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EFFECTS OF PLASTICS POLLUTION IN SOIL: AN OVERVIEW

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Abstract:

The objective of this paper is to discuss plastic pollution consisting of main sources, effects, and possible control. Soil pollution is instigated by plastic waste (due bulk production and inappropriate treatment), agriplasticulture, and flooding from waters among others. In soil, macroplastics is easily converted to microplastics or nanoplastics by agents. Most of the additives (which are mostly toxic) can easily leach to the soil to affect soil animals, microbes or be absorbed by the plants. Intake/ absorption/adsorption of plastics or additives by plants or animals channeled the toxic chemicals along the food chain. Plastics can be able to traverse the cellular membrane in eukaryotic or prokaryotic cells owing to their lipophilic constituents. Plasticiphere or eco-corona confer the plastics with tendency to act as vehicle for shuttling of toxic chemicals or adopt microbes in the plasticiphere. Some microbes utilize processes such as co-metabolism to degrade plastics or their chemicals. Albeit, this field received few attention, some studies have revealed that plastics can be able to adhere to plant body(root), can be incorporated to reach leaves and other parts of the plants. It can also be able to affect growth and *physiology of plants. Plastics in soil can alter soil quality, deplete soil organic matter stock, increase soil water repellence, reduce crop productivity, degrade soil, and increase greenhouse gases emissions. Plastics tend to change biological, chemical, and physical properties of soil. Parable, increased soil organic carbon, reduces soil organic matter accessibility to microbes, adhere to soil extracellular enzymes. To control plastics, laws and regulations shall be properly implemented. There is need for creating awareness among the public and stakeholders. Production innovation should be championed to make plastics that are biodegradable and recyclable.*

Keywords: Plastics, pollution, soils, waste, earthworm, plasticiphere

INTRODUCTION

Nowadays, plastic represent one of the largest and most economically important sector to our society. Parable, plastics are extensively used in packaging, car manufacturing, building and construction, and agriplasticulture. Global plastic production has reached unprecedented levels, with 322 million tons of plastics produced globally in 2015. Equally, 6, 300 million tons of plastic waste were generated, 9% of which was recycled, 12% incinerated, and 79% channeled to landfills or seeped to the environment. Inappropriate/inadequate plastic waste treatment, increased production, agriplasticulture, and relations, are global public health issues. Consequently, plastics reached our soils and in turn lead to pollution. Soil can store over 40, 000 microplastics tons per kilogram in its fold (Machado *et al*., 2019).

While the issue of plastics in an aquatic environment has been gaining attention, the problem of plastic pollution in soil has remained widely unexplored. Therefore, the public need to be sensitized on basic information of plastic pollution. The objective of this paper is to discuss plastic pollution consisting of main sources, effects, and possible solution.

SOURCES AND PATHWAYS OF PLASTICS IN SOIL

Terrestrial or soil environment gets plastics through ways and fashions. The main sources are either from land or aquatic litter (plastic waste) or plasticulture (Gionfra, 2018). Intentional agricultural sources of plastics to soils are: sewage sludge (which is added to agricultural soils), Controlled fertilizer (a method of encircling fertilizers with plastics to control release of fertilizer chemicals), Plastic mulching (an act of using plastic films on crops and seeds for protection), Plastic composting (an act of using household waste on soils as fertilizers).

Therein, there are plastics in the litter (Gionfra, 2018; Machado *et al*., 2019).

Sources of plastics to soil through agriculture

Plastics find their way to terrestrial environments through different sources. A distinction of sources and pathways can be made based on the type of plastic particles found in the environment – whether as intentionally or otherwise.

1. **Sewage sludge** – A widespread practice which is an important source of plastics contamination in soil is the application of sewage sludge from municipal wastewater treatment plants as a fertilizer for agricultural land. The practice is common in many developed regions, with Europe and North America processing approximately 50% of sewage sludge for agricultural use. Developing countries like Nigeria also deposits sludge in their farms. It is estimated that annual additions of microplastics to agricultural land in Europe are between 125 and 850 tonnes of microplastics/million inhabitants. This translates into a yearly input of microplastics in European and North American farmlands of 63,000-43,000 and 44,000-300,000 tonnes respectively (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).
2. **Controlled-release fertilisers** (CRF) – CRF is a fertilization technology which provides a system to reduce both the quantity of fertiliser needed per unit of area and manages the time of

