Hazardous effects of plastic wastes on land biodiversity: A review

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Abstract

Plastic pollution is ubiquitous throughout the world's ecosystem. Increase in the world's plastic production and use, inefficient recycling, indiscriminate disposal, synthetic nature and non- biodegradability of plastics have made it a considerable threat to biodiversity. The impact of plastic wastes on humans and the environment is becoming apparent. However, information on the impacts of plastic wastes on biodiversity is mostly directed towards marine environment with scarce information on land biodiversity although terrestrial environment is the major source of marine contamination. Terrestrial plastic waste contaminants are derived from long term used plastic containers and single-use plastic products, which are introduced by anthropological means, flood water, sewage and wind dispersal. Gradual breakdown of large plastic wastes give rise to microplastics, which increase its abundance in the environment. Plastics threaten wildlife in terms of entanglements, ingestion and chocking, which often results in loss of body parts or mortality. Plastics as vectors of invasive species in marine ecosystem have been widely established. Although not much is known on the importation of invasive species on terrestrial ecosystem by plastic wastes, there is possibility that plastic waste can be a potential vector of terrestrial alien species. Contamination of soil with microplastics alters soil habitats and disturbs the natural biophysical properties of the soil environment that leaves a negative impact on soil biota by reducing their activities and indirectly affecting food production. Accumulation of plastic wastes provides breeding ground for disease vectors, which has contributed to increased prevalence of emerging infectious diseases. This review examines the impact of plastic wastes on terrestrial biodiversity as it affects soil organisms, land animals and breeding of disease vectors.

Keywords: Animals, biodiversity, land, plastic wastes.

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Introduction

Plastic is a synthetic, non-biodegradable polymeric material derived from crude oil, natural gas or coal. Most land pollutants are light weight single-use plastic products and packaging materials, which are improperly disposed of at the locations where their usefulness is ended. Plastic pollution is the accumulation of plastic objects and particles such as plastic bottles, bags, microbeads in the earths' environment that adversely affect humans, wildlife and their habitat. There is rapid increase in global plastic production; by 2030, the world's yearly production of plastics is estimated to be in the tune of 619 million tons (Malhotra 2019). Only nine percent of the world's plastic waste has been recycled (Rhodes 2018). With the present rise in production and utilization of plastic products and if poor waste management system continues, then by 2050, there will be around 500 million tons of plastic wastes in landfills and the environment (Rhodes 2018; Kumari *et al* 2022).

Economic growth and industrialization have brought larger amount of plastic products into the society and the resultant plastic wastes (Teuten *et al* 2009). Plastic pollution has become one of the most pressing environmental issues due to this increase in production and use of plastics (Ryan, 2018). With very few being recycled, the rest are released into the environment (Geyer *et al* 2017) with about one-third of these plastic wastes ending up in soils or fresh water (de Souza Machado *et al* 2018). Globally, Europe, China and North America are the major producers of plastics while some African countries have been rated high in plastic waste generation due to poor waste management practice (Jambeck *et al* 2015; Akindele and Alimba 2021). In Nigeria, plastic wastes constitute about 20% of the total wastes and consist mainly of water sachets popularly known as 'pure water' and shopping bags (Dumbili and Henderson 2020). Heaps of littered plastic wastes clogged drainage systems and water ways, as plastic wastes are a common sight in Nigeria (Ezeokpube *et al* 2014; Dumbili and Henderson 2020).

The synthetic nature and persistence of plastics in the environment poses a serious threat to the environment and biota (de Souza Machado *et al* 2018). Degradation of plastic gives rise to particulate plastics (Bradney *et al* 2019). Particulate plastics are further categorized into

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microplastics, which are plastic particles less than 5mm (de Souza Machado *et al* 2018) and nanoplastics (<1µm) (Bradney *et al* 2019). Particulate plastics are traceable in food chain and may accumulate across multiple trophic levels (Dissanayake *et al* 2022). As at two decades ago, plastic debris was reported to be found in 267 species of animals worldwide, including 86% of all sea turtle species, 44% of all sea bird species, and 43% of all marine mammal species (Derraik 2002). Terrestrial microplastic pollution has been estimated to be four to twenty-three times higher than marine microplastic pollution and this could have long-lasting effects on the ecosystem (de Souza *et al* 2017).

