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Plastics production, environmental menace and recycling-A review

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ABSTRACT

Plastic waste has now become a global issue, causing widespread concern about its impact on our oceans and our well-being. Plastic waste has exacerbated the environmental problem in several developing countries, including Nigeria. Growing human population, economic progress, and urbanization have exacerbated waste management and generation issues. This review paper, on the other hand, examines the environmental issues associated with plastic waste. It also identifies the parameters that will promote long-term plastic waste management.

1. Introduction

1.1 Plastic and its production

Plastics are petrochemical substance made from fossil fuel; a versatile and robust material commonly used in numerous applications such as; packaging, construction material, household and personals care products. (d'Ambri`eres, 2019; Milios et al., 2018; Mrowiec, 2017; Rodrigues et al., 2019; Uvarajan, Gani, Chuan, and Zulkernain, 2021). It was a Belgian chemist Leo Baekeland that created the first fully synthetic plastic in 1907. The demand for plastics has increased tremendously with regard to their flexibility in the last few decades. For the rapid increase of population in world, the amount of plastic waste also increases rapidly (Ahmed and Raju, 2015; Babayemi, Innocent, Oladele and Roland, 2019); a substantial growth in the consumption of plastic is observed all over the world in recent years and this has led to huge quantities of plastic-related

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wastes. A recent study conducted by Jambeck et al. (2018) and Agyeman et al. (2019) revealed that about 300 million tonnes of plastic waste (PW) were produced annually in the world where 8 million of them are being dumped into the oceans.

A substantial growth in the consumption of plastic is observed all over the world in recent years (Ferronato and Torretta, 2019). Moreover, Wang *et al*. (2020) reported that 400 million metric tonnes of plastic products were produced in 2018 and predicted to reach 500 million metric tonnes by 2025. In the European Union countries, about 50 kg of plastic was used by a person annually while 68 kg in the United States (Thiounn & Smith, 2020). Polyethylene and polypropylene seem to be the most domineering among the types available. Wahab et al. (2007) found that the plastic industry in Malaysia was monopolised by polyethylene and polypropylene. Similar thoughts shared by Khoonkari et al. (2015) also highlighted that polyethylene terephthalate (PET) is one of the polyesters widely used in the packaging industry in various forms. PET is majorly used as it has high strength due to its weight, is shatter proof and does not react with water and food; widely avail- able with its relatively low price in the market (Begum et al., 2020; Simsek et al., 2019).

Every year, approximately 6.5 billion tons of plastic wastes are generated globally; the disposal of these plastics poses a considerable threat to the environment (Chougule *et al.,* 2017). According to Gu and Ozbakkaloglu (2016) worldwide, plastic products contribute substantially to an ever-increasing volume of municipal solid waste (MSW) streams. In 1950, global plastic production was 1.5 million tons, which grew to around 370 million tons in 2019, with Asia as the largest contributor (51%), followed by the North American Free Trade Agreement (NAFTA) countries (PlasticEurope, 2021; Statista, 2019). It has been observed that a total production of plastics in 2015 recorded more than 322 million tons/year, and will increase to 400 million tons in 2020, with global plastic's production of 3.4% compared to 2014, expected to double in about 20 year time and possibly quadruple by 2050 (Alabi *et al.,*2019). Based on their response to the application of heat, plastics can be categorised into two main types namely thermoplastic and thermosets. Thermoplastics are plastics that can be melted and remolded repeatedly when heat is applied. Thermosets on the other hand, undergo irreversible chemical changes when heat is applied, thus cannot be reheated and remolded (Arhant and Davies, 2019; Brouwer et al., 2018; Post et al., 2020). Based on the particle size (PW) can be divided into microplastic which is less than 5 mm in diameter and macroplastic which are more than 20 mm in diameter.

