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ENVIRONMENTAL IMPACT OF PLASTICS WASTE DISPOSAL ON LAND AND AIR POLLUTION: A REVIEW

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Abstract

This paper discussed the effect of environmental pollution as a result of plastics disposal. Little efforts are involved in some parts of the world associated to plastic waste collection, recycling and reuse. The identification and discussion of environmental pollution generated by plastic production and waste generated in the environment, negative impact of plastic waste disposed on our environment are performed in this paper and some technological measures for plastic waste reduction were highlighted. Although plastic polymers are not considered toxic, some residual monomers contained in the materials can be hazardous. Also, many chemical compounds used in the plastics manufacturing as additives, in particular plasticizers are dangerous to human health and the environment, along with some degradation products that may be released during the plastic life cycle. Plastic pollution is capable of affecting air, waterways and land as a large percentage of land creatures have died due to the fact that plastic is non-biodegradable and it causes hazards to soil. Plastic pollution in soils poses a major threat to soil health and soil fertility that are directly

linked to food security and human health. Plastics also emit toxic gasses when exposed or heated up. It blocks drainage lines and fill up land space causing floods and erosion thereby causing deterioration of the Nigerian roads. Plastics wastes are also harmful to human health; they may contain harmful acids which may lead to death. However, with the declination of oil prices and increase in plastic wastes, the world is tending towards energy and sustainable development. Recycling is one of the most important actions currently available to reduce these impacts and represents one of the most dynamic areas in the plastics industry today. Recycling provides opportunities to reduce oil usage, carbon dioxide emissions and the quantities of waste requiring disposal. This paper therefore seeks to identify favorable technological methods for plastic wastes management in Nigeria as a tool for solution to diversification and implementation.

Introduction

Advancement in technology and industrialization has brought with them the problem of waste management. Solid wastes such as plastic are now recognized as the greatest contaminants of land, air and water resources. A plastic is a polymeric material that may contain other substances to improve performance and/or reduce costs. Plastics are inexpensive, lightweight, strong, durable, erosion-resistant materials, with high thermal and electrical insulation properties. However, quite frequently plastics are also categorized according to key characteristics that are of relevance to manufacture, product design and end-use. Examples include thermoplastics and thermosets. Thermoplastics are plastics that can be melted when heated and hardened when cooled. These characteristics are reversible and may theoretically be carried out indefinitely, meaning that these materials can be reheated, reshaped, cooled and re-used repeatedly. Thermosets, on the other hand, are a family of plastics that undergo a chemical change when heated that creates a three dimensional network that cannot be re-melted and reformed. Historically, plastics were mostly produced in Europe and the United States. However, this has recently shifted to Asia. China is now the leading producer with 28% of global

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

production in 2015, while the rest of Asia, including Japan, produces 21% [plastic Europe 2016], i.e. nearly half the global production in 2015. Plastics contribute to economic growth (Plastic Europe, 20160) , but their current production and use pattern, on a linear model of 'take, make, use, and dispose', is a primary driver of natural resource depletion, waste, environmental degradation, climate change, and has adverse human health effects.

Current data estimate that plastics represent 4% to 12% by volume of the solid waste stream. Precisely because of their large visibility, plastic wastes (and particularly non-durable plastic products) have been viewed as a serious solid waste problem. Almost all aspects of daily life involve plastics, in transport, telecommunication, 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 application 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 and Neal, 2009). Substantial quantities of plastics have accumulated in the natural environment and in landfills. Around 10 percent by weight of the municipal waste stream is plastic (Barnes *et al.,* 2009). Plastic is one of the materials present in our everyday life, since it is used for a variety of purposes as it is inexpensive, versatile, lightweight and durable. Plastics together with rubbers have an interesting history of their development, to when the modern life cannot be considered without these two group of materials. While the rubber became indispensable at the beginning of the 20th century, the plastic industry started its major growth since 1930 (Brydson, 1999; Rosato and Rosato, 2013), with four major groups of thermoplastics which included polystyrene, polyvinyl chloride, polyolefins and polymethilmethacrilate (Fried, 2003). World production of plastics amounted 280 million tons in 2011 (Plastics Europe, 2012), of which: 235 million tons of primary materials (used in the production chain); 45 million tons used to produce the coating, welding, spraying, painting and varnishing; this represents an increase of 3.7% of world's production of plastic from the 270 million tons in the year 2010.

