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Plastic pollution and its adverse impact on ecosystem

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Abstract
The accumulation of plastic and products made of plastic in the environment lead to plastic pollution which imposes a hazardous effect on wildlife and human food chain. The plastics have a chemical configuration by which they are resistant to environmental degradation rusting to high incidences of environmental pollution due to slow degradation. Plastic pollution occurs by plastic goods which vary according to its chemical configuration. It depends on the method of its polymerization and the method of natural degradation. Depending on the size, plastic pollutants are categorized into micro-, meso-, or macro debris. Since 1950 to 2021, about 6.3 billion tones of plastics have been produced worldwide, 9% and 12% of which have been recycled and incinerated, respectively. Human population increase and consistent demand for plastics and plastic products are responsible for continuous increase in the production of plastics, generation of plastic waste and its accompanied environmental pollution. We have reviewed in this paper, the most relevant literatures on the different types of plastics in production, the hazardous chemical constituents, prevailing disposal methods and the detrimental effects of these constituents to air, water, soil, organisms and human health viz-a-viz the different disposal methods. Papers that reported environmental and public health effects of plastic constituents but not plastics directly were also reviewed. Varieties of plastics used in the production of many consumable products including medical devices, food packaging and water bottles contain toxic chemicals like phthalates, heavy metals, bisphenol A. brominated flame retardants, nonylphenol, polychlorinated biphenylethers, dichlorodiphenyldichloroethylene, phenanthrene etc.

Keywords: Plastic, Pollution, Environmental, Natural, Production, Chemicals

Introduction

“Plastics are made up of synthetic organic polymers which are widely used in different applications ranging from water bottles, clothing, food packaging, medical supplies, electronic goods, construction materials, etc. In the last six decades, plastics became an indispensable and versatile product with a wide range of properties, chemical composition and applications. Although, plastic was initially assumed to be harmless and inert, however, many years of plastic disposal into the environment has led to diverse associated problems. Environmental pollution by plastic wastes is now recognized widely to be a major environmental burden especially in the aquatic environment where there is prolong biophysical breakdown of plastics” detrimental negative “effects on wildlife and limited plastic removal options. In many instances, sheeting and packaging plastics are disposed of after usage, however, because of their durability, such plastics are located everywhere and persistent in the environment. Research on the monitoring and impacts of plastic wastes is still at the infancy stage, but thus far, the reports are worrisome. In human occupational and residential environment, plastics made of petrol-based polymer are present in high quantity. At the end-of-life of these plastics, they are usually land-filled together with municipal solid waste. Plastics have several toxic constituents among which are phthalates, poly-fluorinated chemicals, bisphenol A (BPA), brominated flame retardants and Land, oceans and large water bodies are mostly affected from these pollutions.

The marine animals dwelling in the oceans suffer from an altered digestive physiology for the accidental consumption of plastic materials mixed with their feed. Antimony trioxide which can leach out to have adverse effects on environmental and public health. Plastics in electronic waste (e-waste) have become a serious global environmental and public health concern due to its large production volume and the presence of inadequate management policies in several countries."
Reports "from China, Nigeria, and India indicated that plastic hazardous substances from e-wastes can migrate beyond the processing sites and into the environment. The plastics exposed to ocean decompose rapidly than those to land. The debris waste products formed due to plastics are categorized into primary and secondary wastes. Secondary plastic wastes are produced from the degradation of primary wastes. The human population, wind and ocean currents, coastline geography, urban areas and trade routes contribute to the extent of spread of plastic pollution in our environment."

Research Questions

The research questions (RQ) addressed through this literature review are given below:
"RQ1. What are the different uses and applications of plastics?"
"RQ2. What are the different environmental impacts of waste plastics? What are the different types of techniques available for the management of waste plastics?"
"RQ3. How the degradation of waste plastics take place in the environment? Which management technique is typically used for handling waste plastics?"
"RQ4. Is it possible to convert waste plastics into useful products?"