Terrestrial biodiversity is impacted by plastic wastes through plastic ingestion and entanglements of land animals when mistaken for food or used as nesting materials or shelter (Blettler and Mitchell 2021). When integrated into the soil as microplastic, it can be ingested, incorporated and accumulated into the bodies and tissues of soil organisms (Browne *et al* 2008) limiting their activities and biodiversity. Increasing emergence of vector-borne infectious diseases has become a public health concern; this has been propagated through availability of breeding sites provided by plastic wastes (Krystosik *et al* 2020) in both urban and rural settlements.

Majority of encounters of terrestrial biota with plastic wastes may have gone unreported or under-reported since most of the researches conducted on the impact of plastic wastes on biota and the environment are directed towards aquatic ecosystems, while there is scare knowledge on impacts of plastic wastes on land ecosystem. Therefore, there is need for more researches on impacts of plastic wastes in this facet to fill this knowledge gap. This is important to increase the awareness on harmful effects of plastic wastes on terrestrial ecosystem and to inform government policies and environmental conservation interventions especially in the African continent.

Background

Sources of land plastic wastes

Plastics exist in the environment in various forms, ranging from long term used plastic containers such as liquid containers, house furniture, clothing and accessories to single-use plastic products.

The most common single-use plastics found in the environment are food wrappers, plastic bottles, water sachets, grocery bags, plastic lids, straws and disposable plates. Potential sources of microplastics are synthetic textiles, tires, personal care products, city dust, road marking, plastic pellets etc. (Kumari *et al* 2022). These plastics get into the environment through anthropological throw-away cultures, flood water, compost and wind disposal (Zylstra 2013; de Souza Machado 2018; Bradney *et al* 2019). Deposition of sewage sludge is another source of land contamination with microplastics (Huerta- Lwanga 2016).

Larger plastic materials degrade progressively to greater number of microplastics, which increase plastic abundance in the environment (Rhodes 2018). Allen *et al* (2009) reported that airborne microplastics could be transported to remote sites, which are as far away as 95km from the source, with the aid of strong airflow, this can also be suspended in the air (Prata 2017; Liu and Schauer 2021). Sea birds are known to transfer marine-derived nutrients and wastes to the terrestrial islands (Grant *et al* 2021). Recently, Grant *et al* (2021) reported that marine plastic wastes ingested by seabirds are re-introduced to the terrestrial islands by the birds. Seabirds could expel ingested plastics through regurgitation and excretion. Plastics can also be recovered from the carcass of dead birds (Hutton 2004)

Microplastics can be transferred to terrestrial ecosystem by ontogenic transference. Al-Jaibachi *et al* (2018) reported that microplastics ingested by developmental stages of terrestrial insects whose larvae develop in fresh water bodies can be passed to the terrestrial adult stages in the course of the life cycle. Mayflies, mosquitoes, midges and dragon flies are among terrestrial insects whose larvae develop in freshwaters. Upon emergence to adult stage, many are preyed upon by terrestrial vertebrates, which potentially propagate the re-introduction of microplastics from fresh water to terrestrial ecosystem. A study conducted by Akindele *et al* (2020) on ingestion of microplastic by fresh water insects in Nigeria revealed that *Chironomus* sp, (Diptera), *Siphlonurus* sp. (Ephemeroptera) and *Lestes viridis* (Odonata) irrespective of their different feeding guilds contain ingested microplastic in varying proportions.

Effects of plastic wastes

Effects of plastic wastes on soil organisms

Plastics have been found to limit the growth and activities of soil microorganisms, which in turn reduce the soil nutrients and productivity (Udochukwu *et al* 2021). Microplastics, when introduced in the soil led to the decrease in the population of nematode worms and microarthropods including oribatid mites, dipteran larvae, lepidopteran larvae and hymenopterans (Lin *et al* 2020). Inhibition of movements of microarthropods due to the filling of soil pores by microplastic has been reported by Kim and An (2019). Earthworm (*Lumbricus terrestris*), when exposed to various concentrations of microplastic in litter exhibited retarded growth and mortality at high concentrations (Huerta Lwanga *et al* 2016). Lin *et al* (2020) suggested that microplastic ingestion, change in habitat condition due to presence of microplastics and blockage of migratory routes are major factors that gave rise to the decrease in abundance of the exposed macroarthropods. Ingestion of microplastics by terrestrial organisms has been proven (Huerta Lwanga *et al* 2016). Microplastic ingestion could cause intestinal blockage and tissue damage in nematodes and earthworms (Ivar do Sul and Costa 2014; Huerta Lwanga *et al* 2016; Liu *et al* 2018). Studies have shown that microplastics can be translocated from the gut to circulatory system and can accumulate in tissues (Browne *et al* 2008). Soil nematodes are a group of important invertebrates that enhance decomposition of organic materials and nutrient cycling in the soil (van den Hoogen *et al* 2019).

