European Journal of Environmental and Civil Engineering

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tece20

Reusing plastic waste in the production of bricks and paving blocks: a review

Turkeswari Uvarajan, Paran Gani, Ng Chuck Chuan & Nur Hanis Zulkernain

To cite this article: Turkeswari Uvarajan, Paran Gani, Ng Chuck Chuan & Nur Hanis Zulkernain (2021): Reusing plastic waste in the production of bricks and paving blocks: a review, European Journal of Environmental and Civil Engineering, DOI: 10.1080/19648189.2021.1967201

To link to this article: https://doi.org/10.1080/19648189.2021.1967201

Published online: 23 Aug 2021.

EUROPEAN JOURNAL OF ENVIRONMENTAL AND CIVIL ENGINEERING
https://doi.org/10.1080/19648189.2021.1967201

Taylor & Francis
Taylor & Francis Group

REVIEW ARTICLE

Reusing plastic waste in the production of bricks and paving blocks: a review

Turkeswari Uvarajan[a], Paran Gani[a,b], Ng Chuck Chuan[c] and Nur Hanis Zulkernain[a]

[a]Centre of Research and Innovation, Quest International University Perak, Ipoh, Malaysia; [b]School of Applied Sciences, Faculty of Integrated Life Sciences, Quest International University Perak, Ipoh, Malaysia; [c]China-ASEAN College of Marine Sciences, Xiamen University Malaysia, Selangor, Malaysia

ABSTRACT

The environmental concern of plastic waste (PW) generation has escalated to an alarming level due to the versatility and high demand in various applications. In order to search for an effective way to utilise PW, reusing them for the production of construction material appears as an environmentally-friendly approach. This is also because conventional construction materials often consume high energy during production has caused many environmental impacts. This review paper summarises the previous studies on reusing various PW as raw material and aggregate for construction and its properties with special attention to bricks and paving blocks. This paper begins by illustrating on the properties of plastics and the impacts of PW to the environment. Followed by discussion on reusing PW and its impacts on the overall properties of construction material. This review found that limited studies had been conducted on the usage of PW in the production of the paving block. Besides, most of the studies focused predominantly on compressive strength and water absorption as the main parameters to evaluate the characteristics of bricks and paving blocks. It is concluded that the use of PW in construction material could possibly serve as a sustainable source for construction material in the future.

ARTICLE HISTORY
Received 26 May 2021
Accepted 7 August 2021

KEYWORDS
Plastic waste; plastic brick; PESTLE analysis; plastic paver; construction material

1. Introduction

Plastics are synthetic materials derived from fossil fuel used in a wide variety of forms in our everyday lives. The demand for plastics has increased tremendously due to their flexibility in the last few decades. 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 being dumped into the oceans. According to Malaysian Plastic Manufacturers Association (Malaysian Plastic Manufacturers Assosiation (MPMA), (2018), about 2.03 million tonnes of PW was produced annually in Malaysia, which primarily produced for packaging purposes followed by the electric and electronic sectors.

The increasing generation of PW has cause many environmental problems due to its low biodegradability (Ritchie & Roser, 2018). Many initiatives are taken to reduce the accumulation of PW such as recycling and banning single-use plastic. 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 (Ferronato & Torretta, 2019).

CONTACT Turkeswari Uvarajan sf_turkeswariuvarajan@qiup.edu.my, turkesconan@gmail.com Centre of Research and Innovation, Quest International University Perak, Ipoh 30250, Malaysia

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). Apart from that, the addition of PW could elevate the properties of construction material such as compressive strength, water absorption rate and durability. However, there are limited studies available regarding PW in the production of construction material as bricks and paving blocks (Bolden et al., 2013; Ferreira et al., 2012; Gawande et al., 2012; Manju et al., 2017; Mansour & Ali, 2015; Tam, 2011).

The main purpose of this review article is to provide an evaluation on the recent usage of recyclable PW as both raw construction material and aggregate in the production of bricks and paving blocks. Both advantages and disadvantages of using PW as raw material and aggregate are further elucidated. Besides, the PESTLE analysis was conducted to analyse various factors correlating with reusing PW as construction material.

2. What is plastic?

Plastics are a petrochemical substance made from fossil fuel and gas used in large quantities in developed and developing countries (Gilbert, 2016; Palm & Myrin, 2018; Vaverková, 2019). Plastics can be categorised into two main types based on their response when heat is applied: namely thermoplastic and thermosets. Thermoplastics are plastics that can be melted and remolded repeatedly when heat is applied, whereas thermosets on the other hand, undergo irreversible chemical changes when heat is applied, thus cannot be reheated and remolded (Arhant & Davies, 2019; Brouwer et al., 2018; Post et al., 2020). Plastics is a versatile and robust material commonly used in numerous applications such as; packaging, construction material, clothing, household, personals care products, and transportation (d'Ambrières, 2019; Milios et al., 2018; Mrowiec, 2017; Rodrigues et al., 2019).

Laville (2019) and Palansooriya et al. (2020) stated that 40% of the demand for plastic products belonged to throwaway plastic packaging which increased from 2 million tonnes in the 1950s to 380 million tonnes in 2015. A wide range of conventional materials such as glass, steel and wood are replaced by plastics due to the prominent characteristics and generation of plastic growing steadily over the 50 years (da Costa et al., 2016; Devezas et al., 2017). Awuchi and Awuchi (2019) found that every person discards at least two pieces of PW daily. Moreover, Wang et al. (2020) and Zhou et al. (2021) reported that 400 million metric tonnes of plastic products were produced in 2018 and predicted to reach 500 million metric tonnes by 2025. About 300 billion plastic bags were produced annually where 13 million out of it ended up in the marine environment which has cause the death of 100,000 marine wildlife (Wang et al., 2020). In the European Union countries, about 50 kg of plastic was used by a person annually while 68 kg in the United States (Plastic Insight, 2014; Thiounn & Smith, 2020).

Wahab et al. (2007) found that the plastic industry in Malaysia was monopolised by polyethylene and polypropylene which is also in line with the study conducted by (MPMA). 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 shatterproof and does not react with water and food. Moreover, PET is also widely available with its relatively low price in the market (Begum et al., 2020; Simsek et al., 2019).