Review of Literature

Plastics "are inexpensive, lightweight, strong, durable, corrosion-resistant materials, with high thermal and electrical insulation properties. The diversity of polymers and the versatility of their properties are used to make a vast array of products that bring medical and technological advances, energy savings and numerous other societal benefits (Andrady & Neal 2009) [5]. As a consequence, the production of plastics has increased substantially over the last 60 years" from around 0.5 "million tonnes in 1950 to over 260 million tonnes today. In Europe alone the plastics industry has a turnover in excess of 300 million euros and employs 1.6 million people (Plastics Europe 2008). Almost all aspects of daily life involve plastics, in transport, telecommunications, clothing, footwear and as packaging materials that facilitate the transport of a wide range of food, drink and other goods. There is considerable potential for new applications of plastics that will bring benefits in the future, for example as novel medical applications, in the generation of renewable energy and by reducing energy used in transport (Andrady & Neal 2009) [5]. Virgin plastic polymers are rarely used by themselves and typically the polymer resins are mixed with various additives to improve performance. These additives include inorganic fillers such as carbon and silica that reinforce the material, plasticizers to render the material pliable, thermal and ultraviolet stabilizers, flame retardants and colourings. Many such additives are used in substantial quantities and in a wide range of products (Meeker *et al*. 2009). Some additive chemicals are potentially toxic (for example lead and tributyl tin in polyvinyl chloride, PVC), but there is considerable controversy about the extent to which additives released from plastic products (such as phthalates and bisphenol A, BPA) have adverse effects in animal or human populations. The central issue here is relating the types and quantities of additives present in plastics to uptake and accumulation by living organisms (Andrady & Neal 2009; Koch & Calafat 2009; Meeker *et al*. 2009; Oehlmann *et al*. 2009; Talsness *et al*. 2009; Wagner & Oehlmann 2009) [5]. Additives of particular concern are phthalate plasticizers, BPA, brominated flame retardants and anti-microbial agents. BPA and phthalates are found in many mass produced products including medical devices, food packaging, perfumes, cosmetics, toys, flooring materials, computers and CDs and can represent a significant content of the plastic. For instance, phthalates can constitute a substantial proportion, by weight, of PVC (Oehlmann *et al*. 2009), while BPA is the monomer used for production of polycarbonate plastics as well as an additive used for production of PVC. Phthalates can leach out of products because they are not chemically bound to the plastic matrix, and they have attracted particular attention because of their high production volumes and wide usage (Wagner & Oehlmann 2009; Talsness *et al*. 2009). Phthalates and BPA are detectable in aquatic environments, in dust and, because of their volatility, in air (Rudel *et al*. 2001, 2003). There is considerable concern about the adverse effects of these chemicals on wildlife and humans (Meeker *et al*. 2009; Oehlmann *et al*. 2009). In addition to the reliance on finite resources for plastic production, and concerns about additive effects of different chemicals, current patterns of usage are generating global waste management problems. Barnes *et al*. (2009) show that plastic wastes, including packaging, electrical equipment and plastics from end-of-life vehicles, are major components of both household and industrial wastes; our capacity for disposal of waste to landfill is finite and in some locations landfills are at, or are rapidly approaching, capacity (Defra *et al*. 2006). So from several perspectives it would seem that our current use and disposal of plastics is the cause for concern (Barnes *et al*. 2009; Hopewell *et al*. 2009)."

Effects of Plastics

Plastic "pollution represents one of the major perceived threats to biodiversity. Due to its abundance, durability and persistence in the environment, it is a cause of special concern. In the oceans, plastic debris accounts for over 90% of all encounters between debris and individuals. By comparing the listed encounters with the International Union for Conservation of Nature (IUCN) Red List, at least 17% of species affected by entanglement and ingestion were listed as threatened or near threatened."

Fig 1

The "interaction of organisms with plastic debris results in a wide range of consequences, both direct and indirect, including the potential occurrence of sub-lethal effects, which, owing to their uncertainty, may be of considerable concern. Broadly, the presence of larger plastic materials in the ocean may result in entanglement and ingestion, potential creation of new" habitats, and dispersal *via* rafting, including transport of invasive species.

Fig 2

Entanglement "and ingestion frequently causes harm or death, although gathered data appears to suggest that entanglement is far more fatal (79% of all cases) than ingestion (4% of all cases). Debris may also constitute new habitats, and derelict fishing gear, for example, has been shown to cause not only death by "ghost fishing", but also to constitute new habitats for invertebrates. The dispersal of species in the marine environment, particularly species with no pelagic larval stage, has increased in recent decades. Highly dependent on oceanic currents, numerous species have always rafted on natural materials such as wood, but industrialization and the continuous increase of the presence of plastic debris in the oceans suggests that rafting is playing" an active role "in their scattering. This holds true for invasive species as well. A clear example is the detailed presence of a ciliate, Halo folliculina, a pathogen that may be the culprit of the skeletal eroding disease that has affected Caribbean and Hawaiian corals."

Fig 3

Less "attention has been paid to the effects of plastics in freshwater systems, in spite of the fact that rivers are the dominant source of plastic pollution to oceans, as well as a significant sink accumulating plastics originating from multiple sources. It is therefore reasonable to assume that the potential effects are identical to those described for plastic debris found in the marine environment."