Microplastics leach into soil and water sources from plastic waste dumps and landfills and contaminate the underground water, which many species rely on (Teuten *et al* 2009). Also, through bioturbation, microplastics are incorporated into the soil (Huerta Lwanga *et al* 2017, de Souza Machado *et al* 2018). Chlorinated plastics are known to contain harmful chemicals, additives and monomers (Teuten *et al* 2009), which seep into underground water placing soil organisms at risk of poisoning. Chemicals from ingested microplastics can be released into the digestive fluids and consequently transferred to the tissues of the organism (Teuten *et al* 2009). Decrease in population of these soil fauna as a result of impact of plastic pollution will indirectly threaten food security due to loss of soil fertility (de Souza Machado *et al* 2018).

Entanglements of plastics on land animals

Not much attention has been paid on impacts of plastic pollutants on land animals (Townsend and Barker 2014). One of the main environmental impacts of plastic waste is animal entanglement (Ryan 2018). Land animals are exposed to risk of entanglement (Townsend and Barker 2014), ingestion and chocking (Mee *et al* 2007; Teuten *et al* 2009). There are reported cases of accidental ingestion of plastic wastes by land mammals including elephants, hyenas, zebra, camels and cattle, resulting in death of these animals (Lai 2022). Ingestion of balloon by desert tortoise (*Gopherus agassizii*) and loss of limb as a result of balloon tangling has been reported (Walde *et al* 2007). Animals ingest plastics when they mistake it for food or prey due to its shape, colour or smell (Savoca *et al* 2016; Grant *et al* 2021) or by feeding on a prey that has ingested plastic (Hammer *et al* 2016). Plastic ingestion can block the digestive tract, which could lead to reduction in stomach volume and starvation of the animal involved (Derraik 2002). Wildlife can get entangled in plastic waste and become immobilized, injured and susceptible to environmental hazards and predation (Lai 2022).

Ospreys (*Pandion haliaetus*) are known to incorporate litter items to their nests, including bags, robes, toys (Bierregaard *et al* 2016), bailing twines (Blem *et al* 2002) and even plastic bottles (Ryan 2018). Blem *et al* (2002) in their studies observed that Osprey birds used twine obtained from agricultural lands in nest making. This led to twine entanglement on nestlings' legs and beak leading to starvation and death. Nestlings while leaving the nest have also been found to be suspended by the twine and would die without an intervention. Poly (2020) reported entanglement of adult Baltimore Orioele (*Icterus galbula*) with fishing net wrapped around its neck. The bird was found hanging dead on a tree branch near a reservoir in Ohio. A dead Barn Owl suspended by a fishing line in a tree at Chippewa Lake, Medina County was reported by Jones *et al* (2018). Incidence of death by strangulation was also reported of a female mourning dove (*Zenaida macroura*) through entanglement by a monofilament fishing line (Parker and 2007). Although bird entanglements by plastic and other synthetic materials appear to be greater among sea birds (Ryan 2018), impact on land birds should not be neglected. Fishing gear has been implicated in most bird entanglements both on water and land (Ryan 2018 and Jones *et al* 2018).

Plastic waste as pathway to invasive species

Plastics constitute one of the vectors for diverse invasive species, ranging from macro fauna to toxic microorganisms, which are capable of causing great damages in places far from their initial origin (García-Gómez *et al* 2021). Information on plastics as vectors of invasive species on terrestrial environment is scarce, but invasion of alien species on marine ecosystem vectored by plastic wastes has been widely documented (Burns and Winn 2006; Gregory 2009; García-Gómez *et al* 2021). Invasive species are primarily spread by human activities, often unintentionally and there has been an unprecedented rate of new introductions in recent years (Kim *et al* 2021). Invasive species are capable of causing extinction of native plants and animals, competing with native organisms for limited resources, altering habitats and thereby reducing biodiversity (Finch *et al* 2010). Invasion and colonization of native habitat by alien plants species can negatively impact animal species through alteration in habitat structure, hiding and shade cover, food abundance, arthropod emergence cycles, nesting and denning substrates, animal species composition, predation and parasitism rates (Finch *et al* 2010). Plastic packaging of imported goods may contain viable seeds, which can easily spread upon disposal to new environment. Encysted pathogens of human diseases can also be imported with plastic packaging, exacerbating the spread of emerging infectious diseases (Union of Concerned Scientists 2001).

