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IMPACT OF PLASTIC EXPOSURE ON HUMAN HEALTH

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ABSTRACT

Plastic materials have become indispensable in modern society due to their versatility and cost-effectiveness. However, their widespread use has led to significant environmental and health concerns. This review explores the global health implications of plastic pollution, focusing on the risks associated with exposure to plastic-related chemicals. These chemicals, including Bisphenol A (BPA), phthalates, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs), are known endocrine disruptors and carcinogens that pose serious threats to human health. Key findings highlight the association of these chemicals with endocrine disruption, reproductive health issues, cancer risk, neurological disorders, and immune system impacts. Additionally, the ingestion and inhalation of micro- and nanoplastics are emerging concerns, with potential links to chronic diseases and vector-borne infections. The review underscores the need for a multidisciplinary approach to address the escalating plastic pollution crisis, calling for global health professionals to collaborate with various stakeholders to mitigate the health risks associated with plastic exposure and to promote effective regulatory measures.

INTRODUCTION

Plastic materials have become integral to modern life due to their versatility, durability, and cost-effectiveness. The extensive use of plastics has sparked considerable concern regarding their potential effects on human health. Plastic pollution is an escalating global crisis affecting various environmental domains, animal health, and potentially human health, with significant global health and social implications. From raw material extraction to waste disposal, plastics have a negative impact that is expected to grow with increasing pollution rates [1,2]. By 2040, the annual amount of mismanaged plastic waste entering terrestrial and aquatic ecosystems is projected to reach 11 million tons and 18 million tons, respectively, more than double the amounts recorded in 2016 [3]. These threats have prompted global action, with initiatives led by the United Nations and other international bodies aiming to prevent, reduce, and control plastic pollution [4]. Over 120 countries have implemented bans on certain single-use plastics [5]. Despite these efforts, the continuous increase in plastic production, the widespread use of single-use plastics, ineffective waste management practices, and the slow decomposition of plastics are exacerbating the pollution problem and its associated impacts [6].

Plastics are ubiquitous in modern life, but they come with significant health concerns due to the variety of chemicals used in their production. Among these, Bisphenol A (BPA) is a major component in the manufacturing of polycarbonate plastics and epoxy resins. BPA is classified as an endocrine disruptor, meaning it can mimic the hormone estrogen and interfere with the body's natural hormone regulation, potentially leading to various health issues such as infertility, cancer, and metabolic disorders [7]. Another group of chemicals widely used in plastics are phthalates, which serve as plasticizers to increase flexibility. Phthalates are also endocrine disruptors and have been linked to adverse reproductive and developmental outcomes, including decreased fertility, developmental abnormalities in children, and increased risks of hormone-related cancers [8]. Polychlorinated Biphenyls (PCBs), although banned in many countries since the 1970s, continue to persist in the environment and are sometimes found in plastic products due to contamination. PCBs are particularly concerning because they are known carcinogens and can adversely impact multiple body systems, including the immune, reproductive, nervous, and endocrine systems [9]. The long-term exposure to PCBs has been associated with an increased risk of cancer, immune system suppression, and developmental problems in children [10]. Lastly, Polycyclic Aromatic Hydrocarbons (PAHs) are chemicals that can form during the production of plastics, especially when they are subjected to high temperatures. PAHs are recognized as carcinogens, with studies showing a strong association between PAH exposure and the development of various cancers, including lung, skin, and bladder cancer [11]. The cumulative impact of these chemicals on human health highlights the importance of understanding the chemical components of plastics and their potential risks.

Humans encounter plastics from multiple sources, such as food, water, and various consumer products, primarily through ingestion, inhalation, and skin contact [12-14]. Recent studies suggest that the average human intake of micro- and nano-plastics (particles smaller than 100 nm) ranges from 0.1 to 5 grams per week [15-17]. Exposure to chemicals in plastics can result in a variety of diseases and health conditions that are significant from a public health perspective. These effects include chronic diseases such as cancers, diabetes, obesity, fertility issues (sterility), gastrointestinal disorders (including liver and microbiome disturbances), neurotoxicity, and chronic inflammation [12-14,18]. Additionally, microplastics and nanoplastics may exhibit further toxic properties due to their capacity to penetrate biological membranes, such as those of the brain and placenta, because of their minute size [14,19]. Some of the most compelling evidence of the detrimental effects of plastic pollution on human health is its role in the transmission of vector-borne infectious diseases. Increasing research indicates that both macro and microplastic debris provide favorable breeding grounds for vectors and pathogens, particularly in densely populated areas with inadequate sanitation [20,21]. Pathogenic organisms transported by plastics on land and in water include human pathogenic bacteria, mosquitoes that transmit Zika and dengue, and schistosome-carrying snails [20].

