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PERSPECTIVES AND CHALLANGES

"Contributions to Sustainable Environment"

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A Review of Sustainable Plastic Waste Management

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ABSTRACT

India is currently the 12th highest contributor to the mismanagement of plastic waste, generating 9.4 million tonnes of plastic waste annually. Plastic pollution in the ocean has severely impacted almost all species groups, with negative consequences observed in almost 90% of evaluated species. Even if plastic inputs were to stop today, micro plastic levels in the ocean are projected to double by 2050 and possibly increase 50-fold by 2100 under some scenarios. Moreover, plastic debris entangles marine and freshwater organisms, causing them to suffocate, drown, or starve. In addition, specialists predict that approximately 10% of plastic waste generated will make its way into the ocean. The release of toxic substances is creating a significant danger to the environment, vegetation, and the health of humans and animals. Recycling and landfills are discussed as potential solutions, but the former should only be used if the amount of energy consumed in the recycling process is lower than the energy required producing new materials. A significant sustainability drawback of landfills is that none of the material resources used for plastic production are recovered, resulting in a linear material flow rather than a cyclic one.

KEYWORDS: **Plastic, micro plastic, marine, waste management, recycling, landfill.**

1 Introduction

India has been identified as a significant contributor to plastic waste mismanagement, and its per capita plastic consumption is much lower than that of developed nations. However, India is projected to climb to fifth on the list of highest contributors to plastic waste mismanagement by 2025. The review highlights the impact of plastic pollution on the marine environment, which affects almost all species groups and reduces the productivity of critical marine ecosystems. Plastic waste also poses significant ecological risks in various habitats, including secluded lakes and the deepest parts of the ocean. The review examines conventional technology for plastic waste management, such as recycling and landfilling. While recycling is one approach to reducing plastic waste, it must be applied only when the amount of energy consumed in the recycling process is lower than the energy required producing new materials. Meanwhile, constructing landfills is becoming increasingly challenging due to limited space. The review highlights the importance of exploring alternative methods to manage plastic waste in India to reduce its environmental impact.

2. PLASTIC GENERATION IN INDIA

In 2019, India produced approximately 9.4 million tonnes of plastic waste annually, a mere 3.1% of the total global plastic waste generation of over 380 million tonnes annually. Regarding global plastic consumption, the packaging and construction sectors consume 42% and 17%, respectively. However, India's packaging and construction sectors consume 35% and 23%, respectively [1]. The total waste generated in India includes 8% of plastic waste [2]. India has been identified as the 12th highest contributor to the mismanagement of plastics waste, despite having a population size similar to that of China. However, by 2025, it is projected to climb to fifth on the list [3]. India's per capita plastic consumption stands at approximately 10 kg per annum, which is significantly lower than the United States, where the annual per capita consumption of plastic is the highest in the world at 110 kg [4].

3. ENVIRONMENTAL IMPACT OF PLASTICS

The annual surge of plastic pollution in the marine environment directly results from the worldwide mass production of polymers and inadequate management of plastic waste. Due to their robustness and weight, plastic materials can travel vast distances and remain in the marine ecosystem for extended periods. As a result of the widespread usage of plastics, contamination has spread to various habitats, including secluded lakes and the deepest parts of the ocean [5]. Plastic pollution has severely impacted the ocean, affecting almost all species groups, with negative consequences observed in almost 90% of evaluated species. This pollution enters the marine food web and significantly reduces the productivity of critical marine ecosystems such as coral reefs and mangroves. Multiple regions, including the Mediterranean and Arctic sea ice, have exceeded plastic pollution thresholds that pose significant ecological risks, and more regions are expected to follow in the future. Even if plastic inputs were to stop today, microplastic levels in the ocean are projected to double by 2050 and possibly increase 50-fold by 2100 under some scenarios [6].

It is nearly impossible to eliminate plastic from the ocean after it has entered it. Additionally, plastic disintegrates in the ocean, with macroplastics becoming microplastics and microplastics transforming into nano plastics [7]. Plastic debris, mainly abandoned fishing gear, entangles marine and freshwater organisms, causing them to suffocate, drown, or starve. Several studies have indicated that aquatic creatures frequently consume and accumulate these novel pollutants in their digestive tracts [8]. In addition, specialists predict that approximately 10% of plastic waste generated will make its way into the ocean [9].

Moreover, according to the World Economic Forum (2016), the ocean's plastic mass will surpass that of fish by 2050. The occurrence of meso, macro, and microplastics (MPs) in aquatic ecosystems is causing concern due to their possible threats to aquatic and human life. Although plastics are inert, MPs with toxic additives and accumulated pollutants can have adverse ecological consequences. Reports indicate that internal tissues can absorb MPs and have toxic effects on critical organs such as the lungs, liver, and brain cells, highlighting their severe health risks [10].

