World Journal of Pharmaceutical and Life Sciences
WJPLS
www.wjpls.org
SJIF Impact Factor: 7.409

EASIER TO USE, HARDER TO SAVE THE ENVIRONMENT: A REVIEW ON PLASTIC POLLUTION

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Article Received on 30/06/2024 **Article Revised on 20/07/2024** **Article Accepted on 10/08/2024**

ABSTRACT

Introduction: The environment is a vast and varied collection of many forms of biodiversity. A single breach in biodiversity can result in numerous changes ultimately causing environmental disruption. Maintaining the environment is crucial for sustaining the ecosystem's balance. An ecosystem's imbalance can be caused by a variety of factors, one of which being plastic waste. This paper discusses the negative effects of plastic on biodiversity, highlighting the numerous issues it poses to both humans and other animals on the globe. This overview also includes a discussion of some of the measures that the Indian government has implemented. Reviewing the paper's concept aims to bring attention to the drawbacks and direct exploitation of plastic. **Methods:** We searched in various research databases on PubMed, ResearchGate, Government portals and newspaper articles. the effects of microplastics and macroplastics on human health, landfills, and marine life are all explored in this narrative review synthesis. Furthermore, the policies and initiatives put in place by the Indian government to mitigate the impacts of plastic. **Result:** Out of the 430 million metric tons of plastic produced annually, two thirds are thrown away after just one use. Plastic has a significant impact on both human health and marine life. Reducing the impact of plastic on the environment and human health can be achieved through raising awareness of the problem, changing to a plastic-free lifestyle, and abiding by the law. **Conclusion:** It is imperative to protect the environment, human health, and heterogeneity from plastic pollution. There is an urgent need to reduce the harm that plastic is causing. To mitigate the effects of plastic on both the environment and human health, it is imperative to implement sustainable systems and solutions. To solve this situation, further study and action are desperately needed.

KEYWORDS: Plastics, Plastic pollution, Marine life, Health impacts, Landfills, Initiatives.

SEARCH CRITERIA

The review was prepared from findings after conducting a search using PubMed, Google scholar, ResearchGate, Government portals, Newspaper articles. The keyword used to search were “plastic pollution”, “plastics”, “Marine life”, “Human health”, “Landfills”, “Initiatives” with the Boolean operators of “AND”, “OR”. The last accession to the online databases was conducted in May 2024. For information to be included in this review, the manuscripts had to meet the following criteria: information related to plastics and its impact on the environment, marine species, human health and landfills and the initiative taken by induna government to reduce the plastic pollution.

INTRODUCTION

Environment is a wide and substantial collection of many biodiversity. One hole in a biodiversity can cause many changes which leads to disturbance in an environment. Conservation of environment is of utmost importance to maintain the balance of the ecosystem. There are many factors which leads to the imbalance in an ecosystem, one of the major problems is Plastic pollution. On average, the world is producing 430 million tonnes of plastic per year – two thirds of which are only used for a short period of time. Plastics are the largest, most harmful and most persistent fraction of marine litter, accounting for at least 85 per cent of total marine waste Plastic packaging is the reason for the majority (36%) of plastic production. 46 per cent of plastic waste is land filled, 22 per cent becomes litter, 17 per cent is incinerated and 15 per cent is collected for recycling, with less than 9 per cent actually recycled after losses.[1] India generates around 3.4 million tonnes (MT) of plastic waste, based on a newspaper that only 30 per cent of it is recycled. According to the report, which has been prepared in association with the Indian Institute of Science (IISc) and Praxis Global Alliance,

Maharashtra, Gujarat and Tamil Nadu together contribute 38 per cent to the total plastic waste that is generated in India.[2] Plastics are ubiquitous in the environment. They leave a substantial carbon footprint throughout their life cycle, accounting for 3.4 % of global greenhouse gas emission. Throughout the lifecycle of plastic harmful chemicals are released into air, water, and soil posing severe risks related to the environment and human health. The purpose of the current review is to learn about the effects of plastic pollution, which we use in our daily lives since it has many benefits, but which is also harming our ecosystem and making it more difficult for us to have a sustainable future.

PLASTIC

The word plastic is originated from "pliable" which means "easily shaped".

Plastics are a group of materials, either synthetic or naturally occurring, that may be shaped when soft and then hardened to retain the given shape. plastics are polymers. Plastic is a material consisting of a wide range of synthetic or semi-synthetic organic compounds that are malleable and, therefore, can be molded into solid objects. Plasticity is the general property of all materials that involves permanent deformation without breaking. Polymers' name is derived from their elastic and plastic properties.[3] There are many types of plastic, but the majorly classified types are Microplastics and Macro plastics.

