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ABSTRACT

Global concern has grown over the growing number of marine debris, especially plastic garbage, in our oceans. Understanding the degree of plastic waste contamination in marine habitats, the routes through which microplastics enter the bloodstream of humans, and any potential health effects are necessary. This study investigates the sources and buildup of plastic debris in marine ecosystems by a thorough analysis of the literature. The routes by which these microplastics enter the human body are given special consideration, including ingestion through tainted seafood, inhalation of airborne particles, and cutaneous absorption, the potential for tissue damage and inflammation caused by microplastics as transporters for harmful substances. In addition, it explores the potential for bioaccumulation and biomagnification in the food chain, as well as the long-term impacts of microplastics on human health. The results of this study highlight the urgent need for action to reduce the potential health concerns brought on by exposure to microplastics and address plastic waste pollution. The report emphasises the significance of establishing efficient waste management techniques, encouraging recycling programmes, and adopting sustainable practices to reduce plastic usage.

Keywords: *Marine debris, Plastic waste, Microplastics, Human blood, Nanoparticles etc.*

INTRODUCTION

Marine debris refers to any human-generated solid material that enters and pollutes our oceans, including plastics, metals, glass, and other waste products. Among these, plastic waste has become a major concern due to its durability, widespread use, and inadequate disposal practices. It is estimated that more than 8 million metric tons of plastic waste enters oceans yearly. This waste often takes centuries to decompose, leading to long-lasting pollution and negative impacts on marine ecosystems [1]. About 7800 metric ton of plastic is been produced until 2015 [2]. Research states that marine debris primarily consists of thrown out and scrap plastics [3,4]. A nearly 60 million tonne increase in plastic production occurred from 2014 to 2019, producing approximately 370 million tonne of plastic in 2019. [5, 6]). Due to the relatively low cost and convenience of manufacturing plastic products [7-9], The soil and oceans are polluted with hundreds of tons of plastic. Plastic debris accounts for 60-80% of marine litter [10-11]. Plastic particles that float on the surface of the ocean are composed of low-density plastic particles that break into smaller particles when they are submerged in water [12-13]

The discovery of microplastics in the oceans of the world, including Antarctica, is significant in recent years [14-15]. Over the past four decades, microplastics have been accumulating in the oceans as man-made litter. [1, 16-17]. Since the introduction of plastics into the environment, plastic pollution has become a global health concern [16]. Microplastics (MPs) were first identified in plankton samples in the 1960s, with increasing abundance over time. MPs range in size from 1 -5 mm including prime plastics such as microbeads or microfibers, as well as secondary plastics created by fragmentation of nano plastic into finest particles [18].

Microplastics are small plastic particles measuring less than five millimetres in size. They can enter our ecosystems through various origins, sources, like disintegration of big plastic debris, microbeads in personal hygienic items, and fibres released from fabricated clothing. Those tiny particles are jeopardising marine life and have recently been found in humans as well [19]. In recent years, studies have discovered microplastics in various human tissues and organs, including the gastrointestinal tract, lungs, and even the placenta. These findings have raised

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concerns about the potential health impacts of microplastic ingestion or inhalation. While the exact mechanisms and long-term consequences are still being explored, it is essential to understand the potential risks associated with this discovery. Some studies suggest that microplastics have the potential to release harmful chemicals, act as carriers for other toxic substances, and cause inflammation or tissue damage. Plastic fragments may be transferred to organ via the bloodstream, which is scientifically convincing. The placenta of a pregnant woman has been demonstrated to be porous to polystyrene beads with diameters of 50, 80, and 240 nm. [20] Plastic particles were found in placental and foetal tissues following acute respiratory contact with micro polystyrene spheres (20 nm) in rats [21]. Small polystyrene microparticles accumulated in the liver, kidney, and intestine of mice after administration. [22,23]. This is quite sufficient evidence of harmful effects seen in Humans as well as other organisms [24].

During the last few years, the use of plastic is increasing due to being of durable and versatile in nature since then the pollution caused by plastic is increasing and slowly it is posing a serious threat to environment and other organisms including human. The first fully synthetic plastic was firstly introduced in 1907 by Leo Baekeland [25]. The need of plastics was to save the natural resources as they are not so abundant in nature. In the 1950s, since the introduction of plastic onto the market, worldwide manufacturing numbers and ocean plastic trash have expanded rapidly [26-27].

The ocean has accumulated an estimated 14.5 million tonnes (Mt) of the 359 million tonnes (Mt) produced in 2018 [28- 29]. Smaller plastic particles can cause hazardous effects on marine biota if they are ingested by them. As use of plastics are increasing because of their durability and versatility in nature.

Although large-scale plastics production commenced in the early 1950s, approximately 8.3 billion tonnes, constituting three-quarters of the total produced, have since accumulated in waste disposal sites or littered the environment [30].

