The Challenge Microplastics Pose to Public Health in Georgia

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ABSTRACT

Microplastics (MPs) represent an emerging environmental and public health concern due to their pervasive presence across ecosystems and their potential to accumulate in the human body. This review investigates the various exposure pathways, health effects, and detection methods of MPs, while assessing Georgia's current response and preparedness. Microplastics (MPs) are found in air, water, soil, food, and even human biological samples such as stool, placenta, and lungs. Health risks include oxidative stress, inflammation, endocrine disruption, immune dysfunction, and reproductive harm, with vulnerable populations—such as pregnant women and infants—being particularly at risk. While international research and regulation are advancing, Georgia lacks comprehensive monitoring systems, public awareness, and national policies addressing MP-related health risks. The lack of Georgian data was identified as a limitation of the study. Detection techniques, such as spectroscopy and chromatography, are essential tools for understanding the extent of exposure. This study highlights the urgent need for interdisciplinary research, national-level monitoring, and incorporation of MPs into Georgia's environmental and health frameworks.

***Key words**: Microplastics, environmental pollution, exposure pathways, endocrine disruption, Georgia, plastic waste management*

INTRODUCTION

Many significant advances are being made in how products are manufactured and shipped worldwide. This has, however, introduced a key issue that is underrecognized – microplastics (MPs), which are environmental pollutants that have widespread human exposure, even though their impact on health remains largely unknown. These solid plastic nanoparticles, often referred to as microbeads (Lee, *et al.,* 2023) and categorized as a primary type of microplastic, are classified according to their source of manufacture and are made up of polymer blends and functional additives which often contain residual impurities that form unintentionally through the disintegration of larger plastic items such as car tyres and synthetic textiles. Additionally, some MPs are intentionally produced and incorporated into function-specific products such as exfoliating beads in facial and body scrubs (European Chemicals Agency, 2025; Rochman et al., 2013), as well as in engineered filaments from materials which shed microfibers when washed. While most studies into MPs have focused on synthetic microbeads, it is necessary to consider unintentional sources of microplastic pollution such as secondary MPs, of which a significant quantity of plastic particles are in the environment. Additionally, the chemical and physical properties of nanomaterials are known to significantly worsen their toxicity and harmful effects. While the size and shape of primary MPs are typically uniform, secondary MPs vary widely in these characteristics, making it challenging to accurately evaluate their potential health risks (Fadare, 2020).

The harmful effects of MPs that have accumulated in marine zooplankton have been studied at length and found to have an impact on the marine ecosystem and on human health. Zooplankton was exposed to polystyrene MPs (50 nm or 10 μm) for 24 to 48 hours, using particles derived from disposable cups and snack packaging. Gene expression analysis revealed changes in antioxidant genes and enzymes linked to oxidative stress, though the differences were not significantly noticeable (Cho et al., 2019). Still, smaller MPs were found to be more toxic. Sizes of both types of microplastic particles were found to have accumulated in the zooplankton, with some even detected in female plankton oocytes, suggesting the potential for transmission to be intergenerational. This raise concerns that MPs have the potential to enter the human body via the food chain as they accumulate in plankton which are at the bottom of the food chain, and are subsequently transferred to predators when consumed (Cho et al., 2019).

Another potential source of exposure can occur through paint fragments released into the environment due to abrasion, as well as through direct ingestion, skin contact, or inhalation from contaminated air, water, seawater or soil (Enyoh, 2020). Inside the body, MPs may accumulate and combine with natural tissues which cause irritation and inflammation. Another potential cause is exposure to poisonous compounds. One potential method which may increase human exposure to MPs is when they are not effectively removed during decontamination of grey water, or they end up in the ocean, thereby posing a threat to ecosystems and human health. Studies have documented various harmful effects, including the accumulation of MPs in aquatic organisms, resulting in inflammation, malnutrition, decreased fertility, and even death (Lee, 2023).

This paper aims to review the pathways, sources and impacts of MPs on human well-being and the understanding of MPs as a health-related issue in Georgia.