application. The N, P and K nutrient combinations are encapsulated within a nutrient pill, a coating made with a polymer. The coating allows the fertiliser to diffuse into the soil over a given time period. While the technology offers a number of benefits for agriculture, it also represents an important source of microplastics contamination. The nutrient pill does not degrade after the nutrients have been released. Secondary microplastics are released during municipal solid waste collection, processing, transportation and landfilling. In addition, wind contributes to the dissemination of microplastics, either across land, or from land to water and vice versa. On land, secondary microplastic contamination is also linked to the use of agricultural plastics, such as polytunnels, silage bailing and plastic mulches. Additional plastic items used for agricultural purposes and which therefore represent potential sources of microplastic contamination in soil are containers, packaging and netting. Fragmentation on land is then enhanced through sunlight, which has a greater impact on these plastics than it does on those in the water (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).

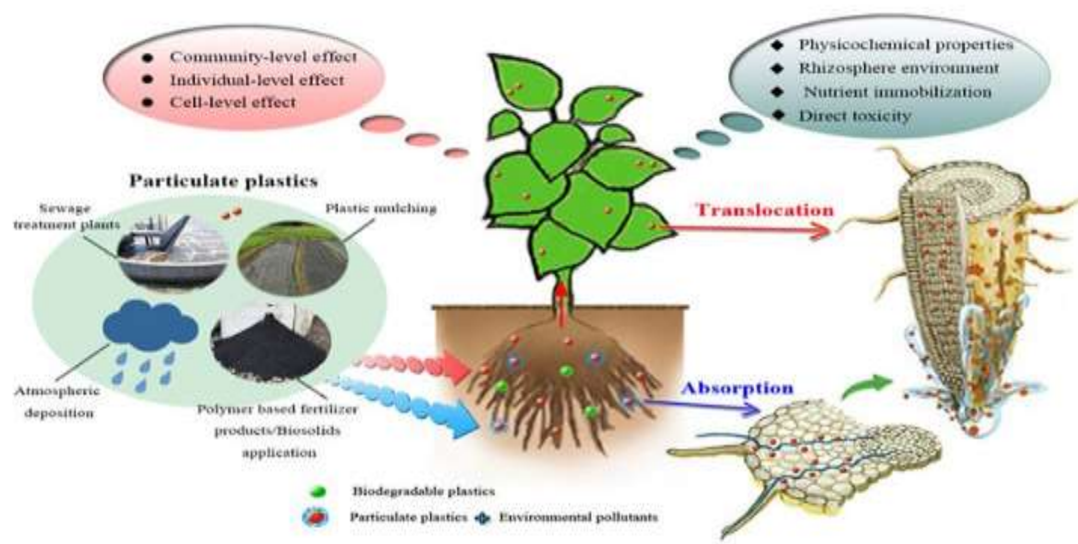
3. **Plastic mulching** – Plastic mulching is the use of plastic films on crops acting as insulation to protect seedlings and shoots. This technique is widely used due to the economic benefits its application offers, including increased crop yields, better crop quality, prevention of soil erosion and reduced pest pressure. Nevertheless, while the plastic mulches create the ideal microclimatic conditions to increase productivity, they also have a number of limitations. Plastic mulches are generally made of polyethylene (PE) which does not degrade well in the soil and therefore is associated with discharges of plastic residues. The use of PE also adds to the problem of recovering and recycling used mulching films. In some cases, plastic mulches are made with oxo-plastics. When used for this purpose, littering may increase as oxo-plastics are sold to farmers as products not to be collected after use.

However, research shows that the biodegradability potential of oxo-plastics is limited, therefore the use of oxo-plastic mulches contributes to plastic pollution in soil(Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).

4. **Plastic greenhouse** – Among the plastics used for agricultural purposes, plastics covering greenhouses have been identified as a source of plastic litter on land. The application of plastic greenhouses is a particularly intense practice in the Spanish province of Almeria (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).
5. **Plastics in compost** – Organic fertilizers obtained from household and industry recycled bio-waste are increasingly being applied on agricultural land and considered as an environmentally sound practice with several beneficial effects on soil. Nevertheless, recent studies have shown that the use of bio-waste as a source of fertilizer represents a potential source of microplastics contamination in terrestrial environments. This is due to the fact most bio-waste from households and industry contains plastics. For instance, an investigation carried out by the Italian Composting Council showed that organic waste collected in Italy had an average contamination of 4.9%, with non-compostable plastics representing the principal material found. Procedures such as sieving and sifting can help reduce the amount of plastics in fertilizers. However, small plastic particles are more challenging and are rarely removed completely (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).

