



Plastic Pollution: Causes, Effects, and Solutions

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ABSTRACT

Overview: This comprehensive study examines the causes, effects, and potential solutions to plastic pollution. The study synthesizes current research findings and discusses key challenges and opportunities for addressing this urgent issue.

Contribution to the Body of Knowledge: Plastic pollution has become a global environmental crisis, with profound impacts on ecosystems, wildlife, and human health. Strategies for reducing plastic consumption, improving waste management systems, and promoting sustainable alternatives are explored. Additionally, the role of policy interventions, public awareness campaigns, and technological innovations in mitigating plastic pollution is discussed. By understanding the complexities of plastic pollution and implementing effective strategies, society can work towards a cleaner and healthier environment for future generations.

Methods: The study employed a mixed-methods approach, combining qualitative analysis of policy documents and literature reviews with quantitative assessments of historical, socio-economic and cultural factors. Data was collected from various sources, including government reports, academic publications, and international organizations. Data was obtained from respondents by means of interviews, questionnaires and project observation schedules. The sample consisted of two hundred and fifty respondents. Frequency, percentages, tables, graphs and pie-charts were used to analyze the quantitative and qualitative data obtained. Data was then analyzed manually in some cases and also, a combination of software MS Access and MS Excel.

Results: The study found that addressing plastic pollution requires concerted efforts from governments, industries, communities, and individuals to adopt sustainable practices and mitigate its adverse impacts on the environment and society.

Recommendation: addressing plastic pollution requires a multi-faceted approach involving collaboration between governments, businesses, communities, and individuals to enact meaningful change and protect the environment for future generations.

Keywords: Environmental Impacts, Marine Debris, Micro Plastics, Plastic Pollution, Sustainability, and Waste Management.

1. INTRODUCTION

Pollution refers to the introduction of contaminants into the natural environment that cause adverse changes. These contaminants can be in various forms such as chemicals, particles, or energy, and they can originate from natural sources or human activities. Pollution can affect air, water, and soil, as well as ecosystems, wildlife, and human health. Examples of pollution include air pollution (from vehicle emissions, industrial activities, etc.), water pollution (from sewage, industrial discharge, agricultural runoff, etc.), soil pollution (from pesticides, heavy metals, etc.), and noise pollution (from traffic, industrial machinery, etc.) (Upadhyaya, 2019). Chanda and Chitondo (2024) on the other hand defines waste management as the systematic process of collecting, transporting, processing, recycling, and disposing of waste materials in a manner that is environmentally friendly, socially responsible, and economically viable. The background and significance of waste management stem from various interconnected factors such as environmental protection as improper waste disposal can lead to pollution of land, water, and air.

Common sources of plastic pollution include improper disposal of plastic waste, littering, inadequate recycling infrastructure, and micro plastics from the breakdown of larger plastic items. Plastic pollution has far-reaching impacts, including entanglement and ingestion by marine animals, disruption of ecosystems, contamination of food and water sources, and even the release of harmful chemicals as plastics degrade. Addressing plastic pollution requires a combination of efforts, including reducing plastic consumption, improving waste management practices, promoting recycling and reuse, and developing alternative materials that are less harmful to the environment (Barrett et al, 2020).

Plastic pollution has emerged as one of the most pressing environmental challenges of the 21st century. With the widespread use of plastics in various industries and consumer products, the accumulation of plastic waste in the environment has reached alarming levels. From oceans and waterways to

terrestrial ecosystems, plastic pollution poses significant risks to biodiversity, ecosystem integrity, and human well-being (Bank and Hansson, 2019). This review provides a comprehensive analysis of the causes, effects, and potential solutions to plastic pollution, drawing upon a wide range of scientific literature and empirical studies. what are plastics and what is plastic pollution

Plastics are synthetic materials made from polymers, which are long chains of molecules. They are typically derived from petrochemicals, although there are also bioplastics made from renewable sources such as corn starch or cellulose. Plastics are incredibly versatile materials and are used in a wide range of applications due to their durability, flexibility, and low cost. They can be found in everything from food packaging and household items to automotive parts and electronics. Around 275 million tonnes of plastic waste is generated each year around the world and between 4.8 million and 12.7 million tonnes is discharged into the sea. Plastic pollution refers to the accumulation of plastic waste in the environment, particularly in oceans, rivers, lakes, and on land. Plastic pollution occurs when plastic products are improperly disposed of or not recycled. Due to their durability, plastics can persist in the environment for hundreds of years, causing significant harm to wildlife and ecosystems (Abbott and Sumaila, 2018).

The history of plastic pollution can be traced back to the widespread adoption of plastics in the mid-20th century. Here's a brief overview: Plastics were developed in the late 19th century, with the first synthetic polymer, Bakelite, invented by Leo Baekeland in 1907. Initially, plastics were celebrated for their versatility and durability, offering solutions to various manufacturing and consumer needs. Following World War II, there was a significant increase in plastic production due to advancements in technology and the availability of cheap petrochemicals. Plastics became ubiquitous in everyday life, replacing traditional materials like wood, metal, and glass in many applications. In the post-war era, there was a surge in the production of single-use plastics such as bottles, bags, and packaging (G20, 2021). These items offered convenience and affordability but also contributed to a culture of disposability. As plastic consumption grew, waste management infrastructure struggled to keep pace. In many parts of the world, plastic waste was disposed of in landfills or openly dumped, leading to environmental pollution.

In the 1960s and 1970s, researchers and environmentalists began to raise concerns about the accumulation of plastic waste in the environment. The first documented instance of plastic pollution in the ocean was reported in the 1970s, highlighting the impact of plastic debris on marine ecosystems. Throughout the late 20th and early 21st centuries, awareness of plastic pollution increased, driven by scientific research, media coverage, and grassroots activism. Organizations and governments began to recognize the need for action to address the issue. In recent years, there have been various initiatives aimed at reducing plastic pollution, including bans on single-use plastics, promotion of recycling and waste reduction, cleanup efforts, and development of alternative materials and packaging solutions (GDOT, 2020). Despite these efforts, plastic pollution remains a significant environmental challenge, with millions of tons of plastic entering the oceans each year and impacting ecosystems, wildlife, and human health. Addressing plastic pollution requires concerted action at the local, national, and global levels to reduce plastic consumption, improve waste management practices, and promote sustainable alternatives.