METHODOLOGY

A literature review was conducted in order to determine what effects MPs may have on health, including the perception – or lack thereof – among the Georgian populace as a whole, as well as institutions and organizations. A systematic approach was applied to ensure the identification, selection, and analysis of relevant sources.

Search Strategy

A literature search was conducted in four major electronic databases: PubMed, Scopus, Web of Science, and Google Scholar. The search included articles published between *2000* to *2025*. Keywords and Medical Subject Headings (MeSH) terms related to microplastics were used in various combinations, including: *"Microplastic," "plastics," "health impacts," "human exposure," "Georgia,".* Boolean operators (AND, OR) were applied to refine the search strategy. Reference lists of relevant studies and reviews were also screened to identify additional eligible articles.

Eligibility Criteria

Studies were included if they met the following criteria: Published in peer-reviewed journals in English or Georgian; Conducted on adult populations; Focused on prevalence, risk factors, prevention, or management of health disorders due to microplastics; Used quantitative, qualitative, or mixed-method approaches, or were systematic reviews/meta-analyses.

Studies were excluded if they: Were case reports, editorials, opinion papers, or conference abstracts; Focused exclusively on surgical/medical interventions without broader discussion of risk or prevention; Were duplicates or inaccessible in full text.

Study Selection

All identified manuscripts were imported into reference manager software and screened for duplicates. Titles and abstracts were reviewed against the inclusion criteria. Full-text articles of potentially eligible studies were retrieved and assessed for final inclusion. Any discrepancies were resolved through discussion.

Data Extraction

A standardized data extraction form was developed. Information collected included: Author(s), year of publication, and country; Study design and microplastics characteristics; Key focus, such as mechanizm of microplastics' effect on the human body or ways of prevention; Main findings and recommendations.

Data Synthesis

Findings were synthesized thematically and organized under major domains: microplastics and health risk factor; Individual and lifestyle-related factors; Preventive strategies and interventions and Management approaches.

The results were summarized narratively, highlighting patterns, gaps, and implications for future research and practice.

Ethical approval

As we conducted a literature review, ethical approval was not required. The literature review was conducted collaboratively by both authors. The first author conceptualised the review framework, developed the search strategy, and conducted the initial screening of articles. The second author was responsible for data extraction, critical appraisal, and synthesis of the evidence. Both authors contributed equally to the interpretation of findings, writing, and final revision of the manuscript.

RESULTS

The global output of plastic products reached 460 million tons annually, though only 9% undergo recycling. It is further estimated that this number will increase to 1.2 billion tons by 2060 (Global Plastics Outlook, 2022).

The various factors that determine the toxicity of MPs include the chemical and physical properties of the particles, as well as exposure time and additives. The main types of additives detected included polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). Plastic materials such as plastic jugs and fishing nets are broken down over time by radiation, wear-and-tear of machinery, and other ecological variables which causes plastics to degrade into more modest particles, bringing about secondary MPs (Dris et al., 2016).

Human MP exposure occurs in multiple ways simultaneously, with oral intake being the predominant source (Prata et al., 2019). MPs have also been detected in various other sources including bottled water, drinking water, milk, salt, seafood, sugar and tea bags (Praveena et al., 2021; Zhang et al., 2020; Kutralam-Muniasamy et al., 2020; Danopoulos et al., 2020; Hernandez et al., 2019; Feng et al., 2019; Li et al.,2018; Karami et al., 2017; Liebezeit et al., 2013). Shellfish consumption alone is responsible for exposing Europeans to 11,000 plastic particles per person per year (van Cauwenberghe & Janssen 2014), and 39,000 – 52,000 particles per person per year from other food sources (Cox et al., 2019). Large quantities of MPs may also be deposited in soil, especially in agricultural systems (Rillig et al., 2020). These MPs (especially those with a negative charge) could be absorbed by plants via their roots and deposited in the stems, leaves, and fruits (Schwab et al., 2020; Rillig et al., 2020).

MPs have now become omnipresent in the climate. Studies have identified them in the oceans and seas, streams, lakes, soils, and the air, raising concern over their ability to influence human well-being (Kosuth et al., 2018).