EFFECTS OF PLASTICS ON SOIL

In soil, macroplastics is acted upon by agents such as wind, water, microbes etc. to form microplastics or nanoplastics which are more active (Sarkingobir *et al*., 2020ab). Therein, most of the chemical additives (of which are mostly toxic) are loosely bound to the plastic polymer chains, hence the additives can easily leach to the soil to affect soil animals, microbes or be absorbed by the plants. IN the event of intake/ absorption/adsorption of plastics or additives by plants or animals (eg. Earthworm, Collembola) transport the toxic chemicals to the subsequent steps of the food chain. Very tiny plastics (nanoplastics) can be able to traverse the cellular membrane in eukaryotic or prokaryotic cells because of their lipophilic constituents (Sarkingobir *et al*., 2020ab). Plasticiphere or ecocorona give the plastics capacity to act as vehicle for shuttling of toxic chemicals. Plastics have ability to adopt microbes in the plasticiphere. Some microbes utilize processes such as co-metabolism to degrade plastics or their chemicals. Albeit, this field received late attention, some studies have revealed that plastics can be able to adhere to plant body (root), can be incorporated to reach leaves and other parts of the plants. It can also be able to affect growth and physiology of plants. Plastics in soil can alter soil quality, deplete soil organic matter stock, increase soil water repellence, reduce crop productivity, degrade soil, and increase greenhouse gases emissions (Qi *et al*., 2018; Environmental Investigation Agency, 2019; Guao *et al*., 2020). Plastics tend to alter biological, chemical, and physical properties of soil. Parable, increased soil organic carbon, reduces soil organic matter accessibility to microbes, adhere to soil extracellular enzymes (and increase their half-life).



Source: Guao *et al*., 2020

CHALLENGING BEHAVIOURS OF PLASTICS

Consumer plastics basically contain resins, fibers, and additives. The resins (monomers) can contain remnants of un-polymerized units which can leach to food or other materials that are in contact with the plastics product some these plastics even carcinogenic. They include polyurethanes (flexible foam in furniture, bedding, carpet backing), PVC (pipes, wire cable coatings, packaging), epoxy resins (coatings adhesives, composites like carbon fiber, fiber glass) polystyrene (food packaging, CD cases, hard plastic in consumer products) (Sciences for Environment Policy, 2011). In the other hand, a wider range of chemicals are added to plastics to confer specific properties. Nearly, 93% of plastics are composed of monomers, while, the 7% composed additives. The plastic with highest number of additives is PVC (SEP, 2011) are of diverse functions. Softeners and plasticizers are added for flexibility, stabilizers and antioxidants are for durability against heat or sunlight and flame retardants. The most said toxic additives are flame retardants such as polybrominated biphenyl's(PBDE) polychlorinated biphenyl's (PCBs) phthalates, lead compounds (Women in Europe for a Common Future,n.d.; Group of Experts on the Scientific Aspects of Marine Environmental Protection, GESAMP; 2015; UNEP Prontiers, 2016; Laville, 2019; Romje, 2019; Rosane, 2019). There are quite a number of processes or properties of plastics or NPs which aid in making them readily harmful to biological systems. Some of these processes or properties are outlined below:

1,3 – butadiene- Is used as a monomer make rubber, plastic and relations. In humans, short term exposure to this chemical can lead to headache, fatigue, low blood pressure, central nervous system damage, and unconsciousness. Long-term exposure can cause cancer and chances of leukaemia (Sarkingobir *et al*., 2020ab).

Benzene-Is used as a solvent in making monomers during polymerization. Benzene is a bone marrow poison. Short-term exposure to benzene in humans causes headache, tremors, drowsiness, dizziness, and high exposure can cause death. I was shown to be associated with blood cancer (Sarkingobir *et al*., 2020ab).

Styrene -It can travel through the air to food and our body. Styrene exposure causes irritation of eyes, skin, and nose in humans. High exposure causes changes invasion, slow reaction times, cancer and problem in maintaining balance in humans (Azoulay et al, 2019).

Toluene -Toluene is used as solvent in production of plastics. Short-term exposure causes fatigue, weakness, memory loss, nausea and loss of appetite in humans. Long-term exposure causes irritation of the eyes, or lungs, headache and dizziness (Sarkingobir *et al*., 2020ab).

