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The Impact of Microplastic Exposure on Neurological Disorders- Implications for Psychiatric Health

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Abstract

Plastics have revolutionized modern society due to their durability, affordability, and versatility, leading to a surge in global production now exceeding 400 million tons annually and it is expected to be 1 billion tons within the next three decades. Environmental factors like sun exposure and oxidation contribute to the formation of microplastics (MPs), particles smaller than 5 mm, which may pose potential health risks, particularly neurological and psychiatric disorders, such as Alzheimer's (AD), Parkinson's (PD), and Autism Spectrum Disorder (ASD), affecting a substantial portion of the global population. MPs can enter the human body through ingestion, inhalation, and dermal contact, with ingestion being the major route. MPs have been found in food items like seafood, bottled water, and table salt, leading to significant annual intake by humans. Inhalation of MPs from the air is another critical exposure route, especially in occupational settings. Although dermal contact is less significant, nanoplastics could potentially penetrate the skin barrier, raising health concerns. MPs in the body can translocate to distant tissues, exacerbating conditions during inflammation. Studies have shown MPs reaching organs like the liver, spleen, and brain, causing oxidative stress, inflammation, and potential neurodegenerative effects. This paper underscores the urgent need for further research to understand the impact of MPs on neurological health and to address this growing public health issue.

Keywords: Microplastic; Neurological Disorders; Brain Health; Depression

Abbreviations

MPs: Microplastics; AD: Alzheimer's; PD: Parkinson's; ASD: Autism Spectrum Disorder; PS: Polystyrene; GFAP: Glial Fibrillary Acidic Protein; EDCs: Endocrine-Disrupting Chemicals; MPs: Microplastics.

Introduction

Plastics, which are durable, low-cost, and rapidly produced Anelia M, et al. [1] have contributed to some of the greatest recent advancements in society. These breakthroughs, in combination with many other daily uses for plastics, have led to an almost exponential increase in global plastic production over the past century that has now surpassed 400 million tons per year, with a projected increase to over 1 billion tons within the next ~30 years (OECD). This booming plastic production, however, has also led to a significant pollution problem as up to ~70% of the world's plastic ends up in landfills or is mismanaged in the environment (OECD).

In addition these plastics being exposed to other environmental factors, esspecially UV radiation (sunlight) and oxidation, have been shown to result in the formation of microplastics (MPs) [2]. MPs as plastic particles less than 5 mm in diameter, being also purposely produced for use in paints, detergents, and personal care products, such as toothpaste, sunscreen, and cosmetics [3] can have adverse health effects, including neurological disorders including Alzheimer's (AD) and Parkinson's (PD), as well as Autism Spectrum Disorder (ASD); followed by increased risk of psychiatric symptoms, including depression, anxiety, and other cognitive impairments.

This is of particular importance, as those neurological and psychiatric disorders represent a substantial and still growing burden of disease worldwide, globally, affecting up to 3.40 billion cases in 2021, and making them the leading cause of health loss worldwide, affecting over 40% of the global population. This includes neurodevelopmental disorders, neurodegenerative diseases, and neurological consequences of other conditions [4].

Given an urgent need for greater prioritization and resources to tackle this critical public health issue, along with the booming environmental issue of MPs production, the further research efforts contributing to better understanding of the impact of MPs exposure on the incidence of neurological disorders and overall mental health and well-being are crucial. Therefore, the main aim of this paper is to provide the latest evidence on the relationship between microplastic exposure and risk of specific neurological and mental conditions.

Routes of Microplastic Exposure

MPs can enter the human body through various routes, including ingestion, inhalation, and even absorption through the skin including dermal contact of these particles, contained in products, textiles or in the dust [2].

Ingestion and Diet Sources of MPs

Ingestion is considered the major route of MPs in humans, accounting for the estimated intake ranging between 39,000 and 52,000 MPs per person a year. Interestingly, MPs have been reported in certain foods items, including mussels, commercial fish, table salt, sugar and bottled water, so their ingestion is likely. The ingestion of MPs could be adsorbed in the intestine by cells, covering an intestinal tissue, known as Peyer's patches, depending also on adherence to the gastrointestinal mucus, whereas insoluble particles, such as polystyrene (PS) latex particles may penetrate the intestinal mucus through the increase in solubility due to the adsorption of intestinal contents. Human exposure through ingestion is very likely since our food and environment are contaminated with microplastics. However, the risk of ingesting microplastics is not known since little research has been conducted on estimating the overall human exposure and its effects [2].