3. Problems related to plastics

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 (Khoonkari et al., 2015; Balakrishnan & Flora, 2017; Garcia & Robertson, 2017). 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 (Kaiser, 2010; Wilcox et al., 2015). Rochman et al. (2013), Worm et al. (2017) and Harvey (2019) found that PW has become the center of attention since it does not break down in the natural environment and polluting the waterways. 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.

British Plastic Federation (2008) reported that about 4% of petrochemical feedstock is directly used in the production of plastic annually. An equal amount of fossil fuel is required to provide energy for the production of plastics. The U.S. Energy Information Administration (EIA) (2020) highlighted that most plastic products were produced using natural feedstock from crude oil refining. As a byproduct of natural gas processing, hydrocarbon gas liquids (HGLs) are produced which consist of olefins such as propylene (C_3H_6) and ethylene (C_2H_4) that are used as direct inputs in plastic manufacturing.

Sharuddin et al. (2018) and Thiounn and Smith (2020) reported more emphasis on the availability of petroleum and natural gas supply for an increasing future population than the ecological effects of dumping vast quantities of PW into the waterways. Similarly, plastic production that mainly relies on the finite source of fossil fuel will increase atmospheric carbon dioxide (CO_2) (Abdul-Latif et al., 2020; Cunningham et al., 2020; Dormer et al., 2013). According to Geyer et al. (2017), about 40% of the globally produced PW was discarded in a year and among 79% of these PW was accumulated in the landfills.

3.1. Microplastic

Based on the particle size (PW) can be divided into two (a) microplastic which is less than 5 mm in diameter and (b) macroplastic which are more than 20 mm in diameter. Various studies have reported on the inconsistent size characterisation of microplastic which prevents the direct comparison to evaluate the abundance, distribution and composition of microplastic in a various environment (Filella, 2015; Hidalgo-Ruz et al., 2012). 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; Hurley et al., 2018; Woodall et al., 2014).

Dubaish and Liebezeit (2013) highlighted that microplastics could be detected in sewage sludge and soil even after five years in the same location where it was previously discarded. Pinto Da Costa et al. (2020) and Wright and Kelly (2017) estimated that about 250 million tonnes of accumulated plastic will be ended up in the ocean by 2050 if no actions were taken. Microplastics can be are classified into primary and secondary microplastic. Primary microplastic is purposely manufactured by extrusion and grinding process to be used as raw material in other sectors such as cosmetics and microfibers from the textiles industry (Gouin et al., 2015; van Sebille et al., 2015). Meanwhile, the secondary microplastics are created through mechanical, chemical or photolytic degradation of bigger pieces of plastic into fragmented pieces or fibers such as fishing nets where plastic enter into the natural environment like a marine ecosystem (Alomar et al., 2016; Andrady, 2011; Hernandez et al., 2017; Van Cauwenberghe et al., 2015).

A considerable amount of studies also found that microplastics enter into the water bodies from the municipal wastewater treatment plants (Michielssen et al., 2016). About 0 to 9000 particles of microplastics can be found per cubic meter effluent in the wastewater treatment plant (Mintenig et al., 2017). Besides, Talvitie et al. (2015) also 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 microplastic pollution. In contrast, Carr et al. (2016) and 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 are further purified in the secondary and tertiary processes. Thus, a minimum amount of microplastic will be 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.

The main difficulties circle microplastic is the monitoring process due to wide distribution, sampling and identification (Eerkes-Medrano et al., 2015; Hale, 2017; Sobek & Gustafsson, 2014). Plastics with a higher volume-to-surface area ratio increases the difficulties in monitoring processes that affect public health and the environment (Science for Environmental Policy, 2011). 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). Avio et al. (2015) and Li 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 μm and less in size in each animal.

Apart from that, microplastics also act as a vector that carries harmful toxic compounds in the water into the marine organism's body via bio-accumulation (Ma et al., 2016). 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 (Wright et al., 2013). Cunningham and Sigwart (2019), Shruti et al. (2019) and Bakir et al. (2014) 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.

3.2. Impacts of plastic waste on environment

According to d'Ambrières (2019) and United Nations Environment Programme (UNEP) (2015), only 9% of the used plastic that ended up in landfills are recycled while four to 12 million metric tonnes of PW ended up in the oceans annually. Awuchi and Awuchi (2019) and Herberz et al. (2020) highlighted that most of the PW ended up in landfills are single-use plastics. Landfilling was considered as the most common and conventional method to waste management as they are affordable and require minimum attention on treatment, cleaning and separation (Torretta et al., 2016; Vaverková, 2019). However, due to limited space, landfilling has become the least preferable method and causing a major problem to the environment. Most of the PW remains at landfill sites due to improper waste management, resulting in long-term soil and underground water contamination that caused by the degradation of PW (Eriksen et al., 2014; Ihesiulor & Ugoamadi, 2011; North & Halden, 2013; Webb et al., 2012). Zmak and Hartmann (2017) and World Economic Forum Gilbert et al. (2016) estimated that the planet Earth could be covered with PW if all the waste is continuously to be sent for landfilling.

In recent years, there is growing concerned about potential environmental and public health effects related with landfills due to the types and quantities of toxic pollutants (Teuten et al., 2009; Nagy & Kuti, 2016). Alabi et al. (2019), Klemeš et al. (2020) and Pan et al. (2020) reported that PW which dumped into landfills might cause biotic and abiotic plastic degradation that eventually leach and contaminate nearby ecosystems. Besides that, gases like methane and carbon dioxide are released into the environment when decomposing the PW in landfills which contributes to the greenhouse gas emission (Alabi et al., 2019; Shen et al., 2020; Vishwakarma, 2020; Yadav et al., 2020).

Furthermore, recycling plastic could save energy as compared with producing a new material using virgin plastic. For instance, about 130 million kilo Joule (kJ) of energy are saved with one tonne of plastic being recycled. This could contribute to an annual energy saving worth 3.5 billion barrels of oil, equivalent to 176 billion USD (Hopewell et al., 2009).

