World Journal of
Experimental Biosciences

Volume 14, Number 01: 03 – 09
P-ISSN: 2313-3937, e-ISSN: 3070-0647
2026

Review article

A Comprehensive Review of Plastic Pollution: Public Health and Environmental Impacts, Sources, and Mitigation Strategies

Miyada Khazaal Hassan[1]*, Shaimaa Abdul-Kareem[1]

ABSTRACT

Plastic is a basic material widely used in various consumer and industrial sectors from construction and vehicles to electronics and agriculture. In recent years, plastic pollution has put pressure on environment and threatens human safety worldwide due to massive global plastic production which has led to waste generation problems that exceed society's ability to mitigate them efficiently. This review discusses the types of plastic pollution as plastic chemical composition consist of long polymers that are resistant to the degradation by decomposing organisms. Natural processes break down plastic materials into small particles, leading to the formation of microplastics and nanoplastics, which can easily disperse over the environment. Consequently, plastic pollution affects terrestrial and marine ecosystems, causing serious effects on environment, economic, and organisms health. In addition, the article reviews the main sources of plastic including house hold, industrial, agriculture, and medical plastic waste. It also reveals the major problems caused by plastic waste, especially its environmental and human health impacts, as chemical materials in plastic cause several health issues like reproductive disorders, hormonal disruption, and neurological disease. It also highlights the importance of control measures andcoordinated global endeavor to minimize single-use plastic, improve recycling systems, and create international partnerships in order to decrease the effects of plastic pollution on the planet and public health.

Keywords: Environmental impacts, microplastics, plastic pollution, public health.

Citation: **Hassan MK, Abdul-Kareem S.** (2026) A comprehensive review of plastic pollution: public health and environmental impacts, sources, and mitigation strategies. *World J Exp Biosci* 14:03-09. DOI: 10.65329/wjeb.v14.01.02

Received January 03, 2026; Revised February 20, 2026; Accepted: March 08, 2026; Published: April 3, 2026

1. INTRODUCTION

One of the most important and dangerous environment issues in the world is the plastic pollution. In the last decades, plastic has become indispensable because of its desirable properties like insolubility, durability, non-degradability, and affordability. At the same time, these properties contribute to its persistence and lead to environmental pollution [1]. Over time, plastic does not degrade, but rather it breaks down to very small particles called microplastic and nanoplastics, which can persist for hundreds of years in the environment. A study estimated the amount of plastic wastes dumped into the ocean up to 8 million tons annually [2] this increasing amount of waste threatens the marine biodiversity as these plastic particles accidently ingested by many marine organisms including fish, birds, and turtles leading to gastrointestinal obstruction, suffocation, or even death. The transfer of these tiny particles through the food has health problems to the humans, as these particles have been found in drinking water, seafood, and human tissue [3].

Plastic pollution not only affects the environment and human hea-

* Correspondence: **Dr. Miyada Khazaal Hassan.** E-mail: miyada.k.765@sc.uobaghdad.edu.iq
Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq, 10071.
Full list of author information is available at the end of the article.

lth but also impacts the economy, negatively affecting the fishing, tourism, and maritime transport sectors and resulting in economic losses estimated at billions of dollars annually. Additionally, the cost of cleaning plastic waste is placing increasing financial pressure on governments, particularly in developing countries that lack the infrastructure for effective waste treatment [4].

There are many factors that contribute to the increase of plastic waste, most notably reliance on single-use plastic, overproduction, and weak waste management systems. Plastic used for packaging accounts for an estimated 40% of total plastic production and is often disposed of after only one use [5]. Even though many developed countries have plastic management systems, the amount of plastics that are actually recycled is about 9% of the total global production. The remainder is often dumped in landfills, burned, or leaks into natural ecosystems [6], Furthermore, in developing countries plastic pollution is even more severe due to the lack of effective waste collection and recycling infrastructure. Rivers in Asia and Africa are major conduits for transporting plastic waste to the oceans [7]. It has been estimated that individuals consume about 11,000 microplastic particles in a year per person from eating shellfish [8]. The amount of plastic particles entering the person annually is expected to range from 39,000 to 52,000 particles per individual [9]. Furthermore, plastic can become widespread in soil, especially in agricultural environments [10]. These plastic molecules may infiltrate the water transport system within plants, then move to the other parts of the plant [11]. Once microplastics enter agricultural systems, they can cause food pollution, which can heighten the risk of human exposure [12].