Plastic pollution poses a range of environmental and health risks. It can entangle and suffocate marine animals, be ingested by wildlife, and leach harmful chemicals into the environment. Additionally, micro plastics have been found in drinking water, seafood, and even in the air we breathe, raising concerns about potential impacts on human health (Farady, 2019). Plastic pollution is considered a global environmental crisis for several reasons. Plastic waste is ubiquitous, found in oceans, rivers, forests, and even remote areas. Its widespread presence highlights the extensive reach of human activities and the scale of the pollution problem. Plastics are extremely durable and can persist in the environment for hundreds to thousands of years. This persistence means that once plastic is introduced into the environment, it remains there for a long time, posing a continuous threat to ecosystems and wildlife. Marine animals, birds, and terrestrial wildlife often mistake plastic debris for food or become entangled in it, leading to injury, suffocation, and death. This disrupts ecosystems and can threaten entire species (EREF, 2016). Over time, larger plastic items degrade into smaller fragments known as micro plastics, which are less than 5mm in size. Micro plastics are easily ingested by a wide range of organisms, including plankton, fish, and birds, and can accumulate up the food chain, potentially reaching humans. Plastics can leach harmful chemicals into the environment, posing risks to both wildlife and human health. Additives used in plastics, such as bisphenol A (BPA) and phthalates, have been linked to various health issues, including reproductive problems and developmental disorders.

Plastic pollution imposes significant economic costs on communities and governments. These include the expenses associated with cleanup efforts, damage to industries such as tourism and fishing, and impacts on human health care systems. The production, transportation, and disposal of plastics contribute to greenhouse gas emissions, exacerbating climate change. Additionally, plastic pollution can interfere with the natural carbon cycle by disrupting ecosystems and altering the balance of carbon storage in soils and oceans. Plastic pollution diminishes the beauty of natural landscapes and iconic landmarks, affecting tourism and cultural heritage sites. It also reflects poorly on societal values and environmental stewardship (Bao et al, 2018). Addressing plastic pollution requires concerted efforts at local, national, and international levels, including reducing plastic production and consumption, improving waste management systems, promoting recycling and innovation in plastic alternatives, and raising awareness among consumers and policymakers.

1.1 Statement of the problem

Plastic pollution has emerged as a significant environmental challenge, posing threats to ecosystems, wildlife, and human health worldwide. Despite increased awareness and efforts to address this issue, plastic pollution continues to escalate due to the persistent use and improper disposal of plastics. However, addressing plastic pollution requires a comprehensive and collaborative approach involving stakeholders from government, industry, academia, and civil society (Barrett, 2020). Effective strategies should encompass reducing plastic production, improving waste management infrastructure, promoting sustainable alternatives, and fostering public awareness and behavior change. Additionally, international cooperation is crucial to develop and

implement policies and regulations that mitigate plastic pollution on a global scale, ensuring a cleaner and healthier environment for current and future generations.

1.2 Purpose of the study

The purpose of this study was to comprehensively assess the scope, scale, and impact of plastic pollution on the environment, ecosystems, wildlife, and human health. This involves quantifying the amount of plastic waste generated, its distribution in different environments (land, water, air), and its ecological and health consequences and further it was to generate knowledge, evidence, and insights that can support informed decision-making, drive effective action, and ultimately contribute to mitigating the environmental, ecological, and health impacts of plastic pollution.

1.3 Objectives of the Study

1. To quantify and characterize plastic pollution
2. To assess ecological and health impacts of plastic pollution
3. To develop and evaluate mitigation strategies on plastic pollution

1.4 Theoretical Framework

Several theories can help us understand the causes, effects, and solutions to plastic pollution. This study was guided by one prominent framework, the Systems Theory, the systems theory as a formalized concept has roots in multiple disciplines, but it is often credited to biologist Ludwig von Bertalanffy. He introduced the concept in the 1920s and further developed it in the 1930s and 1940s. However, it's important to note that the idea of systems and systemic thinking has been present in various forms throughout history across different cultures and disciplines. Bertalanffy's work helped to formalize and popularize the notion of a systems approach to understanding complex phenomena across multiple domains. The Systems Theory views plastic pollution as a complex system with interconnected parts (Farady, 2019). Systems Theory allows us to understand that plastic pollution is not caused by a single factor but rather by a combination of interconnected factors within the system. These include overconsumption of plastic products, inefficient waste management systems, lack of recycling infrastructure, industrial practices, and societal behaviors driven by convenience culture and marketing. Plastic pollution has multifaceted effects on the environment, ecosystems, human health, and economies. Systems Theory helps in understanding these effects as interconnected and often leading to feedback loops. For example, plastic waste in oceans harms marine life, disrupts ecosystems, and can eventually enter the food chain, affecting human health. Economic effects include costs associated with cleanup efforts, loss of tourism revenue due to polluted beaches, and impacts on fisheries and aquaculture. Systems Theory suggests that addressing plastic pollution requires a holistic approach that considers the entire system, including upstream solutions (reducing production and consumption of single-use plastics, promoting alternatives), midstream solutions (improving waste management, recycling infrastructure), and downstream solutions (cleanup efforts, policy interventions, public awareness campaigns). Solutions should aim to address the root causes of plastic pollution rather than just its symptoms.

Other theories that can complement the understanding of plastic pollution include: Ecological Systems Theory: This theory focuses on the interactions between individuals and their environment, emphasizing the importance of considering various levels of influence, such as individual, community, and societal factors, in addressing plastic pollution. Then, there is the Behavioral Theory as understanding human behavior is crucial in addressing plastic pollution, as many of the causes stem from human actions and consumption patterns. Behavioral theories can inform strategies for promoting pro-environmental behaviors, such as reducing plastic use, recycling, and supporting policies aimed at mitigating plastic pollution. Lastly is the Political Economy Theory (EREP, 2016). This theory examines the role of political and economic structures in shaping environmental issues like plastic pollution. It helps in understanding the power dynamics, interests, and incentives that influence policy-making, corporate behavior, and consumer choices related to plastics. By integrating insights from these theories, policymakers, businesses, and communities can develop more effective strategies for preventing and mitigating plastic pollution.