1.1.1 Microplastic

Microplastics is identified as one of the emerging threats of plastic pollution in aquatic and marine environments (Alomar et al., 2016; Cincinelli et al., 2017). Microplastics are classified into primary and secondary microplastic. Primary microplastic is purposely manufactured by extrusion and grind-ing process to be used as raw material in other sectors such as cosmetics and microfibers (Gouin *et al.,* 2015); while, the secondary microplastics are created through mechanical, chemical or photolytic degradation of bigger pieces of plastic into fragmented pieces (Hurley *et al*., 2018). The source of the pollution is not yet agreed on. However, a considerable amount of studies found that microplastics enter into the water bodies from the municipal wastewater treatment plants (Michielssen et al., 2016). About 9000 particles of microplas- tics can be found per cubic meter effluent in the wastewater treatment plant (Mintenig *et al.,* 2017). Talvitie *et al*. (2015) found effluents in wastewater treatment plants have three times higher microplastic contents than the receiving water bodies despite the highly efficient wastewater treatment system. As a result, this indicated that wastewater treatment plants could be a possible source of micro- plastic pollution. However, in a contrary report Estahbanati and Fahrenfeld (2016) found a different connection between microplastics and wastewater treatment plants that most of the microplastics are removed in the primary treatment zones via solid and sludge settling process. The effluents were further purified in the secondary and tertiary processes. Thus there was a minimum amount of microplastic discharged into the surface water. Following that, Ziajahromi *et al*. (2017) reported that about 0.21 to 1.5 microplastic particles per litre could be found in the final wastewater effluent due to efficient treatment process.

1.2 Impact of plastic waste on the environment

PW is now widely recognised as a major contribution to environmental pollution, especially in marine and aquatic environment, resulting in a detrimental impact on wildlife (Wilcox *et al*., 2015). The large amount of disposable plastic products and the low recycling rate have caused serious pollution to the soil, environment and the marine environment. Microplastic could pose major biological problems to aquatic organism such as fish and mollusks, which often mistake these microplastics as food sources and such phenomena happen at all trophic levels (Van Cauwenberghe *et al.*, 2015). (Ma et al., 2016). reported that the marine organism's gut was predominantly filled with 1.5 to 7.6 polyethylene type of microplastic that was about 250 mm and less in size in each animal Similarly, Seuront (2018) indicated that the microplastic ingestion by microscopic organisms like zooplankton could pose adverse effects on the food chain. This will lead to health implications in the marine organisms such as blockage in the digestive tract, reduction in energy reserve disruption in the reproductive system and even alteration in deoxyribonucleic acid (DNA) level (Cunningham and Sigwart, 2019). Shruti *et al*. (2019) revealed that the effect of microplastic on a particular individual, group and population of fishes is still not fully established despite the ubiquity of microplastic pollution since most of the studies focusing on quantifying the microplastic in the environment.

Plastic pollution has become ubiquitous in terrestrial and aquatic ecosystems; in natural and built environments, raising concerns about potential harm to humans and nature alike. Plastic waste exposed to the environment creates problems and is of significant concern for all life forms. Plastic production and accumulation in the natural environment are occurring at an unprecedented rate due to indiscriminate use, inadequate recycling, and deposits in landfills. The environmental problems created by PW are evident in the increasing level of global plastic pollution in both land and ocean when thrown away aimlessly, leaving traces of dangerous chemicals (Balakrishnan and Flora, 2017; Garcia and Robertson, 2017). Due to its versatility and wide-scale uses, plastic litter and even small-sized particles, MPs, and NPs are present in soil (Kumar, Sarma and Bandyopadhyay, 2021), sub-surface systems (Lusher, Tirelli O'Connor and Officer, 2015; La Daana *et al.,* 2018) groundwater (Kumar and Sharma, 2021; Mintenig, Loder, Primpke and Gerdts, 2019; Panno *et al.*, 2019) atmosphere (Zhang et al.,2020; Mbachu, Jenkins, Pratt and Kaparaju, 2020; Chen, Fu, Yang and Wang, 2020), wetlands (Su, Nan, Hassell, Craig and Pettgrove, 2019), rivers (van Emerik *et al.*, 2020; Kumar and Sarma, 2021; Gonzalez-Pleiter et al., 2021;, Singh, Kumar and Sarma, 2021; Barcelo and Pico, 2020; Zhang et al., 2020), and marine environments [Bujaczek, Kolter, Locky and Ross, 2021; Amelia *et al.*, 2021; Pauna *et al*., 2019; Shen *et al*.,2020), among others, and they are also accessible in high-altitude ecosystems (Stefansson et al., 2021). Alabi *et al*. (2019) and Pinto Da Costa et al. (2020) found that the PW distribution is related to the human population, where the increase of human population will directly increase the demand for plastic products leading to environmental pollution.