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

Environmental plastic pollution is discussed with a special focus on (agricultural) soils. Soils are a crucial interface in the environment. It is, therefore, likely that pollutants such as micro- and nano-plastic particles that are introduced into the soil can accumulate or be discharged from the soil through, e.g., erosive processes or deep displacement, and thus be transferred to other environmental compartments like the oceans

CATIGORIES OF PLASTICS IN OUR ENVIRONMENT

Plastics consumption generates large volumes of very persistent waste. There are seven catigories of plastics with large applications and use (Tachwali *et al.*, 2007):

(1) Polyethylene terephthalate (PET) - of which plastic bottles, fast food containers, plates, cups are made;
(2) High Density Polyethylene (HDPE) - used for manufacturing of colored plastic bottles, fabric softener, engine oil;
(3) Polyvinyl Chloride (PVC) – used for bottles and glass dish detergents, plastic mats;
(4) Low Density Polyethylene (LDPE) - of which juice bottles, cans mustard, beer bottles, other packaging systems are made;
(5) Polypropylene (PP) - used for bottle of syrups, yogurt jars etc.;
(6) Polystyrene (PS) - of which egg cartons, plastic cutlery, Petri dishes, plastic tubes etc.;
(7) Other type of plastic of which bottles and other

Environmental pollution

The result of deteriorating environmental situation in various countries and regions where environmental pollution is the most intense climate is warming; ozone layer is depleting, desertification. According to the definition adopted by the UN organization, "pollution is exogenous chemical substances encountered on a suitable place, at the appropriate time and in inadequate quantities."(Bjelajac 2011). According to the analysis (taken in early 20th century), it is concluded that the most polluted spheres are atmosphere and hydrosphere. Even the state of cosmic space around our planet raises serious concerns. In order to define the concept of the

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

environment, we must consider the basic ecological unit that has its own laws, which is characterized by complex factors of animate and inanimate nature. This unit is called an ecosystem. Environmental pollution consists of five (5) basic types of pollution, namely; air, water, soil, noise, and light. Air pollution is by far the most harmful form of pollution in our environment. Air pollution is cause by the injurious smoke emitted by cars, buses, trucks, train, and factories, namely sulphur dioxide, carbon monoxide and nitrogen oxides.

Environmental pollution can be natural and man-made pollution. Natural pollution includes; soil erosion, volcanic eruption desertification, earth quake and earth tremor. While man-made pollution includes; domestic activities (sewage, noise, dust, solid waste etc.), industrial pollution (electromotive waves, noise, industrial effluent, gaseous emission etc.), Agricultural pollution (herbicides, insecticides, vibration through machines, flora and fauna etc.), commercial activities (noise, vibration, solid waste include plastics, refuses, gases, particulates etc.) other man-made pollution are automobile emission and lumbering, (Bichi 2015)

The sources of pollution on the land includes; solid waste, overgrazing, land scarification, mining, land despoliation. A Pollution source in the air includes; noise in cities, heat, photochemical smog, automobile exhaust emission, industrial gases, dust/particulates from construction site, radioactivity etc.) (Bichi 2015) .The man as a conscious being has a great influence on the environment. According to the methodology of the World Health Organization, there are 26 risk factors to health, some dating from the environment that are considered to cause many diseases in the population children aged 0 to 19 years. The impact of economic and other activities on the environment may be different in character: direct (immediate) and indirect synergy. From the perspective of environmental effects of pollution are usually described in terms of which we have already pointed out: degradation, devastation, endangering the environment, in different time periods. It is possible to perceive the effects of pollution in air, water, soil, wildlife, human health, and so on. We can speak of long-termed and short termed effects of pollution. It can be very important to understand the concept of the working environment, if it is connected with the concept of