Microplastic can enter the body via three routes: ingestion, inhalation, and skin contact. When these particles enter the body they are distributed throughout the body by blood and can be absorbed by many organs [9]. It has been revealed that plastic particles reach distant organs, including the kidney, brain, heart, lung, testis, and placenta. Consequently, microplastics accumulate in these organs and persist in the body leading to various disorders ranging from minor respiratory disease to carcinogenesis and reproductive problems [13]. Additionally, microplastics have the potential to damage cellular function, triggering inflammation and oxidative stress. The evidence emphasizes the toxic nature of microplastics, especially when present with other environmental pollutants, which may synergistically exacerbate the health impacts [14].

Plastic pollution has developed into a chronic and serious environmental problem in modern life. Despite the economic progress achieved over the past decades, this growth has been shown to be coupled with a notable increase in pollution levels, leaving serious impacts on human health and ecological balance, and disrupting some essential natural systems, such as the climate system [15].

2. TYPES OF PLASTIC POLLUTION

2.1. Macroplastic

These plastic particles are larger than 5 mm, and accounted for 88% of the entire plastic discharge into the environment in 2019, equivalent to approximately 20 million metric tons, causing widespread pollution over various ecosystems. A significant portion of this pollution is attributed to disposable plastic items, like bottles, cigarette butts, bags, food-grade plastic, cups, and straws [4].

Primary microplastics: These are tiny plastic particles mainly produced for industrial and commercial uses. They are found in many products such as skin exfoliants, cleaning agents, plastic care products, and synthetic fabrics. Some of these particles, such as microbeads less than 5 mm in size made of polyethylene and polypropylene, are used in cosmetics [17]. These microbeads have specific properties such as viscosity, stability, and shape, and sometimes act as abrasives. Another type is produced from textiles like synthetic fabrics and cigarette filters, known as microfibers, which can enter the environment during various stages of a textile’s lifecycle from production to disposal [18]. Although these plastics are made for specific purposes, they can be unintentionally released into the environment. These primary microplastics can adsorb and carry other toxic substances, increasing their environmental impact [1].

Secondary microplastic: When plastic enters ecosystems, it undergoes various processes, including mechanical movement, physical changes, and biological activity. Under the influence of ultraviolet radiation, low temperature, and constant friction with waves and sand, plastic gradually begins to break down and the chemical bonds in the plastic disintegrate generating finer particles over time. These small fragments are known as secondary microplastics because they result from the disintegration of larger plastics. The common forms of secondary microplastics include fragments and fibers [19]. These particles are a major source of microplastic spread in aquatic environments [3]. Table (1).

2.2. Nanoplastics:

Ultra-fine particles (less than 100 nanometers) that spread in water and air and pose a threat to the food chain. The spread of nanoparticles in the environment occurs through advanced fragmentation of plastic particles and through direct emission from the breakdown of plastic materials such as plastic films, foams, plastic manufacturing factories, and other sources. These tiny plastic particles create risk, because they can enter the cells easily and even penetrate the subcellular components, leading to harmful effects at the molecular level of organisms [20]. It has been revealed that nanoplastics can penetrate biological barriers and accumulate in body tissues and organs, resulting in adverse health effects. In addition, many other environmental toxins, such as toxic hydrocarbons and heavy metals, can be adsorbed onto nanoplastics, resulting in greater chemical toxicity [21]. For this reason, studies in this field are still ongoing, because many of the environmental and health impacts of these particles are not yet fully understood [20].

3. PLASTIC POLLUTION SOURCES

Plastic pollution is a critical environmental problem worldwide, as it poses increasing risks to all ecosystems. That results from weak plastic waste management and recycling systems coupled with widespread use of plastics [17]. The main categories of plastic pollution can be classified into the following:

3.1. Household and Municipal Waste

Household waste is one of the primary sources of plastic pollution worldwide, particularly single-use plastic items. These wastes are very difficult to manage as they can spread into the natural environments easily and the rate of their recycling is low. The wastes include plastic bottles, cups, food packaging plastic, cutlery, straws and bags [22].

3.2. Industrial Activities and Packaging

The manufacturing of plastics and the spoilage of end products produce large amounts of waste that can easily pollute the environment. Commercial food industries play a key role in increasing the use of plastic containers in packaging and transportation, leading to the accumulation of plastic waste across all ecosystems. Dris et al. revealed that most of the world's total plastic demand is in the packaging sector [23].

Table 1. Types and sources of microplastics

Types of microplastic	Type of microplastic	Source of microplastic	Reference
Primary microplastics	Microbread	skin care and cosmetic products like exfoliating scrubs and	**[17]**
	Microfiber	Textiles like synthetic fabrics, carpets, and furniture. Personal products, like cigarette filters, tissue, and face masks.	**[18]**
Secondary microplastics	Fragments	Generated from larger plastic.	**[19]**
	Fiber	**Textiles, like clothes, bonds, and nets.**	**[19]**

3.3. Fishing and Marine Transport

Water bodies particularly marine ecosystem, are primary sources of plastic pollution. Fishing nets when abandoned or lost, cause considerable harmful effects to marine habitats. In the same manner, waste from boat and ships waste like plastic ropes, plastic life jackets, and floats remain on the surface of the water for a long period of time. It is estimated that the maritime transport sector and fishing account for a large proportion of total marine plastic waste [24].