1.5 Significance of the Study

Understanding plastic pollution is critically important for several reasons. Plastic pollution poses a significant threat to ecosystems and biodiversity. It contaminates land, waterways, and oceans, harming wildlife through ingestion, entanglement, and habitat destruction. Understanding plastic pollution helps us grasp the extent of environmental degradation and the urgency of addressing it to protect ecosystems. Plastic pollution has implications for human health. Plastics can leach harmful chemicals into the environment, potentially entering the food chain and posing risks to human health through the consumption of contaminated seafood or water. Understanding these health risks is essential for safeguarding human well-being. Plastic pollution carries economic costs at various levels. Cleanup efforts, waste management, and environmental remediation incur significant expenses for governments, businesses, and communities. Plastic pollution also impacts industries such as tourism, fisheries, and agriculture, affecting livelihoods and economic development. Plastic pollution disproportionately affects vulnerable communities, including those living in coastal areas, low-income neighborhoods, and developing countries with inadequate waste management infrastructure. Understanding the social dimensions of plastic pollution highlights the importance of addressing environmental justice issues and ensuring equitable access to clean environments. Plastic pollution is a global issue that transcends national boundaries. Understanding its global interconnectedness emphasizes the need for international cooperation and collective action to mitigate its impacts effectively. This understanding fosters a sense of shared responsibility among nations, businesses, and individuals to address plastic

pollution through collaborative efforts. Plastic pollution is symptomatic of broader unsustainable consumption and production patterns. Understanding its root causes and environmental implications is crucial for transitioning toward more sustainable practices, including reducing plastic usage, promoting recycling and circular economy models, and innovating alternative materials. Plastic pollution has long-term consequences for future generations. By understanding the magnitude of the problem and its enduring effects on the environment, society, and economy, we can make informed decisions and take proactive measures to mitigate its impact and preserve a healthier planet for future generations. Hence, understanding plastic pollution is essential for addressing its multifaceted challenges and advancing environmental conservation, human health, social equity, economic prosperity, and global sustainability.

2.LITERATURE REVIEW

2.1 Causes of Plastic Pollution

The proliferation of plastic pollution is influenced by various interconnected factors. Here are some key factors. The mass production of plastic, particularly single-use plastics, contributes significantly to pollution. The ease of production and versatility of plastic have led to its pervasive use in various industries, exacerbating the pollution problem. Insufficient waste management systems, especially in many developing countries, result in improper disposal of plastic waste. Lack of recycling facilities, landfill space, and incineration capabilities means that a significant portion of plastic waste ends up in oceans, rivers, and natural environments (Munnoetal, 2021). Consumer behavior plays a crucial role in the proliferation of plastic pollution. Societal reliance on convenience-oriented products packaged in plastic, coupled with a throwaway culture, leads to excessive plastic consumption and disposal. Many people are unaware of the environmental impacts of plastic pollution and the importance of proper waste disposal. Education and awareness campaigns are essential to change consumer attitudes and promote responsible consumption and disposal practices.

Weak regulations or inadequate enforcement of existing regulations allow industries to continue producing excessive plastic without sufficient accountability for its disposal. Strengthening regulations on plastic production, use, and disposal can help mitigate plastic pollution. The globalization of supply chains often involves extensive packaging and transportation of goods using plastic materials. Addressing plastic pollution requires a coordinated effort across borders to regulate production and waste management practices. In some cases, viable alternatives to plastic may be limited or more expensive, leading industries and consumers to continue relying on plastic despite its environmental consequences (Wyer, 2021). Investing in research and development of sustainable alternatives can help reduce plastic consumption. Addressing plastic pollution requires a multifaceted approach that tackles these interconnected factors through policy interventions, public awareness campaigns, technological innovations, and collaborative efforts between governments, industries, and communities.

Also, the proliferation of plastic pollution can be attributed to several key factors related to waste disposal patterns, littering, and the increased use of plastic products: Improper disposal of plastic waste, such as throwing it into open dumps, landfills, or burning it openly, contributes significantly to plastic pollution. Inadequate waste collection and management systems exacerbate this problem, especially in regions with limited infrastructure and resources. Littering of plastic items, such as bottles, bags, and packaging materials, is a common practice in many urban and natural environments. Individuals discarding plastic items irresponsibly in public spaces, streets, beaches, and water bodies contribute to the accumulation of plastic pollution. The widespread adoption of plastic products in various industries and daily life has led to a surge in plastic consumption. Items like plastic bottles, bags, and packaging materials are convenient and cost-effective, driving their increased production and use (Erogunaiye, 2019). The prevalence of single-use plastics, such as disposable water bottles, straws, and food packaging, contributes significantly to plastic pollution. The convenience and affordability of these items have fostered a culture of disposability, encouraging excessive consumption and disposal.

Further, inadequate recycling infrastructure and low rates of plastic recycling contribute to the accumulation of plastic waste in the environment. Many plastic items are not designed for easy recycling, and recycling rates remain relatively low compared to overall plastic consumption. The packaging industry plays a significant role in the proliferation of plastic pollution. Excessive packaging, including overwrapping and use of non-recyclable materials, contributes to the generation of plastic waste (Daly, 2019). Moreover, the use of plastic for packaging purposes is often driven by cost-effectiveness and durability. Industries such as fast fashion and consumer goods rely heavily on plastic packaging and materials. The rise of disposable fashion and consumer goods packaged in plastic exacerbates plastic pollution, as these items are often used briefly and discarded. Nevertheless, addressing plastic pollution requires concerted efforts to address these factors through policies promoting waste reduction, improved waste management infrastructure, public awareness campaigns encouraging responsible disposal practices, and initiatives promoting the use of sustainable alternatives to plastic. Collaboration between governments, industries, communities, and individuals is essential to mitigate the impacts of plastic pollution on the environment.