The size of plastic marine trash, which ranges from several metres to a few nanometres, is a mixture of chemicals and macromolecules (polymers). It includes a variety of things, including fishing equipment, industrial pellets, cosmetic microbeads, water sources, covers, straws, cigarette butts, bottles, bags, and agricultural plastics, as well as the fragmented waste that results deterioration of all. This is now present everywhere within the marine environment, comprising beaches, seafloor, sediments, the water table, and surface of the water. Plastic waste poses a severe threat to marine ecosystems and the overall health of our planet. Tons of plastic enter our oceans each year, causing immense harm to marine life, habitats, and ecosystems. The durability of plastics and their inability to biodegrade over time exacerbates the issue, leading to long-lasting pollution. Marine animals often mistake plastic debris for food or become entangled in it, resulting in injuries, suffocation, and even death. Additionally, the ingestion of plastic can cause internal injuries, digestive system blockages, and impair the animal's ability to thrive and reproduce. This disturbance in the delicate marine food chain has far-reaching consequences for the entire ecosystem. Plastic debris microplastics, which are tiny pieces that result from this breakdown, that can be marine organisms consume and subsequently enter higher organisms including human's food chain. This raises concerns about the potential transfer of harmful chemicals and toxins to humans through the consumption of contaminated seafood. The presence of plastic waste in our oceans has significant environmental and economic consequences also. It disrupts coastal ecosystems, damages coral reefs, contributes to the formation of dead zones, and affects tourism and fisheries industries. The environmental cleanup costs and the economic losses incurred due to these impacts are substantial, further highlighting the urgent need to address the issue. The issue of marine debris, particularly plastic waste, is a pressing concern that demands immediate attention. By understanding the devastating impacts of plastic waste on marine ecosystems and human health, proactive steps can be taken to reduce plastic consumption, promote recycling, and foster a culture of sustainability.

2. Sources and types of Marine Debris

2.1 Land-based Sources:

1. Mismanaged Waste: The improper disposal of waste by individuals, households, and businesses on land is a significant source of marine debris. This includes littering, inadequate waste management

infrastructure, and illegal dumping. This debris is carried by wind, rivers, and stormwater runoff into water bodies, ultimately reaching the oceans [31-32]. It harms marine life through entanglement, ingestion, and habitat destruction.

2. Stormwater Runoff: Rainwater runoff picks up debris from streets, sidewalks, and other surfaces, carrying it into rivers, streams, and eventually the ocean [33]. Stormwater runoff carries pollutants, including plastics, chemicals, and other debris, which negatively impact water quality and marine ecosystems.

3. Littering: Discarded items such as food packaging, cigarette butts, and plastic bottles left behind by individuals at beaches and recreational areas.

4. Industrial Activities: Manufacturing plants, and construction sites contribute to marine debris through the release of materials, waste, and by-products. Chemicals, plastics, and other debris can be discharged into waterways, causing pollution and harming marine organisms.

5. Agricultural activities can lead to the introduction of debris into water bodies through the use of plastic mulch films, irrigation systems, and improper disposal of agricultural waste. Along with this use of CRFs which reduce cost and reduce nutrient runoff level in water system. Plastics and other debris can enter waterways, affecting aquatic life and ecosystems.

6. Municipal Solid Waste: Poor waste management practices in cities and towns leading to trash leakage into rivers and coastal zones.

2.2 Ocean-based Sources:

1. Fishing Gear: Abandoned, lost, or discarded fishing nets, lines, and traps pose a significant threat to marine life due to entanglement and trapping [34-35]. This continues to entangle marine animals, leading to injury, suffocation, and death. It also causes damage to coral reefs and other sensitive habitats.

2. Shipping and Maritime Activities: Shipping vessels, including cargo ships and recreational boats, contribute to marine debris through accidental spills, cargo loss, and deliberate dumping of waste and garbage. It can harm marine life through entanglement, ingestion, and physical damage. It also poses risks to navigation and can damage coastal ecosystems. (Table 1 & 2)

3. Offshore Exploration and Production: Oil and gas exploration and production activities, including drilling platforms, pipelines, and associated infrastructure, can result in pollution and debris discharge into the oceanic environment. Debris from offshore activities can harm marine life, disrupt habitats, and cause oil spills, leading to devastating environmental consequences.

4. Recreational Activities: Debris originating from recreational boating, water sports, and beachgoers, such as plastic bottles, food packaging, and personal care items.

5. Illegal Dumping: Deliberate disposal of waste and debris by individuals or companies in marine environments, often to evade proper disposal costs or regulations.

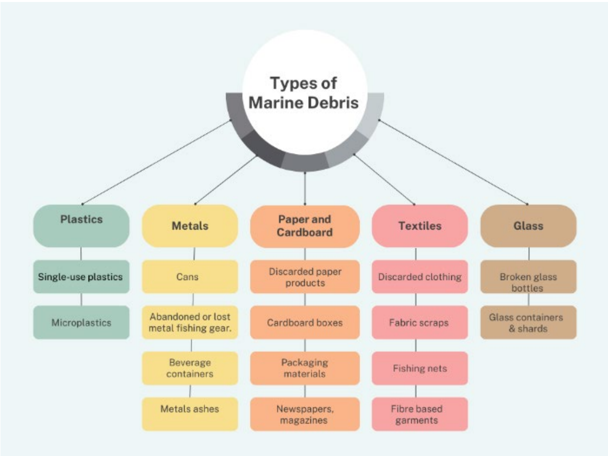

Fig. 1 – Types of Marine Debris

An overview of marine littering, which is human-made trash that has been purposefully or unintentionally dumped in a lake, sea, ocean, or river, is shown in Fig. 1. This type of waste is particularly hazardous since it has the potential to physically hurt marine creatures, obstruct navigation, and have a negative effect on marine ecosystems. The most common sort of marine garbage is probably plastic debris. It includes things like bottles, bags, straws, fishing equipment, and microplastics, which are tiny plastic particles smaller than 5 mm. Plastics are particularly damaging because they don't biodegrade and stay for hundreds to thousands of years in the environment. Aluminium cans and other metal garbage are included in category 2 (metal debris). Some metal waste can deteriorate and emit poisonous materials into the ocean, harming marine life. also comprises Fish, marine animals, seabirds, and other marine species can all be killed by lost or abandoned fishing gear. Nets, lines, pots, and traps are included in this. Microfibers, a type of small synthetic thread that is shed from garments and other textiles after washing, might end up in the water and be consumed by marine animals, perhaps harming them. 4 - Glass Debris: This category contains broken bottles and other glass waste, among other things. Both marine life and people who come into contact with these goods may be at risk. Other comprises Debris made of rubber includes tyres and balloons. These things have the potential to harm marine life if they are consumed, and they can break down and release poisons into the sea. Battery trash, oil waste, and other chemical waste are examples of products that might leak dangerous chemicals into the sea, affecting marine life and ecosystems.