3.4. Medical Waste

Healthcare tools are one of the known items that deplete considerable amount of single use plastic including gloves, tubes, and syringes. These iems are essential to prevent infection, but the improper disposal resulting in accumulation of hazardous plastic materials in the environment. In addition, their incineration and uncontrolled sterilization can lead to the release of toxic materials like dioxins [25].

3.5. Agricultural Waste

Many plastic products like plastic drip irrigation systems and greenhouse covers have been widely used recently in modern agriculture. Over time, these materials are fragmented by sunlight and other processes into very small particles known as microplastics, which negatively affect soil and water quality used in agriculture [26].

3.6. Waste from tourism activities

Tourism and recreational activities are indirect sources of plastic pollution, as visitors contribute to the accumulation of plastic materials on beaches and natural areas. This leads to the degradation of coastal environments and harms wildlife and marine life [27].

4. FATE OF PLASTICS IN ECOSYSTEMS

Plastic waste breaks down in the environment as a result of physical and biological factors into fine particles [28]. These particles accumulate in organisms and travel through the food chain, increasing their level at higher orders and posing a negative effect on human health. They have been found in plankton, fish, and seabirds, making them a global environmental problem [29].

5. EFFECTS OF MICROPLASTIC POLLUTION ON ECOSYSTEMS

Human activities cause a profound effect on ecosystems, with microplastics contaminates exist in nearly all environmental matrices, even in remote territories like the Arctic and the Tibetan Plateau [30; 31]. Their proliferation is attributed to urbanization and industrial activities, raising considerable environmental concerns, especially since unmonitored microplastics can cause ecosystem disruptions [32]. As a result of increasing microplastic pollution, these particles are entering the bodies of animals and humans. They can be acquired directly or indirectly from the environment through food chains [33]. They accumulate particularly in filtering organisms such as mollusks and plankton, with blue mussels containing 36 ± 7 particles/100 g, Pacific clams 47 ± 16 particles, and fish containing approximately 35 particles in their digestive tracts [34]. They have also been recorded in terrestrial animals such as chickens (up to 105 particles/g feces) and sheep (1000 particles/g) [35]. Humans are exposed through food, water, and air, as microplastics have been detected in sugar, honey, salt, beverages, water, and inhaled air [9]. Studies have shown the presence of microplastic particles in human feces, with an average of 20 particles ranging from 50 to 500 micrometers per 10 grams, mostly polypropylene and polyethylene terephthalate [11].

6. POTENTIAL IMPACTS ON HUMAN HEALTH

The hazardous effects of microplastics on human health depend on the type and duration of exposure and the organs affected. When these particles are ingested, they could cause gastrointestinal disturbances. As shown in figure (1), a study has revealed that the polystyrene particles were detected in the colons of mice exposed to these particles and caused multiple disorders, including epithelial barrier dysfunction, decreased production of intestinal mucus, damage to tight junctions proteins, and alteration in the intestinal microbiota. These particles have also been found in other organs like kidney and liver and were shown to have many negative effects like oxidative stress, inflammation, disturbance in lipid and energy metabolism [36].

Another effect of microplastics is linked to cardiac disruption and reduced heart function by stimulating the cardiomyocyte death caused by mitochondrial damage and oxidative stress [36]. In parallel, muscle cell growth and division are inhibited, which finally leads to the impairment of skeletal muscle regeneration [37]. In addition, these microplastics shifting the gene expression in bone marrow cells and inhibit the differentiation of leukocyte disrupting the hematopoiesis [38]. Other effects observed in mice were behavioral disorders and cognitive impairment [39], as well as, reproductive problems and offspring malformations. When microplastics reach the testes of male mice, they injure the epithelial cell of seminiferous tubules, decrease testosterone level, cause spermatogenic cells death and result in reduced sperm count and motility [40]. They also infiltrate the ovaries in females, leading to fibrosis and death of granulosa cells [41].

For human impacts, microplastics have been found in different human specimen including urine, blood, feces, and even in the placenta, which may cause potential health effects. To date, the evidence suggests that the toxicity mechanisms of microplastics at the cellular level are motivated by oxidative stress [42].