On the other hand, PW incineration could result in release of carbon dioxide that cause air pollution and global warming (Chandegera et al., 2015; Cudjoe & Acquah, 2020). Even though incineration method is considered as an alternative option to landfills, however the release of toxic chemicals though this process is harmful to the environment (de Weerdt et al., 2020; Hamilton et al., 2020; Hardesty et al., 2015). Harmful chemicals such as furans, dioxins, polychlorinated biphenyls (PCBs) and mercury are some of the byproducts released which is detrimental to both nature and humans (Creton, 2017; Ihesiulor & Ugoamadi, 2011; Moharir & Kumar, 2019; Singh & Sharma, 2016). Along with these chemicals, soot and ashes produced through the incineration of PW which could settle on nearby plants, soil and water bodies (Padanyi & Foldi, 2014). Moreover, these harmful chemicals might react with the water bodies causing alteration in the pH and functions of the ecosystem (Isangedighi et al., 2018; Rajmohan et al., 2019). Subsequently, rainfalls could assist these pollutants to penetrate into soil and contaminate the groundwater which eventually may bio-accumulate in the food chain (Nagy & Kuti, 2016; Wanner, 2020).

Nonetheless, incineration is also used as an alternative method to eliminate the increasing amount of PW and reduce the need for new landfill sites (Assamoi & Lawryshyn, 2012; dos Santos et al., 2020; Istrate et al., 2021). Any energy content that can be used for the generation of electricity such as fuel for blast furnaces and cement kilns as well as the processing of diesel fuel by liquefaction processes, can be recovered through the plastic incineration process (Bruvoll, 2001; Escamilla-García et al., 2020 Yang et al., 2021).

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 (Vaverková, 2019; Borrelle et al., 2020).

However, these plastics might stay in the environment for decades (Andrady, 1994; Vaverková, 2019). Pocket Guide to Marine Debris (2003) reported that a plastic bottle would takes about 450 years to be fully decomposed. Meanwhile, Thompson et al. (2009b) found that there are fewer data on the accumulation of PW in the terrestrial and freshwater habitats than the marine environment. Similar thoughts shared by Bellasi et al. (2020) and Winton et al. (2020) that studies involving plastics in the freshwater systems are fewer than the marine ecosystem. Hence, this creates available knowledge gaps and causing trouble in understanding the total extend of the plastic problem.

Eriksen et al. (2014) and Ocean Crusaders (n.d.) reported that 5 trillion of plastic pieces floating on the ocean, and it takes about one year for the ocean to degrade the PW yet not entirely. Eriksen et al. (2014) also added that harmful chemicals like bisphenol A (BPA) could be released into the water during this degradation process, which is dangerous for marine organisms. Besides, the degradability of plastics depends on many factors such as temperature, oxygen level andultraviolet (UV) light exposure of the particular environment such as salt water and benthic environment (Auta et al., 2017; Weinstein et al., 2016). Moreover, the salty environment and cooling impact of the oceans could lengthen the degradation process of PW (Awuchi & Awuchi, 2019). Barnes et al. (2009) and Lelchat et al. (2020) found that the darkness and cold temperature of a benthic zone could affect the degradation rate of PW to be slower.

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). At the same time, Rochman et al. (2013), Min et al. (2020) and Beltrán-Sanahuja et al. (2020) have shown sorption of chemicals such as polychlorinated biphenyls (PCB) and polybrominated diphenyls (PBDE) from the seawater in PW depends on few factors such as physico-chemical properties and type of chemicals being exposed. Rochman (2015) found that due to the continuous weathering process, the PW being altered which elevated the concentration of chemical contamination accumulated on the surface.

The International Union for Conservation of Nature (IUCN) (Union for Conservation for Nature (IUCN) 2018), reported that most of the PW found in the marine environment originated from land, such as urban and storm runoff as well as sewer overflow. Urban coastal population growth is the essential reason for the intentional or unintentional accumulation of PW in the marine environment (Vegter et al., 2014).

3.3. Impacts of plastic waste on wildlife and humans

The high number of cases where animals are affected by PW increased annually. Harvey (2019) stated that about 597 cases in 2018 where PW affecting the wildlife, mostly marine animals were reported in England and Wales that constituted to about 21% of increment as compared to 473 cases in 2015. Jambeck et al. (2018) and Tokyo Institute of Technology (2020) reported that about 700 marine species have been interacting with PW from ingestion of tiny pieces and entangled with larger pieces of PW. Tokyo Institute of Technology (2020) also added that all seven known sea turtles species are the most affected animals with the presence of PW in marine environment. PW also hinders the growth of animals and plants besides polluting the soil and ocean (Marn et al., 2020; Wang et al., 2020). Reddy (2018) reported that about 800 animal species worldwide were affected by plastic debris which is a significant type of the marine debris. In 2050, about 99% of seabird and many other species will suffered from entanglement or plastic ingestion and 17% of these species will be listed as threatened or near-threatened species (Gall & Thompson, 2015; Wilcox et al., 2015).

Rodríguez et al. (2012) and Law (2017) suggested that the prevalence of these occurrences shows the severity of PW widespread among marine environments ranging from land surface until the benthic zone. Vegter et al. (2014) claimed that despite growing awareness of this problem, it is still difficult to recognise and minimise PW impacts on the marine biota. Besides that, Eriksson et al. (2013) stated that the effects of PW generally depend on various factors such as size, accumulation and degradation rate of PW and the ecological, economical, and social value of the particular habitat. However, extra precaution must be taken to distinguish between contaminants originating from the organism and PW (Teuten et al., 2009; Lusher, 2015).

Awuchi and Awuchi (2019) and Alabi et al. (2019) found that animals are more likely to die due to PW ingestion than entanglement. Boerger et al. (2010), Choy and Drazen (2013) and Wright et al. (2013) highlighted that microplastic ingestion has been observed in almost every genus level in the Animalia kingdom. Moreover, the susceptibility towards ingestion of PW varies according to the species (Vegter et al., 2014). Most of the animals ingested PW found in the ocean by mistaking it as a food source like jelly fish, cuttlefish and other small fishes since plastics have similar floating patterns like the other marine organisms (Hammer et al., 2012). Awuchi and Awuchi (2019) highlighted similar findings in seabirds as they have often mistaken the floating PW as their prey.

Moreover, the parent birds also unintentionally feed their nestlings with PW as food (Rodríguez et al., 2012). As a result, these animals which feed on PW will suffer from starvation, malnutrition and death as the PW damages its digestive system (Galloway, 2015). Furthermore, the ingestion of PW can lead 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).