environmental protection in the context of discussions on environmental management. This can be done for many reasons. First, because of the connection of the working environment as part of the environment, there are connections and processes related to the operation and are of importance to the issue of the environment. There are several provisions in the law on safety and health at work and other regulations governing this area, which are directly relevant to the understanding of the relationship between the working environment and the environment. It is necessary to know not only the notion of working environment but also to bear in mind the definition of a number of other terms such as "hazardous materials", "danger", "dangerous phenomenon", "risk", "risk assessment", and so on. According to this law work environment defines the working environment in which the work is performed under specific operating conditions in the workplace, working procedures and relationships in the work process. Unfavorable changes in the environment caused by human activities, causing a change in the inflow of energy, radiation levels physico-chemical and microbiological composition of environmental pollution can be defined. The harmful effect of pollution, their effect is manifested in the anatomical and morphological structure, metabolism, growth process, at all levels of cellular organization, from the molecular to the cellular level, through individual and population to biocenosis and ecosystems.

According to (Avery-Gomm *et., al.* 2019), plastic pollution is thought to be a planetary boundary threat, as it is irreversible (low degradation, impossibility to recover all plastics), at planetary-scale, and likely to disrupt Earth system processes, either by having negative effects on ecosystems or by altering the physicochemical properties of the environment. However, removing all plastics from the environment seems impossible due to widespread environmental pollution with plastic particles of all sizes (Brennholt *et., al.* 2018)

Environmental Hazard of Plastic Waste Disposal

More plastic has been produced in the last years than was produced in the previous years. Globally, plastics demand rose from over 320 million tons in 2015 to more than 330 million tons in 2016 alone (Plastic Europe, 2017). This

implies that plastic waste is rapidly increasing its damage on all ecological systems and life (Kaza et., al. 2018). Invariably, plastics have affected man's daily living and its continued usage and production especially in most low-income nations is now worrisome, since they may not be able meet up with the advanced techniques of plastic waste management (Uwaegbulam et., al. 2018). Moreover, the qualities of plastics such as light weight and durability that make them so unique have in turn become a disposal problem. For instance, when used plastic products are trashed into the environment, they endure for long time in the surrounding due to the fact that they are durable, while those thrown into water bodies continue to float on the surface because they are of low density (Hopewel et., al. 2009). Thus, the damage these wastes are getting to life and the ecosystem is increasing thereby causing severe environmental hazards such as water pollution, soil pollution and air pollution.

Impact of plastic waste disposal on land pollution

Soils are the basis for food production and are linked to all other environmental compartments. An essential entry path of plastics and especially of micro plastics and also nano-plastics into agricultural soils is via organic fertilization. It is currently estimated that between 43 and 50 percent of all micro plastics introduced into the soils enter it via organic fertilizers (ECHA 2019). Contaminated plastics can discharge toxic substances into the soil, which could later flow into underground and other water sources in the surroundings. This can cause severe damage to the organisms consuming it water. With several types of plastics, landfill areas are constantly piling up large. About 90 percent of the micro plastic contained in the wastewater is retained during the treatment process and accumulates in the sewage sludge (Carr. et., al. 2016, Tagg, and Labrenz, 2018). Apart from that, synthetic polymers are regularly added during the drainage and treatment process of the sewage sludge. There are also many bacteria and pathogens in these landfills that promote the, biodegradation of plastics (Arthur and Sina, 2009). Land filling and pollution occurs when plastic wastes are not properly disposed of, they are carried by wind or animals and fill up land spaces, blocked drainages, pipes as shown in Figure 1 this chemical then get deposited into the soil, thus contaminating crops and nearby water source. The picture below shows PETE bottles blocking

