

A REVIEW ON EFFECTS OF NANOPLASTICS ON HUMAN BODY

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ABSTRACT

Nanoplastics-plastic particles smaller than 1000 nm-have arisen as a major environmental problem as a result of plastics widespread use and insufficient disposal worldwide. While massive plastic debris is visible in the environment, tiny plastic particles, such as nanoplastics, offer particular risks due to their small size, persistence, and ability to cross biological barriers. This review investigates the creation, environmental pathways, origins, and transport mechanisms of nanoplastics, with a focus on their prevalence in air, water, and soil, as well as their subsequent absorption into the human body by ingestion, inhalation, and, to a lesser extent, skin contact. Recent studies have shown a number of health hazards connected with nanoplastic exposure, including respiratory and gastrointestinal issues, liver and kidney damage, neurotoxicity, and alterations to the endocrine, reproductive, and cardiovascular systems. These negative consequences are related to mechanisms such as oxidative stress, inflammation, microbiota dysbiosis, and the activity of plastic-associated endocrine disrupting chemicals. Importantly, some nanoplastics can penetrate biological barriers such as the blood-brain and placental barriers, creating concerns among vulnerable populations. Current regulatory measures for nanoplastics are insufficient, with the majority of laws focusing on microplastic and plastic waste management.

INTRODUCTION

Synthetic materials called plastics are usually composed of organic polymers and other chemical additives, such as phthalates, bisphenols, and flame retardants, which give them special qualities.^[1]Plastics are employed in many commercial applications due to their hydrophobicity, low cost, ease of production, and adaptability. Although the number of plastics produced is growing annually, recycling, repurposing, and reuse methods have not kept pace, especially in some developing nations.^{[2][3]} An estimated 6.3 billion tons of plastic garbage were

produced globally between the 1950s and 2015. That amount will rise to 26 billion tons by 2050.^{[4][5]} if this trend keeps up. But only 21–26% of the plastic garbage was properly burned and recycled. The remainder is burned in open pits or dumped into the environment, which pollutes the soil, water, and air with plastic.^{[6][7]} Large plastic particles can be broken down into smaller pieces of plastic garbage once they have entered the environment through interactions with other environmental elements.^{[8][9][10]} Another significant direct cause of plastic pollution in the environment is the

widespread manufacturing of microscopic plastic particles and their inclusion to consumer goods like personal care items that are thrown away after use.^{[11][12][13]} Plastic particles can be classified as either microplastics (MPs) or nanoplastics (NPs) based on their diameter; MPs are smaller than 5 mm, while NPs range in diameter from 1 to 100 or 1000 nm was illustrated in **Figure 1** ^{[14][15][16][17][18][19]}

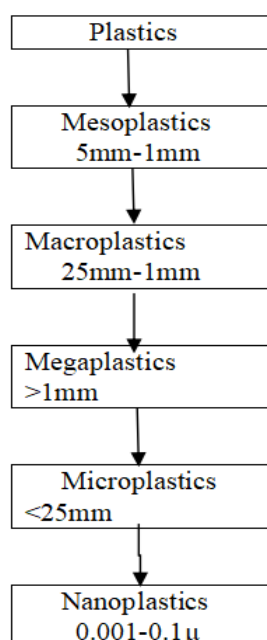


Fig (1): Conversion of plastic to nanoplastic

SOURCES OF NANOPLASTICS

Sources of nanoplastics may include main and secondary sources:

Intentionally produced at the nanoscale, primary nanoplastics find usage in medicinal, industrial, and agricultural applications, including personal care products, nano medicine, nano imaging, and nano sensors. In the process of making polymers, they can also be produced.^{[20][21]} Secondary nanoplastics are produced when bigger plastic trash (macro- and micro-

plastics) breaks down and fragments as a result of environmental physical, chemical, and biological processes.^{[20][21][22][23]} This disintegration may transpire due to:

- Mechanical Abrasion, such as that caused by road tyre wear or wastewater from laundry
- Photo Degradation, or exposure to sunshine
- Weathering of Chemicals and Biological life
- Key Environmental Sources

Tire wear: Environmental nanoplastic loads are greatly increased by the friction from tires, which releases particles in the nano- and microscale range.