Plastic causes an overabundance of problems when discarded into our environment. Plastic bags block waterways and clog sewers, providing breeding grounds for insects like mosquitoes that in turn proliferate malaria sickness. In poorer countries, plastic waste is burned as heat for cooking, exposing people to toxic emissions and contributing to poor air quality. Floating plastic debris worldwild is a threat to biodiversity. The Organization for Economic Cooperation and Development estimated that in 2019, plastic products were responsible for 3.4% of global greenhouse gas emissions throughout their life cycles, with 90% of these emissions coming from the production and conversion of fossil fuels into new plastic products. The World Economic Forum projects that without intervention, the global plastics industry will account for 20% of total oil consumption and up to 15% of global carbon emissions by 2050.

Plastic pollution can alter habitats and natural processes, reducing ecosystems' ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social well-being. According to Vaverkov´a (2019) the plastics longevity in the environment is still questionable due to their non-degradable and robust properties as it has only been mass produced in the past 70 years. However, these plastics might stay in the environment for decades (Borrelle *et al*., 2020). Besides that, when the plastics degrades, it will first break down into tiny pieces but the polymer itself might not degrade fully over time which may lead to the accumulation of plastic and result in environmental issue (Lelchat *et al*., 2020; Thompson et al., 2009a).

Several studies reported small-sized plastics as vectors for the transport of heavy metals and other toxic chemicals in different natural ecosystems because of the large surface-to-volume ratio and because of modifications in plastics properties. These modifications include increases in the surface area, adherence, flakes, fractures, avulsions, etc., which ultimately encouraged the adsorption and attachment of toxic chemicals onto their surfaces (Rillg *et al.,* 2019; Brennecke *et al.,* 2016; Hartmann *et al.,* 2017; Deng *et al*., 2020; Atugoda, Wijesekara, Werellagama, Jinadasa and Bolan, 2020; Atugoda *et al.,* 2021). There are many factors that affect the degradability of plastic. These factors are temperature, oxygen level and ultraviolet (UV) light exposure of the particular environment such as salt water and benthic environment (Auta *et al.*, 2017; Weinstein *et al.*, 2016); the salty environment and cooling impact of the oceans could lengthen the degradation process of PW (Awuchi and Awuchi, 2019; Lelchat *et al*. (2020). Besides that, when the plastics degrades, it will first break down into tiny pieces but the polymer itself might not degrade fully over time which may lead to the accumulation of plastic and result in environmental issue (Thompson *et al.,* 2009a).

1.3 Impact of plastic waste on the Marine

Marine pollution is the result of discharge of untreated wastewater, dumping of solid wastes and other polluted runoff from a variety of land-based activities directly into our rivers and coastal waters. (Sustainable Development Goal). Research indicates that more than 1,500 species in marine and terrestrial environments are known to ingest plastics (Van Raamsdonk *et al.,* 2020; McNeish *et al*., 2018). Plastic ingestion by aquatic organisms animals blocks their breathing pathways, leading to death (Kasamesiri and Thaimuangphol, 2020; Prata, da Costa, Duarte and Rocha-Santos2019; Neves, Sobral, Ferreira and Pereira, 2015; Bellas *et al*., 2016). Tokyo Institute of Technology (2020) reported that about 700 marine species have been ingesting tiny pieces of PW; with the seven known sea turtles species being the most affected animals in marine environment. Besides, Gabbatiss (2018) reported that the chemicals from plastics could cause behavioral changes in marine animals and make them vulnerable for predators' attacks. Plastics create major challenges for aquatic ecosystems; the pollution poses a threat to the marine environment. Eriksen *et al*. (2014) added that harmful chemicals like bisphenol A (BPA) could be released into the water during this degradation process, which is dangerous for marine organisms. Ingesting plastic is often fatal to animals because plastic blocks their digestive tracts, causing them to starve. Many marine species, such as turtles and dolphins, mistake plastic fragments for food.