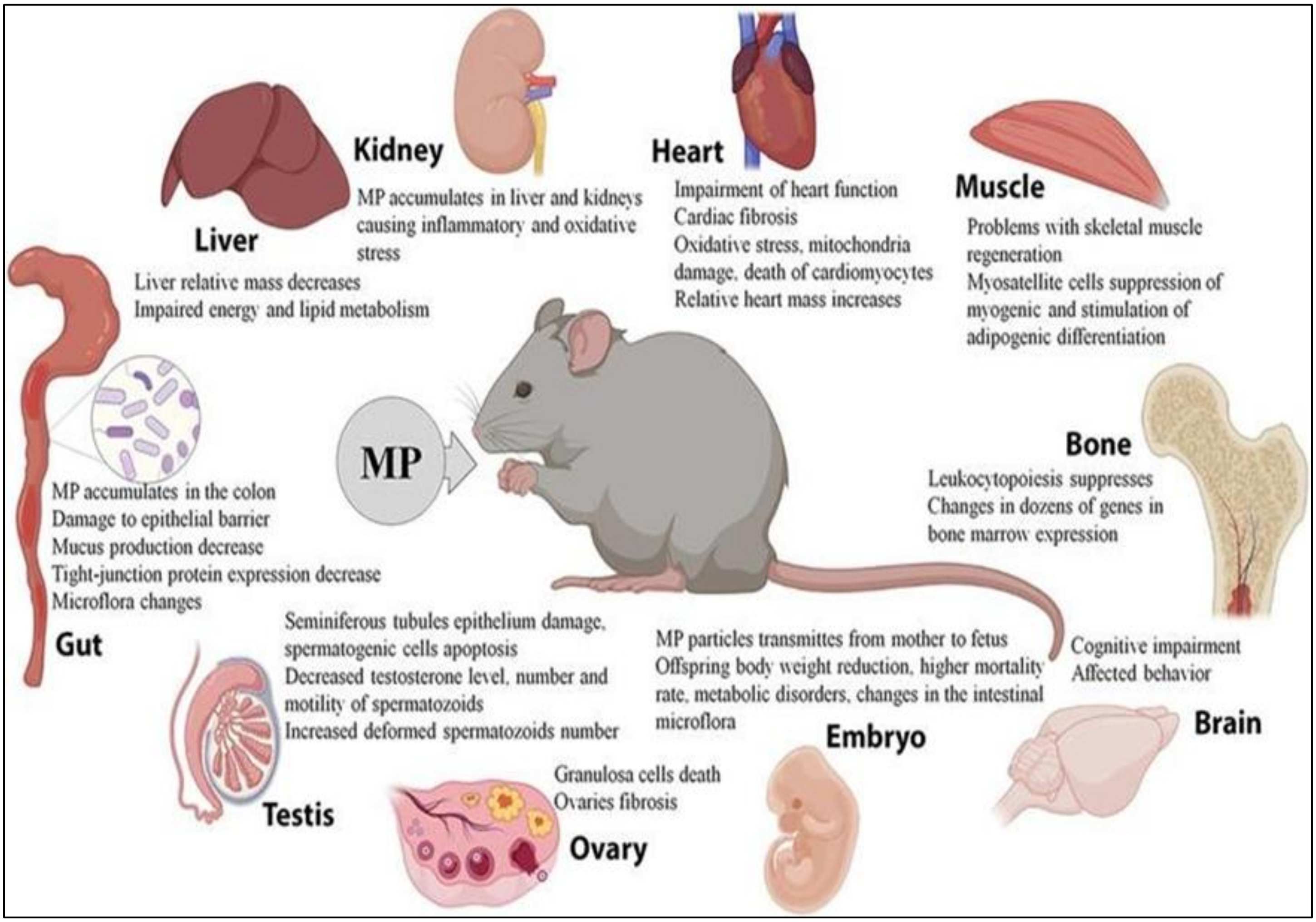

Fig. 1. Systemic effects of microplastic (MP) exposure on mammalian organs and tissues. Microplastics accumulate in multiple organs, including the liver, kidneys, gut, heart, muscle, bone, brain, and reproductive systems, leading to inflammation, oxidative stress, metabolic disturbances, tissue damage, and impaired physiological functions. Adverse outcomes include disruption of intestinal barrier integrity, reduced reproductive capacity, altered gene expression, and potential transgenerational effects through maternal transfer to the embryo [42].

Another study has shown that microplastics are implicated in many health effects including oxidative stress, nervous system inflammation, and protein aggregation, which are essential processes in the development of neurodegenerative diseases such as Parkinson's and Alzheimer's [44].

In addition, plastic may serve as a medium that transports and stores human pathogenic viruses and bacteria, this can enhance the spread of infectious diseases within the environment. Continuous exposure to microplastics may increase person's 'body burden,' or the quantities of plastic accumulated in their tissues. Many factors determine the risks and severity of health effects of plastic pollution such as lifetime exposure, dynamic human development, and personal manner [45].