Wastewater from washing: Synthetic fibres from clothing that are shed during washing can find their way into wastewater streams and further break down into nanoplastics.

Materials in touch with food: Plastics used for food storage and packaging have the potential to leak micro- and nanoplastics into food, which humans may consume

Marine litter: Over time, large pieces of plastic garbage in rivers and oceans break up to become nanoplastics, which are then widely dispersed across marine environments.

Atmospheric deposition: The detection of nanoplastics in air samples suggests that atmospheric transport is a major source of environmental pollution.^{[20]-[24]}

TRANSPORT OF NANOPLASTIC

Transport of nanoplastic through soil:

The movement of nanoplastics through soil is directly demonstrated by experimentation in a highly referenced study by Heinze et al. (2021) which focusses on the function of earthworm bioturbation. Palladium-doped polystyrene

nanoplastics (256 nm in diameter) were tracked in the study using deep-burrowing earthworms (*Lumbricus terrestris*) in soil microcosms. Nanoplastics were shown to exhibit significant vertical transport, with particles travelling from the top 2 cm to the lowest sampling layer (30 cm) in less than a week. Earthworms may burrow more than 100 cm in the wild, indicating that much deeper conveyance may be feasible in the environment.

Mechanism: Earthworm consumption and subsurface excretion served as the main transport mechanism, which led to the buildup of nanoplastic in the drilosphere (burrow walls). Compared to the surrounding soil matrix, the concentrations of nanoplastics in the drilosphere were orders of magnitude greater.

According to recent assessments, nanoplastics can move through soils both horizontally and vertically, depending on the nature of the particles, the soil, and biological inter^{[25] [26]}

Transport Of nanoplastic through water:

Recent studies and review papers emphasise that nanoplastics (NPs) are new pollutants that can enter the human body from aquatic environments mainly through ingestion, inhalation, and, to a lesser degree, skin contact.

The most important way that humans are exposed to nanoplastics is through ingestion. Drinking water (including tap and bottled water), shellfish, table salt, and other items tainted by NPs either directly from water sources or through the food chain are all affected. Consuming seafood and drinking water from plastic pipes are two significant causes.

Nanoplastics have the ability to penetrate the gastrointestinal tract, enter the bloodstream, and build up in different organs after being consumed. Because of their small size (less than 100 nm), some

NPs can pass through biological barriers like the placenta and blood–brain barrier, which raises worries regarding possible effects on delicate tissues.^{[27]–[31]}

of the gut bacteria to absorb and retain energy is intimately related to these effects.^[52] Numerous processes impact the liver, such as oxidative stress, mitochondrial malfunction, fibrotic and inflammatory pathway activation, and hepatocyte uptake. Bacterial compounds such as LPS produce oxidative stress, which harms cells and encourages liver disease. Fibrosis, inflammation, and mitochondrial dysfunction are also brought on.

Transport Of nanoplastic through air:

Atmospheric Presence and Sources: Textile fibres, urban dust, and wave-mediated ocean-to-air transfer are some of the sources of the ubiquitous presence of nanoplastics in the atmosphere. -bursting and -breaking procedures.

NPs can be aerosolized by these processes, which enables them to enter and remain in the atmosphere. Because of their small size, they have a long atmospheric lifetime and can travel great distances, even across continents and oceans.