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

drainage in Mubi North Local Government. Plastics wastes are hardly recycled in Nigeria with less than 12% being recycled and about 80% of these wastes end up in landfills and dump sites (Babayemi et., al. 2018). Meanwhile landfills have been reported to contribute about 20% of Green House Gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), sulphur and nitrogen gases, and fossil fuels (Verma et., al. 2016). Usually, most of these gases are released via organic matter (e.g. plastics) decomposition, not only are they able to cause landfill fires due to their flammability, they also reduce solar radiation, thereby leading to global warming (Hanafi 2018 , Okon 2018). Also, leachates from landfills contains heavy metals including lead, cadmium, mercury, pesticides, disinfectants, pharmaceutical wastes, organics and chemicals substances that could contaminate the groundwater. While mixture of toxic substances and decomposing organic matter from landfill sites could also alter the structure and texture of soils, hence hindering good agricultural practices and subsequently impact negatively on biodiversity (Hakeem et., al 2019).

Studied carried my (Burmamu et., al. 2014) on the environmental impact and management strategies of solid waste in Jimeta they observed that the problem of polythene bags is that they are not biodegradable and can remain in soils for many years without been decomposed which creates eye sore in the environment. They fly, litter and make the environment dirty as wind blows across the dumpsites; they are transported to other places by dry deposition. Small containers and barrels were the only collection, storage and dumping materials available in Jimeta.

Figure 1: Plastic bottles blocked drainages

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

Impact of plastic waste disposal on the air pollution

Air pollution is a mixture of solid particles and gases in the air. Car emission, chemicals from factories, dust, pollen and mold spores may be suspended as particles. In some cities of Nigeria like in Ibadan, Lagos, Kaduna, Kano etc., it is not hard to experience smog and poor air water due to burning of solid wastes (mainly plastic materials) as a means to waste management. These practices have continued to exist because of lack of enlightenment, ignorance of the effects and lack of waste collection infrastructure and sometimes stubbornness of the people. The painful thing is that they don't realize that the side-effects of plastic waste combustion are airborne particulate emission (soot) and solid residue ash (black carbonaceous colour) which can travel thousands of kilometers, depending on prevailing atmospheric conditions and enter our food chain possess a high potential of causing health and environmental concerns (Hanafi 2018). Plastic burning as an alternative method to plastic waste land filling is destruction, as there are lingering doubts over the possibility of atmospheric emission of harmful chemicals and heavy metals during the process of burning these plastic wastes. For example, plastic waste fumes emit ammonium substances and polyvinyl chloride. While polychlorinated biphenyls (PCBs), dioxins and furans are released into the atmosphere through burning of plastics which in turn bring about excessive possible environmental contamination (Alabi 2019). Plastic burning is less used for waste management compared to recycling. In addition, toxins released from plastic and food waste combustion can raise danger of heart disease, aggravate respiratory ailments, damages kidney, liver, nervous system, skin, causes cancer and possibly death (DESA 2013). Hence measures need to put in place such as recycling to reduce the rate of plastic waste burning in Nigeria.

The open burning or incineration of plastics has three negative effects: it releases CO_2 and black carbon – two very potent climate-changing substances (Wiedinmyer, 2014, Reyna 2018.) burning plastics, especially containing chlorinated and brominated additives, is a significant source of air pollution, including the emission of unintended POPs (uPOPs) such as chlorinated and brominated dioxins, furans, and PCBs (Valavanidid, 2008, Verma, R 2016) and burning plastic poses severe threats to plant, animal and

human health, because toxic particulates can easily settle on crops or in waterways, degrading water quality and entering the food chain (ibid 2016)