MICROPLASTICS

Microplastics are pieces of plastic measuring < 5 mm in length. Microplastics consist of chemicals like carbon, hydrogen, phthalates, polybrominated diphenyl ethers (PBDEs), and tetrabromobisphenol A (TBBPA). Microplastic particles can be harmful to marine life. Ingested plastic fragments can cause changes in feeding and reproductive behavior as well as increased mortality.[4] Microplastics are incapable of breaking down naturally. Microplastics have been found in a variety of environments, including oceans and freshwater ecosystems. Microplastics differ in color and density, considering the type of polymers, and are generally classified according to their origins, i.e., primary and secondary. About 54.5% of microplastics floating in the ocean are polyethylene, and 16.5% are polypropylene, and the rest includes polyvinyl chloride, polystyrene, polyester, and polyamides.[5] The microplastic level of different coastal and marine ecosystems nearly ranged from 0.001-140 particles/m3 in water and 0.2-8766 particles/m3 in sediments at different aquatic environments over the world.[6]

The global coverage and long retention times of microplastic waste in fluvial systems (ranging from years to centuries) create long-lasting and widespread potential for its fragmentation and the production of secondary micro- and nano plastics.[7] Chemical effects of micro plastics in humans are reproductive and developmental toxicity, allergies, carcinogenicity and immunotoxicity.[8] Physical effects of microplastics are inflammation, abdominal pain, bloating, oxidative stress, endocrine disorders.[9] The mortality and injury of aquatic birds, fish, mammals, and reptiles caused by plastic aggregation and digestion are among the effects of Microplastics on the environment.[10] The impact of MNPs on organisms found in freshwater habitats has also attracted extensive attention. Studies have shown that different concentrations of MNPs in the terrestrial aquatic ecosystems have various degrees of influences on the growth, development, behavior, reproduction, and mortality of aquatic animals (represented by Daphnia and zebrafish).[11]

MACROPLASTICS

Macroplastics are typically categorized as anything larger than 5 millimeters. Macroplastics in the environment are a concern due to their longevity and ability to accumulate. Made up of Polypropylene (PP) accounts for the largest share, followed by low-density polyethylene (LDPE) and high-density polyethylene (HDPE). These three plastics have a lower density than water. The polymers polyvinyl chloride (PVC), polyurethane (PUR), polyethylene terephthalate (PET) and (expanded) polystyrene ((E)PS) have a higher density than water.[12] These materials are found floating on the surface, at the depths of the ocean floor or even brought to land from the tides. There are many major contributors to macroplastics, including but not limited to, commercial fishing wastes, consumer products and construction wastes.[13] Chemicals such as polybrominated diphenyl ethers (PBDEs) can cause health problems including kidney damage and thyroid cancer in various animal species.[14] Floating macroplastics also have apparent impacts on marine megafauna through ingestion or entanglement. As they degrade over time, they can generate large numbers of microplastics – and like their smaller counterparts, macroplastics can carry chemicals and invasive species.[15] indirect or unintentional ingestion where they confuse their food with plastic or feed on animals that have already ingested the plastic and interaction such as collision.[16] Macroplastics are estimated to be one of the main sources of marine plastic pollution and secondary microplastics, and have direct negative effects on ecosystem health and human livelihood.[17] Large organisms may consume macroplastics, which might clog their digestive tracts and cause famine. Those that have been known to die from malnutrition include whales, dolphins, and porpoises that have washed-up dead-on beaches and had stomachs full of plastic.

	Microplastics	Macroplastics
Size	<5 mm in length	>5 mm in length
composition	Carbon, hydrogen, phthalates, PBDEs, TBBPA, polyethylene (54.5%), polypropylene (16.5%), polyvinyl chloride, polystyrene, polyester, polyamides	Polypropylene (PP), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyurethane (PUR), polyethylene terephthalate (PET), expanded polystyrene ((E)PS)
Human health effect	Reproductive and developmental toxicity, allergies, carcinogenicity, immunotoxicity, inflammation, abdominal pain, bloating, oxidative stress, endocrine disorders	Health problems such as kidney damage and thyroid cancer due to PBDEs
Marine life(species)	Affects birds, fish, mammals, reptiles; impacts on Daphnia and zebrafish in freshwater ecosystems. influence in growth, development, behavior, reproduction and mortality	Ingestion and entanglement by marine megafauna such as whales, dolphins, and porpoises, leading to gut blockage and starvation
Environmental impact	Persistent in oceans and freshwater ecosystems, long retention times (years to centuries), contribute to secondary microplastics	Persistent in the environment, degrade into microplastics, transport invasive species, direct negative effects on ecosystem health