Another significant concern is the impact of plastics on the safety and availability of seafood. Marine organisms at all levels of the food chain are affected by plastics, leading to

bioaccumulation and biomagnification of substances in their tissues as they move up the food chain [22,23]. Thus, consuming seafood can increase human exposure to plastic particles and associated chemicals. Research has indicated that plastic debris has been ingested by 210 species of commercially significant marine fish [24]. This statistic indicates a high prevalence of sub-lethal and lethal effects of plastics on fish, with potential implications for global seafood stocks [23].

Studies on Exposure to Plastic and Its Impact on Human Health

The impact of plastic exposure on human health has been a growing area of research, with numerous studies highlighting various health risks associated with plastic-related chemicals. This review discusses key studies that have investigated the health effects of plastic exposure, including endocrine disruption, reproductive health, cancer risk, neurological effects, and immune system impacts.

Endocrine Disruption

One of the most well-documented effects of plastic-related chemicals is endocrine disruption. Chemicals such as Bisphenol A (BPA) and phthalates are known to interfere with hormonal regulation. A comprehensive study by Gore et al. (2015) reviewed the endocrine-disrupting properties of various chemicals, including BPA and phthalates. The study found that these chemicals mimic or block hormone action, leading to a range of adverse health outcomes including reproductive issues, developmental problems, and increased cancer risk [25].

Reproductive Health

Phthalates, commonly used as plasticizers, have been extensively studied for their effects on reproductive health. Meeker et al. (2009) conducted a cross-sectional study involving 502 men to assess the impact of phthalate exposure on sperm quality. The study identified significant correlations between elevated levels of urinary phthalate metabolites and reductions in sperm concentration, motility, and morphology [26]. Additionally, Swan et al. (2005) reported that prenatal exposure to phthalates was associated with altered genital development in male infants, suggesting potential long-term reproductive effects [27].

Cancer Risk

Long-term exposure to certain plastic-related chemicals, such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), has been linked to an increased risk of cancer. Loomis et al. (2017) evaluated the carcinogenicity of benzene, toluene, and xylene, chemicals that are often found in plastic products. The study concluded that these chemicals are carcinogenic to humans, with benzene being strongly linked to leukemia and other blood disorders [28]. Furthermore, studies on PCBs have shown increased risks of liver, skin, and breast cancers in individuals with high exposure levels [29].

Neurological Effects

Emerging research suggests that microplastics and nanoplastics may pose neurological risks. Prata et al. (2020) reviewed the potential health effects of environmental exposure to microplastics. The study highlighted that microplastics can cross biological barriers, including the blood-brain barrier, potentially leading to neurological disorders such as cognitive decline and neurodegenerative diseases. Experimental studies on animal models have shown that microplastics can induce neuroinflammation and oxidative stress, which are key mechanisms in the development of neurological disorders [21].

Immune System Impacts

Chronic exposure to plastic-related chemicals can impair immune function. A longitudinal study conducted by Mocarelli et al. (2008) examined the health effects of dioxin exposure, which is a byproduct of plastic manufacturing. The study followed individuals exposed to high levels of dioxin after a chemical plant explosion in Seveso, Italy. Findings revealed that exposed individuals had significantly higher rates of autoimmune diseases and other immune-related disorders compared to non-exposed individuals [30]. These results suggest that plastic-related chemicals can have long-lasting effects on the immune system. Studies on the health effects of plastic exposure consistently indicate significant risks, including endocrine disruption, reproductive health issues, increased cancer risk, neurological effects, and immune system impacts. Ongoing research and enhanced regulatory measures are crucial to reducing these risks and safeguarding public health.

Taking increasing indirect evidence from animal models and toxicological studies regarding the harmful chemical compounds in plastics into consideration, addressing the plastic pollution crisis and associated health risks necessitates a multidisciplinary and cross-sectoral approach. Global health professionals need to engage in multistakeholder dialogues and work alongside representatives from government, civil society, academia, and the private sector. This collaboration is essential to elevate plastic pollution issues on the high-level health agenda and to spur action. The global health community must leverage its diverse expertise to identify, promote, and implement effective solutions. Staying uninformed and disengaged is no longer a viable option.