Far "less documented are the potential effects of polymeric materials in terrestrial environments, although their presence has been documented in home gardens, areas of higher population density or points of convergence of anthropogenic activity, such as urban environments or in the vicinity of waste processing facilities. Larger debris are also commonly found in agricultural soils, owing to the increased usage of plastics in traditional agricultural practices (*plasticulture*), such as plastic mulching, for increased productivity and lower consumption of water60, or the use of plastic films in tunnels or for wrapping hay bales. Hard plastics are also frequently present as containers for numerous products used in agriculture, and the sewage sludge used for fertilisation or soil conditioning, may also contain pieces of plastic that are deposited in the soil. Yet, in spite of the reduced body of research pertaining to the (biological) effects of larger plastic materials in terrestrial environments, it is again conceivable that some animals may ingest and, at least partially, become entangled, in these materials. In fact, this has been reported for some ruminants, with plastic debris found in the stomach contents of sheep and goats."

In turn, for "smaller plastic pollutants, such as micro plastics, pollution has been described in freshwater, marine, terrestrial and atmospheric ecosystems. Although the increased awareness and focus of research has led to significant advances in the understanding of the behavior of micro plastics in the environment, there is still much that is undetermined, in particular with regard to the ability to accurately forecast the exposure scenarios and predict exposure hotspots. The already described complexity of the (bio)degradation processes contributes to a higher degree of intricacy, as do biofouling, ingestion and egestion (which may occur far from the location of exposure) processes. This introduces randomness in the distribution of" these materials, as well as changes to the properties of the micro plastics, with concomitant unpredictability on their environmental fate.

Owing to "their small size, micro plastics may be ingested by multiple organisms, such as planktonic and higher organisms (Figure), including mammals, birds and fish. Although the exact mechanisms of toxicity of these materials are still ill understood, the effects are potentially due to either (1) ingestion-induced stress, such as physical blockage, energy expenditure for egestion and false satiety; (2) leakage of chemicals, such as additives, from plastics and; (3) exposure to contaminants adsorbed (and subsequently released) by micro plastics such as persistent organic pollutants (POPs). Cnidarians, annelids, ciliates, rotifers, copepods, amphipods, euphausiids, mussels, barnacles, tunicates, birds and fish have all been demonstrated to ingest these small sized polymers within laboratorial settings."

Interestingly, results "showed that the uptake of micro plastics depends not only on their shape and size, but, perhaps less intuitively, also on their colour, with the preferential ingestion of yellow particles. This is likely due to their similarity to prey. The direct consequences of the ingestion of micro plastics include obstruction of the digestive tract and internal injury, frequently leading to reduced food consumption and concomitant decreased nutrition. This potentially results in starvation and death. In air-breathing organisms, micro plastics have been described to lodge in gills, which may translate into reduced respiration rates. Works focusing on the effects of these highly pervasive materials in terrestrial settings remain limited. Yet, although soils greatly differ from aquatic environments, the features that are essential to biota are identical, as many organisms thrive in small bodies of water that exist at or just below the surface, rendering them essentially aquatic organisms."

Micro plastics can also be ingested by earthworms and mites, likely leading to their presence and accumulation throughout food webs. For example, significant reductions in the growth rate of the earthworm *Lumbricus terrestris*, accompanied by higher mortality rates, were observed. These earthworms also carried micro plastics from litter in their burrows and effectively size-selected and downward transported these materials into the soil. It was also observed that only the smaller particles to which the earthworms were exposed to were egested, which could have profound implications on the fate and risk of micro plastics in terrestrial ecosystems, given the preponderant role earthworms play in shaping the physical properties of soils.

Environmental impacts of plastics and micro plastics

"End of life" does "not equate "end of impact". In fact, because plastic materials persist and pollute long after their intended use, it has become clear that there is no such thing as "end of life" for plastics. Depending on how plastic is handled, it may pose a significant threat to the environment and to the climate when it reaches the waste phase of its life-cycle. According to a 2021 report, the global plastic waste management by 2015 broke down as illustrated" in Figure

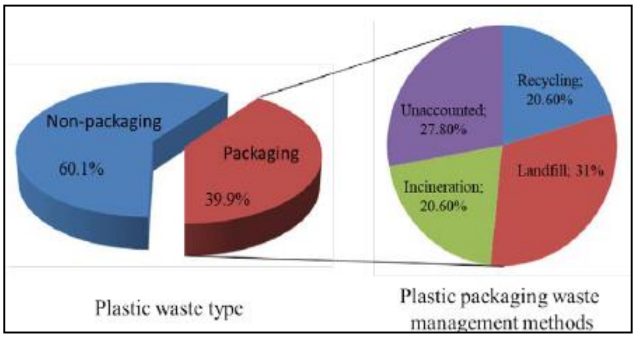

Fig 4: Global plastic waste management, 2015. Adapted from Hamilton *et al.*, 2021

The "last figures indicate that in Europe (inside and outside the EU) 7.2 million tonnes of plastic post-consumer waste were landfilled, while 9.4 million tonnes were collected for recycling and approximately 12.4 tonnes were incinerated."