2.2 Effects of Plastic Pollution

Plastic pollution has far-reaching consequences for ecosystems, wildlife, and human health. In marine environments, plastics pose a significant threat to marine life through entanglement, ingestion, and habitat degradation. Sea turtles, seabirds, marine mammals, and fish are particularly vulnerable to the harmful effects of plastic debris. Moreover, the fragmentation of larger plastic items into micro plastics has led to widespread contamination of aquatic ecosystems, with potential implications for food webs and ecosystem functioning (Bai and Givens, 2021). On land, plastic pollution contributes to soil degradation, visual pollution, and adverse impacts on terrestrial wildlife.

Plastic pollution has numerous detrimental effects on ecosystems, wildlife, and human health: On the Ecosystem Effects include habitat destruction since plastics can accumulate in natural habitats such as oceans, rivers, forests, and even urban areas, leading to the destruction of habitats for various species.

There is altered biogeochemical cycles as plastics can disrupt nutrient cycles by interfering with the decomposition process, affecting soil health and the balance of ecosystems. Micro plastic contamination comes in as plastic debris breaks down into smaller fragments called micro plastics, which can infiltrate soil and water, affecting the entire ecosystem, including microorganisms, plants, and animals (CCME, 2020). Wildlife effects include ingestion as many animals' mistake plastic debris for food, leading to ingestion. This can cause internal injuries, blockages in the digestive system, malnutrition, and even death. Entanglement comes in as animals such as marine mammals, birds, and fish can become entangled in plastic debris, leading to injuries, restricted movement, and death. Toxicity is another effect as plastics can absorb and concentrate toxic pollutants from the environment. When ingested by animals, these toxins can accumulate in their tissues and biomagnify up the food chain, posing health risks to predators.

Human Health Effects include direct ingestion where humans can inadvertently ingest micro plastics through contaminated food and water sources. The long-term health effects of this ingestion are not yet fully understood but could include inflammation, organ damage, and the accumulation of toxins in the body. The other effect on humans is chemical exposure as chemicals used in the production of plastics, such as bisphenol A (BPA) and phthalates, can leach out of plastic products and into the environment. These chemicals are known to interfere with hormone regulation and have been linked to various health issues including reproductive problems, developmental abnormalities, and certain cancers. Air pollution is another effect on humans: When plastic waste is burned, it releases harmful pollutants into the air, contributing to respiratory problems and other health issues in nearby populations (Abbott and Sumaila,2019). Hence, addressing plastic pollution requires concerted efforts at various levels, including policy interventions, waste management strategies, public awareness campaigns, and innovations in materials and recycling technologies.

Plastic pollution has significant consequences on marine environments, impacting ecosystems, wildlife, and the health of ocean habitats: Plastic pollution also has physical impact on marine life due to ingestion as marine animals often mistake plastic debris for food. This can lead to internal injuries, blockages in digestive systems, malnutrition, and ultimately death. Species affected include seabirds, turtles, fish, and marine mammals. On entanglement, larger plastic items like fishing nets, lines, and packaging materials pose a risk of entanglement to marine animals. This can cause injuries, impaired movement, suffocation, and drowning (Alimi et al, 2018). Chemical pollution is another effect by leaching of toxic chemicals since plastics can absorb and concentrate harmful pollutants from seawater, including persistent organic pollutants (POPs) and heavy metals. When ingested by marine organisms, these toxins can accumulate in their tissues, potentially harming their health and the health of animals higher up the food chain. There is also release of additives. Chemical additives used in the production of plastics, such as bisphenol A (BPA) and phthalates, can leach out of plastic debris into the marine environment, posing risks to marine life.

Plastic pollution causes ecological disruption bringing about habitat destruction since plastic debris can smother benthic habitats such as coral reefs, seagrass beds, and ocean floors, affecting the organisms that rely on these habitats for shelter, feeding, and reproduction. Also, they bring about altered food webs. Plastics can disrupt marine food webs by affecting the distribution and abundance of species. This disruption can have cascading effects throughout the ecosystem, impacting predator-prey relationships and biodiversity (Davies, 2018). The economic impact of plastic pollution are losses in fisheries and tourism as plastic pollution can damage marine ecosystems that support fisheries and tourism industries. Reduced fish stocks, beach closures due to pollution, and negative impacts on marine biodiversity can lead to economic losses for coastal communities. Plastic pollution transports invasive species bringing about rafting effect as floating plastic debris can act as "rafts" for invasive species, transporting them across oceans to new habitats where they can disrupt native ecosystems and outcompete local species. Hence, addressing plastic pollution in marine environments requires global cooperation and concerted efforts to reduce plastic waste, improve waste management infrastructure, promote sustainable alternatives to single-use plastics, and enhance public awareness of the importance of marine conservation (G20, 2021).

Micro plastics, which are small plastic particles typically less than 5 millimeters in size, pose a significant threat to aquatic ecosystems due to their widespread distribution and persistence. Here's how micro plastics contribute to contamination of aquatic systems: Many aquatic organisms, including zooplankton, filter feeders, and small fish, ingest micro plastics unintentionally while feeding. These particles can accumulate in their digestive tracts, leading to physical harm, reduced feeding efficiency, and interference with nutrient absorption. Micro plastics can bioaccumulate in the tissues of aquatic organisms as they move up the food chain. Predators that consume contaminated prey can accumulate higher concentrations of micro plastics in their bodies, increasing the risk of exposure to toxins associated with micro plastics (Hoffman and Hittinger,2017). Micro plastics have a high surface area to volume ratio, making them efficient at adsorbing and concentrating organic pollutants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals from the surrounding water. These pollutants can then be released into the tissues of organisms upon ingestion of micro plastics, potentially causing toxic effects. Micro plastics may also release chemical additives used in their manufacturing process, such as plasticizers, flame retardants, and UV stabilizers, into the aquatic environment. These additives can have harmful effects on aquatic organisms and ecosystem health.