Table 1. Types of Marine Debris in detail

Plastics	Metals	Glass	Rubber	Paper and Cardboard	Textiles	Wood	Other Materials
Single-use plastics such as plastic bottles, food containers, cutlery, straws, and packaging materials.	Aluminium cans and beverage containers	Glass bottles and jars	Discarded tires	Paper products, including packaging, newspapers, magazines, and cardboard boxes	Clothing items, such as synthetic fibre-based garments	Timber and lumber	Foam products, including polystyrene foam
Fishing gear: Discarded or lost fishing nets, lines, traps and other equipment	Steel or iron objects, including parts of ships, machinery, and construction materials	Broken glass from various sources, including containers and windows	Rubber fragments from various sources, such as rubber gloves, balloons, and sporting equipment	Paper and cardboard fragments from various sources	Fabric scraps and remnants	Abandoned or lost wooden objects, such as pallets, crates, and fishing gear	Ceramic and pottery fragments
Microplastics include microbeads, microfibers, and fragments from larger plastic items.	Abandoned or lost fishing gear made of metal, such as hooks, weights, and traps		Abandoned or lost rubber fishing gear, including rubber nets		Discarded fishing nets made of synthetic fibres		Rubber or plastic balloons & Miscellaneous items like rubber bands, cigarette butts, and personal care items

3. Emphasis on plastic waste due to its ubiquity and persistence in marine environments

Due to ubiquity plastics have become an integral part of our daily lives, with a vast array of products made from this versatile material [36]. From packaging to consumer goods, textiles to medical devices, plastics are widely used and globally distributed. As a result, plastic waste is generated in large quantities across the globe, making it a major contributor to marine debris. Plastics are highly durable materials, designed to -withstand degradation and resist natural processes of decomposition. Once in the marine environment, plastic waste can persist for hundreds of years, slowly breaking down into smaller fragments known as microplastics. This longevity allows plastics to accumulate over time, exacerbating their presence and impact on marine ecosystems and due to this waste poses severe ecological consequences for marine life and habitats. Marine animals, such as seabirds, turtles, and marine mammals, mistake plastic debris for food or become entangled in larger items like fishing nets. Ingestion of plastics can lead to internal injuries, starvation, and death. Plastic debris also damages and alters marine habitats, including coral reefs and seafloor ecosystems. The fragmentation of larger plastic items, combined with the breakdown of microbeads and microfibers from consumer products, has led to the pervasive presence of microplastics in marine environments. These tiny particles pose a distinct concern as they are accessible by a variety of marine creatures, potentially ranking the food chain and spreading the impacts of plastic pollution throughout the ecosystem and they are easily transported to long range by marine circulation, leading to in the widespread distribution of plastic debris. Gyres, large systems of circulating ocean currents, are known to accumulate and concentrate plastic debris. The most well-known example is Great Pacific Garbage Patch, an area of marine debris positioned in central Pacific Ocean, North. These accumulation zones highlight the significant role of plastics in marine debris and emphasize the urgent need for mitigation strategies [37-38].

4. Objective

The objective of the review is to layout a thorough and current synthesis of existing research and knowledge in these areas. The review aims to accomplish and summarize existing research. This review gathers and synthesize published studies, scientific articles, reports, and other relevant sources on marine debris, focusing specifically on plastic waste and the presence of microplastics in human blood. It also highlights the harmful impacts of plastic waste on marine ecosystems and biodiversity. It will emphasize the ecological consequences of plastic pollution and the urgent need for mitigation and prevention strategies. This paper aims to delve into the emerging field of research regarding the discovery of microplastics in human blood. It will examine the methodologies used to detect and analyse microplastics in blood samples, as well as the prevalence, distribution, and potential health implications associated with their presence. This will also help to identify knowledge gaps and research needs. It will pinpoint areas where more studies are needed to comprehend the sources better, fate, transport, potential health effects of nano plastics in human blood, as well effective strategies for mitigating plastic waste pollution and provide policy and management implications: The review will discuss the implications of the findings for policy-making, management strategies, and public awareness campaigns.

5. Processes influencing the transport and distribution of plastics in the ocean

5.1 Ocean Currents:

Ocean currents, driven by various forces such as wind, temperature gradients, and Earth's rotation, are the primary drivers of plastic transport in the ocean. The major processes associated with ocean currents include:

a) Surface Currents: Surface currents, driven primarily by wind, move large volumes of water across the ocean surface. Plastics floating on the surface can be carried by these currents, leading to their long-distance transport. Major surface currents, known as gyres, [38] have been identified in different ocean basins, like the southern Pacific Gyre and the northern Atlantic Gyre. These gyres can accumulate and concentrate plastic debris, forming "garbage patches" [39].

b) Subsurface and Coastal Currents: Below the surface, subsurface currents can transport plastics within the water column. These currents can result from a combination of wind-driven and density-driven processes. Plastics submerged beneath the surface can be carried horizontally and vertically, contributing to their dispersal and vertical distribution. Coastal currents are influenced by factors such as tides, winds, and local topography. They can transport plastics from nearshore areas to offshore regions, as well as along coastlines, leading to the accumulation of plastic waste in specific coastal areas [40, 41].