Besides, Gabbatiss (2018) also reported that the chemicals from plastics could cause behavioral changes in marine animals and make them vulnerable for predators' attacks. Apart from that, Rochman et al. (2014) also suggested that the chemicals leached or absorbed by the plastic such as plasticisers and heavy metals, could disrupt the growth of animal embryos. Seuront (2018) indicated that microplastic leachates have a biological effect on gastropod such as *Littorina littorea* where it decreases its vigilance and antipredator responses in *L. littorea*. Comparable thoughts were shared by Carson et al. (2011) that PW accumulation could alter the physico-chemical process in the habitat, resulting in alteration of marine wildlife species from different parts of the ocean.

Several wildlife has died by drowning or suffocating entanglement caused by fishing nets, plastic cup holders, and plastic bags (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. Richards and Beger (2011) reported that there was a decline in the habitat of shallow-water coral reefs caused by the fouling in fishing lines, abrasion and suffocation. Besides that, Barboza and Gimenez (2015) also suggested that the marine organisms have rapidly colonised the floating PW on the ocean that left for an extended time.

Moreover, PW contaminants penetrate into the pelagic and benthic zone due to its small sizes. 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 (Erren et al., 2009; Karleskint et al., 2012).

Till present, studies on the effects of plastic on humans were narrowed and focus on specific topic only. Azoulay et al. (2019) commented that due to the insufficient information, it failed to address the importance and effects of plastic on human health at every stage of plastic life-cycle ranging from extraction to disposal. The uncertainties make informed decision-making process difficult from consumers up to the policy-makers level. 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 chemicals and could disrupt human's endocrine system. Andrews (2012) and Awuchi and Awuchi (2019) shared similar findings where the chemical additives used in plastic production is carcinogenic and may cause endocrine disruptors in humans. Meanwhile, Barboza et al. (2020) found that seafood consumers are not aware of the microplastic exposure as the impact is in a minute quantity. On the other hand, Rainieri and Barranco (2019) revealed a significant research gap that urgently required to be filled on microplastic ingestion by humans through seafood on human health.

Also, Chris and Dan (2017) and Kosuth et al. (2017) revealed that about 83% of tap water samples collected worldwide contained PW. One of the additives added in the production of plastic products is Bisphenol A (BPA) where the exposure these chemicals may cause severe biological effects such as fertility disruption (Cantonwine et al., 2013; Caporossi et al., 2020; Matuszczak et al., 2019; Ziv-Gal & Flaws, 2016). Apart from that, BPA is also said to cause damages to the gene responsible for thyroid hormone, body development and metabolism (Awuchi & Awuchi, 2019; Matuszczak et al., 2019).

4. Plastic recycling

Plastic recycling can be divided into two main process of (a) mechanical and (b) feedstock recycling. Mechanical recycling involves heating the thermoplastic waste up to its melting point and remolding the recovered polymer into pellets or directly in secondary materials. Meanwhile, feedstock recycling or commonly known as chemical recycling involves transforming the polymers by using heat or chemical agents to yield hydrocarbon products that can be used in the production of new polymer or fuel (Assamoi & Lawryshyn, 2012; Devasahayam et al., 2019; Lee & Liew, 2020; Meys et al., 2020; Schyns & Shaver, 2021). The main objective of chemical recycling is to elevate monomer yield under shorter time and milder conditions (Coates & Getzler, 2020; Khoonkari et al., 2015; Solis & Silveira, 2020). Chemical recycling can be further accelerated by the addition of catalysts like ionic liquid, enzymes and metal salts (Abdelaal et al., 2011; Sinha et al., 2010).

Pacheco et al. (2012), Francis (2016) and Thiounn and Smith (2020) stated that there are four stages of recycling: (1) primary recycling, (2) secondary recycling, (3) tertiary recycling and (4) energy recovery. In primary recycling, PW is turned into a new product by altering any of its properties. In contrast, in secondary recycling which is also known as mechanical recycling, the PW is physically reprocessed without altering its chemical properties to produce a new product for a different purpose than the original (Briassoulis et al., 2013; Corvellec et al., 2013; de Camargo & Saron, 2020). Tertiary recycling or chemical recycling uses chemical to break down the PW into its hydrocarbon monomers through hydrolysis or pyrolysis, which can produce polymer and fuels. In energy recover, the PW is incinerated to save energy in the form of heat (Corvellec & Bramryd, 2012; Marques et al., 2018).

4.1. Difficulties faced in plastic recycling

Mourshed et al. (2017), Willis et al. (2018) and Liang et al. (2021) highlighted that the recycling and reuse rate of PW is still unsatisfactory, despite the ongoing governments' initiatives. The Environmental Protection Department (2019) of Hong Kong reported that the public awareness of plastic recycling is still weak, and declining from 2013 to 2015. Similarly, the incentives given by the government for plastics recycling technology at the end-of-life of PW is still limited (Datta & Kopczyńska 2016; Eriksen et al., 2019; Garcia & Robertson, 2017; Vollmer et al., 2020).

These phenomena might be due to (1) insufficient recycling services or recycling collection points by government and recyclers and (2) lack of adequate knowledge of the citizens (Fielding et al., 2016; Maio et al., 2013). Malaysian Plastic Manufacturers Assosiation (MPMA) (2018) reported that the total consumption of virgin plastics in Malaysia had increased in the last few years. About 40% of these plastics are imported due to the unavailability of required grade and type in the local market. In 2015, about 34.5 metric tonnes of PW were generated among the municipal solid waste. Only 9% of it was recycled and 16% was incinerated, and 75% was left at the landfill (Thiounn & Smith, 2020). Jeswani et al. (2021) and Lazarevic et al. (2010) argued that the inefficiencies of plastic recycling could make notable environmental changes if recycled plastic is replacing virgin plastic in production.

One of the main problems in plastic recycling is the various combination of the additives such as dyes and types of plastic added during the production process to produce the desired final product (Hahladakis et al., 2018; Merrington, 2017; Nkwachukwu et al., 2013). The combination of raw materials makes the melting point and other properties of the PW to differ even within the same resin code. Thus, the whole sorting process becomes difficult to produce a new product (Eureka Recycling, n.d; d'Ambrières, 2019).

For example, plastic bottles that are usually produced through blow-molded method cannot be recycled together with tubes or trays produced through injection-molded method due to difference in the types of additives (Jambeck et al., 2015). The price for recycled plastic material varies on few factors such as colour, shape, processing method, nature of the material and the price of virgin plastic in the market (Singh et al., 2017; Sommerhuber et al., 2015; Wahab et al., 2007).

