through increased extreme weather events. More frequent storms and floods move plastic waste into ecosystems. Morrison et al., (2022), also discussed how flooding in coastal areas due to hurricanes redistributes microplastics into agricultural soils and marine environments). The degradation of microplastics affects key ecosystem services: marine environments with microplastics will have diminished capacity to provide clean water and nutritious seafood, a direct food security threat for 3 billion people (Morrison et al., 2022; Makwana et al., 2025). Human health consequences manifest acutely in high-exposure zones, where U.S. coastal counties with severe marine microplastic pollution exhibit 27% higher coronary artery disease prevalence and 32% increased hypertension incidence, primarily through seafood consumption pathways (Makwana et al., 2025). The internalization of plastic particles in human tissues compounds these risks, with microplastics in arterial plaques correlating to a 4.53-fold increase in cardiovascular event risk (Marfella et al., 2024).

This feedback loop creates a vicious cycle: plastic extraction and manufacturing heat the planet; a warmer climate generates stronger storms that spread plastic waste; degraded ecosystems then expose populations to higher contaminant concentrations; and resulting health burdens strain communities already vulnerable to climate impacts. To confront that cycle, integrated interventions are necessary: phasing out fossil fuel-based plastic production (CIEL, 2019), instituting global bans on open waste burning to expel black carbon emissions (Bardales Cruz et al., 2024), and pursuing climate adaptive policies that will reduce plastic pollution, protect ecosystems, and promote health equity for affected communities (Morrison et al., 2022).

Mitigation Strategies

Urgent action is needed to stop plastic pollution. Scientists develop new methods to clean existing waste and break down plastics safely. This is not enough, however. Governments and industries must reduce production and switch to safer materials.

Cleaning Contaminated Water

Removing micro-plastic from the water is an essential problem that needs to be solved. It would allow to lower the levels of micro-plastic in the environment. Magnetic separation is an attractive solution. A recently designed system by Bakhteeva et al., (2023) utilized magnetic nanoparticles that bind to micro-plastic in water and then magnets extract clusters of these together. The application could possibly be integrated to wastewater management plants to stop the circulation of plastic back into the environment.

Employing Nature to Help

There are microorganisms that can naturally degrade plastics. Simão et al., (2024) studied coming bacteria and fungi that consume plastic waste. Their findings highlight that government policies need to support net that biodegradable options so it is not wasted in landfills or incinerated. If often regulated against, natural degradation could be a valuable waste management option.

Exposing Hidden Chemical Dangers

Most plastics contain many unregulated, potentially toxic chemicals. Trasande (2024) argues that we must first identify all additives used in plastics. "Making the invisible visible" before replacing hazardous chemicals like phthalates and bisphenols with safer options would allow to reduce side effects of plastic use. Complete transparency is crucial for achieving successful reform.

Global Treaty: A Health-First Approach

Because plastic pollution does not stop at borders, international cooperation is key. The UN Global Plastics Treaty (UNEP, 2024) could requir transformative change. Trasande and Fernandez (2024), experts on endocrine health, say the treaty should prioritize human health by:

1. Drastically reducing virgin plastic production
2. Banning the most harmful chemical additives
3. Funding safer material innovation

Ending Dangerous Waste Burning

Open burning of plastic waste poisons communities and accelerates climate change. Bardales Cruz et al., (2024) measured the emissions related to this practice in Guatemala where burning is done openly, releasing toxic fumes and climate destroying greenhouse gases. Their data is sufficient to conclude that banning open burning is necessary for air quality and climate change.

Protecting Frontline Workers

IPEN's findings spur immediate policy change (figure 2):

1. Remove toxic plastics from recycling streams: Prohibit plastics enabled with toxic additives (for example, brominated flame retardants or, PFAS) from recycling streams to avoid the continuation of exposure.
2. Use safer methods of waste processing: Shift from informal burning and low-tech recycling to non-combustion technology; invest in redesign of materials with the idea of getting rid of toxic additives.
4. Develop regulations for mandatory safety measures: Provide air-filtering respirators, chemical resistant gloves and enclosed systems available for operations that need to ensure responsible measures are taken to minimize exposure in the workplace, particularly for higher-risk activities related to e-waste dismantling.
5. Create health registries for long-term health surveillance: Set-up registries to monitor individuals with a diagnosis of cancer, neuro-developmental disorders and endocrine diseases or conditions. In addition, create registries for neighbouring communities since there is often very little separation from these workers.