PLASTIC POLLUTION

We produce about 430 million tonnes of plastic waste every year. Around the world, one million plastic bottles are purchased every minute, while up to five trillion plastic bags are use worldwide every year.[18]

Every day, the equivalent of 2,000 garbage trucks full of plastic are dumped into the world's oceans, rivers, and lakes. Every year 19-23 million tonnes of plastic waste leaks into aquatic ecosystems, polluting lakes, rivers and seas.[19] Plastic is the major component of litter and is widely reported within the environment.[20] Plastic pollution can alter habitats and natural processes, reducing ecosystems' ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social well-being.[19] Plastic which is left behind in the environment causes problematic crisis in many biodiversity which is seen in ocean, landfills and fresh water, from these sources it affecting the health of humans and animals as the final product. plastic had been found to be persistent polluters of many environmental niches, from Mount Everest to the bottom of the sea.[21] Around the world, one million plastic bottles are purchased every minute, while up to five trillion plastic bags are used worldwide every year. In total, half of all plastic produced is designed for single-use purposes – used just once and then thrown away. Plastics including microplastics are now ubiquitous in our natural environment. They are becoming part of the Earth's fossil record and a marker of the Anthropocene, our current geological era. They have even given their name to a new marine microbial habitat called the "plastisphere".[18]

IMPACT OF PLASTIC IN MARINE POLLUTION

The ocean is intrinsic to our life on earth. Covering three-quarters of the earth's surface, contain 97% of the earth's water, and represents 99% of the living spaces on the planet by volume. They provide key natural resources including food, medicine, biofuels and other products. Plastics account for 85 per cent of marine litter[22] Worryingly, marine pollution is reaching extreme level, with over 17million metric tons clogging the ocean in 2021, a figure set to double or triple by 2040. Plastic is the most harmful type of ocean pollution[23] Land-based and sea-based sources are the primary sources of these containments in various modes that enter the ocean.[24] Every year, and estimated 5 to 12 million metric tonnes of plastic enters the ocean. About 89% of plastic found on the ocean floor are single use items like plastic bags.[23] Rivers are a major source of plastic waste in the oceans. Rivers draining densely populated, rapidly developing coastal regions with weak waste collection systems are particularly important sources, and it is estimated that between 88-95% of marine plastics comes from only 10 rivers. Manufactured microplastic beads are released to the environment from cosmetics such as toothpaste, abrasive scrubbers and sunscreen. They enter the ocean by way of urban runoff, sewage discharge, and direct face-off of cosmetic.[25] Marine plastic pollution has become a critical issue on a global scale, bringing detrimental environmental impacts, including the death of marine species caused by plastic entanglement and ingestion.[26] Southeast Asia is considered the biggest contributor of marine plastics.[27] Plastic pollution is a widespread problem affecting the marine environment. It threatens ocean health, the healthiness of marine species, food safety and quality, human health, coastal tourism, and contributes to climate change.[19] The most visible impact of plastic debris are the ingestion, suffocation and entanglement of hundreds of marine species.[28] Plastic remnants have been found in digestive systems of many water species, including every marine turtle species and nearly half of all surveyed seabird and marine mammal

species.[22] The ocean is the ultimate destination for much plastic, and plastics are found throughout the ocean, including coastal regions, the sea surface, the deep sea, and polar sea ice.[29] The plastics entering into the marine environment may remain for hundreds and thousands of years, during which they get fragmented due to the mechanical and photochemical processes resulting in the formation of microplastics (< 5 mm) or Nano plastics (< 1 μm).[30] Global Plastic Watch puts plastic waste produced per Indian at four kilograms each year. The Ganges, the second most polluted river in the world, discharges 1,05,000 tonnes of plastic (roughly the weight of over 200 blue whales) each year into the Indian Ocean. What makes plastics a worrisome pollutant in our rivers is their tiny form, called microplastics, which are about the size of a sesame seed (0.5 mm) or less.[31] Plastics are produced by polymerization of highly reactive and often toxic chemical monomers, 98% of them derived from fossil fuels. They are designed to be stable, durable and resistant to degradation. Because of these properties, discarded plastic that reaches the marine environment can persist for decades and travel long distances. Plastic waste is now ubiquitous in surface waters, on the coasts, in estuaries, on the high seas, and even in the deepest and most remote parts of the ocean.[25] micro-plastic pollution on 0.92 km2 of a long beach in the Tamil Nadu. Seventy-two samples have been isolated from the water, wet sand and dry sand. The micro-plastic particles were more abundant in wet sand than in water or dry sand.[32]