7. METHODS FOR CONTROLLING PLASTIC POLLUTION

7.1. Raising public awareness

Governments must promote and launch awareness campaigns and programs to inform the consumers about the environmental and health effects caused by microplastics, in particular, their negative effects on humans and other living organisms by using various approaches like multi-media awareness-raising efforts, educational programs, and workshops in institutions [13].These programs should also teach people to adopt sustainable behaviors like the use of reusable alternatives or eco-friendly materials, and encourage daily practices that decrease the utilization of single-use plastics. Through these methods, individuals can better understand their responsibilities toward the environment and reinforce the effort to prevent plastic pollution [46].

7.2. Political-level solutions

Governments have several policy tools at their disposal to decrease single-use plastics and encourage recycling, including legislative bans on specific kinds like shopping bags, microplastics, and food packaging. Economic tools like taxes and fees can also be used to decrease utilization and fund environmental initiatives such as recycling programs and education. Another basic method is extended product responsibility (EPR) that requires companies to manage plastic waste and share responsibility with local authorities to minimize environmental impacts of plastic [47].

As the plastic crisis grows, in 2022, the United Nations Environment Programme (UNEA) adopted a landmark, legally binding global agreement on plastics to reduce production and manage waste, which was finalized in 2024 and entered its implementation phase thereafter [48]. At the same time, the agreement supports the development of innovations like the production of plastics that can be fragmented by natural processes, improved recycling technologies, and utilization of enzymes capable of breaking down plastics materials [49].

7.3. Recycling

Enhancing recycling includes reinforcement infrastructure by developing waste sorting centers and facilitating the collection of recyclables. Plastic products can also be manufactured to be more easily recycled, avoiding plastics composed from many layers that make the process difficult. In addition, policies that encourage the circular economy can be utilized by supporting the use of recycled waste plastics to manufacture new products like clothing and furniture [50]. Although many studies suggest that recycling processes are primary waste management strategies, their performance is limited because of pollution, economic inefficiencies, low rates, and the production of lower quality items. Besides, textile manufactured from recycled plastics release microplastics raising concerns and questions about their use [51].

7.4. Use of eco-friendly alternatives

Governments need to offer sustainable and effective alternatives accessible to everyone, as the loss of essential products like plastic could disproportionately impact the poorest communities [52]. Eco-friendly options should match or surpass the quality of the items they replace, considering their environmental impact during manufacturing, especially in the production process. For example, paper bags are a common alternative, and although their quick decomposition is beneficial, they consume more energy to produce, are more costly, and require more space for collection and disposal [47].

In developing countries, these alternatives are impeded by infrastructure limitations, in addition the waste sort at home and institute is not in correct way, as a result the recycled plastic could be contaminated and produced less value recycled plastics. Besides weak management in landfill and lack essential systems to contain emissions and leachate [50].

8. CONCLUSION

The widespread use of plastic has led to one of the most significant environmental problems, because of its effect on both ecosystems and human health. The plastic materials particularly microplastic and nanoplastics, have properties that make them resistant to be degraded by natural processes and persist in the environment for many years, resulting in their accumulation in air, water, soil, and food chain. In spite of government's attempts to reduce the plastic use, production and consumption continue to rise. To control this pollution, many methods must be integrated including raising public awareness, enhancing recycling process, using alternative or recyclable materials, and reduce use of plastics. Therefore, addressing plastic pollution is not only an environmental choice, but a necessity for global health and sustainability of the planet.

Acknowledgments

We would like to thank the staff of the Department of Biology, College of Science, University of Baghdad for their support and advice.

Funding information

This work received no specific grant from any funding agency.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could be perceived as influencing the work reported in this paper.

Ethical Approval

Not applicable

Authorship contribution statement

Hassan M.K.: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

Abdul-Kareem S.: Data curation, Resources, Writing – review & editing.

All authors have read and agreed to the published version.

Availability of data and materials

Data sharing is not applicable to this article as no new datasets were created or analyzed during the current study. All information used is available in the cited literature.

9. REFERENCES

[1] **Ziani K, Ionita-Mindrican CB, Mititelu M, Neacsu SM, Negrei C, et al.** (2023) Microplastics: a real global threat for environment and food safety: a state of the art review. *Nutrients* **15**(3):617. DOI: 10.3390/nu15030617. PMID: 36771324, PMCID: PMC9920460

[2] **Geyer R, Jambeck J, Law KL.** (2017) Production, use, and fate of all plastics ever made. *Sci Adv* **3**(7):e1700782. DOI: 10.1126/sciadv.1700782. PMCID: PMC5517107

[3] **Gao L, Su Y, Mehmood T, Wang Z, Peng L, Zhang N.** (2025) UVA-induced weathering of microplastics in seawater: surface property transformations and kinetics. *Front Mar Sci* **12**:1519668. DOI: 10.3389/fmars.2025.1519668 .