5.2. Ekman Transport:

Ekman transport refers to the net movement of water caused by the interaction of wind and the Earth's rotation. It influences the surface transport of plastics by causing water movement at an angle to the wind direction. This results in the movement of plastic debris in a direction slightly in the Southern Hemisphere to the left and to the right of the direction of the wind respectively [42].

5.3. Stokes Drift:

Stokes drift is a phenomenon where water particles move in a circular motion due to the interaction between wind-generated waves and currents. Stokes drift can affect the horizontal transport of plastics, especially smaller fragments and microplastics, by causing them to move in complex patterns [43].

5.4. Upwelling and Downwelling:

Upwelling and downwelling are vertical movements of water in the ocean. Upwelling occurs when deep, nutrient-rich water rises to the surface, while downwelling involves the sinking of surface water. These vertical movements can influence the distribution of plastic debris by bringing plastics to the surface or transporting them to deeper layers of the ocean which is proved by research done on coastal models [44].

5.5. Wind-Driven Transport:

Wind plays a significant role in the transport of plastic debris in the ocean. Strong winds can generate surface waves that propel floating plastics, particularly lightweight items, across the ocean surface. Wind-driven transport can lead to the dispersal of plastics over long distances, including from land-based sources to remote oceanic regions.

6. Environmental Impacts of Plastic Waste

Plastic waste can directly physically harm to marine organisms, including seabirds, turtles, fish, and marine mammals, can suffer from ingestion and entanglement in plastic debris. Animals may mistake plastics for food, leading to internal injuries, blockages, and malnutrition. Entanglement in plastic fishing gear and other debris can cause suffocation, drowning, and impaired mobility, leading to injuries and reduced reproductive success. Secondly plastics can release toxic chemicals into the marine environment, posing additional risks to marine organisms. Additives, such as plasticizers and flame retardants, can leach out of plastics, exposing organisms to harmful substances. Persistent organic pollutants (POPs), which can attach to plastic surfaces, can accumulate in the tissues of marine organisms, potentially leading to toxic effects and disrupting their physiological functions. Plastic waste can also modify marine habitats, including coral reefs, seagrass beds, and rocky shores. Large plastic items, such as discarded fishing nets and ropes, can smother and damage benthic habitats, altering the physical structure and reducing habitat complexity. This degradation can disrupt critical nursery areas, spawning grounds, and shelter for marine organisms, leading to a decline in habitat quality and overall ecosystem health. Plastic waste can interfere with trophic interactions, affecting the transfer of energy and nutrients through the food web. Plastics can be mistaken as prey items by filter-feeding organisms, zooplankton, and small fish, leading to the ingestion of microplastics. This ingestion can cause reduced feeding efficiency, energy imbalance, and reduced growth rates. Consequently, this disruption can impact higher trophic levels, such as seabirds, marine mammals, and predatory fish, which rely on the abundance and composition of prey species. Ingestion of plastics by turtles [45-47]. It has been thoroughly established that at least 44% of oceanic bird species consume plastics [48], and there are confirmed instances of species like the black-footed albatross giving plastic granules to its young [1].

Plastic pollution can lead to changes in species composition within marine ecosystems. Certain species may be more tolerant or attracted to plastic debris, altering community dynamics and favouring the proliferation of specific organisms. For example, floating plastic can provide a substrate for invasive species, altering the competitive balance and potentially displacing native species. The exposure of marine organisms to plastic pollution can have genetic and evolutionary consequences. This can lead to genetic changes within populations over time, potentially affecting organisms' ability to adapt to other environmental challenges. Microplastics pose a particular threat to marine biodiversity. These particles several different types of creatures, including filter feeders, zooplankton, and also little fishes, with the potential to bioaccumulate through the food chain. Microplastics can disrupt feeding, growth, reproduction, and behaviour, impacting the survival and reproductive success of affected organisms thus entering humans' food chain also. As a result, plastic litter poses a serious concern to the marine ecology by acting as a vector for microorganisms [49], obstructing the GIT [50], causing fatalities [51], and finally having an impact on people. creatures, particularly marine creatures, frequently consume macro- and micro-plastic trash, which builds up in their gastrointestinal tract, liver, and intestines. Fish, prawns, mussels, oysters, and other marine animals that are regularly ingested by humans have been shown to contain tiny particles of plastic [8, 52- 54]. Being at the peak of the food web, humans in particular have been linked to a number of illnesses, including inflammation and dyspnea, by plastic particles smaller than 5 micrometres [52-53, 55-65].

7. Case studies highlighting specific examples of plastic waste's detrimental effects on marine and human life

7.1 Case Study: Sea Turtles and Plastic Ingestion

According to study by Emily M Duncan, evidence suggests that small juvenile marine turtles from the Pacific and Indian Ocean consumed plastic often (>1 mm). The frequency of ingestion appears to be higher in samples from the Pacific than the Indian Ocean, which may point to varying levels of vulnerability between oceans [66]. To assess contributing factors (such as species and turtle size), collaborative combined datasets to achieve larger sample sizes and longer time series over multiple ocean basins will be crucial in the future. This is because access to samples from this life stage was limited, making deeper analysis impossible. Additionally, the inclusion of information on plastics smaller than 1 mm, which has previously been found to be pervasive in marine turtles, would probably increase the frequency of reported ingestion in this study [67].

In contrast to other juvenile life stage studies, Indian Ocean specimens were dominated by filamentous segments composed of polyethylene, polypropylene and nylon, which were predominantly green and blue. One of the main sources of marine litter in the region is indeed abandoned fishing gear (ALDFG), often made of plastic fibres, in similar studies of turtles in northern Australia [68-73]. Findings from locally relevant river inputs indicate that fishing gear made of polyethylene, polypropylene and nylon may contribute to ALDFG in the environment [72]. This ghost gear has the ability to decompose into bioavailable parts after an extended period of decomposition [74-75].