Micro plastics can settle and accumulate in sediments, where they may persist for long periods of time. This can affect benthic organisms living in or on the seafloor, disrupting their feeding, burrowing, and reproduction behaviors. Micro plastics can serve as vectors for transporting pathogenic microorganisms in aquatic environments. Bacteria and other pathogens can attach to micro plastic surfaces, facilitating their dispersal and potentially increasing the risk of disease transmission among aquatic organisms (INTERPOL,2020). Micro plastics can alter trophic interactions within aquatic food webs by affecting the behavior, physiology, and reproductive success of organisms. This can have cascading effects on ecosystem structure and function. Exposure to micro plastics may disrupt important biological processes in aquatic organisms, such as growth, development, reproduction, and immune function, thereby affecting population dynamics and ecosystem stability. Therefore, addressing the contamination of aquatic systems by micro plastics requires comprehensive strategies to reduce plastic pollution at its source, improve waste management practices, enhance monitoring and research efforts, and promote sustainable alternatives to single-use plastics. Collaboration among governments, industries, researchers, and the public is essential to mitigate the impacts of micro plastics on aquatic ecosystems and safeguard aquatic biodiversity and human health (Kaza et al, 2018).

2.3 Solutions to Plastic Pollution

Addressing plastic pollution requires a multifaceted approach involving various strategies aimed at reducing plastic consumption, promoting reuse, and incentivizing eco-friendly alternatives. Some strategies include implementing bans and restrictions. Governments can enact laws to ban or restrict the production, sale, and use of single-use plastics, especially those that are non-recyclable or difficult to manage. This includes items like plastic bags, straws, and certain types of packaging. Promoting reusable alternatives by encouraging the use of reusable alternatives to single-use plastics. This can include promoting reusable shopping bags, water bottles, coffee cups, and food containers (Zimmerman et al. 2020). Campaigns and incentives can be launched to encourage individuals to adopt these alternatives. Education and awareness is another strategy which involves raising awareness about the environmental impacts of plastic pollution through educational campaigns. Inform the public about proper waste management practices, the importance of recycling, and the benefits of reducing plastic consumption. Extended Producer Responsibility (EPR) is a good strategy as well by implementing EPR policies that hold manufacturers responsible for the entire lifecycle of their products, including proper disposal and recycling (Henneberry, 2020). This encourages companies to design products with recyclability and sustainability in mind.

Incentivizing eco-friendly packaging is a strategy where government offers incentives or tax breaks for businesses that use eco-friendly packaging materials such as biodegradable plastics, compostable materials, or alternatives like paper or glass. Another strategy is that of investing in recycling infrastructure: Improve recycling infrastructure and facilities to make it easier and more efficient for people to recycle their plastic waste. This includes increasing the availability of recycling bins, improving sorting technologies, and investing in facilities that can handle different types of plastics. Encouraging innovation is a strategy in which governments support research and development into alternative materials that can replace plastics or biodegradable plastics that are less harmful to the environment. Encourage innovation in packaging design to minimize waste and environmental impact (Abt Association, 2019). Community clean-up initiatives is a strategy where government through relevant local authorities organize community clean-up events to remove plastic waste from beaches, rivers, and other natural environments. These events not only help to clean up existing pollution but also raise awareness about the issue. Another strategy is international cooperation where governments work together on a global scale to address plastic pollution. This can involve international agreements and partnerships to coordinate efforts, share best practices, and implement solutions across borders. Last but not the least is consumer behavior change by encourage consumers to make environmentally conscious choices by providing information about the environmental impact of different products and packaging. Encourage them to choose products with minimal packaging or packaging made from recycled materials (Allen, 2021). By implementing a combination of these strategies, it's possible to make significant progress in reducing plastic pollution and promoting a more sustainable future.

Addressing plastic pollution requires a comprehensive approach involving various stakeholders and strategies. Here are solutions across different domains: The first solution is policy interventions where governments should implement regulations banning or restricting the use of single-use plastics such as bags, straws, and utensils, enforce laws requiring manufacturers to take responsibility for the entire lifecycle of their products, including proper disposal and recycling, introduce schemes where consumers pay a deposit on plastic bottles and containers, which is refunded upon return, encouraging recycling, impose taxes or levies on plastic products to discourage their use and encourage alternatives and provide financial incentives or subsidies for businesses and consumers to switch to eco-friendly packaging and products (Allen et al., 2020). The second solution to plastic pollution is technological innovations where governments should invest in research and development of biodegradable plastics that break down harmlessly in the environment, develop enzymes capable of breaking down plastic waste into non-toxic byproducts, invest in innovative recycling technologies such as chemical recycling and pyrolysis to efficiently process plastic waste, explore and promote the use of alternative materials like plant-based plastics, paper, and compostable packaging and utilize blockchain technology to enhance transparency and traceability in the plastic supply chain, ensuring accountability and responsible waste management (Bao et al., 2018).

The third solution to plastic pollution is consumer behavioral change where governments should launch campaigns to educate consumers about the environmental impact of plastic pollution and encourage behavior change, encourage the adoption of reusable alternatives such as bags, bottles, and containers through incentives and awareness programs, organize challenges or initiatives encouraging individuals and communities to reduce their plastic consumption and waste generation, encourage consumers to choose products with minimal packaging or packaging made from recycled materials, and to support companies with sustainable practices, as well as employ behavioral economics principles to nudge consumers towards more environmentally friendly choices, such as default opt-ins for reusable options (Castellon, 2021). The fourth solution to plastic pollution is corporate responsibility and here, governments should encourage companies to adopt sustainable packaging designs that minimize waste and environmental impact, implement waste reduction strategies such as redesigning products to use less plastic, optimizing packaging sizes, and improving supply chain efficiency, engage corporations in product stewardship programs where they take responsibility for collecting and recycling their products, promote the adoption of certifications and standards for sustainable packaging and responsible waste management practices as well as encourage corporate investment in circular economy initiatives that promote resource efficiency and minimize waste generation (Carr, Liu and Tesoro, 2016). By integrating these solutions and engaging various stakeholders, we can effectively mitigate plastic pollution and move towards a more sustainable future.