The major routes of releasing plastic-related persistent organic pollutants (POPs) such as flame retardants, dioxins, and furans in India and other developing nations are the open incineration of municipal solid waste and informal plastic waste recycling, including electronic and electrical waste [11]. The release of toxic substances is creating a significant danger to the environment, vegetation, and the health of humans and animals. Polystyrene can harm the Central Nervous System, while the hazardous brominated compounds are carcinogenic and mutagenic. Dioxins, lethal persistent organic pollutants, settle on crops and waterways, eventually making their way into our food and bodies. The most dangerous component of dioxins, 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD), called red to as Agent Orange, can cause cancer and neurological damage and disrupt reproductive, thyroid, and respiratory systems. Burning plastic waste can increase the risk of heart disease; aggravate respiratory conditions like asthma and emphysema, cause rashes, nausea, and headaches, and damage the nervous system[12].

4. CONVENTIONAL TECHNOLOGY FOR PLASTIC WASTE MANAGEMENT

4.1. Recycling

Recycling allows the wastes to be reintroduced into the consumption cycle, generally in secondary applications because, in many cases, the recycled products are of lower quality than the virgin ones. Recycling must be applied only when the amount of energy consumed in the recycling process is lower than the energy required producing new materials. Plastics can be recycled using two different approaches: mechanical and feedstock recycling. In the first case, the plastics are recycled as polymers, whereas in the second, plastic wastes are transformed into chemicals or fuels [13].

4.2. Landfill

Although it is a conventional waste management method, constructing landfills is challenging in some countries due to limited space. While a well-managed landfill can minimize immediate environmental harm beyond the impacts of waste collection and transportation, there are potential long-term risks, such as groundwater and soil contamination from certain additives and plastic breakdown, which can lead to persistent organic pollutants.

A significant sustainability drawback of landfills is that none of the material resources used for plastic production are recovered, resulting in a linear material flow rather than a cyclic one [14]

4.3. Incineration

While this process reduces the need for landfilling plastic waste, there are concerns that hazardous materials may be released into the atmosphere. This is especially true for mixed plastic waste containing halogenated additives and PVC, which can release dioxins, furans, and other polychlorinated biphenyls into the environment. The choice of incinerators is crucial, as it is not typically done in a controlled manner that can reduce pollution from off-gases to acceptable levels. Consequently, this method of plastic waste management is often not preferred, as the cost of treating the gases is frequently higher than the energy recovered [15]

With modern incineration technology, solutions are available to address any incineration-related issues without causing harm to the environment and, in many cases, recover the calorific value from the waste being incinerated. Waste incineration plants can use heavily contaminated plastic waste collected from various waste streams for energy recovery. However, this recovery system is generally considered the most expensive among all the other alternatives.

It is important to note that incineration of plastic waste may lead to generating harmful pollutants like dioxins and furans, which is highly undesirable. Therefore, caution must be exercised when considering incineration as an option for plastic waste management to minimize environmental pollution.

5. RECENT TECHNOLOGIES FOR PLASTIC WASTE MANAGEMENT

5.1. Plastic to Road Construction

The use of plastics in the construction of roads provides a novel approach to recycling post-consumer plastics. Plastic roads can be constructed entirely from plastic or a combination of plastic and other materials. In India, flexible roads are being constructed successfully using a specially designed technique involving waste plastics in the road laying process.

Plastic types can be used for road construction, such as Polystyrene (PS) sourced from rigid packaging, cartons, plates, and vending cups. Polypropylene (PP) is obtained from ketchup bottles, yogurt cups, and similar items. Polyethylene (PE) in both high and low densities is acquired from plastic bags, water bottles, shampoo bottles, Etc. It should be noted that using PolyVinyl Chloride (PVC) sheets or Flux sheets is not recommended.

5.2. Plastic to Alternate Fuel

Co-processing is when materials like plastic waste are used in industrial processes to replace primary fuel and raw materials. This is done in cement, lime, steel production, and power plants. Co-processing plastic waste benefits the cement industry and waste management authorities, as it saves fossil fuel and raw material consumption and reduces the need for other plastic waste disposal methods. Additionally, using this method eliminates the need to invest in other plastic waste practices and helps reduce landfill waste. Plastic waste used for co-processing is called alternative fuel and raw material (AFR).

5.3. Plasma pyrolysis

The plasma pyrolysis method is considered environmentally friendly and is recognized under the Kyoto Protocol as a way to reduce global warming. It operates on a zero-discharge philosophy, and all input materials are recycled back into nature or the market to protect human health and the environment. Plasma technology has the potential to generate electricity and hydrogen from various types of waste without emitting harmful substances like dioxin, furan, and mercury. The EPA recommends that municipalities install plasma facilities to eliminate the need for landfills [16].

6. CONCLUSION

India produces a relatively small amount of plastic waste compared to the global average. However, it is projected to climb to fifth on the list of plastic waste contributors by 2025. Plastic waste has a significant environmental impact, with plastic pollution in the ocean affecting almost all species groups and reducing the productivity of critical marine ecosystems. Plastic disintegrates in the ocean, and macroplastics become microplastics and nanoplastics, posing significant ecological risks. Plastic-related persistent organic pollutants are released through open incineration of municipal solid waste and informal plastic waste recycling in developing nations, creating a significant danger to the environment and health of humans and animals. Conventional technology for plastic waste management includes recycling and landfills. However, recycling should only be applied when the energy consumed in the recycling process is lower than the energy required to produce new materials.

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