MARINE SPECIES

Numerous marine species are affected by plastic debris through entanglement, nest incorporation, and ingestion, which can lead to lethal and sub-lethal impacts. Over 600 marine species are affected by plastics. Nearly 45000 marine animals have ingested plastics and 80% were injured or killed. Plastics can pierce animals from inside or cause starvation, entanglement, loss of body parts and suffocation.[33] Human activities have led to microplastic contamination throughout the marine environment. As a result of widespread contamination, microplastics are ingested by many species of wildlife including fish and shellfish.[34] Since most of the plastic debris that reaches the ocean remains floating for years as it does not decompose quickly, it leads to dropping of oxygen level in the water, severely affecting the survival of marine species. Birds consumes plastic inadvertently; they choke on it which cause a steady decline in their population. Marine plastic pollution poses a threat to the oceanic ecosystems that are vital for humanity's sustenance, oxygen supply, livelihoods, and overall welfare.[24] Excessive environmental microplastic exposure will cause toxicity damage and then initiate the detoxification mechanism in Amphioctopus fangsiao digestive gland to maintain homeostasis. This study revealed that microplastic can cause adverse consequences on cephalopods, providing novel insights into the toxicological effect of microplastic exposure.[35] Microplastics attached to pathogenic bacteria have stronger toxic effects on mussels, which also suggests that Microplastics with pathogenic bacteria might have an influence on the immune system and cause disease in mollusks. Thus, MPs may mediate the transmission of pathogens in marine environments, posing a threat to marine animals and human health.[36] Microplastics discovered in the commercially significant dried fish products of major dry fish markets of India, which included polypropylene (21 %), low density polyethylene (17.5 %), polystyrene (15.5 %), and others.[37] The digestive tract content of 302 specimens of 22 fish species were analyzed using the KOH digestion method (500 g/5 L), stereoscopic visual identification and infrared spectroscopy. A total of 69 microplastics were found in the digestive tract of 7% of the analyzed fishes. 55% of the ingested microplastics were filaments, 23% fragments, 19% films, and 3% foam.[38]

LANDFILLS

Around the globe, mainly in developing countries where waste reduction and management procedures are not robust or thoroughly followed, waste is accumulated in landfill sites.[39] Here is limitation on our understanding of the impact of single-use plastics and microplastics on the terrestrial environment.[40] Plastics dumped in landfill pose a risk, because they pose significant environmental impacts for the health of people and animals that rely on water drawn from the under-lying water table. Research has proven that carcinogenic substances gradually build-up in landfill.[41],[42] Single-use plastics can have a significant impact on the terrestrial food chain. Plastic bags and food containers every so often carry food particles and smells that attract vermin to eat the plastic.[43] The plastic becomes perpetually embedded in the animals' digestive tracts, blocking the passage of food, and leading to death by starvation or infection. Birds and large mammals especially farm animals are documented as being found dead after feeding on plastic bags. Furthermore, birds use pieces of plastic in building their nest.[44] In a nest, freshly hatched chicks will peck away at pieces of plastic, which they may swallow up. Ecosystems are increasingly damaged when plastic litter mounds up along the shores of lakes, reservoirs, and inland waterways, disrupting the nesting patterns of waterfowl and other aquatic animals. This will have flow-on impacts on other animals along the food chain, such as tiny insects and other small animals, which are a primary source of food for higher carnivores and reptiles occupying wetlands.[41]

Though much of the modern-day discussion regarding the environmental impacts of plastic pollution concentrates on natural environments, it is critical to mention that less is understood about its impact on human health.[45] Land plastic contaminants have the capability to quickly enter the human food chain via agricultural livestock.[46] There is a surge of single-use plastic waste particles, which make their way into urban areas and the environment that support the agricultural natural and environments.[47] Recent research findings

indicate that microplastic contamination is found everywhere on land and in freshwater as in the marine environment, but not much attention has been given to its impact in both freshwater and terrestrial ecosystems hence less is known. The ultimate fate of plastic in landfills is a major concern, particularly as there is no established method of determining whether the plastic degrades, biodegrades, or is recalcitrant. Degradation or biodegradation may have potential negative effects such as the destabilization of the structural stability of the landfill. The majority of MPs in groundwater come from landfills.[42]