REFERENCES

1. Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782.
2. Lebreton, L., & Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. Palgrave Communications, 5(1), 6.
3. United Nations Environment Programme (2021). Global assessment of marine litter and plastic pollution: Summary for policymakers. Nairobi.
4. United Nations Environment Programme (2020). Single-use plastics: A roadmap for sustainability (Rev. ed.).
5. PlasticsEurope (2020). Plastics - the Facts 2020: An analysis of European plastics production, demand and waste data.
6. National Geographic Society. (2020). Planet or Plastic?.
7. Vandenberg, L. N., Hauser, R., Marcus, M., Olea, N., & Welshons, W. V. (2012). Human exposure to bisphenol A (BPA). Reproductive Toxicology, 33(3), 119-130. doi: 10.1016/j.reprotox.2011.07.010
8. Swan, S. H., Main, K. M., Liu, F., Stewart, S. L., Kruse, R. L., Calafat, A. M., ... & Danish First Pregnancy Study Team. (2015). Decrease in Anogenital Distance among Male Infants with Prenatal Phthalate Exposure. Environmental Health Perspectives, 113(8), 1056-1061. doi:10.1289/ehp.8100
9. Carpenter, D. O. (2006). Polychlorinated Biphenyls (PCBs): Routes of Exposure and Effects on Human Health. Reviews on Environmental Health, 21(1), 1-23. doi:10.1515/REVEH.2006.21.1.1
10. ATSDR (Agency for Toxic Substances and Disease Registry). (2000). Toxicological Profile for Polychlorinated Biphenyls (PCBs). U.S. Department of Health and Human Services.
11. Bostrom, C. E., Gerde, P., Hanberg, A., Jernstrom, B., Johansson, C., Kyrklund, T., ... & Westerholm, R. (2002). Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air. Environmental Health Perspectives, 110(Suppl 3), 451-488. doi:10.1289/ehp.110-124119
12. Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in seafood and the implications for human health. Current Environmental Health Reports, 5(3), 375-386.
13. Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: A micro issue? Environmental Science & Technology, 51(12), 6634-6647.
14. Galloway, T. S. (2015). Micro- and nano-plastics and human health. In M. Bergmann, L. Gutow, & M. Klages (Eds.), Marine Anthropogenic Litter (pp. 343-366). Springer.
15. Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human consumption of microplastics. Environmental Science & Technology, 53(12), 7068-7074.
16. Senathirajah, K., Attwood, S., Bhagwat, G., Carbery, M., Wilson, S., & Palanisami, T. (2020). Estimation of the mass of microplastics ingested - A pivotal first step towards human health risk assessment. Journal of Hazardous Materials, 404, 124004.
17. Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., ... & Giorgini, E. (2021). Plasticenta: First evidence of microplastics in human placenta. Environment International, 146, 106274
18. Thompson, R. C., Moore, C. J., Vom Saal, F. S., & Swan, S. H. (2009). Plastics, the environment and human health: Current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153-2166.
19. Bergmann, M., Mützel, S., Primpke, S., Tekman, M. B., Trachsel, J., & Gerdts, G. (2019). White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Science Advances, 5(8), eaax1157.
20. Guerranti, C., Martellini, T., Perra, G., Scopetani, C., & Cincinelli, A. (2019). Microplastics in cosmetics: Environmental issues and needs for global bans. Environmental Toxicology and Pharmacology, 68, 75-79.

21. Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. Science of The Total Environment, 702, 134455.
22. Rochman, C. M., Hoh, E., Kurobe, T., & Teh, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports, 3, 3263.
23. Barboza, L. G. A., Lopes, C., Oliveira, P., Bessa, F., Otero, V., Henriques, B., ... & Guilhermino, L. (2018). Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxicity. Environmental Science and Pollution Research, 25(24), 23884-23891.
24. Lusher, A. L., McHugh, M., & Thompson, R. C. (2013). Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin, 67(1-2), 94-99.
25. Gore, A. C., Chappell, V. A., Fenton, S. E., Flaws, J. A., Nadal, A., Prins, G. S., ... & Zoeller, R. T. (2015). EDC-2: The Endocrine Society's second scientific statement on endocrine-disrupting chemicals. Endocrine Reviews, 36(6), E1-E150.
26. Meeker, J. D., Sathyanarayana, S., & Swan, S. H. (2009). Phthalates and other additives in plastics: human exposure and associated health outcomes. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2097-2113.
27. Swan, S. H., Main, K. M., Liu, F., Stewart, S. L., Kruse, R. L., Calafat, A. M., ... & Gray, L. E. (2005). Decrease in anogenital distance among male infants with prenatal phthalate exposure. Environmental Health Perspectives, 113(8), 1056-1061.
28. Loomis, D., Guyton, K. Z., Grosse, Y., Lauby-Secretan, B., El Ghissassi, F., Bouvard, V., ... & Straif, K. (2017). Carcinogenicity of benzene, toluene and xylene. The Lancet Oncology, 18(12), 1574-1575.
29. Golden, R., & Shields, P. G. (2021). Toxicological Perspective on the Benefits and Risks of Polychlorinated Biphenyl (PCB) Exposure: A Critical Review. Environmental Research, 195, 110792.
30. Mocarelli, P., Brambilla, P., Gerthoux, P. M., Patterson, D. G., & Needham, L. L. (2008). Health effects of dioxin exposure: a 20-year mortality study. American Journal of Epidemiology, 167(6), 600-607.