Besides, a limited potential buyer for the collected PW also contributed to being another factor for recycling to be a less preferable method. Most industrialists opt to produce a plastic product from a new non-renewable source, which is more cost-effective than recycled plastic (d'Ambrières, 2019; Khan et al., 2019). Nonetheless, the quality of plastic resin degrades when it is reheated, limiting its market value (Leal Filho et al., 2019).

Apart from that, PW collectors and recyclers often exploit the incentives and penalties system. For example, some plastic collectors recover the PW at the initial stage but did not send it to the recyclers for recycling but receive the incentives from the government and earn more by avoiding the charges related to recycling (Wang et al., 2020). The subsidies given by the government are not sufficient to cover the whole recycling process yet some recyclers who secretly disposed of the PW obtained it from the collectors (Long et al., 2019).

Another problem in plastic recycling is the cost of equipment. The efficiency rate of plastic recycling can be enhanced when the cost of the machines is more affordable (Ihesiulor & Ugoamadi, 2011; Milios et al., 2018; Zhao et al., 2018). Besides that, most of the raw materials for plastic production are imported, indirectly increasing the overall operational cost. The affluence of the recycling process depends on many factors such as cost of recycling, availability, the convenience of recycling facilities and awareness towards recycling (Carlsson, 2005; Sidique et al., 2010). d'Ambrieres, (2019) and Garcia and Robertson (2017) reported that the preparation process before plastic recycling is costly, labour intensive and require huge amount of energy. These high production cost will increase the price of the consumer's goods. When the PW is recycled and used as raw material, it will help to reduce the overall operational cost.

The plastic recycling method cannot be applied to all polymers as each type of plastic has distinct physical and chemical properties. Thermoplastics like PET are more likely to get recycled than other types of plastics due to the increasing trend of market demand (Khoonkari et al., 2015; Wang et al., 2019; Zander et al., 2018). Besides that, melting different plastics together will result in phase separation between oil and water layers. This will cause weakening of the structural strength in the final product, limiting the further application of plastic. Although the mechanical recycling method is a more preferable option, it is limited due to elaborated process and susceptibility of PW degradations (Ragaert et al., 2017; Thiounn & Smith, 2020). An alternative method to mechanical recycling is chemical or feedstock recycling. Chemical recycling allows the production of monomers or feedstock like fuels, which can be used in many fields to replace petrochemicals.

4.2. Proposed solutions in plastic recycling

Providing sufficient incentives and fundamental amenities to the PW collectors and recyclers could increase the recycling rate. Nakatani et al. (2017), Milios et al. (2020) and Wang et al. (2020) suggested that recycling of plastic involves three main key players; the collectors, recyclers and government. The main responsibility of the collectors is to collect the PW and channel it to the recyclers to use their technology to process the waste. Nevertheless, it is the government's responsibility to promote the plastic recycling industry by introducing relevant incentives and penalties. Other than that, the willingness of stakeholders to participate in the plastic recycling process would influence its effectiveness (Zaman, 2013; Nodoushani et al., 2016; Jia et al., 2019).

Besides, searching an alternative plan for regular plastics by using biodegradable plastics could be another feasible option. However, the cost of using the existing raw material to produce biodegradable plastics is more expensive than the petroleum-based plastics (Kabir et al., 2020; Oever et al., 2017).

5. Reusing plastic waste in construction sector

Over the last decade, studies on reusing PW in the construction industry as alternative material is increasing gradually. Reusing PW as a part of the construction material is considered by many researchers in recent times (Corinaldesi et al., 2015; Mir, 2015; Mohammadinia et al., 2019; Rajput & Yadav, 2016; Rokdey et al., 2015). Some studies showed PW can be added to replace the conventional material, but it is not widely used in the commercial-level application. To date, there has been little agreement on reusing PW in construction materials as it might reduce the compressive strength. However, there is evidence that PW enhances the compressive strength of the product (Awoyera & Adesina, 2020; Gu & Ozbakkaloglu, 2016; Kamaruddin et al., 2017; Sultan et al., 2020). Thus, 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.

5.1. Studies on utilisation of plastic waste as construction material

A considerable amount of literature has been published on the addition of PW in construction waste such as concrete, roof tile and cement bricks. This PW is used as raw material and aggregate in the production of construction material. The mechanical properties of construction material are discussed in following sections.

5.1.1. Density

Density of construction material varies according to the amount and types of materials used. Previous studies mostly used polyethylene (PE) in the production of construction material due to its recyclable properties and availability in abundance. Saikia and de Brito (2014) found that the density of concrete decreases as the amount of PET aggregate increases from 5, 10 to 15%. This is probably due to the light weight nature and round shape of PET aggregate that resulted in poor bonding. Similar findings were also recorded by Hameed and Ahmed (2019), where the density of light weight concrete decreased to 2.15 g/cm3 when 10% PET bottles were used as the alternative aggregate.

Besides PE, other types of plastics such as polyvinyl chloride (PVC), polypropylene (PP) and polystyrene also used in the production of construction materials. Kathe et al. (2015) studied using PE, PVC and PP as fine aggregate to replace fine sand in light weight concrete. This study proved that besides PW, aluminum powder additives could also be added to minimise the density. In another study, Akinyele and Toriola (2018) used crushed PP in 5, 10, 15, 20 and 100% to produce concrete as fine aggregate. The density of concrete is reduced as the amount of PP increases. These previous studies highlighted that the addition of PW could reduce the density, produce light-weighed construction material especially concrete in comparison with the conventional construction material. Besides that, it is also found that PW added as an alternative fine aggregate to replace sand to prevent sand exploitation. Besides that, PW also added in the production of self-consolidating concrete (SCC). Ghanem et al. (2021) utilised PP fibers in SCC found the density of PP unreinforced concrete is higher compared to PP reinforced concrete.

5.1.2. Compressive strength

Compressive strength is a widely considered parameter for any construction material. Saxena et al. (2018) utilised PET as fine and coarse aggregate in concrete. The results showed that the size of PW aggregate does play a role in compressive strength as concrete with fine aggregate have lower strength of 5.4 N/mm^2 as compared with coarse aggregate concrete (6.9 N/mm^2). Meanwhile, Saikia and de Brito (2014) used PET as aggregate in various size and shapes; pellet-shaped (PP), coarse particle (PC) and fine particle (PF) in concrete. The findings suggested that the round shape of PP help the PW to mix well with cement paste and achieved the highest compressive strength. The sharp edges of PC and PF resulted in poor bonding and reduced compressive strength.