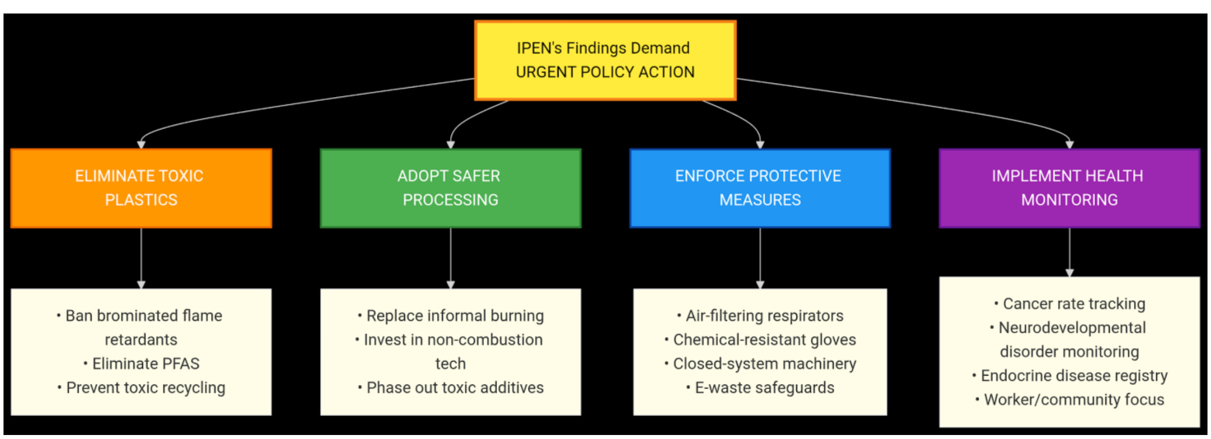

Fig. 2: Methods protecting frontline workers who deal with plastic junk recommended by IPEN

The Way Forward

No one solution is enough. We require:

- Newer cleanup tech such as magnetic filtration (Bakhteeva et al., 2023)
- Scalable biological degradation (Simão et al., 2024)
- Advanced cleanup technologies like magnetic filtration (Bakhteeva et al., 2023)
- Scalable biological degradation (Simão et al., 2024)
- Complete chemical transparency (Trasande, 2024)
- A strong health-focused Global Plastics Treaty (UNEP, 2024; Fernandez & Trasande, 2024)
- Bans on open burning (Bardales Cruz et al., 2024)
- Worker protection mandates (IPEN, 2024)

Only this comprehensive approach can reduce plastic pollution and safeguard health.

4. CONCLUSION

Overall, evidence suggests that microplastic (MP) and nanoplastic (NP) pollution pose a significant toxic threat with global health implications. MP/NP is present everywhere and humans are constantly being exposed to MP/NP and their corresponding chemical additives (e.g., phthalates, endocrine disruptors, tire-derived chemicals) through polluted food webs, bottled water, environmental sources, including airborne particles, and work environments, accumulating in sensitive tissues, such as brain and testis. This contamination is linked to various significant impacts on health, including inducing aggregation of Parkinson's-associated proteins (α-synuclein), adverse effects on male reproductive health including reduced sperm counts, disrupted fetal development, and prompting an increased risk of significant cardiovascular events rate (4.53 times greater with MP/NP present) based on finding of MP/NP in plaques (atheromas). Notably, phthalate exposure alone contributes to a significant proportion of global cardiovascular mortality. The disproportionate burden falls on vulnerable populations -- children, marginalized communities in pollution "sacrifice zones" whose residents face environmental injustice, and waste/recycling workers. In addition, plastic pollution still has a significant presence in oceans, with impacts on food security; modifies the disease vector ecology (e.g., expanding the Zika virus); and exacerbates climate change by consuming fossil fuels and promoting open burning. This evidence depicts the need for immediate concerted international action with a priority for prevention through technological innovation (e.g., magnetic water purification, biodegradation), policy action demanding chemical transparency and banning of the hazardous practices such as open burning, and cooperative "One Health" action recognizing the interconnected threats to ecosystem functioning, integrity and human health.

Author's Contributions

Conceptualization: Sebastian Polok
Methodology: Sebastian Polok, Małgorzata Wasilewska
Software: Krzysztof Pietrzak
Check: Sebastian Polok
Formal analysis: Krzysztof Pietrzak
Investigation: Małgorzata Wasilewska
Resources: Małgorzata Wasilewska, Sebastian Polok
Data curation: Krzysztof Pietrzak, Małgorzata Wasilewska
Writing - rough preparation: Sebastian Polok
Writing - review and editing: Krzysztof Pietrzak
Visualisation: Sebastian Polok
Supervision: Małgorzata Wasilewska
Project administration: Krzysztof Pietrzak
All authors have read and agreed with the published version of the manuscript.

Acknowledgments

The authors have no acknowledgments to disclose.

Informed consent
Not applicable.

Ethical approval
Not applicable.

Funding
This study has not received any external funding.