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3. METHODOLOGY

3.1 Research design

The research design was descriptive survey with both qualitative and quantitative methods of data collection in order to attain the comprehensive results (Kumar,2011). Qualitative method was appropriate to this investigation as it produced detailed data from a small group of participants, while exploring feelings, impressions and judgments. On the other hand, quantitative method made the use of questionnaires, surveys and experiment to gather data that is revised and tabulated in numbers, which allows the data to be characterized by use of statistical analysis (Martyn, 2008).

3.2 Research Sites

The study was carried out in five institutions of Government Ministries (Local Government and Environment), Universities, Local Authorities, and Non-Governmental Organizations (NGO) offices from which respondents were also sampled.

3.3 Population, Sample and Sampling procedure

The population for the study was purposefully drawn from the Lusaka province of Zambia where all the respondents are found. Purposive sampling procedure was used to select the institutions (5) while the simple random sampling procedure was used to select the University lecturers (50); five from each institution, University students (50); five from each institution, Senior Civil Servants (50); five from each Ministry, Senior Officers in Local Authorities (50) ten from from each council from Lusaka Province, senior political party official (50) and NGO executive members (50); four from each organization (Bickel, 2007). The sample size comprised of 250 respondents. Also, the primary data was complimented by the secondary data which was derived from government policy documents, ministerial reports and relevant literature on language use. In the sampling of districts and institutions, the study adopted the stratified cluster random sampling technique. Sampling of the province was done on the basis of concentration of respondents and institutions were then done zone by zone. Universities and other institutions were clustered by zones. Two zones were purposively selected based on the basis of concentration of respondents. The sampling was done at three levels: Sampling zones, universities and other institutions- level 1, Sampling University lecturers and Civil servants in Ministries-level 2, Sampling Senior Officers at ECZ, District Officers, senior party officials and NGO Executive members-level 3.

3.4 Data Analysis

In this research, data was analyzed qualitatively as in-depth interviews, questionnaires and observation schedules were used as data collection instruments. Thematic approach was used, where data analysis started with the categorization of themes from the structured interviews, questionnaires (Khan ,2011). Charts and graphs were used to analyze data. The data gathered was analyzed according to the themes of the study and per the order of the research objectives. Data generated from the interview guide was analyzed manually and also, a combination of software MS Access, SPSS and MS Excel was used to analyze data. Analysis was mainly descriptive, that is, mean, median, mode, range, and standard deviation. Related statistics were applied where possible. Statistical testing took the form of Analysis of Variance (ANOVA), correlation and regression both simple and multiple, (Morales and McKenzie,2019).

3.5 Ethical Issues

The study avoided pressuring respondents to take part in the research. Alternatively, permission consents, assents were obtained from respondents involved in the research and the research topic was strategically selected to ensure that there was no harm whatsoever to the research respondents. In this research, the study was fully conscious of the need to abide by the ethical rule of respecting the privacy of individuals taking part in the research. In the same way, all the respondents of the research were to remain unidentified to the public as all their valuable views, opinions and perceptions were only known by the researchers for use only in the research and participant's identities will forever remain hidden. The study got permission from the Vice Chancellors to interview lecturers and students, from Permanent secretaries to interview senior civil servants in the Ministries of Local Government and Environment, District Council Mayors/Chairpersons to interview Local Government Officials and Executive officers to interview NGO members. The names of respondents would remain anonymous for the sake of confidentiality, Babble,2010). However, the identity of respondents was concealed in the article but for identification in the article, the fifty lecturers were allocated numbers 1 to 50, the fifty students were allocated ordinal numbers 1st to 50th, the fifty NGO members were allocated names of fifty Primary schools in Lusaka, the fifty Civil servants were allocated names of fifty secondary schools in Lusaka while the fifty Local Authority Officers in Districts were allocated names of ten famous roads in Lusaka and then Zones and institutions used pseudo names.

4. FINDINGS AND DISCUSSIONS

4.1 *Quantifying and Characterizing Plastic Pollution*

According to study results, conducting systematic surveys and assessments to quantify the amount and types of plastic pollution in various environments, including oceans, rivers, lakes, soils, and air aims at determining the sources, distribution patterns, and composition of plastic waste, including macro plastics and micro plastics. By understanding the magnitude and characteristics of plastic pollution, researchers can better assess its environmental and health impacts and develop targeted mitigation strategies. The study reviewed that conducting systematic surveys and assessments to quantify plastic pollution in various environments requires careful planning, methodology selection, data collection, and analysis. A generalized guide to conducting such assessments reviewed include defining objectives and scope by clearly defining the goals of the survey, what survey is trying to measure and what specific environments (oceans, rivers, lakes, soils, air) to be assessed and should determine the geographic scope and the timeframe of the study. Literature review will involve review existing literature and research on plastic pollution in the environments you're interested in and understanding the methodologies used in previous studies and their limitations (Acna-Ruz et al, 2018). Then should develop a sampling strategy by determining the sampling locations, selecting representative sites within the chosen environments, considering factors such as proximity to urban areas, industrial sites, and known pollution hotspots and deciding on the frequency and timing of sampling to capture variations. Select sampling methods by choosing appropriate sampling methods based on the environment for oceans: methods like trawling, surface sampling, or remote sensing, for rivers and lakes: use nets, grab samples, or sediment coring, for soils: employ soil coring or sampling at different depths, for air: utilize air sampling devices or passive collectors and ensure that sampling methods are standardized and replicable. On sample collection, should collect samples following the chosen methodology as well as ensure proper labeling, documentation, and preservation of samples to avoid contamination (Chamas et al, 2020).