Propylene and propylene oxide-Propylene is used in the production of plastic fibers. Moderate exposure to propylene causes dizziness, drowsiness, and unconsciousness in humans. Propylene oxide is a classic carcinogen (Sarkingobir *et al*., 2020ab).

Polycyclic aromatic hydrocarbons (PAHs)-Certainly, about 100 chemicals are called PAHs. They are environmental toxicants and have negative health impacts. PAHs such as anthracene, perantherene, and pyrene can cause reproductive problems, tumours, low birth weight and birth defect in mice. Anthracenes cause headaches, nausea, loss of appetite, and inflammation of stomach and intestines. It also delays reaction time, and weakness (Saskachewan Ministry of Environmental, 2012; Azoulay et al., 2019).

Fragmentation – is a property of breaking down to smaller pieces through physical means. Degradation – refers to breaking down to smaller pieces through chemical means. Plastics have sorption properties in the sense that it can adhere or take in other chemical substances which might be harmful (Rist and hartmann, 2017; Giedre and Bethanie, 2018). Plastics ingested can bioaccumulate, or translocate (transported) within the body (Leslie, 2014). Biomagnification is a characteristic of plastics. It is an increase in concentration, along the food chain at the higher level. Plastics interaction causes-oxidative stress, inflammation, granulocytoma formation, lysosomal membrane destabilization, neutrophil trap release, cytokine regulation, non-specific responses (internalization) of plastics, lipid peroxidation, necrosis, perturbation of membranes ,activation of detoxification pathways, DNA stand break(Brande – levindsen, n.d.; Centre for the Study of the Economies, 2018; EarthDay Network, 2018; Giofra *et al.*, 2018; Environmental Investigation Agency, 2019; Food and Agriculture Organization of the United Nations, 2019; Fox, 2019).

Degradation-Is the breaking down of plastics into smaller pieces as a result of chemical action (Sarkingobir *et al*., 2020).

Biodegradation- Is the situation when exposure of plastics to UV rays, oxygen, high temperature, and microbes lead to degradation of nanoplastics to yield water, carbondioxide, energy, and new biomass (UNEP Frontiers, 2016; FAO, 2019).

Retention in biota- Tiny plastics can be taken up and retained in the biological systems, and potentially transport them to other places or incorporate them in the food chain (UNEP Frontiers, 2016; Gionfra *et al*., 2018).

Uptake by tissues, **cells-** Some studies examined the occurrence of tiny plastics in tissues or body-fluids. It was demonstrated that, plastics accumulate in the lysosomes, leading to breakdown and expulsion of enzymes and death of cells or organisms (FAO, 2019; ACS, 2020).

Vector to chemicals- Plastics have the ability to shuttle chemicals along. They can attached to hydrophobic or hydrophilic compounds and serve as conveying vehicle to chemicals including persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons(PAHs), and other hydrocarbons (ACS, 2018; Revel *et al*., 2018). Other chemicals include: DDTs, nonylphenol (NP), HCH, (PCBs), Polychlorinated biphenyls, polychlorinated dibenzofurans (PCDF), polychlorinated dibenzo-p-dioxins (PCDD). Plastics also transport microbes around their contacts (Wagner *et al*., 2014; ACS, 2018).

Leaching – Nanoplastics take in chemicals through sorption and these chemicals are easily leached to the environments or organisms. They also leach their additives to the environment or organisms. They also leach their additives to the surrounding. This leaching property is hastened by UV light or heat (Gebeshuber, 2007; Prust *et al*., 2020). Major or most of plastics release toxic monomers linked to cancer and reproduction effects. It might be due to incomplete polymerization, or heat/ UV/ mechanical actions. Many chemicals are found in plastics. Bisphenol A is monomer in some plastics, which disrupts hormones, causes cardiovascular disease, type 2 diabetes. Phthalates are industrial plasticizers found in plastics such as PVC. They are extremely found in plastics such as personal care materials. Certain phthalates are reported as endocrine disruptors (Science for Environment Policy, 2011).

Biomagnification- Plastics tend to increase in concentration in the tissues of organisms at successively higher levels in food chain (UNEP Frontiers, 2016).