Juvenile turtles are known to take refuge under sargassum rafts and other floating objects [76], and may eat rope fibres if food adheres to floating ALDFG. may increase. Results from the Pacific Ocean are consistent with other studies, in which the recorded debris is predominantly hard plastic debris and predominantly clear and white in colour [77-81]. Smaller newly hatched chicks appear to suffer the most from plastic waste, which has also been observed in the North Pacific [78].

High intake levels indicate a potential for serious adverse health effects. Loggerhead turtles left behind after hatching in Florida ate up to 287 and were reported to be in poor initial health. Animals are classified from lean to debilitated to epibiotic covered [81]. Plastic ingestion is associated with morbidity and mortality, but these are often difficult to pinpoint because there is no associated pathology [82-86]. The case study that follows shows how harmful plastic garbage is to marine turtles. As a result, their digestive systems may get obstructed, which may result in internal harm, obstructions, or even death. Furthermore, the existence of plastics can provide a false sense of satiety, which can result in undernutrition and decreased fitness. Not only are sea turtles physically harmed, but their population dynamics and ability to reproduce are also affected.

b. Case Study: Microplastics in Human Blood

A study is conducted in Netherlands in 2021, where blood was collected from 22 anonymized healthy, non-fasting adult volunteers. The analytical method used is Double-Shot Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS). Blood concentration data for PMMA, PP, PS, PE, and PET show that 77% (n = 17 of 22) of donors have quantifiable (>LOQ) mass of have plastic in their blood. The pattern of polymer types and concentrations varies from sample to sample. PET was the most common (>LOQ values in 50% of all donors tested), followed by PS (36%), PE (23%) and PMMA (5%). PP > LOQ could not be even in any donors. The three most frequently measured polymers above LOQ were also present at the highest concentrations. The particle size range of interest in this study was 700–500,000 nm due to the pre-analytical filtration step and the inner diameter of the needle used for blood collection, and was dependent on the individual polymer concentrations detected (below 7.1 µg/ml), particles were probably present in the blood samples in the low or micron range. The results of this investigation show that plastic particles exist in human blood [24].

Table 2 – Categorization of Microplastics

Size-Based Categorization	Primary Microplastics: These are microplastics that are manufactured intentionally produced in small sizes. Eg. microfibers from textiles, and pellets or nurdles used in plastic manufacturing processes.
	Secondary Microplastics: They are derived from the degradation and fragmentation of larger plastic items. Over time, exposure to environmental factors like sunlight, waves, and abrasion can break down larger plastics into smaller fragments, resulting in secondary microplastics.
	Nanoplastics: Nanoplastics are the smallest category of microplastics, measuring less than 1 micrometer (0.001 mm) in size. These particles can be created through the breakdown of larger microplastics or through direct release, such as the intentional use of nanoplastics in certain applications.
Origin-Based Categorization	Fragmented Microplastics includes microplastics that result from the mechanical fragmentation of larger plastic items. For example, plastic bottles, bags, or fishing gear that have broken down into smaller fragments due to physical forces like wave action or abrasion.
	Fibrous Microplastics are thin, elongated particles that are primarily composed of synthetic fibers. They originate from sources such as textiles, including clothing, carpets, and upholstery, as well as from synthetic ropes and nets.
	Film Microplastics are thin, flexible sheets or films that have degraded from larger plastic items like plastic bags, packaging materials, or plastic wrap. These sheets can break down into smaller fragments due to exposure to environmental conditions.
	Microbeads are tiny spherical particles used in personal care and cosmetic products, such as exfoliating scrubs and toothpaste. They are intentionally manufactured in small sizes and are designed to be washed down the drain, eventually reaching water bodies.

8. Prevalence and distribution of microplastics in marine environments

The prevalence and distribution of microplastics in ocean habitats are widespread and have been documented globally. Microplastics have been found in high concentrations in marine sediments worldwide. They accumulate in coastal areas, estuaries, and nearshore regions where land-based sources, rivers, and currents transport them. They are also prevalent in surface waters, including oceans, seas, and lakes. They can be transported by ocean currents, rivers, and atmospheric deposition. High concentrations have been observed in areas with high human population density, industrial activities, and shipping routes. Coastal areas and beaches are hotspots for microplastic accumulation. They receive inputs from both land-based and ocean-based sources, such as rivers, stormwater runoff, and direct littering. Wave action and tidal currents contribute to the redistribution and accumulation of microplastics along the coast. Microplastics have been found in a variety of marine organisms, including fish, shellfish, seabirds, marine mammals, and invertebrates. These organisms can ingest or become entangled in microplastics, leading to potential health impacts and trophic transfer through the food chain. Even organisms who are distant and remain in very remote marine territory, like Arctic and Antarctic regions, are not immune from microplastic fouling. Long-range transport via ocean currents and atmospheric deposition can transport microplastics to these remote areas, highlighting the global extent of microplastic contamination. According to a study by Kosuth et. al., 2018, the occurrence of anthropogenic particles in 12 various varieties of Laurentian Great Lakes beer, 12 different brands of commercial sea salt, and 159 samples of tap water from throughout the world. 81% of the water from the tap samples examined had anthropogenic particles in them and 98.3% of the particles analysed were fibres with a length of between 0.1 and 5 mm [87].