The effect that MPs have on nature is significant. The ingestion of MPs by marine creatures can cause severe adverse effects, such as damage to the gastrointestinal system and can additionally result in an energy imbalance (Besseling et al., 2014). Even more significantly, MPs can cause harmful synthetics like industrial natural contaminations, heavy metals, and other unsafe substances that adhere to surfaces to accumulate in organisms. These pollutants are then transferred to life forms that ingest these MPs, posing a risk not exclusively to the creature devouring the particles but primarily to those higher up the food chain, including people.

MPs have also been detected in the atmosphere above certain cities. Although research in this area is limited, studies suggest that the primary source of airborne MPs is synthetic textiles, with filaments being the most commonly found in the atmosphere. Moreover, these particles can be directly inhaled due to their small size, thus posing potential health risks especially for industrial workers. The distribution of these filaments and their spread are influenced by climate conditions and human activities (Chang et al., 2020).

Human Health Risks of Microplastics

According to Schwabl et al. (2019), MPs were discovered in human stool sample research. They can travel through the human gastrointestinal system and then be excreted, though they may also accumulate inside the body. They are dangerous for the digestive tract and might cause inflammation or other negative health outcomes such as the development of gut dysbiosis and intestinal and metabolic disorders (Browne et al., 2011).

MPs also have the potential to be carriers for harmful toxins, which contain several additives that are quite often chemicals such as flame retardants, plasticisers and stabilisers that can seep into the environment and then settle on the faces of microplastic particles, which are abundant everywhere (Teuten et al., 2009). These chemicals can change various hormone functions within the human body, and can therefore cause diseases such as infertility, imbalances in the hormone system, and anomalies in fetal development (Teuten et al., 2009).

Similarly, MPs introduced into the human body may react with the immune system and cause inflammatory responses or dysfunction of the immune system. The long-term effects of microplastic exposure on health remain largely unknown. However, chronic exposure to MPs may potentially be linked to the development of respiratory ailments, cardiovascular diseases, and possibly cancer, as inferred from animal studies (Schwabl et al., 2019; Dris et al., 2016).

The toxicological impacts of MPs on human well-being are largely unknown and have only recently came to the forefront, yet current research indicates that MPs can cause harm at the cellular level. For example, they can have a negative impact on the overall well-being of an individual, potentially causing long-term medical complications, including malignant growth and neurological harm (Besseling et al*.,* 2014). Moreover, compound pollutants related to MPs may pose extra dangers, as these poisonous substances can be delivered into the body upon ingestion, worsening the negative impacts.

A study conducted by Prata et al., (2018) explored the toxicity of MPs inhaled by humans. The findings indicated that a potential route of human exposure could be attributed to microplastic particles present in the atmosphere. Prolonged exposure to low levels of airborne MPs may be linked to respiratory and cardiovascular diseases, with the severity of health effects depending on individual susceptibility and the specific characteristics of the particles.

MPs can disrupt the intestinal microbiome, causing an imbalance between beneficial and harmful bacteria. This imbalance may lead to various gastrointestinal symptoms including abdominal pain, bloating, and altered bowel habits (Jin et al., 2018).

When inhaled, MPs can induce oxidative stress in the airways and lungs, leading to inflammation and tissue damage. This may result in respiratory symptoms such as coughing, sneezing and shortness of breath. Additionally, reduced blood oxygen levels caused by microplastic exposure can contribute to fatigue and dizziness (Wright & Kelly 2017).

Although MPs are generally thought to be unable to penetrate the epidermis (Schneider, 2009), they can nevertheless raise the risk of exposure by adhering to the skin (Prata, 2018). For instance, using consumer goods such as face cream and cleanser that contain MPs will raise the chance of PE exposure (Hernandez et al., 2017). When protective mobile phone cases are used, the constant wear-and-tear may produce microplastic particles that are then transferred to human hands (Li et al., 2023). Additionally, children may come into contact with MPs on the ground while they are crawling or playing. Certain common plastic additives, such as triclosan (TCS), bisphenols (BPs), phthalates, and brominated flame retardants (BFRs), may be absorbed via the skin when exposed to MPs (Wu et al., 2022).