HUMAN HEALTH

Plastic particles have been found in hundreds of marine species in all major taxa, including species consumed by humans.[29] Consuming plastic could lead to cancer, effects on hormone levels, and heart damage.[48] Plastics have been found in the blood of even new born babies. Burning of plastic results into formation of a class of flame retardants called as Halogens. Methylmercury and PCBs are the ocean pollutants whose human health effects are best understood. Exposures of infants *in utero* to these pollutants through maternal consumption of contaminated seafood can damage developing brains, reduce IQ and increase children's risks for autism, ADHD and learning disorders. Adult exposures to methylmercury increase risks for cardiovascular disease and dementia.[49] Manufactured chemicals - phthalates, bisphenol A, flame retardants, and perfluorinated chemicals, many of them released into the seas from plastic waste. Fish is the potential source of exposure to chemical pollutant, especially mercury (Hg) and this is a grave concern for many consumers, especially pregnant women, as this could affect their fetuses.[50] Between 1950 and 2015, some 6,300 million metric tons of plastic waste were generated. The majority of this waste, about 4,900 million metric tons, ended up in landfills and the environment.[51] On the basis of trends from that period, researchers estimated that by 2050 the amount of plastic waste in landfills and the environment would reach 12,000 million metric tons.[21] In addition to outright mortality, such ingestion can lead to the transfer of plasticizer chemicals to organisms, leading to accumulation in tissues, toxic effects, and trophic transfer, depending on the chemical and the concentration. Microplastics will definitely increase the potential health risks to humans through food chain, especially by commercial fishes.[52] Majority of the Microplastics identified from all the fish species were composed of polypropylene and polyethylene in the form of fragments, which reflects both the widespread use of these polymers for packaging and their environmental fate as riverine plastic debris.[37] Moreover, the detection of Microplastics in the fish species may affect the food chain and eventually pose health risks for humans.[53]

INITIATIVES

The research paper comprehensively reviews global and Indian efforts to combat plastic pollution, emphasizing a roadmap proposed by the UN Environment Programme (UNEP) for an 80% reduction in plastic pollution by 2040.[54] This involves significant changes in plastic production, use, and disposal, with key shifts towards reuse, recycle, and reorient and diversify.[55][56] The highest costs in both throwaway and circular economies are operational, leading to proposed regulations for plastics designed to fit a circular model.[54] India, as the fifth-highest global generator of plastic waste, has implemented impactful measures, including the ban on single-use plastics and the imposition of Extended Producer Responsibility (EPR) on plastic packaging.[45] The Ministry of Environment, Forest and Climate Change (MoEFCC) and the Ministry of Housing and Urban Affairs (MoHUA) have enacted regulations and initiatives under the Swachh Bharat Mission-Urban (SBM-U) 2.0 for effective plastic waste management.[57]

The regulatory framework includes amendments to Plastic Waste Management Rules and initiatives like Material Recovery Facilities (MRFs) under SBM-U 2.0. The narrative review highlights key initiatives such as the awareness campaign launched by the Union Environment Minister, the National Dashboard on Elimination of Single-Use Plastic[58], the EPR Portal for Plastic Packaging[59], and a Mobile App for Single-Use Plastics Grievance Redressal. Innovative projects like the industrial production of Graphene from Waste Plastic, the India Plastic Pact, and the Un-plastic Collective showcase the multifaceted approach towards transforming the plastic system into a circular economy.[60] Additionally, global collaborations like the GIoLitter partnership project and India's participation in the historic agreement involving 175 nations to develop a legally binding agreement on plastic pollution by 2024 demonstrate India's commitment to global initiatives.[61] The narrative review encapsulates these initiatives, reflecting India's endeavors to tackle plastic pollution comprehensively.

CONCLUSION

Global plastic pollution is an issue.[49] Plastic garbage is posing a threat to the planetary boundaries and is undoubtedly building up in landfills and the ocean.