9. Detection and Analysis of Microplastics in Human Blood

There are various techniques such as Microscopy techniques which includes Optical Microscopy which involves the visual examination of blood samples under an optical microscope. Microplastics can be identified based on their morphology, size, and colour. Similarly, Raman microscopy utilizes laser-induced scattering of light to analyse the chemical composition of individual particles. It provides information about the presence and identity of microplastics based on their unique Raman spectra.

Another Spectroscopic Techniques which are widely used is Fourier Transform Infrared (FTIR). Infrared light in a sample is measured to be absorbed by chemical bonds via spectroscopy. It can be utilised to determine the existence of particular polymers, allowing the detection and characterization of microplastics in blood samples. Prior research using Fourier Transform Infrared spectroscopy on human faeces showed that small plastic particles can be eliminated by the digestive system. This study, published in the journal Ann of Internal Medicine, analysed human faeces and blood samples from eight participants from different countries. Using a combination of spectroscopic and microscopy techniques, microplastics were identified in all participants' samples. The study reported an average of 20 microplastic particles per 10 grams of faeces and detected microplastics in 7 out of 8 blood samples [88-89]. With FTIR, plastic particles were also found in human colectomy specimens [90]. Three plastic nanoparticles ranging approximately 5 and 10 m were recently imaged and identified in human tissue from placenta using Raman micro spectroscopy [91, 24].

Another detection technique called Enzymatic digestion requires enzyme, e.g., proteinase K, to break down organic matter in a blood sample. This method can be used to separate microplastics from biological material, allowing for their subsequent analysis. And most commonly used technique is Filtration and Filtration-based Techniques in which blood samples can be filtered using membranes with specific pore sizes to separate microplastics from other components. The retained particles can then be analysed using microscopy or spectroscopic techniques.

10. Factors influencing the occurrence of microplastics in the human body

The consumption of contaminated food and beverages is a significant pathway for microplastic exposure. Microplastics can enter the human body through the ingestion of seafood, drinking water, and other food items that have been contaminated with microplastics during production, processing, or packaging. The type and frequency of consumption of these contaminated items can affect the level of microplastic intake. They can also enter through inhalation of airborne particles. Microplastics present in the ambient air can be released from sources such as atmospheric deposition, indoor dust, and microplastic fibres shed from textiles. Occupation, indoor air quality, and living in urban areas with high pollution levels can increase the likelihood of airborne microplastic exposure. The use of personal care products and cosmetics that contain microbeads or other microplastic ingredients can contribute to microplastic exposure. These microplastics can come into contact with the skin, and over time, they can be absorbed or ingested. Environmental factors play a part in microplastics being present in the human body such as people living in areas with high levels of plastic pollution, proximity to industrial activities, or coastal regions with significant marine plastic debris can increase the likelihood of exposure to microplastics. Plastic packaging materials can release microplastics into the food and beverages they contain. Heat, agitation, and contact with certain types of plastics can facilitate the release of microplastics into the packaged products, which can then be ingested by consumers. Variations in individual metabolism and physiology can influence the fate and accumulation of microplastics in the human body. Some individuals may have more efficient elimination mechanisms, while others may have a higher propensity for microplastic retention and accumulation in tissues. The condition of the gastrointestinal tract and the efficiency of digestive processes can affect the passage and elimination of microplastics. Factors such as gut motility, gut microbiota composition, and the presence of other dietary components may influence the absorption and elimination of microplastics.

Plastic particles identified in human bloodstream are likely to have entered through mucosal contact (either ingestion or inhalation). Except in cases where the skin is injured, dermal uptake of tiny particles is improbable [92]. Respirable airborne particles are those that range in size from 1 nm to 20 m. While the majority of bigger particles are anticipated to be coughed up, eventually eaten, and given an additional chance of absorption via the gut epithelium, ultrafine (0.1 m) inhaled fragments may become absorbed and deposit in the lung [93, 24].

The concentrations of plastic particles listed here are the total of all possible exposure pathways. Environmental sources in the air, water, and food, as well as potentially ingestible personal care items (such as PE in toothpaste and PET in lip gloss), dental polymers, fragments of polymer implants, polymeric nanoparticles for drug delivery (such as PMMA and PS), and tattoo ink residues (such as acrylonitrile-butadiene-styrene particles), are all potential sources of this chemical [24].

11. Health Implications and Potential Risks due to presence of microplastics in human blood

The buildup of microplastics in human blood could have negative impacts on person's health is still an area of active research and ongoing debate. While the exact impacts on human health are not yet fully understood, several potential mechanisms and concerns have been identified. Here is an evaluation of some of the potential health effects associated with the presence of microplastics in human blood such as Microplastics, particularly sharp or abrasive particles, have the potential to cause physical damage to tissues upon contact. This damage can trigger an inflammatory response in the body, leading to localized or systemic inflammation.

In a recent study analysis of tissue samples from 6 patients with liver cirrhosis and 5 healthy individuals was done in Germany, Europe. Based the final protocol, 17 samples in total (11 liver, 3 kidney, and 3 splenic samples) were examined. A robust technique for detecting MP particles in human tissue that range in size from 4 to 30 m was created. Tissue samples were chemically digested, stained with Nile red, and then subjected to fluorescence microscopy and Raman spectroscopy. MPs were not found in any of the liver, kidney, or spleen tissues from patients who did not have underlying liver disease. On the other hand, cirrhotic liver tissues that tested positive for MP exhibited much larger amounts when viewed alongside liver samples from healthy persons. There were found to be six different microplastic polymers, with sizes ranging from 4 to 30 m. Six distinct MP polymers were discovered in the livers of people with liver cirrhosis in this proof-of-concept case series, but not in the liver sample of people without underlying disease [94].