MPs were detected in take-out food containers consisting of common polymer materials (PP, PS, PE, and PET), which are common and used extensively (He et al., 2021; Du et al., 2020). According to estimates, individuals who eat take-out meals four to seven times a week may consume 12 to 203 microplastic particles through the containers.

Infants and pregnant women are particularly vulnerable to microplastic exposure (Sripada et al., 2022). The discovery of MPs in the human placenta highlights the possibility that these non-biodegradable substances could impact the developing fetus and the human body over multiple generations. Therefore, the possible effects of early exposure for embryonic development and newborns should receive further investigation. The Developmental Origins of Health and Disease (DOHaD) theory states that persons who experienced difficulties during their early development are more likely to develop obesity, diabetes, cardiovascular disease, and other chronic illnesses as adults (Barker, 1995).

Concern has been raised by new discoveries of micro- and nanoplastics in breast milk and human reproductive organs, including the fetal and maternal sides of placentas, testes and semen. To assess the potential hazard they pose to the human reproductive system, more research is required (Ragusa et al., 2022; Ragusa et al., 2020; Liu et al., 2023; Ragusa et al., 2022; Zhao et al., 2023; Hu et al., 2024).

Endocrine-disrupting chemicals (EDCs), brominated flame retardants (BFR), and toxic metals like lead, cadmium, arsenic, and chromium further poses a serious health risk (Turner & Filella, 2021). Since these chemicals impact not only the reproductive system but also other facets of our endocrine, metabolic, and neuro-developmental systems, the reviews were restricted to EDCs, though there are numerous other additives that may have negative health impacts as well.

Moreover, a variety of additives such as phthalate plasticizers and/or polybrominated biphenyls, which are used as flame retardants and may result in detrimental biological effects such as endocrine disruption or may cause cancer (Rhodes, 2018). Around 95% of adults in the USA had detectable levels of bisphenol-A (BPA) in their urine. Infertility and other negative health impacts have been linked to exposure to endocrine-disrupting chemicals BPA and di-2-ethylhexyl phthalate (DEHP) (North & Halden 2013).

Detection of Microplastics in Biological Samples

It is essential to assess the prevalence of MPs in different human organs, tissues, and biological matrices due to their pervasiveness in the environment and possible toxicity to humans. MPs have been found in a variety of samples, such as sputum, liver, lungs, placenta, stool, as well as skin, face, and head washes.

Three primary categories are used to group the techniques used to examine MPs in human samples:

1. **Microscopy** – This includes stereo and optical microscopy, scanning electron microscopy (SEM) and fluorescence microscopy following Nile Red staining.

2. **Spectroscopy** – Techniques such as Raman spectroscopy and Fourier-transform infrared spectroscopy (FTIR).

3. **Separation Techniques** – These involve chromatography combined with mass spectrometric detection, including pyrolysis gas chromatography-mass spectrometry (py-GC-MS) and high-performance liquid chromatography with tandem mass spectrometry (HPLC-MS/MS).

The size and shape of MP particles were assessed using microscopes. MPs between 0.1 mm and 1 μm can be seen using stereo and/or optical microscopes, but MPs bigger than 0.1 mm can be seen with the naked eye. MPs smaller than 1 μm must be examined using an electron microscope. Nevertheless, MPs can occasionally be confused with other particles like cellulose or ceramics.

The most popular instruments for the first visual and physical characterization of MPs in human samples are optical microscopes, in particular stereomicroscopes (Wibowo et al., 2021; Abbasi & Turner, 2021; Huang et al., 2022; Ragusa et al., 2021; Amato-Lourenço et al., 2021; Ibrahim et al., 2021), as they tend to be more readily available, reasonably priced, and dependable in the majority of laboratories. Further evidence of MP presence can also be obtained by polarized light microscopy (Abbasi & Turner, 2021) and fluorescence microscopy following Nile Red staining (Abbasi & Turner, 2021; Horvatits et al., 2022). However, the chemical makeup of the particles cannot be ascertained using these instruments and techniques alone.