Negative Impact of Plastic waste disposal in the Environment

Plastics production consumes up to 6% of global oil production and is projected to increase to 20% by 2050 if current consumption patterns persist (Hopewell, 2009). Plastics are therefore a major contributor to greenhouse gas emissions: CO2 emissions from the extraction and processing of fossil fuel as plastics feedstock; and the combustion of waste plastics, emitting 390 million tones of CO2 in 2012 (Ibit 2016). On current trends, emissions from the global plastics sector are projected to increase from 1% in 2014 to 15% of the global annual carbon budget by 2050 (Ibit 2016)

Some plastics contain toxic chemical additives, which are used as plasticizers, softeners or flame retardants. These chemicals include some persistent organic pollutants (POPs) These chemicals have been linked to health issues such as cancer, mental, reproductive, and developmental diseases (North and Halden, 2013).

It is difficult to recycle some plastics without perpetuating the harmful chemicals they contain. Furthermore, some plastics are very thin, for example, plastic bags and films, or multi-layered, for example, food packaging, making them difficult and expensive to recycle (Ibid 2017). The lack of universally agreed standards and adequate information about the content and properties of some plastics also discourage recycling.

Plastics stay in the environment for a long time; some take up to 500 years to break down; this causes damage, harms biodiversity, and depletes the ecosystem services needed to support life. After climate change, plastic is the biggest threat to the future of coral reefs: it increases the likelihood of disease outbreaks by more than 20 times, threatening marine habitats that provide food and coastal protection (Lamb, 2018)

In the marine environment, plastics are broken down into tiny pieces (microplastics35) which threaten marine biodiversity [Browne. 2013]. New knowledge suggests that micro plastics are an emerging source of soil pollution (Rillig, 2012. Duis and Coors, 2016). The impacts of micro plastics in soils, sediments and freshwater could have a long-term damaging effect on

terrestrial ecosystems globally through adverse effects on organisms, such as soil-dwelling invertebrates and fungi, needed for important ecosystem services and functions [Machado 2018]. Up to 895 micro plastic particles per kilogram have been found in organic fertilizers used in agricultural soils (Weithmann 2018).

A significant proportion of disposed plastic ends up in municipal solid waste (MSW) (Ibid 2015). In many developing countries (Wilson, 2006), inadequate or informal waste management systems mean that waste is usually burned in open dumps or household backyards, including in cities linked to the top ten rivers which transport plastic waste to the sea. In other places, MSW is incinerated.

Technological/Engineering Management of Plastic waste Disposal in the Environment

Waste management is based on the hierarchy of the four R's: (Reduce, Reuse, Recycle, and Recover). Even though the priority is to reduce and reuse, intervening in production and consumption, some waste will be produced and should be properly managed as a resource (Thompson et., al 2009) through a suitable Integrated Waste Management System (Schneider and Ragossnig 2015). Reusing packaging is difficult, requiring recovery, sorting, and refill of packaging, and so it is scarcely used outside high-valued goods, such as electronics and vehicles (Liu et., al 2018). The following are some of the technological plastic waste management.

(1) Plastic recycling:

Re-use of materials and its separation from waste is called recycling. This involves the collection, separation, processing and manufacture of new products from the used items or materials. Everything that can be reused and not thrown away is recycling. Recycling can be:

- Primary (recycling which after proper preparation materials used to obtain the same product).
- Secondary (recycling, in which recyclable materials are conventionally processed using new technologies to the maximum possible efficiency) (*Todić 2008.* Recycling of plastics is one

INTERNATIONAL JOURNAL – ASD
VOL. 13 NO.2 MAR-2021 ISSN: 2760-4106

method for reducing environmental impact and resource depletion. Fundamentally, high levels of recycling, as with reduction in use, reuse and repair or re-manufacturing can allow for a given level of product service with lower material inputs than would otherwise be required. A range of plastics can be recycled including: polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and ABS (a copolymer of acrylonitrile, butadiene and styrene) polymers.