According to Wilcox *et al*. (2015) about 99% of seabird and many other species will suffer from entanglement of plastic ingestion by 2050. Marine mammals also become entangled in plastic debris, causing drowning and suffocation, or becoming easy prey for predators. Styrofoam products, containing possible carcinogens such as benzene and styrene, are highly toxic when ingested and can damage animals' lungs, nervous systems, and reproductive organs. Chemicals ingested by these animals can make their way up the food chain onto our dinner plates (Lelchat *et al.,* 2020). Jambeck *et al*. (2015) projected that marine litter may harm almost 600 species by 2050; 90% of seabirds will be under threat due to plastics ingestion (Pazos, Bauer, Gómez, 2018; Silva-Cavalcanti *et al.*, 2017), and approximately 15% of the marine species come under endangered categories because of the ingestion and entanglement of plastics (Collard, 2019; Khan *et al.,*2020; Pegado *et al.,* 2018; Slootmaekers, *et al.,* 2019).

1.4 Impacts of plastic waste on wildlife and the Human Health

The high number of cases where animals are affected by PW increased annually. Alabi *et al.* (2019) found that animals are more likely to die due to PW ingestion than entanglement. Choy and

Drazen (2013) high-lighted that microplastic ingestion has been observed in almost every genus level in the Animalia kingdom. Besides polluting the soil and ocean (Marn *et al.*, 2020). PW also hinders the growth of animals and plants. Reddy (2018) reported that about 800 animal species worldwide were affected by plastic debris (Hamlet *et al.,* 2020). Harvey (2019) found about 3200 cases recorded in 2018 regarding damages done to wildlife due to discarded equipment like fishing nets and hooks that caused entanglement, deep wounds in the flesh and cutting off the blood supply. PW absorbs and accumulate other contaminants found around the marine environment like nonylphenol, PCBs and phenanthrene (Chandegera *et al.*, 2015). As a result, this would inevitably affect the food chain and be harmful to humans since toxic chemicals released by the PW could poison the marine organisms that are commonly used for human consumption.

Awuchi and Awuchi (2019) also shared findings where the chemical additives used in plastic production is carcinogenic and may cause endocrine disruptors in humans. According to the United Nations Environment Programme, microplastics have also been found in human livers, kidneys, and placentas. Additionally, the International Union for Conservation of Nature found that carcinogenic chemicals found in plastic products can leach into tap water, which may cause developmental, reproductive, neurological, and immune disorders. Some animal studies have raised similar concerns about endocrine-disrupting effects. Chris and Dan (2017) revealed that about 83% of tap water samples collected worldwide contained PW. Meanwhile, Barboza *et al.* (2020) found that seafood consumers are not aware of the microplastic exposure as the impact is in a minute quantity. Parent birds unintentionally feed their nestlings with PW as food leading to blockage and paralysing the gastrointestinal tract, chronic infection, and thus reduce the health level, which affect both adult and juvenile animals (Gray *et al.*, 2012); causing them to suffer from starvation, malnutrition and death (Galloway, 2015).