The role of plastic wastes in vector breeding and spread of diseases

Trash (including plastic wastes) accumulation is among the risk factors of infectious diseases. Plastic pollution has become a major environmental health risk that promotes many vector-borne diseases (VBDs) such as dengue, chikungunya, zika, malaria, filariasis and zoonotic reservoirs (Krystosik *et al* 2020). The arbovirus vector, *Aedes* species, is notorious for the transmission of zika, dengue and chikungunya. *Aedes aegypti* and *A. albopictus*, prefer man-made containers for breeding. These breeding sites, mainly plastics include plastic bags, tea cups, buckets, tires, drums, coconut shells and other discarded household items (Chen *et al* 2009; Vijayakumar *et al* 2014; Jain *et al* 2016). Increasing deposition of waste plastic containers around households suggests an impending increase in the risk of vector-borne infectious diseases; nearly half of the world's population is at risk of dengue infection (MacCormack-Gelles *et al* 2018). In rural communities, these neglected diseases could remain undiagnosed, giving rise to high morbidity and mortality.

Microplastics can act as vectors of various parasitic pathogens. Significant number of parasites have been found clinging to the microplastics in marine water, which made their way to the sea from land (de Souza Machado *et al* 2017). *Leptospira interrogans* and *L. icterohaemorrhagia* are both causative agents of leptospirosis, a severe illness that may result in liver or kidney failure. They are common in urban areas where there is accumulation of trash but can also be found in debris littered around the rural households including buckets, jars, barrels and old tires (Munoz-Zanzi 2014; Krystosik *et al* 2020). Constituent of plastic waste has been found to reduce the life cycle duration of certain mosquito species. In the report of Valsala and Asirvadam (2022), the introduction of various concentrations of biphenol A (BPA), a derivative of plastic waste into the breeding water of the filarial vector, *Culex quinquefasciatus* reduced the duration required for adult emergence progressively. This completion of life cycle of this vector in rapid succession invariably results in a surge in the population of this vector, which in turn poses a greater public health risk of higher prevalence of the mosquito borne diseases as well as hampers control efforts.

Debris contained in discarded plastics attracts rodent pests, vectors of Bubonic plague, Lassa fever and scrub typhus (Vallee *et al* 2010; Munoz-Zanzi 2014). Rats and mice live in close proximity to humans and are common in crowded urban areas where plastic wastes constitute the common litter. Through their fur, saliva, urine and droppings, rats and mice can transfer diseases from contaminated areas and accelerate the spread of these diseases at a rapid rate (Meerburg *et al* 2009). Plastic wastes also play a role as carriers of pathogenic bacteria. Plastics are easily colonized by microorganisms soon after they are discarded in the environment. Pathogenic bacteria, fungi and even viruses have been isolated from surfaces of plastic wastes (Meng *et al* 2021; Liu and Schauer 2021) and which could be contracted through ingestion or direct contact.

Zoonotic protozoan parasites of terrestrial origin, including *Toxoplasma gondii*, *Cryptosporidium parvum*, and *Giardia enterica* have been found contaminating polyethylene microbeads and polyester microfibers in marine waters (Zhang *et al* 2022). Presence of microplastics have been detected in fish and other wildlife (Al-Jaibachi *et al* 2018), in this case, they constitute mediators of pathogen transmission to both wildlife and human (Zhang *et al* 2022).

The Covid-19 virus, SARS-CoV-2 can be vectored by plastics (Liu and Schauer 2021). Contaminated gloves and masks used as preventive barriers against infection with Covid-19 have been found indiscriminately disposed of in certain quarters (Caruso 2019). Since SARS-CoV-2 is able to survive on plastic for up to 78hours (van Doremalen *et al* 2020), airborne SARS-CoV-2 microplastic could extend to longer distances with the virus remaining viable (Liu and Schauer 2021).

Conclusion

The impact of plastic wastes on terrestrial biodiversity cannot be ignored. Plastic wastes impact land animals through entanglements and ingestion, and consequently, death. Contamination of natural habitat of soil organisms reduces activities of soil biota and threatens food security. Increase in prevalence of vector-borne diseases due to plastic waste is of serious concern. Efforts should be geared towards mitigation of harmful effects of plastic wastes on terrestrial wildlife through policies that regulate plastic production, use and disposal. Policies such as tax imposition on plastic production, ban on indiscriminate disposal of plastic wastes and environmentally sound management of plastic wastes are recommended.

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