The current patterns of plastic production, use, and disposal are not sustainable and are responsible for significant harms to human health, the environment. The chemicals leach out of plastics, enter the environment, cause pollution, and result in human exposure and disease.[29] and also it threats the marine species. The accumulation of microplastics in the environment owing to plastic waste mismanagement has become an undeniable problem worldwide. This may result in tremendous adverse effects on environmental sustainability and human health.[65]

EPR concept addresses the responsibility towards a greener and cleaner environment even after completion of the production chain. The manufacturers of plastic

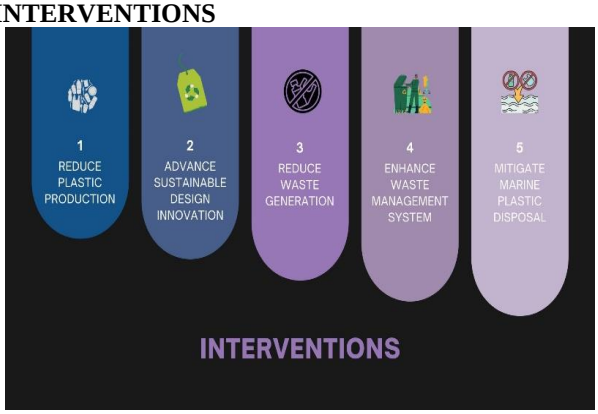
products and packaging items or material can be encouraged to collect packaging (e.g., food and beverage containers) and recycle plastic through funding and operational activities toward the EPR.[24]

Governments and policy change have a pivotal role to play in creating the critical legislative framework to stimulate mitigation actions that contribute to a reduction in plastic waste at source. The need for action is pressing and the scale of the problem indicates no single action will be sufficient. We need to simultaneously apply multiple actions including, reduction, re-use, and recyclability as a matter of urgency.[20]

In summary, it is the integrated issue of how we use our resources that must concern. It is clear that only by moving from the current linear, 'take, make, dispose (waste-creation)' model for resource consumption, to the systemic, circular alternative of 'reduce, reuse, recycle, regenerate'.[66]

The current literature lacks clinical and epidemiological studies. Conducting human population studies can elucidate the association between the Microplastics exposure and health outcomes. With advanced analytical technologies, new experimental models, and well-informed interdisciplinary research collaborations, we expect to gain deeper insight into the risk of Microplastics to liver health, which will benefit the development of mitigation strategies and policies.[67] Pay attention to fixes rather than just issues. Organize engaging sessions, talk about solutions and success stories, and communicate with the audience. Demonstrate improvements and spur action.

INTERVENTIONS



RECOMMENDATION

Plastic-free sustainable living

- Choose plastic free sustainable shopping, carry reusable bags, coffee mugs, non-plastic water bottles, choosing food with no plastic packing, food wraps, buy local products, and refill containers, plastic-free face wash, dry creams, makeup, deodorant, shampoo and other products which get washed into the ocean straight from the bathroom.[18]

Legislation

- Regulation of plastic product manufacturing and consumption without sacrificing food safety or public health through taxes or restrictions. supplying environmentally appropriate substitutes for recyclable materials.[62]

Awareness and Education

- Promoting plastic awareness programs through social media, we can able to stop using single use plastics and save the environment and human health. Education and awareness must focus on practical actions, including the reduction in consumption of harmful products, reduction in littering, and improving recycling rates. Education is the potent path to control the plastic pollution. social media is a powerful educational information outlet.[63][64]
- Shifting Consumer Demand If the market for plastic-free items grows, businesses may need to reconsider and redesign their product line, even though there are now few viable alternatives and development plans are needed to support them.[22] Boosting the market for recycled plastics through incentives, penalties, or levies on non-renewable goods.

Strategies

- To decrease waste and increase recycling rates, implement waste collection methods that adhere to the "pay-as-you-throw" concept[51] such as door-to-door collection and deposit-refund systems.[52]
- To reduce the negative effects on the environment, garbage can be collected and recycled using renewable energy.[53]
- By taking into account the anticipated end-of-life of items, including reuse, repair, and recyclability, implementing Life Cycle Assessment (LCA) for each product and process enhances eco-design.[54,55]
- When bio-based plastics are used instead of fuel-based polymers, the environmental effects are lessened.[56,57]
- Reduced manufacturing of degradable plastics that release dangerous fragments is one way to address the issue; biodegradable polymers, on the other hand, are only used for applications such as agricultural films and require special collection and waste treatment protocols.[58]
- Improving e-waste's capacity to be recycled is essential, and waste-to-energy can be used as a temporary disposal option.[48]

Partnership

- Governmental agencies work with influential people and organizations. Interacting with private companies and industry organizations.

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