Further, the study reviewed that laboratory analysis must be done and should analyze samples for plastic content using appropriate techniques such as spectroscopy, microscopy, or chemical extraction, quantify the types and amounts of plastics found and consider collaborating with specialized laboratories if necessary. Data analysis comes in and should collate and organize the data collected from the laboratory analysis, use statistical methods to analyze the data, including calculating averages, trends, and spatial distributions and consider using GIS (Geographic Information System) for spatial analysis (Cannon, 2020). In interpretation and reporting, researchers should interpret the results in the context of your objectives and existing literature, discuss findings, including any patterns observed, hotspots identified, or changes over time, consider the implications of the results for environmental management and policy and prepare a detailed report summarizing the methodology, results, and conclusions. On quality assurance and peer review, researchers should implement quality control measures throughout the study to ensure accuracy and reliability of results as well as consider peer review of the study design, methodology, and findings to enhance credibility. Dissemination and communication is the last aspect where researchers share the findings through scientific publications, conferences, and reports and communicate results to stakeholders, policymakers, and the general public to raise awareness and promote action against plastic pollution (Bank and Hansson, 2019). However, researchers should remember that plastic pollution assessment is a complex and interdisciplinary field, and collaboration with experts from various disciplines (e.g., environmental science, chemistry, engineering) can enhance the quality and reliability of your study.

4.2 *Ecological and Health Impacts of plastic pollution*

According to study results, evaluating the ecological and health impacts of plastic pollution on ecosystems, wildlife, and human population involves conducting ecological studies to assess the effects of plastic ingestion, entanglement, and habitat disruption on marine and terrestrial organisms. Additionally, it should investigate the potential health risks associated with the ingestion of plastic-contaminated food and water, including the transfer of toxic chemicals and pathogens. By identifying vulnerable species and ecosystems, as well as potential human health concerns, researchers can prioritize conservation efforts and public health interventions. valuating ecological and health impacts of plastic pollution on ecosystems, wildlife and human population. By statistics the evaluation of ecological and health impacts of plastic pollution was highest on human health at 40%, followed by ecological impacts at 35% and then wildlife impacts at 25% as illustrated in Figure 1 below

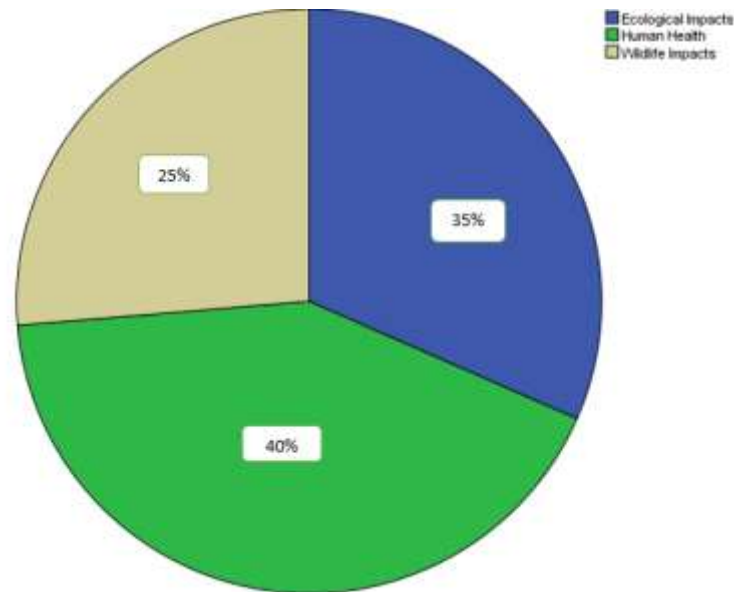


Figure1: Ecological and Health Impacts of Plastic Pollution

The study reviewed that plastic pollution poses significant ecological and health impacts on ecosystems, wildlife, and human populations. An evaluation of the human health impacts reviewed that humans can be exposed to plastic pollution through contaminated water and food sources, leading to ingestion of micro plastics and associated chemicals. The chemicals present in plastics, such as phthalates and BPA, have been linked to adverse health effects including endocrine disruption, reproductive issues, and increased risk of certain cancers. Plastics in the environment can act as vectors for pathogens, potentially spreading diseases to humans through contaminated surfaces or water sources and that plastic pollution can also have economic ramifications through impacts on industries like fishing, tourism, and healthcare due to increased cleanup costs and loss of revenue from affected ecosystems (Lebreton et al, 2017).

On ecological impacts, the study reviewed that plastic debris can accumulate in various ecosystems such as oceans, rivers, and forests, altering habitats and interfering with natural processes. Many marine and terrestrial species suffer from entanglement or ingestion of plastic, leading to injury, suffocation, and death. This can disrupt food webs and lead to population declines. Plastics can leach harmful chemicals such as phthalates and bisphenol A (BPA) into the environment, affecting the physiology and reproduction of organisms and also, plastics can interfere with nutrient cycling processes by blocking sunlight and oxygen exchange in aquatic ecosystems, affecting primary production and nutrient flow (GDOT, 2020).

As regards wildlife impacts, the study further reviewed that animals like seabirds, marine mammals, and turtles can become entangled in plastic debris, leading to injuries, amputations, or death, various marine species mistake plastics for food, leading to gastrointestinal blockages, malnutrition, and internal injuries. This can ultimately lead to population declines and that toxic chemicals released from plastics can bio accumulate in the tissues of animals, potentially leading to reproductive issues, developmental abnormalities, and immune system suppression (Adomat and Grischek, 2021).