The polymer type must be chemically confirmed (Picó & Barceló, 2021) which can be done via spectroscopic methods, especially FTIR and Raman spectroscopy. To determine the kind of MP, the spectra produced by both techniques were compared to pre-existing spectral databases. Two research studies (Luqman et al., 2021; Wibowo et al., 2021) previously conducted directly used offline Raman spectroscopy to identify MPs in feces; however, neither study established the smallest detectable particle size. As shown in the examination of fecal samples, FTIR spectroscopy can also be used to investigate larger MP particles (>100 μm) utilizing the attenuated total reflection (ATR) mode (Schwabl et al., 2019). Effective spectrum analysis is made possible in ATR mode by the interaction of infrared light with an internal reflection element crystal that is in direct contact with the MP.

The main polymer types found in biological samples have been analyzed both qualitatively and quantitatively using chromatographic techniques. By utilizing the excellent identification capabilities of mass spectrometry, these techniques guarantee accurate detection and characterization.

Plastic management in Georgia

Information regarding microplastic management and health effects in Georgia is scarce. Georgia has, however, joined the "zero waste" movement and ratified the statement by the world community calling for a more aggressive and coordinated response to the triple planetary crises of environmental degradation, climate change and biodiversity loss. The National Plastic Waste Prevention Program (NPWPP) was created in response to these crises in accordance with the National Waste Management Strategy (2016-2030), Waste Management Code and the National Waste Management Action Plan of Georgia, with the assistance of international donors. In order to combat the various crises, the world is facing, the European Commission created The European Green Deal, a strategic plan that presents best-practice for managing plastic. Additionally, the NPWPP intends to help Georgia achieve the 2030 Sustainable Development Goals (SDGs) (European Environment Agency, 2019) and implement the EU action plan for a Circular Economy (European Environment Agency, 2015) and adjust the country's policies in accordance with the European Strategy for Plastics (European Commission, 2018).

Prior to the creation of the NPWPP, baseline research was conducted to assess the state of plastic waste management in the nation and pinpoint current issues, their effects, and the underlying causes, all of which were backed up by pertinent data. The study indicated that the amount of waste produced has increased in tandem with the economic progress of the nation. A major cause of environmental pollution has been the careless disposal of hazardous waste and domestic garbage in non-compliant landfills, with most municipal waste being disposed of illegally. The environment is at risk as the officially designated landfills that are currently available have not been managed in compliance with applicable environmental requirements.

The severity of the plastic pollution crisis and unresolved waste management problems has reached critical levels for public health and the environment. The nation has in recent years undertaken a number of significant waste management changes to address these issues. The EU-Georgia Association Agreement, signed in 2014, set forth standards for the implementation of contemporary waste management techniques. In accordance with best international practices and the Association Agreement, the Waste Management Code was enacted on the 15th of January, 2015. The Code outlines the general responsibilities and capabilities of state entities engaged in waste management, which Georgian law did not explicitly defined prior to that date.

Along with defining administrative offenses relating to waste management, littering, and environmental degradation, the Code also establishes maximum fine amounts and standard operating procedures for waste-related infractions. The government of Georgia has created and approved up to 20 bylaws derived from the Waste Management Code in order to introduce more comprehensive waste management methods. The government has stated that Georgia aims to become a nation that recycles and prevents waste. The nation is working to swiftly resolve the environmental difficulties that have accrued and to take on new international challenges.

Georgia banning the usage of plastic bags in 2018 serves as evidence of this. However, plastic production and overall international trade (import, export, and re-export) has increased over the last decade and is likely to keep increasing for the foreseeable future. Plastic products are imported for use in construction, packaging, and other consumer activities, with the main materials being PE, PET, PP, PVC, PU, and PS used in subsequent production processes. In terms of exports, Georgia exports both raw materials for plastic production and some finished goods derived from different kinds of plastic.

Biodegradable plastic makes up a very modest portion of the market for alternative feedstock types. Only the import, production and sale of appropriate compostable and biodegradable bags that satisfy EN 13432:2000 standards are allowed in Georgia, per the Rule of Regulation of Plastic and Biodegradable Plastic Bags (14 September 2018) (UNDP n.d.). However, due to a weak monitoring system (no relevant laboratory and low municipal capacity), as well as the sluggish certification process for the production of compostable and biodegradable bags, this regulation is not fully implemented.