Transport Mechanisms: NPs can stay suspended in the atmosphere for long periods of time due to their small size (<1 μm), which makes it easier for them to spread over large geographic areas.^[32] Compared to bigger microplastics, NPs have the ability to deposit deeper into the respiratory tract, reaching the alveoli and possibly piercing the blood–brain barrier or the circulatory system.^{[30] [32]}

IMPACTS OF NANOPLASTIC ON HUMAN BODY

1. Respiratory System

Inhalation of airborne nanoplastics from dust, clothing, and industrial pollutants is the respiratory system's entry route.^[36] Chronic respiratory conditions like COPD and asthma can result from tissue damage brought on by the lungs and organs overproduction of reactive oxygen species (ROS). The main reason is oxidative stress, which is the equilibrium between ROS generation and antioxidant defenses. Lung cancer, COPD, and asthma are among the respiratory diseases that are associated with oxidative stress and persistent inflammation. Cigarette smoke is one example of a pollutant that damages and promotes healing by causing tissue remodeling, airflow restriction, and inflammation.[a-f] Apoptosis and necrosis, two forms of cell death brought on by pollutants, nanoparticles, or viruses, as well as the production of reactive oxygen species (ROS), which causes oxidative stress and cell damage, are the mechanisms behind the condition. In reaction to ROS and cellular damage, inflammatory cytokines including IL-6 and IL-8 are increased, which encourages tissue destruction and remodeling. Elevated cytokine release and ROS formation can be triggered by alveolar cell uptake in the lungs.^[37-45]

2. Digestive (Gastrointestinal) System

Ingestion through tainted food, water, or drinks is the entry route into the digestive (gastrointestinal) system.^{[46][47]} An imbalance between good and harmful bacteria is known as dysbiosis, and it can result in neurological, immunological-mediated, metabolic, and inflammatory disorders. Additionally, it may cause the intestinal barrier to break down, letting dangerous substances enter the blood. Due to changes in bile acid balances and microbial metabolites, changes in gut microbiota can also result in metabolic abnormalities such obesity, type 2

diabetes, and cardiovascular illnesses.^{[48][49]} Gut dysbiosis leads to oxidative stress, apoptosis, endocytosis, and bloodstream translocation. Excessive reactive oxygen species (ROS) cause oxidative damage, affecting lipids, proteins, and DNA. Elevated ROS and inflammatory mediators can induce programmed cell death, jeopardizing the gut barrier and accelerating disease progression. Inflammation and oxidative stress can also interfere with cellular functions, leading to systemic inflammation and metabolic disorders.^{[50][51]}

3. Entering the Liver (Hepatic System)

Secondary accumulation through systemic circulation following ingesting or inhalation. Energy imbalance brought on by gut microbial dysbiosis can result in metabolic syndrome, obesity, and elevated caloric availability. Liver fibrosis, a major contributing factor to chronic liver illnesses, can also result from it. Additionally, dysbiosis impacts metabolism, resulting in metabolic diseases such as NAFLD and Type 2 diabetes. Additionally, it causes hepatic inflammation, which leads to the development and advancement of NASH and NAFLD. The capacity. These chemicals are taken up by hepatocytes, which causes liver damage and cellular stress.^[53]

4. Renal (Kidney) System

Secondary accumulation through Systemic circulation following absorption in the lungs or gut.^[54] Nephrotoxicity and inflammation in the kidneys can be brought on by gut dysbiosis and exposure to nephrotoxic chemicals. Indoxyl sulfate and p-cresyl sulfate are two examples of toxins that can exacerbate kidney impairment and are brought on by drugs or chemicals. Disturbances in lipid and amino acid metabolism, metabolic waste

products, and impaired energy metabolism can result from alterations in metabolism brought on by intestinal dysbiosis. Morphological alterations including glomerulosclerosis and tubular atrophy may also transpire.^[55] Through inflammation, oxidative damage, apoptosis, and buildup in renal tissue, nephrotoxic substances and dysbiosis can cause kidney injury. When reactive oxygen species (ROS) levels are high, oxidative damage takes place, which damages and malfunctions kidney cells. Apoptosis causes cell death, which results in the loss of functioning renal tissue. Fibrosis is encouraged and renal tissue is further damaged by inflammatory responses like TNF- α and IL-6.^[56]