Similarly, according to study published in Environment International Journal - In this study, six human placenta is collected and examined by Raman Micro spectroscopy to determine whether microplastics are present. In total, 12 bits of microplastic (ranging in size from 5 to 10 m) with spherical or irregular shape were discovered in 4 placentas, 5 of which were on the fetal side, 4 of which were on the maternal side, and 3 of which were in the chorioamniotic membranes. All microplastic particulates were characterized in terms of their morphology and chemical makeup. They were all pigmented; three of them were recognized as stained polypropylene, a thermoplastic polymer, while the remaining nine, which were all used in synthetic coatings, paints, glues, adhesives plasters, finger paints, polymers, cosmetics, and personal care products, could only be identified by their pigments [95].

They can also absorb and accumulate toxic chemicals from the surrounding environment. When present in the bloodstream, these chemicals could potentially be released, leading to toxicological effects on human health. The potential for chemical transfer and toxicity depends on the composition and properties of the microplastics, as well as the chemicals they have absorbed. Microplastics in the bloodstream could potentially trigger immune responses. The immune system may perceive microplastics as foreign invaders, leading to immune reactions, inflammation, and potential immune dysfunction. They may interact with cells, including blood cells, endothelial cells, and immune cells. These interactions could affect cellular functions, such as cell signalling, oxidative stress, and DNA damage, potentially impacting overall cellular health and function. Depending on the size and properties of microplastics could accumulate in various organs and tissues, potentially leading to localized effects or systemic impacts.

Whether plastic particles may be excreted, for example through renal filtering or biliary expulsion, or whether they must be deposited in the liver, spleen, or other internal organs via fenestrated blood vessels and sinusoids determines their eventual fate. The interactions of a particle with biological systems are governed by its size, shape, surface chemistry, charge, and creation of a protein corona on its outer layer [96]. Drug delivery sciences also provide confirmation for the translocation of plastic particles, since they have dosed polymeric pharmaceutical carriers in mammalian test systems [97]. Drug delivery across the blood brain barrier is made possible by the polymeric nanosized carriers [98-103, 24].

METHODOLOGY

A comprehensive review of the existing literature on marine debris, plastic waste, and microplastics is done which involves searching scholarly databases, scientific journals, conference proceedings from PubMed, Google Scholar, Academia, ResearchGate, Scopus, Web of Science, and relevant reports to identify relevant studies, research articles, and publications. A combination of keywords, including "marine debris," "plastic waste," "microplastics," "human blood," and related terms is used to find out the relevant papers. Search results are filtered on the basis of relevance and publication date. Data collection is done from various sources, including scientific studies, research projects, monitoring programs, and governmental reports. This involves collecting data on plastic waste generation, distribution, and impacts, as well as data on microplastics detection and quantification methods. The collected data is analysed to identify trends, patterns, and key findings related to marine debris and microplastics. This involves statistical analysis, data visualization techniques, and qualitative synthesis of the information.

A systematic approach is used to extract relevant data from the selected studies. A data extraction form is created to record key information, such as study objectives, methodologies, sample sizes, findings, and conclusions. Some case studies are attached to highlight specific examples of plastic waste impacts on marine life and studies documenting the presence of microplastics in human blood. Meta-analysis is also conducted to synthesize and quantitatively analyse the results from multiple studies. This provides a comprehensive overview of the overall trends and effects related to plastic waste and microplastics. Various studies are evaluated for existing policies and governance frameworks related to marine debris and microplastics and their effectiveness, gaps, and opportunities for improvement.

RESULT AND DISCUSSION

The devastating effects of plastics is harming whole ecosystem but the current scientific understanding of the health implications of microplastics in human blood is still in its early stages of research which is still unexplored. So, there is a need to establish direct causative relationships and determine the extent of the potential risks. Figure 2 and 3 depicts some possible solutions to reduce plastic waste and Figure 3 presents some actions of plans and strategies that can be followed to reduce marine debris. To determine the long-term impacts of exposure to microplastics, more research is required, including potential carcinogenicity, reproductive effects, endocrine disruption, immune system impacts, and neurological effects. The field of microplastic is complex and involves considering factors such as particle size, shape, composition, dose, duration of exposure, and individual susceptibility. Further studies are required to assess long-term exposure effects, potential synergistic effects with other pollutants, and the potential for chronic health impacts. There are lots of unexplored areas such as microplastics encompass a wide range of polymers and additives, each with its own unique chemical composition. This diversity makes it challenging to generalize the toxicological properties of microplastics as a whole. They can interact with biological fluids and form biofilms, potentially altering their surface properties and toxicological behaviour. Assessing the bioavailability and uptake of microplastics by cells and tissues is complex, as it depends on factors such as size, surface charge, and surface functional groups, which can influence their interaction with biological barriers and cell membranes. They can act as carriers for various chemical additives and adsorb contaminants from the environment. Assessing the toxicological implications requires understanding the release kinetics of these additives and adsorbed chemicals from microplastics, as well as their potential for bioaccumulation and bioavailability in living organisms. They can also interact with biological systems through physical, chemical, and biological mechanisms. They can induce physical damage, trigger inflammatory responses, generate oxidative stress, and disrupt cellular processes. Further research is needed to understand how microplastics are distributed and present across different human body tissues and organs. Studies should assess the accumulation patterns and potential health implications of microplastics in organs such as the liver, kidneys, lungs, and reproductive organs. The further research should be examined how microplastics are taken up by marine organisms, their sources and pathways transferred through the food chain, and ultimately reach humans through seafood consumption.