Plastic waste is naturally very difficult to decompose. If you are re-using packaging waste contributes to reducing the amount of waste and environmental pollution, saving raw materials and energy. The big problem is caused by unlimited use of plastic products and dumping their remains. There are many ways to recycle plastics, although essentially it all boils down to the same operation. The technological process is composed of seven stages:

(1) Waste collection, (2) Identification and selection, (3) Milling, (4) Rinse, (5) Spinning, (6) Material drying and (7) Storage.

Great attention is paid to creating plastics that will be able to break down under the action of microorganisms. These are the so-called biodegradable plastics. Not all plastic products can be replaced with biodegradable plastic. Considering the environmental impacts, recycling is the preferred method of waste management (Bernardo et., al 2016, Ross and Evans, 2003).

Mechanical Recycling: this refers to the processing of plastics waste into secondary raw material or products without significantly changing the chemical structure of the material [Plastics Europe 2020]. It is also the processing of plastic waste into products of different characteristics (Duru et., al 2019). In 2020, Sustainable Packaging Coalition referred to Mechanical Recycling as the operations which attempt to recycle wastes from plastics materials through mechanical processes such as grinding, washing, separating, drying, re-granulating and compounding. In mechanical recycling polymers stay intact, this permits for multiple re-use of polymers in the same or similar product effectively creating a closed loop, therefore, only thermoplastic polymers, such as PP, PE, PET, and PVC, can normally be mechanically recycled (Ignatyev et., al 2014). It is considered to be the best

technology to recycle polyethylene plastic waste materials into virgin raw materials, without altering the basic structure (Abota 2012).

(2) Feedstock and Waste-to-Energy

Waste-to-energy is the production of steam, heat, electricity, or fuel from waste. Waste-to-energy strategies for plastic allow recovering energy and overcoming recycling limitations such as the need for sorting by polymer and competition with virgin plastics. Reformulation of plastics into feedstock uses energy to recover constituents that can be used to produce fuels similar to gasoline (waste-to-energy) or to produce chemicals, lubricants, and carbon black (Schneider and Ragossnig 2015, Liu 2018).

Conversely, oxidation of plastics (incineration), considered high calorific waste (43.3 MJ_kg^{-1} for polyethylene vs. 42.5 MJ_kg^{-1} in heavy fuel oil), produces steam, heat, or electricity allowing energy recovery, reduction of waste volume, and elimination of harmful substances or organisms (Schneider and Ragossnig 2015 , Calcott and Walls 2000). Contaminated or mixed residues that cannot be recycled may be diverted to incineration (Calcott and Walls 2000, Ignatyev et., al 2014). Plastic waste can be used as an energy source in cement furnaces (Mokrzyck 2003), chemical waste incinerators, metal melting ovens (Ignatyev et., al 201)], and electric arc furnaces in steelmaking (Baytekin 2013). The resultant inert ash can be deposited in landfills or used in metal recovery programs (Calcott and Walls 2000) or aggregates in road construction (Ignatyev et., al 2014, Poulikakos et., al 2017).

(3) **Pyrolysis/thermal degradation**: the process of recovering energy and useful chemicals from plastic waste (Faravelli et., al 2001). Pyrolysis of plastic mixtures, focused on the decomposition of polymers at varying temperatures, enables simultaneous decomposition and classification of polymers (Marongiu et., al 2003).

Conclusion

Mismanagement and misuse of durable plastics has led to large accumulations of this material in the environment (plastic pollution), posing a risk to soil, air and water. Reducing environmental pollution is an important goal of sustainable waste management. Recycling is one of the

useful methods aimed at maximum utilization of energy and raw materials from waste. And is the most efficient way of managing plastic waste which has several potential benefits in various industries like construction and clothing amongst many others. Plastics that cannot be recycled can be recovered to produce chemical components (feedstock) or to produce energy (waste-to-energy). Only the waste produced by these activities should be landfilled. In this study we have identified and discussed some impacts and risks posed by 1plastics waste disposal on the soil and air pollution. Major technological/engineering methods of plastics waste disposed on the environment were highlighted.

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