Both on land and at sea, large amounts of plastic garbage flow into the ecosystem, causing serious harm to the economy and ecology. Undesignated dumpsites are found in practically all villages and are typically found close to gorges, riverbanks, and coastal areas. Although there is no official data on the makeup of the garbage, cleanup efforts by activists, local governments, and other donor-funded organizations has revealed that a sizable portion of this debris is made up of plastic (Liverakos, 2021).

The county has not studied the problem of MPs and its health impact. Consequently, there are no statistics or laws to reduce the pollution caused. Furthermore, it is necessary to address the extremely low level of understanding and awareness among stakeholders on the harm caused by MPs (Liverakos, 2021).

DISCUSSION

This review confirms that MPs represent a pervasive and under-recognized threat to human and environmental health. The evidence highlights their widespread presence in the air, water, soil, and food chains, making human exposure nearly unavoidable. Despite growing global concern, there remains a lack of comprehensive public awareness, institutional focus, and regulatory response in countries like Georgia.

One of the key findings is the variety of exposure routes for MPs - oral, inhalational, and dermal - all of which have implications for health. Ingestion through contaminated food and water appears to be the most significant pathway, with evidence showing accumulation in human stool, placenta, and even reproductive organs. Inhalation of airborne MPs, especially in urban and industrial environments, presents another high-risk exposure route. Dermal exposure, although less direct, still poses potential risks due to plastic additives being absorbed through contact with contaminated surfaces or consumer products.

Toxicological evidence from both human and animal studies could potentially lead to numerous negative health effects, including oxidative stress, inflammation, gut dysbiosis, immune dysfunction, endocrine disruption, and reproductive harm. MP detection in breast milk and placental tissues highlights concerns regarding vulnerable populations, particularly infants and pregnant women, as well as potential intergenerational effects. These findings align with the DOHaD theory, which posits a link between early environmental exposures and the development of chronic diseases later in life.

This paper also highlights that although international efforts are progressing, such as the implementation of EU regulations, improved waste management policies, and advanced detection methods, Georgia is still in the early stages of addressing the microplastic issue. While there have been important policy developments, such as a ban on plastic bags and the establishment of the National Plastic Waste Prevention Program, the lack of data on microplastic exposure and its health consequences in the Georgian context is striking.

The methodological advances in detecting MPs in biological samples – using techniques such as Raman spectroscopy, FTIR and chromatography – have significantly improved exposure and risk assessment. However, challenges remain in standardising these methods and interpreting the toxicological significance of findings. Moreover, while studies worldwide highlight alarming exposure levels and potential health outcomes, epidemiological data linking MPs to specific diseases in humans is still limited. The study has several limitations. First, the absence of national data and limited biomonitoring capacity constrained the scope of analysis, necessitating reliance on secondary data sources. Furthermore, the review primarily focused on evidence from high-income countries, as data from low- and middle-income settings remain scarce and fragmented.

In Georgia, gaps in monitoring infrastructure, laboratory capacity, and public and institutional awareness hinder progress. Moreover, local research is sparse, and there is no national-level biomonitoring of MPs in food, water, or biological samples. This highlights the urgent need for increasing technical and human capacity, interdisciplinary collaboration, and the integration of microplastic health risks into national public health and environmental policies.

Human Ethics and Consent to Participate: Ethical approval for this study was obtained from the Ethics Committee of the University of Georgia. Informed consent was obtained electronically from all participants prior to completing the survey. Participation was voluntary, and no incentives were provided.

Authors' contributions: Mehad mahmoud abdulkader mohamed Konswah (M.K.) a medical student, and Lela Shengelia (L.S.) conceptualized the study and designed the literature review methodology. L.S. oversaw data collection and supervised the ethical review process. M.K performed the data analysis and interpretation. Both authors contributed to the literature review and contextual framing. M.K drafted the initial manuscript, and L.S. critically revised it for intellectual content. All authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

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