Hameed & Ahmed (2019) also used PET as aggregate in lightweight concrete production. Similarly, the compressive strength decreases as the amount of PET increases and the highest compressive strength (20.72 N/mm^2) was recorded when 1% of PET was used. In a similar application, Kathe et al. (2015) utilised PVC, PP and PE found that the compressive strength decreases as the amount of PW increases. A similar trend was also observed in Rai et al. (2012) where an increasing amount of PW decreases the compressive strength. In another study by Panyakapo and Panyakapo (2008) melamine was used to produce lightweight concrete. The results showed that a high proportion of melamine decreases the compressive strength of concrete.

These studies showed that replacing PW as aggregate in the production of concrete decreases the compressive strength. This is mainly due to the bond between plastic and cement paste weaken by absorbing a high amount of water. Apart from that, the poor adhesion property of PW with cement plastic reduces the strength regardless of types, size and shape of PW.

Similar results were also reported in fiber-reinforced SCC, where increasing PP decreases the compressive strength Ghanem et al. (2021), due to poor dispersion of fiber. Besides that, the shape of PW could create voids that resulted in poor compressive strength. Zaroudi et al. (2020) demonstrated the compressive strength of SCC increases with PW content up to a certain level and decline with a further increase in PW. The reduction in compressive strength of PW reinforced SCC proved that PW could affect the bond properties and frictional pull-out behaviour (Mastali et al., 2018).

PW is also utilised as in the production of cement mortar and road construction as aggregate. Similar pattern was observed in the compressive strength as a result of mortar from the past studies. High-density polyethylene (HDPE) (Eweed et al., 2018), low-density polyethylene (LDPE) (Ohemeng & Ekolu, 2019) and polypropylene (PP) (Akinyele & Toriola, 2018) were used in the production of mortar. The increasing amount of PW aggregate decreases the compressive strength of mortar. This was mainly to due to the smooth surface of PW aggregate which weaken the adhesion between cement paste at the interfacial transition zone. This may result in high porosity of mortar that reduces the compressive strength.

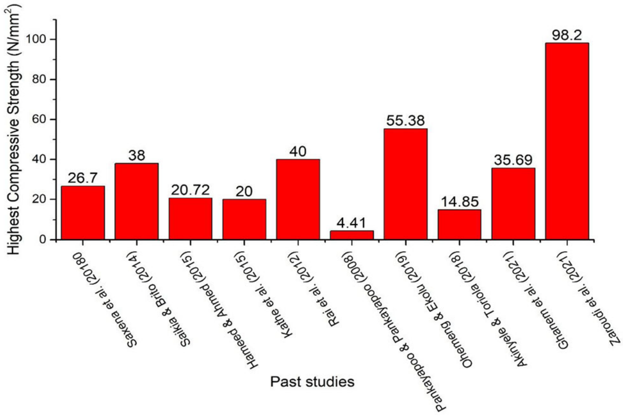

Figure 1. Highest compressive strength of plastic waste included construction based on previous studies.

However, the addition of PW in modified bitumen concrete for road construction showed a positive result (Sarkar & Pal, 2016). The findings proved that robust properties of PW helped to increase the compressive strength in road construction.

In an investigation on utilization of PW in asphalt modifier, Junaid and Jan (2016) used LDPE to produce modified hot mix asphalt (HMA) in various percentages. The findings suggested that increasing amount of LDPE improved the overall strength and performance of HMA. Besides, the LDPE also reduced the tendency of HMA to become soft and less susceptible to temperature change. Similar results were reported by Sultana and Prasad (2012) which evaluated the potential of HDPE, LDPE and PP as a modifier for asphalt concrete and cement concrete pavement. In addition, the asphalt modifier with LDPE aggregate showed higher compressive strength than HDPE and PP aggregate that could be used as a modifier in road construction. Figure 1 shows the highest compressive strength of construction materials from previous studies on construction material.

5.2. Findings on the use of plastic waste in the production of bricks

Bricks have a remarkable history as the main construction and building material. The demand for bricks is expected to be continuously rising due to the substantial increment in new construction projects (The Freedom Group Incorporation Press Release, 2014; Brick Hunter, 2018). Generally, there is two main types of brick used in construction, (a) clay bricks and (b) cement bricks. However, these two types of bricks consumed much energy and raw materials in the production stage, which results in a shortage of the raw materials. Numerous studies have attempted to utilise PW to produce bricks as an alternative option towards the circular economy and environmental protection (Manjarekar et al., 2017; Nursyamsi et al., 2019; Taaffe et al., 2014). PW used in the production of bricks in raw material, aggregate and additive will be discussed in the following sections.

5.2.1. Plastic waste as raw material

5.2.1.1. Water absorption rate. Aiswaria et al. (2018) to produced bricks by incorporating melted PET bottles with manufactured sand (M-sand). The results showed that the water absorption rate decreases as the PET content increases. Similar findings were also recorded when increasing the amount of PET (Hiremath & Shetty, 2014) and PW (Mahajan et al., 2018) could decrease the water absorption rate of the bricks. Besides PET, bricks made of a compact disc (CD) and sand recorded lower water absorption as compared to the conventional bricks (Singh et al., 2017). Thirugnanasambantham et al. (2017) also proved that the water absorption rate of plastic bricks is lower as compared with fly ash bricks. Alighiri et al. (2019) suggested that the low water absorption rate of plastic bricks was due to the low porosity of PET and an increase in the amount of PET. The water absorption rate of plastic bricks is also influenced by the size of aggregate. Misal et al. (2019) demonstrated that the water absorption of bricks with 4.75 mm sand has higher water absorption rate of 5.7% at 1:5 plastic-to-sand ratio as compared with