Inhalation

Inhalation of MPs through the air from the various sources, including synthetic textiles, material abrasion (e.g., car tires, buildings), and resuspension from surfaces is estimated at 26–130 MPs per prerson per day. MPs size and density affect their deposition in the respiratory system, with smaller and less dense particles penetrating deeper into the lungs. Once deposited, microplastics can be cleared by macrophages, translocate to the circulatory system, which in case of overload may cause chronic inflammation, due to their high oxidant activity. In particulary, occupational exposure to airborne microplastics in certain industries has been linked to respiratory symptoms and lung disease, and MPs fibers have been detected in human lung biopsies, including those from cancer patients, suggesting potential respiratory harm under high exposure or susceptibility conditions.

Dearmal Contact

Dermal contact with MPs is considered a less significant route of exposure compared to inhalation or ingestion. However, some studies suggest that nanoplastics (<100 nm) originated from the plastic monomers and additives, like endocrine disruptors bisphenol A and phthalates, present in everyday products may penetrate the skin barrier and negatively impact health. For example, exposure to polyester and polypropylene sutures may lead to low-grade inflammatory reactions, tissue degeneration, most likely resultant from the increased oxidative stress in human epithelial cells. Given the potential adverse effects and widespread exposure to microplastics from sources like dust, synthetic fibers, and cosmetic microbeads, further research is necessary to fully understand the implications of dermal exposure to these particles.

Health Impacts of MPs Exposure

To date, epidemiological studies have shown that people exposed to MPs through the consumption of water, seafood, and regular use of consumer products containing MP, such as clothes, toothpaste, salt, sugar, honey, beer, anything stored in plastic bottles, plastic wrap, or cans/cartons lined with plastic may account higher health risks [3]. The presence of MPs in the crucial organs, like liver lungs blood and even breastmilk appears to be the most dangerous, as MPs have been reported to induce oxidative stress upregulate pro-inflammatory cytokines, decrease cell viability and alter

energy metabolism amongst other negative outcomes [3]. MPs can act locally or translocate to distant tissues post-exposure, particularly during inflammation when the increased permeability of the intestinial barriers can aid penetration. Interestingly, aslo higher permebaility of mucosa developed in the result from poor nutrition and diets high in saturated fats and sugars, such as Western-style diets may also aid MPs accumulation in the body. Studies show that MPs can reach the liver and spleen can also cross the placental and brain barrier; as well as enter the systemic circulation where can cause inflammation, pulmonary hypertension, vascular occlusions, increased coagulability, and blood cell cytotoxicity. Interestingly, MPs found in the liver, kidney, and gut, have been linked with increased oxidative stress, energy balance disturbances, and neurotoxicity [2].

Neurological and Psychiatric Impacts of Microplastic Exposure

Emerging research suggests that exposure to microplastics (MPs) may have significant implications for neurological and psychiatric disorders, with accumulating evidence demonstrating that various forms of MPs can be implicated in the pathogenesis of mental and neurodegenerative conditions. This is primarily due to their potential to negatively impact the gut-brain axis and lead to neurological effects [5]. In particular, ingested MPs have been identified as crucial contributors to the increased risk of developing neurological and psychiatric disorders. MPs have the potential to cross the blood-brain barrier (BBB), accumulate in brain tissue, and consequently lead to neuroinflammation, oxidative stress, and disruption of normal brain function [3].