[4] **Yu RS, Yang YF, Singh S.** (2023) Global analysis of marine plastics and implications of control measure strategies. *Front Mar Sci* 10:1305091. DOI: 10.3389/fmars.2023.1305091.

[5] **Peeken I, Primpke S, Beyer B, Gütermann J, Katlein C, et al.** (2018) Arctic sea ice is an important temporal sink and means of transport for microplastic. *Nat Commun* **9**(1):1505. DOI: 10.1038/s41467-018-03825-5 . PMCID: PMC5915590

[6] **EPA.** (2021) EPA helps states reduce trash, including plastic, in U.S. waterways but needs to identify obstacles and develop strategies for further progress (Report No. 21-P-0130). Office of Inspector General, U.S. EPA.

[7] **Lebreton L, Andrady A** (2019) Future scenarios of global plastic waste generation and disposal Palgrave. *Commun* 5:6. DOI: 10.1057/s41599-018-0212-7 .

[8] **Tanaviyutpakdee PH. Karnpanit W.** (2023) Exposure Assessment of Heavy Metals and Microplastic-like Particles from Consumption of Bivalves. *Foods* 12(16):3018. DOI: 10.3390/foods12163018. PMCID: PMC10453466

[9] **Cox KD, Covernton GA, Davies HL, Dower JF, Juanes F, Dudas SE.** (2019) Human consumption of microplastics. *Environ Sci Technol* 53: 70687074. DOI: 10.1021/acs.est.9b01517 . PMID: 31184127.

[10] **Rillig MC, Lehmann A.** (2020) Microplastic in terrestrial ecosystems. *Science* 368(6498): 1430–1431. DOI: 10.1126/science.abb5979. PMCID: PMC7115994.

[11] **Schwabl P, Koppal S, Konigshofer P, Bbucsics T, Trauner M, et al.** (2019) Detection of various microplastics in human stool: a prospective case series. *Ann Intern Med* **171**(7):453-457. DOI: 10.7326/M19-0618 . PMID: 31476765.

[12] **Najahi H, Banni M, Nakad M, Abboud R, Assaf JC, et al.** (2025) Plastic pollution in food packaging systems: impact on human health, socioeconomic considerations and regulatory framework. *J Hazard Mater Adv* 18:100667. DOI: 10.1016/j.hazadv.2025.100667. PMCID: PMC12535839

[13] **Winiarska E, Jutel M, Zemelka-Wiacek M.** (2024) The potential impact of nano- and microplastics on human health: understanding human health risks. *Environ Res* **251**:118535. DOI: 10.1016/j.envres.2024.118535. PMID: 38460665.

[14] **Zhang X, Yu C, Wang P, Yang C.** (2025) Microplastics and human health: unraveling the toxicological pathways and implications for public health. *Front Public Health* **13**:1567200. DOI: 10.3389/fpubh.2025.1567200. PMCID: PMC12213550.

[15] **Clayton CA, Walker TR, Bezerra JC, Adam I.** (2020) Policy responses to reduce single-use plastic marine pollution in the Caribbean. *Marine Pollution Bulletin* **162**:111833. DOI: 10.1016/j.marpolbul.2020.111833. PMID: 33213855.

[16] **Avio CG, Gorbi S, Regoli F.** (2017) Plastics and microplastics in the oceans: From emerging pollutants to emerged threat. *Mar Environ Res* **128**:2-11. DOI: 10.1016/j.marenvres.2016.05.012 . PMID: 27233985.

[17] **Auta H S, Emenike CU, Fauziah SH.** (2017) Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. *Environment international*. **102**:165-176. DOI: 10.1016/j.envint.2017.02.013. PMID: 28284818.

[18] **Athey SN, Erdle LM.** (2022) Are we underestimating anthropogenic microfiber pollution? A critical review of occurrence, methods, and reporting. *Environ Toxicol Chem* 41:822–37. DOI: 10.1002/etc.5173 . PMID: 34289522.

[19] **Emenike EC, Okorie CJ, Ojeyemi T, Egbemhenghe A, Iwuozor KO, et al.** (2023) From oceans to dinner plates: the impact of microplastics on human health. *Heliyon* 9:e20440. DOI: 10.1016/j.heliyon.2023.e20440. PMCID: PMC10543225

[20] **Ivar do Sul JA.** (2021) Why it is important to analyze the chemical composition of microplastics in environmental samples. *Mar Pollut Bull* 165:112086. DOI: 10.1016/j.marpolbul.2021.112086. PMID: 33578189.