Toxic monomers- There are many plastic monomers that are toxic to biological systems. Parable, styrene increases cancer risk. It has reproductive effects, effects on CNS (depression, fatigue, weakness, hearing loss etc), and effects on kidney, blood, stomach, and respiratory system (Agency for Toxic Substances and diseases, 1992).Vinyl chloride can cause effects on Nervous system, liver damage, and cancer (Agency for Toxic Substances and diseases, 1997). PVC causes pollution due to chlorine, cancer causing vinyl chloride, and ethylene dichloride ,dioxin, cadmium, lead, phthalates, tin etc (Centre for Health, Environment and Justice / Environmental Health Strategy Centre, 2004).

POSSIBLE CONTROL MEASURES

A range of measures are implemented throughout the plastics lifecycle which can either directly or indirectly reduce the leakage of plastics into soils and the wider environment.

Bans and phase-outs – Bans and phase-outs are widely applied to plastic products or even specific uses (e.g. cosmetics) due to the increasing concern over the health and environmental risks of certain plastics applications. Ban on microbeads in cosmetics: Microbeads are small plastics particles often used in cosmetic products. The presence of such particles in the environment (both terrestrial and aquatic) has given rise to a number of national restrictions and bans. A ban on microbeads in cosmetic products has been adopted in several countries including the Netherlands, the US, Canada, Australia, and most recently in the UK. A ban of this kind has the potential to reduce the presence of microplastics in sewage sludge which is then applied in agricultural land. Bans on single-use and/or non-biodegradable plastic bags: Several regulations have been introduced to regulate the use and sale of plastic bags. For instance, a ban on single use plastic bag exists in several countries and municipalities: 132 cities in the US, the city of São Paulo in Brazil (2007), the city of Paris (2007), France (2017) and Australia (with the exception of New South Wales) (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).

Taxes and charges – Taxes and charges are market-based instruments which provide incentives to reduce the use of certain materials, products or specific applications. Landfill tax: 20 EU Member States currently have landfill taxes on waste disposal encourages alternative waste management strategies such as recycling, composting and reuse. In Poland, a tax is applied on the landfilling of selectively collected plastics waste(Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020). .

Waste legislations – As part of the Circular Economy package (COM/2015/0614 final) adopted in 2015, legislative proposals have been put forward to revise the Waste Framework Directive (2008/98/ EC), the Landfill Directive (1999/31/EC) and the Packaging and Packaging Waste Directive (94/62/EC) – these proposals include revised waste management targets. Increased recycling and re-use targets for plastic packaging encourage better management of plastics, reducing leakage to the environment. The EU Strategy for Plastics aims to improve the economics and quality of plastics recycling, one of the objectives being all plastic packaging to be reusable and recyclable by 2030. Ambitious targets of this kind have an important impact on future investments in waste management infrastructure (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020).

Regulations – Regulations can help to determine how fertilizers are manufactured, handled and applied. The European Regulation (EC) No 2003/2003 relating to fertilizers ensures a common market for mineral fertilizers in the EU, however it does not address specific contaminants (such as plastics) or waste-based fertilisers in general. National legislation in some cases provides specific guidelines on contaminants. For example, Germany has one of the stricter regulations on fertiliser quality allowing a maximum of 0.1 weight % of plastics. Yet, particles smaller than 2mm are not taken into account.

Sewage sludge is commonly used as a fertilizer on agricultural land; however, concerns over the potential environmental and human health impacts has led to the introduction of regulations. While these regulations include limits on pollutants, microplastics contamination is hardly taken into account. The EU Directive (EU 86/278/EEC) on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture sets rule on how sewage sludge can be used by farmers. In particular, limits are set on the concentration allowances for 7 heavy metals (Machucha, 2013; Gionfra, 2018; Machado *et al*., 2019; Yong, 2020). Thus, there are some measures which need to be taken to address the looming plastics crises. The measures include:

- Product design- products should be manufactured in such a way that they can be recycled or biodegraded (Sarkingobir *et al*., 2020a).
- Bans- There should be ban on specific plastics, such as the most hazardous ones, non-biodegradable plastics, some single-use plastics.
- Taxes and charges- Elevation of taxes and charges will reduce the demand and supply for certain plastics (Sarkingobir *et al*., 2020a).
- Laws and regulations- There should be laws to screen the use of plastics on soils and indiscriminate refuse dumping.
- Public awareness- efforts are needed to make the public more aware of the dangers of plastic pollution. Knowledge incite reasonable decision making (Sarkingobir *et al*., 2020a).

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CONCLUSION

Plastics can be able to negatively affect soil in the same way it affects other parts of the environment such as air or water. In turn, plastics can affect soil microbes, animals, and plants. Plastics can be incorporated by the plants and shuttle them along the food chain.

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