MPs-induced peripheral inflammation results in BBB disruption, facilitating the dispersion of microplastics into the brain and driving neurotoxicity and neurodegeneration. This disruption leads to functional changes, including neuroinflammation and α-synuclein protein pathology, which supports the role of MPs exposure in the pathogenesis of neurodegenerative diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD) [6]. For example, in AD, exposure to MPs has been shown to promote the formation of amyloid-beta plaques and tau protein tangles in the brain. Specifically, exposure to polystyrene (PS) microplastics in experimental settings has been shown to promote cognitive impairment in mice through the promotion of microglial pyroptosis and aggravation of neuroinflammation [7], thereby supporting the role of environmental factors in the progression of AD. Additionally, MPs penetrating the BBB have been shown to accumulate in brain tissue, correlating with decreased levels of glial fibrillary acidic protein (GFAP), an essential regulatory brain protein associated with the early stages of neurodegenerative diseases, including AD [3]. Moreover, exposure to bisphenols has been shown to trigger BBB dysfunction and memory problems in animal models [7]. This suggests that exposure to chemicals from plastics and microplastics may be a risk factor for developing Alzheimer's disease.

Similarly, in PD, exposure to MPs has been shown to interfere with the dopaminergic system, a critical mechanism underlying the development of PD and its associated motor symptoms. Experimental studies have shown that PS MPs can accumulate in the substantia nigra region, which is rich in dopaminergic neurons, leading to a reduction in dopamine levels and impaired motor function. This study also demonstrated that nanoplastics exacerbated the spread of α-synuclein, including the strong induction of α-synuclein inclusions in dopaminergic neurons in the substantia nigra. Additionally, MPs exposure was correlated with increased oxidative stress and neuroinflammation in the dopaminergic system, potentially resulting in higher risks of motor deficits, tremors, and other PD-like symptoms and dementias [8].

MPs can also be significant risk factors for mental health illnesses, as studies have linked MPs with increased levels of oxidative stress and inflammation in the brain, which can lead to the development of anxiety, depression, and other mood disorders. Experimental studies have shown that exposure to MPs, especially during critical developmental stages, can disrupt brain development and lead to increased anxiety, depression, and abnormal behaviors. For example, exposure to polystyrene particles (PS-Ps) significantly decreased the gene expression associated with development. Interestingly, the expression of the Gabra2 gene, implicated in the formation of synapses and the development of the central nervous system, was decreased in both embryonic and adult animal brains. This reduction was linked with signs of anxiety- and depression-like behavior, as well as abnormal behavior and social deficits among PS-Ps-treated mice [9]. Furthermore, PS-Ps were shown to activate NF-κB-mediated inflammation, resulting in the upregulation of pro-inflammatory cytokines such as TNFα and IL-1β, thereby leading to a pro-inflammatory response in microglia cells. Collectively, these findings highlight that PS-MPs induce anxiety in mice via the activation of the HRAS-derived PERK-NF-κB pathway in the brain [10]. Similar disturbance along with increased risks for mental health issues, including increased the risk of anxiety, sadness in children, whose monther were exposed to endocrine-disrupting chemicals (EDCs) like microplastics during pregnancy and breastfeeding. Epidemiological evidence have shown, that even low doses of phthalates and other chemicals found directly in plastic, during early development can have long-term effects and be a significant contributors for developing depression, anxiety, ADD, or psychotic symptoms in children, whose mothers accounted exposure to MPs at some point in life [11,12].

Overall, the body of evidence underscores the critical need for further research to fully elucidate the mechanisms by which MPs impact neurological health and to develop strategies to mitigate these risks. Addressing microplastic pollution is not only crucial for environmental health but also for protecting human neurological health from potential long-term adverse effects.

Conclusions

The presence of microplastics (MPs) in the environment and their infiltration into human systems through ingestion, inhalation, and dermal contact pose significant health risks. Emerging evidence highlights the potential of MPs to contribute to neurological and psychiatric disorders, including AD, PD, as well as anxiety and depression, through mechanisms involving oxidative stress, inflammation, and neurotoxicity. MPs' ability to translocate to distant tissues further exacerbates these risks, particularly during inflammatory states. The findings underscore the urgent need for comprehensive research to elucidate the full impact of MPs on human health, especially on neurological and mental well-being. Addressing this issue requires a concerted effort to mitigate environmental pollution, enhance public health policies, and prioritize research funding to better understand and manage the health implications of MP exposure. The critical nature of this research is pivotal in protecting global health in the face of escalating plastic production and pollution.

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