Rochman *et al.* (2014) suggested that the chemicals leached or absorbed by the plastic such as plasticisers and heavy metals, could disrupt the growth of animal embryos. Union for Conservation for Nature (IUCN) (2018) reported that invisible plastics were identified in a few samples collected from tap water and sea salt, which contain carcinogenic chem- icals and could disrupt human's endocrine system. One of the additives added in the production of plastic products is Bisphenol A (BPA) where the exposure of these chemicals may cause severe biological effects such as fertil- ity disruption (Caporossi *et al*., 2020). Apart from that, BPA is also said to cause damages to the gene responsible for thyroid hormone, body development and metabolism (Matuszczak *et al.*, 2019). According to the United Nations Environment Program (UNEP, 2018) single-use plastics (plastic bottles, caps, cigarette butts, grocery bags, lids, stirrers, straws, food wrappers, etc.) are evidence of poor waste management systems and our attitude toward natural ecosystems. These plastics have severe health and social impacts; these plastic particles possess toxic chemicals that can be carcinogenic and can also impact the nervous, reproductive, and respiratory systems

2.0 Stopping Plastic Pollution

Once in the ocean and the plastics breaks down into microplastics, drifts throughout the water column in the open ocean, it becomes difficult to retrieve the waste. Mechanical systems, such as Mr. Trash Wheel, a litter interceptor in Maryland's Baltimore Harbor, can be effective at picking up large pieces of plastic, such as foam cups and food containers,The solution is to prevent the entrance plastic waste into the rivers. This could be accomplished with improved waste management systems and recycling,(Shi *et al.,* 2016). Communities and stakeholders should participate in waste management.

Lack of participation of stakeholders and the community in environmental protection leads to the irresponsible dumping of large amounts of waste in the developing world. According to the WHO (2003), genuine involvement of members of the community in defining issues that concern them should be encouraged. As a starting point for material flow management, source separation of MSW whose purpose is to reduce waste generation and recovery of available resources is advisable (Govindan, Zhuang and Chen, 2022; Zhang, Lai, Wang B., and Wang Z., 2019; Chen, Wang and Hou, 2020; Moon, 2021). A "Separate Your Plastic at Source" (SYPAS) initiative should be instilled in every individual across our communities. When source-separation becomes a habit, random plastic dumping will be minimized. Ultimately, this mindset shifts the responsibility of waste management to local communities, driving higher participation—particularly in residential areas. The purpose of source separation is to select the most suitable value-added treatment method to improve the potential of resource utilization (Cudjoe, Yuan and Han, 2020; Li, Yang, Sun, and Wang, 2021; Xiao *et al.*, 2020a). According to physical waste composition and economic conditions in various regions, there are different requirements for source separation. Hong Kong introduced an optical bag system to encourage residents to put food wastes (FW) into green optical bags and other waste into shared plastic bags (Cudjoe *et al.*, 2020). In addition, Bulgaria included three containers: green (glass), yellow (metal and plastic), and blue (paper and cardboard) (Stoeva and Alriksson, 2017).

2. 3.0 Plastic Management and recycling

Many initiatives are taken to reduce the accumulation of PW such as recycling. Recycling PW was not very effective due to its labour intensive process and lower rate where only less than 10% from total PW composition was being recycled (Uvarajan, Gani, Chuan and Zulkernain, 2021). Concrete is ranked as the topmost man-made resource utilized in the construction industry It is mainly composed of cement, fine aggregate, coarse aggregate and water. Large quantities of component materials like sand, stones, cement are used; the demand of which is increasing in geometric progression (Saxena *et al.,* 2018; Veerakumar and Saravanakumar, 2018). This leads to the scarcity of the materials. With this philosophy in view, there is an urgent need for optimum reuse of other waste materials available. In the recent past, attention has been shifted to finding alternative sources and materials for the replacement of aggregates in concrete. Studies have found new methods to reuse the PW as a potential substitute to the conventional construction materials due to its robust characteristics (Yin et al., 2015). Incorporating recycled plastic waste in concrete production is a sustainable approach for both disposing of plastic waste and aggregate scarcity, due to its economic and ecological advantage (El-Nadoury, 2022; Ojeda, 2021; Zulkernain, Gani, Chuan and Uvarajan, 2021). There is a need to analyse the impacts of adding PW into the construction material in terms of the physical properties and compressive strength perspectives.