[21] **Alimba CG, Faggio C.** (2019) Microplastics in the marine environment: current trends in environmental pollution and mechanisms of toxicological profile. *Environ Toxicol Pharm* 68:61-74. DOI: 10.1016/j.etap.2019.03.001. PMID: 30877952.

[22] **Singh P, Sharma P.** (2023) Household Plastic Waste Mis-Management Effect On Environmental Plastic Pollution. *International Journal of Creative Research Thoughts* (IJCRT) 11(5):2320-2882. DOI: 10.13140/RG.2.2.17912.01285 .

[23] **Dris R, Gasperi J, Mirande C, Mandain C, Guerrouache M, et. al.** (2017) A first overview of textile fibers, including microplastics, in indoor and outdoor environments. *Environ Pollut* **221**:453-458. DOI: 10.1016/j.envpol.2016.12.013 . PMID: 27989388.

[24] **Erni-Cassola G, Zadjelovic V, Gibson MI, Christieoleza JA.** (2019) Distribution of plastic polymer types in the marine environment; A meta-analysis. *J Hazard Mater* 369:691-698. DOI: 10.1016/j.jhazmat.2019.02.067. PMID: **30826562.**

[25] **Guo Z.** (2022) Environmental Pollution of Medical Waste and New Medical Plastic Waste Treatment Technology. *Highlights Sci Eng Technol* **26**:72-79. DOI: 10.54097/hset.v26i.3647

[26] **Pratelli A, Cinelli P, Seggiani M, Strangis G.** (2023) Agricultural Plastic Waste Management. *Highlights Sci Eng Technol* 1:198-205. DOI: 10.37394/232033.2023.1.20

[27] **Foschi E, Barbir J, Mersico L, Stasiškienė.** (2025) Tourism intensity and plastic waste management: insights from European capital cities. *Discover Sustain* 6:419. DOI: 10.1007/s43621-025-00977-5 .

[28] **Mao X, Xu Y, Cheng Z, Yang Y, Guan Z, et al.** (2022) The impact of microplastic pollution on ecological environment: a review. *Front Biosci (Landmark Ed)* 26;27(2):46. DOI: 10.31083/j.fbl2702046. PMID: 35226989.

[29] **Hoffmann L, Eggers SL, Allhusen E, Katlein C, Peeken I.** (2020) Interactions between the ice algae Fragillariopsis cylindrus and microplastics in sea ice. *Environment International* 139:105697. DOI: 10.1016/j.envint.2020.105697 . PMID: 32334123

[30] **Halsband C, Herzke D.** (2019) Plastic litter in the European Arctic: what do we know? *Emerg Contam* **5**:308-318. DOI: 10.1016/j.emcon.2019.11.001 .

[31] **Zhang Y, Gao T, Kang S, Allen S, Luo X, et. al.** (2021) Microplastics in glaciers of the Tibetan Plateau: Evidence for the long-range transport of microplastics. *Sci Total Environ* **758**:143634. DOI: 10.1016/j.scitotenv.2020.143634 . PMID: 33243498

[32] **Embrandiri A, Quaik S, Emmanuel MI, Rahma M, Rupani PF, et. al.** (2020) Microplastics: the next threat to mankind? Handbook of research on resource management for pollution and waste treatment. *IGI Global Scientific Publishing* 106-122. DOI: 10.4018/978-1-7998-0369-0.ch006 .

[33] **Smith M, Love DC, Rochman CM, Neff RA.** (2018) Microplastics in seafood and the implications for human health. *Current environmental health reports* 5:375-386. DOI: 10.1007/s40572-018-0206-z . PMCID: PMC6132564.

[34] **Kwon JH, Kim JW, Pham TD, Tarafdar A, Hong S, et. al.** (2020) Microplastics in food: a review on analytical methods and challenges. *Int J Environ Res Public Health* 17(18):6710. https://doi.org/10.3390/ijerph17186710 . PMCID: PMC7559051

[35] **Huerta L, Wanga E, Mendoza Vega J, Quej KV, Chi JD, et. al.** (2017) Field evidence for transfer of plastic debris along a terrestrial food chain. *Scientific reports* 7:14071. DOI: 10.1038/s41598-017-14588-2. PMCID: PMC5658418

[36] **Wang YL, Lee YH, Hsu YH, Chiu IJ, Huang CY, et. al.** (2021) The kidney-related effects of polystyrene microplastics on human kidney proximal tubular epithelial cells HK-2 and male C57BL/6 mice. *Environmental health perspectives* 129(5):57003. DOI: 10.1289/EHP7612. PMCID: PMC8101928.

[37] **Shengchen W, Jing L, Yujie Y, Yue W. Shiwen X.** (2021) Polystyrene microplastics-induced ROS overproduction disrupts the skeletal muscle regeneration by converting myoblasts into adipocytes. *J Hazard Mater* **5**(417):125962. DOI: 10.1016/j.jhazmat.2021.125962. PMID: 33979708.