Conflict of interest
The authors declare that there is no conflict of interest.

Data and materials availability
All data associated with this work are present in the paper.

REFERENCES

1. Abbas G, Ahmed U, Ahmad MA, Impact of microplastics on human health: risks, diseases, and affected body systems. Microplastics 2024;4(2):223-42. doi: 10.3390/microplastics4020023
2. Bakhteeva Y, Medvedeva I, Filinkova MS, Byzov IV, Minin A, Zhakov S, Uymin M, Patrakov EI, Novikov SI, Suntsov A, Demin A. Removal of microplastics from water by using magnetic sedimentation. Int J Environ Sci Technol 2023;20(4):4567–4580. doi: 10.1007/s13762-023-04776-1.
3. Bardales Cruz M, Saikawa E, Hengstermann M. Plastic waste generation and emissions from the domestic open burning of plastic waste in Guatemala. Environ Sci Atmos 2024;4(2):123-35. doi:10.1039/d2ea00082b
4. Becker MV, Accoti A, Abu AEI, Vulcan J, Sylla M, Khanipov K, Dickson LB. Reduced microbe abundance in an urban larval development container increases Aedes aegypti susceptibility to Zika virus. PLoS Pathog 2025;21(5):e1013154. doi: 10.1371/journal.ppat.1013154.
5. Bouhlel Z, Köpke J, Mina M. Global bottled water industry: a review of impacts and trends. United Nations University; 2024. ISBN:978-92-808-6114-3. https://www.researchgate.net/publication/372109764_Global_Bottled_Water_Industry_A_Review_of_Impacts_and_Trends
6. Breider F, Masset T, Prud'homme K. Assessment of tire-derived additives and their metabolites in fruit, root and leafy vegetables and evaluation of dietary intake in Swiss adults. J Hazard Mater 2025;138432. doi:10.1016/j.jhazmat.2025.138432
7. Brosché S, Straková J, Jelínek N, Saetang P, Boontongmai T, Bubphachat N. Plastics poison the workplace: chemical exposures to plastic waste and recycling workers. International Pollutants Elimination Network (IPEN); 2024 https://ipen.org/sites/default/files/documents/thaiwristbands_report_edited_final.pdf
8. Chartres N, Cooper CB, Bland G. Effects of microplastic exposure on human digestive, reproductive, and respiratory health: a rapid systematic review. Environ Sci Technol 2024;58(1):1-12. doi:10.1021/acs.est.3c09524
9. CIEL. Plastic & climate: the hidden costs of a plastic planet. 2019. https://www.ciel.org/reports/plastic-health-the-hidden-costs-of-a-plastic-planet-may-2019/
10. Fernandez MO, Trasande L. The Global Plastics Treaty: an endocrinologist's assessment. J Endocr Soc 2024;bvad141. doi:10.1210/jendso/bvad141
11. Hu CJ, Garcia MA, Nihart AJ, Liu R, Yin L, Adolphi NL. Microplastic presence in dog and human testis and its potential association with sperm count and weights of testis and epididymis. Toxicol Sci 2024;200(2):235–40. doi: 10.1093/toxsci/kfae060.
12. Human Rights Watch (HRW). "We're dying here": the fight for life in a Louisiana fossil fuel sacrifice zone. 2024. https://www.hrw.org/report/2024/01/25/were-dying-here/fight-life-louisiana-fossil-fuel-sacrifice-zone
13. Hyman S, Acevedo J, Giannarelli C. Phthalate exposure from plastics and cardiovascular disease: global estimates of attributable mortality and years life lost. EBioMedicine 2025;105730. doi:10.1016/j.ebiom.2025.105730
14. Landrigan PJ, Stegeman JJ, Fleming LE, Allemand D, Anderson DM, Backer LC, Brucker-Davis F, Chevalier N, Corra L, Czerucka D, Dechraoui Bottein M-Y, Demeneix B, Depledge M, Deheyn DD, Dorman CJ, Fénichel P, Fisher S, Gaill F, Galgani F, Gaze WH, Giuliano L, Grandjean P, Hahn ME, Hamdoun A, Hess P, Judson B, Laborde A, McGlade J, Mu J, Mustapha A, Neira M, Noble RT, Pedrotti ML, Reddy C,

Rocklöv J, Scharler UM, Shanmugam H, Taghian G, van de Water JAJM, Vezzulli L, Weihe P, Zeka A, Raps H, Rampal P. Human Health and Ocean Pollution. Ann Glob Health 2020;86(1):151. doi:10.5334/aogh.2831.