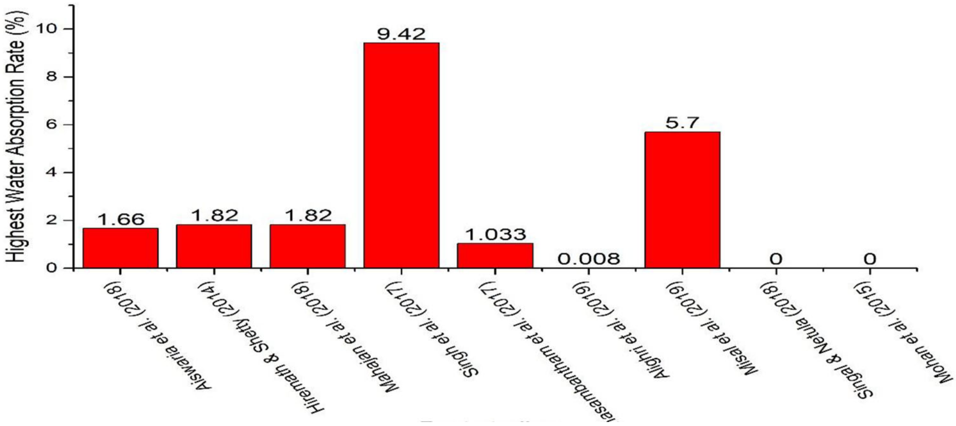

Figure 2. Highest water absorption rate of bricks uttilised plastic waste as raw material based on previous studies.

1.8% when bricks produced with 600 μm sand size. Other studies also demonstrated that bricks made up of PW showed no change in terms of water absorption rate (Singhal & Netula, 2018; Mohan et al., 2016). These studies suggested that the hydrophobicity nature of plastic waste could decrease the water absorption rate of plastic bricks. Figure 2 shows the highest water absorption rate of bricks utilised plastic waste as raw material based on previous studies.

5.2.1.2. Compressive strength. Aiswaria et al. (2018) manufactured bricks by incorporating melted PET bottles with manufactured sand (M-sand). The compressive strength increases along with plastics content up to a certain limit and subsequently, it decreases. Hiremath and Shetty (2014) also demonstrated produce brick using PET waste along with laterite quarry waste and bitumen. The study recorded that the compressive strength of brick depends on the percentage of plastic. Similar thoughts were shared by Mahajan et al. (2018) and Alighiri et al. (2019) as the compressive strength of bricks increases as the amount of PW increases. Another study by Singhal and Netula (2018) indicted that bricks produced using melted PW with stone dust recorded the highest compressive strength of 5.6 N/mm^2. This showed that higher PW content could elevate the compressive strength of the bricks. Mohan et al. (2016) showed that the highest compressive strength (11 N/mm2) was recorded when 70% of PW was used.

Besides PET waste, compact disc (CD) was also utilised to manufacture bricks by Singh et al. (2017). The study suggested that bricks made up of PW have higher compressive strength (10.6 MPa) as compared with the conventional bricks (1.77 MPa) and light-weighted. This is further proved by Thirugnanasambantham et al. (2017) where bricks made up of PE bags can be used as raw material in bricks production replacing clay. The results demonstrated that plastic sand bricks made up of PE bags have the highest compressive strength of 5.56 N/mm^2 as compared to fly ash bricks (3.38 N/mm^2). Following that, Shah et al. (2017) revealed that bricks made up of 100% plastic dust have higher compressive strength as compared to burnt bricks and are lighter in weight. Shiri et al. (2015) also found that bricks made up of LDPE and PP have the highest compressive strength up to 6.30 N/mm^2 which is higher than the clay bricks (3.63 N/mm^2). These studies highlighted that bricks made up of plastics will sustain a higher load and have greater compressive strength than conventional clay bricks.

Besides the amount of PW, the types of PW also assist to determine the compressive of the plastic bricks. Intan and Santosa (2019) proved that bricks with LDPE have less strength as compared with PET due to their molecular weight and intermolecular forces. Another factor which affects the compressive strength of plastic bricks is the size of aggregate. Misal et al. (2019) showed that bricks made up of coarse sand grains of 4.75 mm have higher compressive strength (6.7 N/mm^2) as compared with 600 μm sand (6.5 N/mm^2). The obtained results are attributed to the finer sand which absorbed more water resulting in insufficient water for hydration that caused reduction in workability and strength (Ling et al., 2020).

On the other hand, studies also reported that the addition of PW to the production of bricks decreases the compressive strength. Daftardar et al. (2017), examined LDPE bead as a raw material in bricks manufacturing using an extruder. The findings evidenced that the compressive strength decrease along with

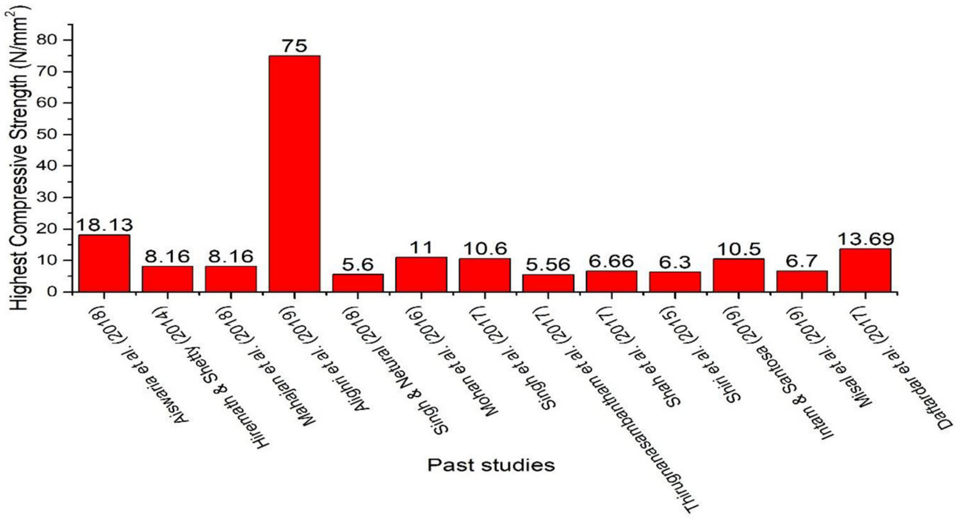

Figure 3. Highest compressive strength of bricks utilised plastic waste as raw material based on previous studies.