Currently, there is a lack of standardized protocols and methodologies for assessing the toxicological and carcinogenic properties of microplastics. Developing standardized testing methods that simulate realistic exposure scenarios and account for variations in microplastic properties is essential for accurate toxicological assessments. Long-term effects of chronic exposure to microplastics and their potential carcinogenic properties require further investigation. Understanding the cumulative effects of prolonged exposure and the potential for microplastics to act as co-carcinogens or promote the effects of other carcinogens is complex and necessitates longitudinal studies. The field of microplastic toxicology is still relatively new, and there are significant gaps in our understanding of the toxicological and carcinogenic properties of microplastics. More research is needed to address these gaps, identification of key mechanisms of toxicity, and assessment of potential long-term health effects and assess the impacts of recycling, waste reduction, and policy measures in mitigating plastic pollution and reducing the presence of microplastics in the environment.

Fig 2 – Solutions to reduce plastic waste

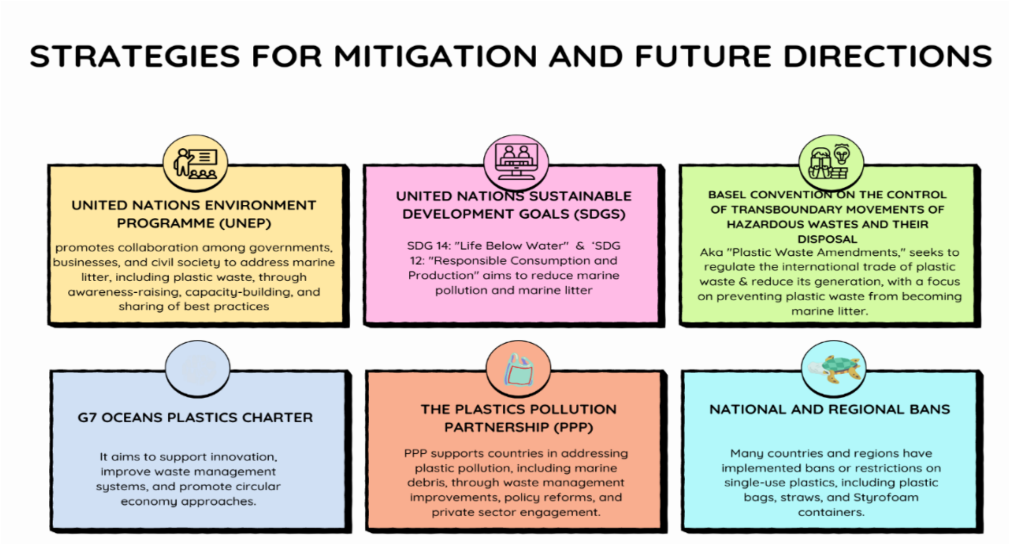

Fig 3 – Strategies for mitigation and Future Direction of Marine Debris

CONCLUSION

In summary, the review of literature on marine debris with a special focus on plastic waste and the discovery of microplastics in human blood. Marine debris, particularly plastic waste, poses a significant threat to marine ecosystems, organisms, and habitats. It is ubiquitous, persistent, and has detrimental ecological consequences. Plastic waste enters the marine ecosystem through various pathways, including improper waste management, stormwater runoff, and industrial activities. It is transported and distributed across the oceans through ocean currents, winds, and other natural processes. Microplastics, tiny plastic particles less than 5mm in size, have been found in various marine environments, including coastal areas, deep sea, and polar regions. They originate from both primary sources (such as microbeads and fibres) and secondary sources (as a result of the destruction and disintegration of bulkier plastic objects). The presence of microplastics in human blood has been documented in several studies, highlighting the potential for human susceptibility to microplastics through various paths, including consumption, breathing, and cutaneous contact. While the health effects of microplastics on human beings are still being studied, there is growing concern about their potential to cause physical, chemical, and biological harm. Microplastics may carry toxic chemicals, act as vectors for pathogens, and disrupt cellular functions, posing potential risks to human health. The assessment of the toxicological and carcinogenic properties of microplastics is challenging due to their diverse compositions, sizes, and shapes. Standardized methods for evaluating the health effects of microplastics are needed to ensure accurate and reliable risk assessments. The review has identified several knowledge gaps, including the need for improved understanding of the sources, fate, and transport of plastic waste, as well as the long-term ecological and health impacts of microplastics. In light of these findings, there is an urgent need for global action to combat marine debris and microplastic pollution. This requires a multi-faceted approach that encompasses: Reduction of plastic waste at its source through measures such as plastic bags, extended producer responsibility, and sustainable product design. Improvement of waste management systems, including effective recycling infrastructure, waste collection, and proper disposal practices to prevent plastic waste from entering marine environments. Promotion of programmes for public education and awareness about the effects of marine debris and microplastics, and to foster responsible consumption and waste management behaviours. Development and implementation of policies and regulations at national and international levels to address plastic pollution and promote sustainable practices. Advancement of research and innovation to develop new materials, technologies, and solutions for plastic waste management, including alternative materials, recycling methods, and circular economy approaches. Collaboration and coordination among governments, industries, scientists, NGOs, and communities to share knowledge, resources, and best practices in tackling marine debris and microplastic pollution. It is essential that global action is taken urgently to prevent further degradation of marine ecosystems, protect biodiversity, and safeguard human health.

Some key strategies that can help combat plastic waste includes-Reducing Plastic Consumption and opting for alternatives that are reusable include cloth bags, metal straws, and refilled water bottles, to minimize single-use plastics. Proper waste management systems, including recycling facilities and awareness campaigns can promote responsible disposal and recycling of plastic waste and to promote knowledge about the impacts of plastic waste through educational initiatives, community programs, and media campaigns.

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