According to San-Antonio-González, Del Río-Merino, Viñas-Arrebola and Villoria-Sáez, (2015a) introduction of plastic waste in concrete is one of the logical methods to reduce the plastic waste problems (Lavang, Sherin and Shubha, 2019; Li and Kaewunruem, 2019; Liwin, Kannan, Ilamparlathi, Pugazharasan and Sharmila, 2019; Using waste material reduces the load on environment as well as reduces cost of production (Chowdhury, Mishra and Suganya, 2015; Jyotsana, Arya and Singh, 2017; Mustafa, Hanafi, Mahmoud and Tayeh, 2019). The use of plastic is also considered a cost-effective prospect (Abdelmoti and Mustafa, 2019; Thorneycroft, Orr, Savoikar and Ball, 2018), especially since the impurity of PW would not affect the concrete properties (Arivalagan, 2020). Previous studies showed that it was possible to use plastic waste in concrete production. Harini and Ramana (2015), Jambeck *et al.* (2018) and several authors explored the use of light aggregate based on polymeric waste, as a material in reducing the unit weight, the cost, the brittleness and the thermal insulation properties of building materials (Ahmed and Raju, 2015; Wongkvanklom, Posi, Homwuttiwong, Sata and Wongsa, 2019).

A significant number of studies has already been conducted, where plastic is used in various ways; high-density polyethylene (HDPE) were used **(**Badache, Benosman, Senhadji and Mouli, 2018; polyethylene terephthalate (PET) da Luz Garcia, Oliveira, Silva and Castro, 2021) and polypropylene (PP) (Islam and Shahjalal, 2021; Ozbakkaloglu, Gu and Gholampour, 2017; Vaccaro, Galvín, Ayuso, Barbudo and López-Uceda, 2021) were used. Plastic aggregates are used as a cementitious material (Bhosale *et al.,* 2019; Sjah *et al.*, 2018); as a fine aggregate (Umasabo and Daniel, 2020) or as coarse aggregate (Islam, M.J. Alam and Islam, M.R 2020) or fiber in concrete composites (Verma and kumar, 2016; Yin, Tuladhar, Sheehan, Combe and Collister, 2016).

Lokeshwari, Ostwal, Nipun, Saxena and Pranay (2019) worked on the utilization of waste plastic as partial replacement of fine and coarse aggregates in concrete blocks. Saikia and de Brito (2014) conducted on the effect of replacing coarse (CA) and/or fine aggregate (FA) in concrete with plastic. Similarly, the influence of adding fine LDPE waste in cement composites, as partial replacement of sand, on density, mechanical strength and durability properties of plastic cement mortars was evaluated by several studies (Jambeck *et al.*, 2018). The influence of shredded LDPE from plastic bags used as partial substitution of fine aggregate on the behaviour of concrete was analysed by Chaudhary, Srivastava and Agarwal (2014); Jain *et al*. (2018a). As a result, the workability, density, mechanical strength and modulus of elasticity of concrete samples decreased with increase in the plastic waste content, while penetrability to water rose. Poonyakan *et al*. (2018) found a significant reduction of thermal conductivity of LDPE-containing concrete composites at 30% volume fraction of LDPE content, when compared with the plain concrete. Other interesting works sought to find a solution to LDPE plastic pollution was presented by Azeko *et al*. (2021).

Pedreño- Rojas Morales-Conde, Pérez-Gálvez and Rubio-de-Hita (2019) verified the feasibility of using PC waste to produce lighter and mechanically improved gypsum composites, by using up to a 60wt% PC waste addition. Improved water-resistant properties of gypsum composites with the incorporation of plastic waste from rejected cables was analysed by Vidales-Barriguete, Atanes-Sánchez, Del Río-Merino and Piña-Ramírez (2020) used high-density polyethylene (HDPE) types of plastic to replace the fine aggregates in the concrete. Amalu, Hashim, Rejith and Vijitha (2019), Mohammed, Ali, Rajab and Hilal (2020) investigated used recycle plastic material to replacing the fine aggregates in the concrete mixture with concrete grade M20 as it is most commonly used in the constructional work. Arivalagan (2016) conducted experiment to identify the advantages of using PET waste plastic as replacement of sand. Jaffe *et al.* (2015) showed that the compressive strength at 28 days for concrete containing 10% and 20% of HDPE remain close to the control sample but when replaced unto 30% the concrete turn unusually weak. Sreenath and Harishankar (2017) stated that replacing sand by LDPP with 10% increased the compressive strength from 34.96N/mm^2 to 38.957N/mm^2. Jaivignesh and Sofi (2017) studied on mechanical properties of concrete using plastic waste as an aggregate. Jibrael and Peter (2016) studied the strength and behavior of concrete containing waste plastic