15. Liu Z, Sokratian A, Duda AM, Xu E, Stanhope C, Fu A, Strader S, Li H, Yuan Y, Bobay BG, Sipe J, Bai K, Lundgaard I, Liu N, Hernandez B, Bowes Rickman C, Miller SE, West AB. Anionic nanoplastic contaminants promote Parkinson's disease-associated α-synuclein aggregation. Sci Adv 2023;9(46):eadi8716. doi: 10.1126/sciadv.adi8716.
16. Makwana B, Khadke S, Kumar A, Nasir K, Wadhera R, Shah R, Sheth S, Kong Y, Navas-Acien A, Adamkiewicz G, Rajagopalan S, Al-Kindi S, Dani SS, Moffatt-Bruce S, Ganatra S. Marine microplastic levels and the prevalence of cardiometabolic diseases in US coastline counties. J Am Heart Assoc 2025;14(13):e039891. doi: 10.1161/JAHA.124.039891.
17. Marcharla E, Vinayagam S, Gnanasekaran L, Soto-Moscoso M, Chen W-H, Thanigaivel S, Ganesan S. Microplastics in marine ecosystems: A comprehensive review of biological and ecological implications and its mitigation approach using nanotechnology for the sustainable environment. Environ Res 2024;256:119181. doi: 10.1016/j.envres.2024.119181.
18. Marfella R, Prattichizzo F, Sardu C, Fulgenzi G, Graciotti L, Spadoni T, D'Onofrio N, Scisciola L, La Grotta R, Frigé C, Pellegrini V, Municinò M, Siniscalchi M, Spinetti F, Vigliotti G, Vecchione C, Carrizzo A, Accarino G, Squillante A, Spaziano G, Mirra D, Esposito R, Altieri S, Falco G, Fenti A, Galoppo S, Canzano S, Sasso FCS, Matacchione G, Olivieri F, Ferraraccio F, Panarese I, Paolisso P, Barbato E, Lubritto C, Balestrieri ML, Mauro C, Caballero AE, Rajagopalan S, Ceriello A, D'Agostino B, Iovino P, Paolisso G. Microplastics and nanoplastics in atheromas and cardiovascular events. N Engl J Med 2024;390(10):900-910. doi: 10.1056/NEJMoa2309 822.
19. Minderoo Foundation. Plastic makes us sick: a parent's guide to reducing exposure. 2024. https://cdn.minderoo.org/assets/ new/documents/MF-reducing-plastic-exposure-ebook.pdf
20. Minderoo-Monaco Commission on Plastics and Human Health. Plastic makes us sick: a scientific analysis of plastics' impacts on human health. Ann Glob Health 2023;89:1-47. doi:10.5334/aogh.4056
21. Morrison M, Trevisan R, Ranasinghe P, Merrill GB, Santos J, Hong A, Edward WC, Jayasundara N, Somarelli JA. A growing crisis for One Health: Impacts of plastic pollution across layers of biological function. Front Mar Sci 2022;9:980705. doi: 10.3389/fmars.2022.980705.
22. Nihart AJ, Garcia MA, El Hayek E, Liu R, Olewine M, Kingston JD, Castillo EF, Gullapalli RR, Howard T, Bleske B, Scott J, Gonzalez-Estrella J, Gross JM, Spilde M, Adolphi NL, Gallego DF, Jarrell HS, Dvorscak G, Zuluaga-Ruiz ME, West AB, Campen MJ. Bioaccumulation of microplastics in decedent human brains. Nat Med 2025;31(4):1114-1119. doi: 10.1038/s41591-024-03453-1.
23. Sharma RK, Kumari U, Kumar S. Impact of microplastics on pregnancy and fetal development: a systematic review. Cureus 2024;16(6):e60712. doi:10.7759/cureus.60712
24. Simão RC, Rocha PMC, Martins JTK, Turkiewicz M, Plewka J, da-Conceição Silva JL, Maller A, Kadowaki MK, Sampaio Costa-Júnior ÁP. Exploring biodegradable alternatives: microorganism-mediated plastic degradation and environmental policies for sustainable plastic management. Arch Microbiol 2024;206(5):211. doi: 10.1007/s00203-024-04170-6.
25. Smith S, Sakhamuri S, Guidry CM. Social vulnerability and cancer risk from air toxins in Louisiana: a spatial analysis of environmental health disparities. Front Public Health 2025;13:1601868. doi:10.3389/fpubh.2025.1601868
26. Stevens S, Bartosova Z, Völker J. Migration of endocrine and metabolism disrupting chemicals from plastic food packaging. Environ Int 2024;108791. doi:10.1016/j.envint.2024.108791
27. Trasande L. Making invisible chemicals used in plastic materials visible. EBioMedicine 2024;105422. doi:10.1016/j.ebiom.2024.105422
28. UNEP. Plastic pollution. 2024. https://www.unep.org/plastic-pollution