[38] **Sun R, Xu K, Yu L, Pu Y, Xiong F, et. al.** (2021b) Preliminary study on impacts of polystyrene microplastics on the hematological system and gene expression in bone marrow cells of mice. *Ecotoxicology and Environmental Safety* 218:112296. DOI: 10.1016/j.ecoenv.2021.112296. PMID: 33962271

[39] **Estrela FN, Guimarães ATB, Araújo APDC, Silva FG, Luz TMD, et. al.** (2021) Toxicity of polystyrene nanoplastics and zinc oxide to mice. *Chemosphere* 271:129476. DOI: 10.1016/j.chemosphere.2020.129476. PMID: 33434826.

[40] **Li S, Wang Q, Yu H, Yang L, Sun Y, et. al.** (2021) Polystyrene microplastics induce blood-testis barrier disruption regulated by the MAPK-Nrf2 signaling pathway in rats. *Environ Sci Pollut Res Int* **28**(35):47921-47931. DOI: 10.1007/s11356-021-13911-9. PMID: 33895957.

[41] **An R, Wang X, Yang L, Zhang J, Wang N, et. al.** (2020) Polystyrene microplastics cause granulosa cells apoptosis and fibrosis in ovary through oxidative stress in rats. *Toxicology* **15**(449):152665. DOI: 10.1016/j.tox.2020.152665. PMID: 33359712.

[42] **Zolotova N, Kosyreva A, Dzhalilova D, Fokichv N, Makarova O.** (2022). Harmful effects of the microplastic pollution on animal health: a literature review. *Peer J* 10:e13503. DOI: 10.7717/peerj.13503. PMCID: PMC9205308.

[43] **Yang Z, DeLoid GM, Zarbl H, Baw J, Demokritou P.** (2023) Micro- and nanoplastics (MNPs) and their potential toxicological outcomes: State of science, knowledge gaps and research needs. *NanoImpact* **32**:100481. DOI: 10.1016/j.impact.2023.100481. PMCID: PMC10841092 .

[44] **Bayattork M, Rahman M, Hossain MI, Zhang Y, Haque ANMA, et. al.** (2026) Impact of Textile-Derived Micro- and Nanoplastics on Brain Health: An Emerging Environmental Risk. *Environ Sci Technol* 60(4):2863-2895. DOI: 10.1021/acs.est.5c10338. PMID: 41560652.

[45] **Moresco V, Oliver D M, Weidmann M, Matallana-Surget S, Quilliam RS.** (2021) Survival of humanenteric and respiratory viruses on plastics in soil, freshwater, and marine environments. *Environ Res* **199**: 111367. DOI: 10.1016/j.envres.2021.111367. PMID: 34029551.

[46] **Schnurr RE, Alboiu V, Chaudhary M, Corbett RA, Quanz ME, et. al.** (2018) Reducing marine pollution from single-use plastics (SUPs): A review. *Mar Pollut Bull* **137**:157-171. DOI: 10.1016/j.marpolbul.2018.10.001 . PMID: 30503422.

[47] **UNEP.** (2018). Single-use plastics: A roadmap for sustainability. Retrieved from: https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability.

[48] **UNEP.** (2023). Turning off the tap: How the world can end plastic pollution and create a circular economy. Nairobi: UNEP.

[49] **Austin HP, Allen M, Donohoe BS, Rorrer NA, Kearns FL, et. al.** (2018) Characterization and engineering of a plastic-degrading aromatic polyesterase. *Proc Natl Acad Sci U S A* **115**(19):E4350-E4357. DOI: 10.1073/pnas.1718804115 . PMCID: PMC5948967 .

[50] **Alaghemandi M.** (2024) Sustainable Solutions Through Innovative Plastic Waste Recycling Technologies, *Sustainability.* 16(23): 10401. DOI: 10.3390/su162310401 .

[51] **Shukla S, Khan R, Roccaro P.** (2025) Plastic Waste Recycling is Insufficient to Mitigate Plastic Pollution: the Need for a Paradigm Shift. *Curr Pollution Rep* 11:62. DOI: 10.1007/s40726-025-00392-4

[52] **Nwafor N, Walker TR.** (2020) Plastic Bags Prohibition Bill: A developing story of crass legalism aiming to reduce plastic marine pollution in

Nigeria. *Marine Policy* 120:104160. DOI: 10.1016/j.marpol.2020.104160.

Author affiliation

1. Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq.

ORCID:
Maiada K. Hassan: https://orcid.org/0009-0006-6270-7484
Abdul-Kareem S: https://orcid.org/0009-0004-6328-4298