Purnomo, Pamudji and Satim (2017) had investigated properties of uncoated and coated plastic aggregates in the concrete mixture as to improve the surface texture of the aggregates. Pedreño- Rojas *et al*. (2019) verified the feasibility of using PC waste to produce lighter and mechanically improved gypsum composites. There are evidences that certain factors influence the results of PW in concrete. Gu and Ozbakkaloglu (2016) stated that the compressive strength of recycled plastic concrete is affected by the percentage of substitution (SPA), w/c ratio, the shape and size of particles.; inhabitation of cement hydration due to the hydrophobic properties of PW; the elevated penetrability and air-content of PW concrete and low cement-plastic bond which was due to the poor bond between cement and the plastics (Al-Hadithi and Alani, 2018; Almeshal, Tayeh, Alyousef, Alabduljabbar and Mohamed, 2020a; Almeshal, Tayeh, Alyousef, Alabduljabbar and Mohamed, 2020b).

4.0 Summary and Conclusions

Plastic pollution has become inevitable for human civilization.. Plastics production is increasing dramatically, and the negative impacts on our ecosystem are also increasing via micro- and nano-sized plastics. Both types of plastics are having significant negative impacts on the ecological functions of natural habitats. Despite the existing knowledge about the impacts of plastic pollution, plastic waste management is at a dismal level, especially in developing countries. Our review provides a comprehensive overview of the ecological, environmental, socio-economic costs, including linkages to climate change and SDGs, in the context of plastic pollution and plastic waste management. Since plastic pollution is ubiquitous, it needs to be treated as a global threat similar to climate change. The SDGs were developed to deal collectively with key global issues; therefore, they provide a global platform and they should properly address plastics pollution and its management to support other top priorities such as food security, human health, and sustainable economic growth promotion. Issues related to plastics are directly or indirectly linked and affecting global goals to achieve SDGs targets. There is need to develop clear mechanisms to address plastic issues for better monitoring, innovations, technology transfer, and collaboration between organizations and citizen science to take collective action. Research and innovation should be encouraged to reduce, reuse, recycle, and recover plastics and find eco-friendly replacements for plastics, and alternative solutions must be emphasized. In addition, empowering and educating communities and citizens to act collectively to minimize plastic pollution and use alternatives options for plastics must be proactively promoted and enforced.

Reusing PW in construction material has proven to be an alternative method instead of recycling or land- filling to tackle PW pollution. The following conclusions can be drawn based on the critical review on the review utilisation of plastic in various construction material: The durable properties of PW enable them to be an ideal material to be used in the construction. However, the smooth and low adhesion property of PW prevents them from binding with other components, thus result in lower compres- sive strength. Studies also found that PW as aggregate up to certain amount could enhance the compressive strength. PW increases the porosity by creating voids due to the low affinity nature of plastics, thus increasing the water absorption rate. There are correlations among the amount of PW added, adhesion force, porosity, water absorption rate and compressive strength. For instance, the high content of PW decreases the adhesion force and creates voids, increasing the porosity and water absorption but decreasing overall compressive strength. Most studies only focused solely on the compressive strength and rate of water absorption to evalu- ate the plastic added construction material's properties. Further studies are required on plastic added construction material considering different parameters such as fire resistance, flexural strength, leach- ing properties and skid resistance.

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