5. Nervous System

After systemic absorption, the nervous system enters by translocation across the blood–brain barrier.^[57] Reduced neurotransmission, synaptic dysfunction, and neuronal cell death are all consequences of neurotoxicity, which is brought on by exposure to hazardous chemicals. Parkinson's and Alzheimer's disease are examples of neurodegenerative diseases caused by neuroinflammation, which is activated by toxins, infections, or gut microbiota. Executive function, memory, and attention may all be impacted by cognitive impairment brought on by neurotoxicity and inflammation.^[58] The processes that can cause neurodegeneration and neuronal death include oxidative stress, inflammation, and DNA damage. Glial cell activation brought on by inflammation results in chronic neurodegenerative diseases, whereas oxidative stress promotes lipid peroxidation, protein oxidation, and cellular malfunction. Endocytosis is also impacted, which is important for receptor trafficking and neuronal maintenance. Neuronal

dysfunction and neurodegeneration result from DNA damage, such as nucleotide alterations and double-strand breaks, which interfere with transcription and signal transmission.^[59]

6. Endocrine System

Systemic circulation, inhalation, and ingestion are the entry points.^[60] Hormonal abnormalities and endocrine disorders include metabolic and reproductive dysfunctions, diabetes, thyroid problems, PCOS, and infertility can result from dysbiosis, an aberration of the gut microbiota that can drastically change hormone synthesis, metabolism, and signaling pathways. Endocrine-disrupting chemicals (EDCs), such as phthalates and bisphenols, can interfere with hormone signaling and receptors, leading to changes in growth, metabolism, reproduction, and development. These substances can also leach into consumer goods and plastics, contaminating food, water, and the environment, and increasing the risk of developmental defects, metabolic diseases, and reproductive problems.^{[61][62]}

7. Reproductive System

Systemic dispersion, maybe transplacental, is the entry route.^[63] Exposure to endocrine-disrupting chemicals (EDCs) can lead to potential infertility and subfertility in both males and females. EDCs disrupt hormone synthesis, secretion, and receptor function, leading to developmental abnormalities, decreased sperm quality, and illnesses like PCOS, endometriosis, and early menopause. They also disrupt hormone levels, causing irregular menstrual cycles, decreased ovarian reserve, impaired follicle development, and altered reproductive organ development. These impacts can occur at any stage of life.^[64] EDCs, such as phthalates and bisphenols, can cause oxidative stress, disrupt reproductive signaling, and cause endocrine disruption.

Oxidative stress damages testicular and ovarian cells, DNA, and proteins, affecting gametes, folliculogenesis, spermatogenesis, and overall reproductive potential. EDCs can also bind to hormone receptors, causing poor reproductive function and abnormal hormone levels, leading to developmental defects, irregular menstruation, and infertility.^[65]

8. Cardiovascular System

Systemic circulation after intestinal or pulmonary absorption is the entry route. Atherosclerosis, hypertension, and endothelial dysfunction are all conditions that can lead to heart attacks and strokes. Atherosclerosis is caused by plaque accumulation in arteries, while hypertension is caused by a balance of vasoactive molecules caused by EDCs and chronic inflammation. Endothelial dysfunction, characterized by blood vessels' inability to dilate and preserve vascular homeostasis, is an early indicator of cardiovascular disease. These conditions also increase the risk of thrombosis, blood clot formation.^[66] Prolonged exposure to environmental contaminants and endocrine disruptors can result in chronic low-grade inflammation of the cardiovascular system. Vascular dysfunction, immune cell recruitment, and atherosclerotic plaque formation are all exacerbated by this inflammation. When antioxidant defenses and reactive oxygen species are out of balance, oxidative stress takes place, which can result in endothelial dysfunction, hypertension, and atherosclerosis. Poor blood flow, hypertension, and vascular stiffness can result from direct interactions with vascular cells.^[67]

9. Hematopoietic (Blood) System

Systemic absorption through the lungs or gut is the entry route. EDCs have the ability to directly affect immunological

and blood cells, causing modifications in lymphocyte differentiation, natural killer cell activity, blood cell numbers, and pro-inflammatory activity. Both men and women may experience negative effects from these alterations, which could affect immunological and blood health. Additionally, EDCs may be genomically harmful, resulting in mutations, chromosomal abnormalities, and hematological malignancies.^[68] EDCs can directly impact blood and immune cells, leading to changes in blood cell counts, natural killer cell function, pro-inflammatory activity, and lymphocyte differentiation. These changes may impair blood health and immunological function, with potential consequences for men and women. EDCs can also cause potential genotoxicity, leading to chromosomal abnormalities, mutations, and hematopoietic cancers was illustrated in **Figure 2.**^[69]