4.3 Developing and Evaluating Mitigation Strategies

According to study results, developing, implementing, and evaluating mitigation strategies to reduce plastic pollution at its source and minimize its environmental impact includes researching and promoting sustainable alternatives to single-use plastics, improving waste management practices, enhancing recycling and circular economy initiatives, and advocating for policy changes and regulatory measures. Furthermore, it involves assessing the effectiveness, feasibility, and scalability of various mitigation approaches through pilot projects, case studies, and longitudinal studies. (Baldwin., Corsi and Mason, 2016) By identifying best practices and innovative solutions, researchers can inform policy-makers, businesses, and communities in their efforts to combat plastic pollution effectively. developing, implementing and evaluating mitigation strategies to reduce plastic pollution and its source and minimize environmental impact

The study reviewed that developing, implementing, and evaluating mitigation strategies to reduce plastic pollution and its sources requires a comprehensive approach involving multiple stakeholders and strategies across various levels. A structured plan involves research and assessment so as to understand the primary sources of plastic pollution in your target area, whether it's from industries, households, or improper waste management and evaluate the environmental impact of plastic pollution on ecosystems, wildlife, and human health. Gather data on the extent of the problem and its consequences. Policy development should follow and researchers should work with policymakers to enact regulations aimed at reducing plastic use, promoting recycling, and penalizing improper disposal, implement incentives for businesses and consumers to reduce plastic usage, such as taxes on single-use plastics or subsidies for eco-friendly alternatives and advocate for Extended Producer Responsibility (EPR) policies that hold manufacturers responsible for the entire lifecycle of their products, including proper disposal((Barrows et al,2018). Public awareness and education is another plan and government through other government and private entities should launch public awareness campaigns to educate individuals about the environmental

impacts of plastic pollution and the importance of reducing plastic usage, integrate environmental education into school curricula to instill sustainable habits from an early age and engage local communities through workshops, clean-up drives, and events to foster a sense of responsibility and ownership.

The other plan the study reviewed was innovation and technology which is cardinal in plastic pollution mitigation and government should invest in research and development of biodegradable or compostable materials as alternatives to traditional plastics, implement advanced waste management technologies such as recycling facilities, waste-to-energy plants, and plastic-to-fuel conversion systems as well as encourage the development and adoption of innovative products designed to minimize plastic usage, such as refillable containers or packaging-free options (Candela et al, 2021). Collaboration and partnerships is another good plan and government should foster collaborations between government agencies, NGOs, businesses, and academia to leverage resources and expertise, engage in international partnerships to address plastic pollution across borders, sharing best practices and coordinating efforts and work with supply chain partners to reduce plastic packaging, improve recyclability, and implement sustainable practices.

Further, the study reviewed monitoring and evaluation as a plan in plastic pollution mitigation in which government through local authorities should continuously collect data on plastic usage, waste generation, and pollution levels to monitor progress and identify areas for improvement, define key performance indicators (KPIs) to measure the effectiveness of mitigation strategies, such as reduction in plastic consumption or increase in recycling rates and as well establish mechanisms for stakeholders to provide feedback and suggestions for refining strategies based on real-world outcomes. There should be continuous improvement and this is where government should remain flexible and adaptable to changing circumstances, adjusting strategies based on new research findings, technological advancements, or feedback from stakeholders, scale up successful initiatives and replicate them in other regions or communities to maximize impact as well as develop long-term plans and commitments to ensure sustained efforts in combating plastic pollution and promoting environmental sustainability (Agamuthu et al, 2019). Also, by following this structured approach and continuously refining strategies based on evaluation and feedback, it is possible to effectively mitigate plastic pollution and minimize its environmental impact over time.

5. CONCLUSION

Plastics are destroying nature due to their harmful effect and plastic bags have become the main cause of land pollution today. The plastic bags entering into the water bodies are a major cause of water pollution and these are deteriorating our environment in every possible way. Plastic pollution is a complex and multifaceted issue with far-reaching ecological and health consequences. Addressing this challenge requires concerted efforts at individual, community, corporate, and governmental levels to reduce plastic consumption, improve waste management infrastructure, and promote sustainable alternatives to single-use plastics. Such actions are crucial to mitigate the detrimental impacts of plastic pollution on ecosystems, wildlife, and human population. Also, plastic pollution represents a complex and interconnected challenge that requires concerted action at the global, national, and local levels. By implementing a combination of regulatory measures, technological solutions, and behavioral changes, society can mitigate the impacts of plastic pollution and transition towards a more sustainable and circular economy. Collaboration among stakeholders, including governments, businesses, civil society organizations, and the scientific community, is essential for achieving meaningful progress in addressing this urgent environmental issue. Further, addressing plastic pollution requires concerted efforts from governments, industries, communities, and individuals to adopt sustainable practices and mitigate its adverse impacts on the environment and society.

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6. RECOMMENDATIONS

Plastic pollution is a significant environmental issue with far-reaching consequences. Addressing plastic pollution requires a multi-faceted approach involving collaboration between governments, businesses, communities, and individuals to enact meaningful change and protect the environment for future generations. Some recommendations on causes, effects, and solutions areas follows:

1. Causes:

- Single-use plastics: The proliferation of single-use plastics, such as bags, bottles, and packaging, contributes significantly to plastic pollution.
- Improper disposal: Inadequate waste management systems, littering, and improper disposal of plastics into water bodies exacerbate the problem.
- Micro plastics: Micro plastics, tiny plastic particles resulting from the breakdown of larger plastics, come from sources like microbeads in personal care products and synthetic clothing.

2. Effects:

- Environmental harm: Plastic pollution harms ecosystems, leading to habitat destruction, wildlife entanglement, and ingestion by marine and terrestrial animals.
- Human health risks: Plastic particles can enter the food chain, potentially exposing humans to harmful chemicals present in plastics.
- Economic impacts: Plastic pollution leads to economic losses in industries such as fishing, tourism, and coastal clean-up efforts.

3. Solutions:

- Reduce, Reuse, Recycle: Implementing the 3Rs principle—reduce plastic consumption, reuse items where possible, and recycle materials—can significantly mitigate plastic pollution.
- Policy interventions: Governments can enact policies such as plastic bags, taxes on single-use plastics, and incentives for sustainable packaging to regulate plastic use and encourage alternatives.
- Public awareness and education: Increasing awareness about the environmental impacts of plastic pollution through educational campaigns can foster behavioral change and promote responsible consumption habits.
- Innovation and technology: Investing in research and development of biodegradable plastics, alternative materials, and innovative recycling technologies can offer sustainable solutions to reduce plastic waste.
- Corporate responsibility: Encouraging businesses to adopt sustainable practices, such as using eco-friendly packaging and reducing plastic in their supply chains, can help mitigate plastic pollution.
- Community involvement: Engaging local communities in clean-up efforts, beach clean-ups, and river clean-ups can prevent plastic waste from entering water bodies and raise awareness about the issue.

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