Only a "fraction of plastic waste is recycled and is an expensive process owing to the inherent separate collection, transportation, processing, and re-manufacture. These considerable costs in combination with the low commercial value of recycled plastic on the one hand and the low cost of virgin polymers on the other seldom renders the recycling process profitable and often requires onerous governmental subsidies. Furthermore, a recent report by DS Smith Packaging showed that 44% of Europeans are unclear as to what materials may or may not be recycled, and in which recycling bin some plastic waste products should go. The same report highlighted that, owing to the COVID-19 pandemic and the associated exponential increase in online shopping, the amount of plastic packaging waste significantly rose. By inappropriately discarding potentially recyclable materials, Europeans may incur in a loss of 1.9 billion euros to the economy. Considering all these factors, it is not surprising that less than 10% of all plastic produced since 1950 has been recycled, while only 12% has been incinerated - a process that is not without its hazards."

While "incineration of plastic is often euphemistically dubbed "energy recovery", the truth is that when plastic is burned it emits greenhouse gases, mainly CO2. However, plastics also often contain additives which are hazardous when released into the environment during incineration, a long known issue. The types, quantities and concentrations of these chemicals vary, depending on the type of plastic waste and on how the incineration process takes place, but there is little doubt that such chemicals impact human health (See Figure). In Europe over the past years efforts have been made to divert plastic waste, especially plastic packaging, from landfills to incineration, a trend more evident in countries that have implemented bans on land filling recyclable waste."

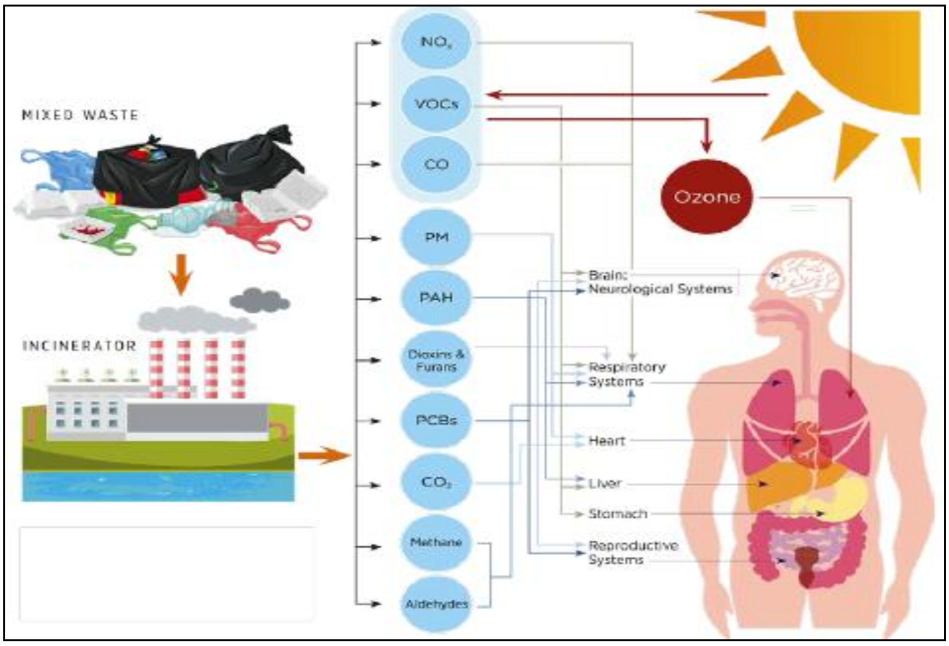

Fig 5: Toxic exposure from incinerated mixed waste, containing plastic. NOx-nitrogen oxides; VOCs-volatile organic compounds; CO-carbon monoxide; PM-particulate matter; PAH-polycyclic aromatic hydrocarbons; PCBs-polychlorinated biphenyl. Image credit: Nonprofitdesign.com. Adapted from Azoulay *et al.*, 2021

Conclusion

For “reducing the incidences of plastic pollution, research endeavors should be employed to convert petroleum based plastics to bioplastics. Also, educating and spreading the awareness among people to clean the water bodies like rivers, ponds and lakes can reduc the mortality of fishes and sea animals due to plastic pollution. The animals exposed to plastic pollution suffer from developmental defects with lesser birth weights for exposure to bisphenol A in fishes and reptiles, long term exposure may lead to stall egg hatching and decreased body weight, tail length, and body length.”

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