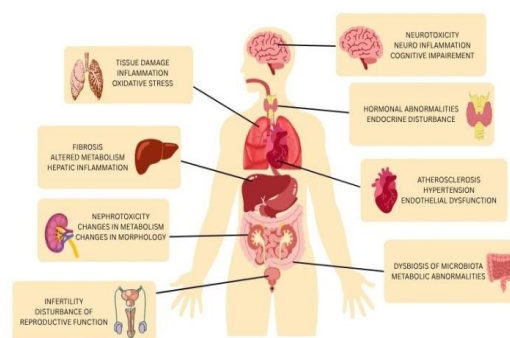


Fig (2): impacts of nanoplastic on human body

DISCUSSION

Nanoplastics are derived via the breakdown of bigger plastics, known as secondary sources, as well as direct industrial manufacturing, known as primaries. Tire wear, textile fibers generated during laundry, food packaging components, and environmental detritus all contribute significantly to their presence. These particles are widely disseminated in

soil, water, and air, resulting in long-term human exposure through the consumption of contaminated food and water, inhalation of airborne dust and fibers, and, less commonly, skin contact. Once inside the body, nanoplastics can penetrate biological barriers and collect in numerous organs, causing a variety of health issues. These include respiratory issues like oxidative stress, inflammation, and diseases like COPD and asthma; digestive problems like gut microbiota disruption, compromised gut barriers, and systemic inflammation; and liver and kidney inflammation, metabolic disturbances, and tissue damage. Furthermore, nanoplastics endanger the nervous system by causing neurotoxicity and cognitive impairments, disrupting endocrine functions that affect hormonal balance and fertility, and contributing to cardiovascular and immune system disorders such as hypertension, immune dysfunction, and blood diseases. Although regulatory measures are emerging, they are still limited and mostly concerned with lowering plastic manufacturing, improving recycling operations, and creating safety standards for plastics that come into contact with food. Overall, nanoplastics are a developing public health concern due to their persistent presence in the environment and the complicated, multi-organ effects they have on humans.

CONCLUSION

Plastic particles smaller than 1000 nanometres, or nanoplastics, have become a common and sneaky environmental contaminant that has serious health effects on people. Because of their tenacity and small size, they can slip through biological barriers that keep out larger particles and enter soil, water, and air. Airborne particles, contaminated food and drink, and, to a lesser extent, skin contact are the main ways that humans are exposed to

nanoplastics. As soon as nanoplastics reach the body, they can go through the digestive system, enter the bloodstream, and build up in important organs like the kidneys, liver, and even the brain by passing through the placental and blood-brain barriers. According to recent studies, exposure to nanoplastics poses a number of health hazards. Among these are gastrointestinal and respiratory issues, liver and kidney damage, neurotoxicity, endocrine disturbance, and problems with the reproductive system. The underlying causes include gut microbiota dysbiosis, chronic inflammation, oxidative stress, and the impact of endocrine-disrupting chemicals (EDCs), which are frequently linked to plastics. These impacts are especially concerning for those that are already at risk, such as pregnant women, newborns, and people with underlying medical issues. Regulatory frameworks are still in their infancy, with the majority of current laws concentrating on managing plastic trash in general and bigger microplastics rather than the particular difficulties presented by nanoplastics. Because nanoplastics are persistent in the environment and can be systemically hazardous, there is an urgent need for focused research, better detection techniques, and all-encompassing regulatory initiatives to reduce exposure and safeguard human health. In conclusion, environmental health is seriously threatened by nanoplastics, which are a growing concern. To tackle this issue, international collaboration, scientific progress, and the creation of strong regulations to restrict nanoplastic contamination and its effects on human health are all necessary.

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