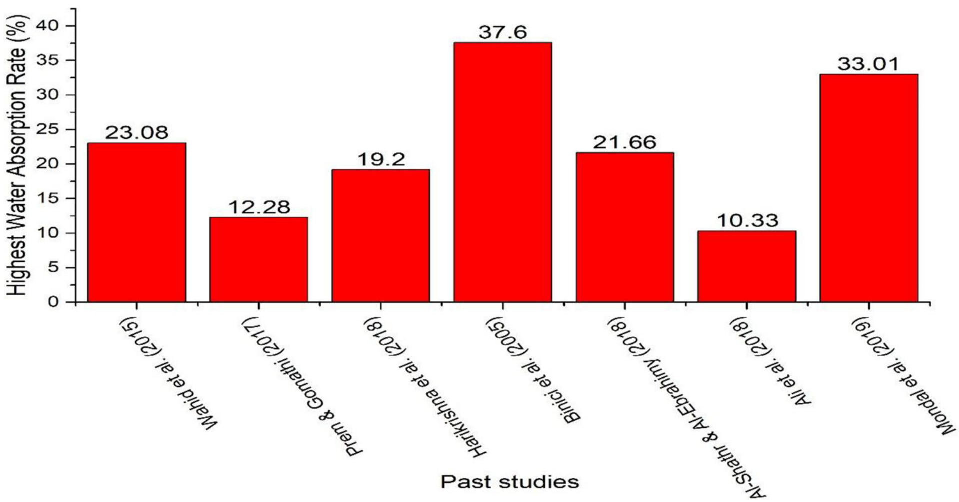

Figure 4. Highest water absorption rate of previous studies on bricks incorporated with plastic waste aggregate.

the amount of LDPE beads despite higher in strength and lower weight as compared with the conventional bricks. Figure 3 shows the highest compressive strength of bricks utilised plastic waste as raw material based on previous studies.

5.2.2. Plastic waste as additive and aggregate

Usage of PW as an aggregate could reduce the needs and demand for natural coarse and fine aggregate (Araghi et al., 2015; Rahmani et al., 2013).

5.2.2.1. Water absorption rate. The water absorption rate of bricks depends on the amount of PW aggregate used. Wahid et al. (2015) observed the water absorption rate decreases as the amount of PET increases. As the PW increases, the porosity decreases due to compaction that resulted in decreased water absorption rate. In contrast, Prem and Gomathi (2017) and Harikrishna et al. (2018) showed the water absorption rate increases along with the amount of PW. The highest water absorption rate of 12.28% (Prem & Gomathi, 2017) and 19.2% (Harikrishna et al., 2018) were recorded when highest

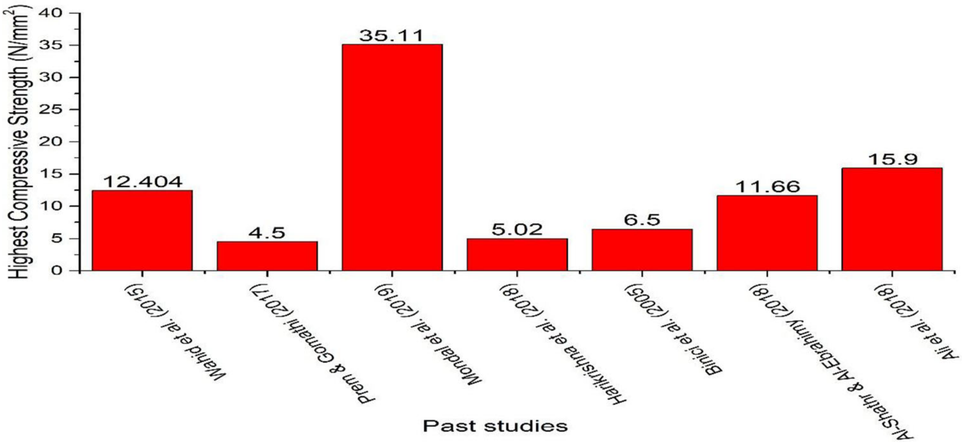

Figure 5. Highest compressive strength of previous studies on brick incorporated with plastic waste aggregate.

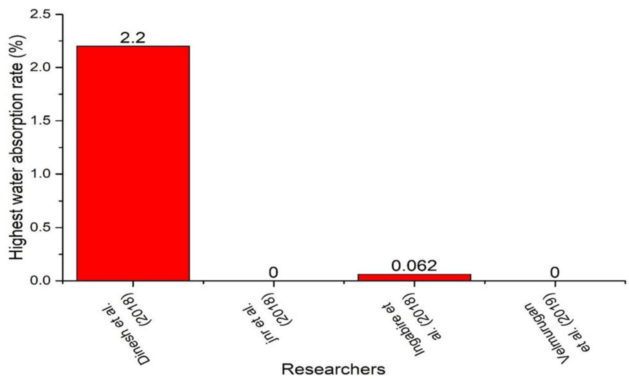

Figure 6. Highest water absorption rate of paving block utilised plastic waste as raw material based on previous studies.

percentage of PW was used. These findings suggested that probably the hydrophobicity and smooth surface of PW have decrease the adhesion force.

Meanwhile, findings also suggest that bricks incorporated with PW aggregate have a similar water absorption rate with conventional bricks. Mud bricks incorporated with PW aggregate have almost similar water absorption rate of 37.6% as compared to conventional bricks (38.7%) (Binici et al., 2005). In another study by Al-Shathr and Al-Ebrahimy (2018), the water absorption rate for the soil bricks with PET aggregate is higher (21.66%) than in the control soil bricks. The rate increases with the amount of waste added due to the voids formed during the firing process which can be filled with water during the curing process. On the other hand, Ali et al. (2018) reported that the HDPE as a sand replacement did not change the water absorption as control sample had higher water absorption rate. Apart from that, different types of PW aggregate also influence the water absorption rate of bricks. Mondal et al. (2019) found that bricks with polycarbonate have higher water absorption rate than polystyrenes and mixed plastics. Figure 4 shows highest water absorption rate of bricks utilised plastic waste as raw material based on previous studies.

5.2.2.2. Compressive strength. Wahid et al. (2015) examined the characteristic of bricks made up of crushed and uniform-sized PET as a replacement for conventional aggregate. The findings showed that the less binding property of plastics decreases the compressive strength as the PET amount increases. Besides PET, the compressive strength of bricks made up of HDPE and PE (Prem & Gomathi, 2017) and mixture of polycarbonate and polystyrene (Mondal et al., 2019) aggregates also decreases as content of

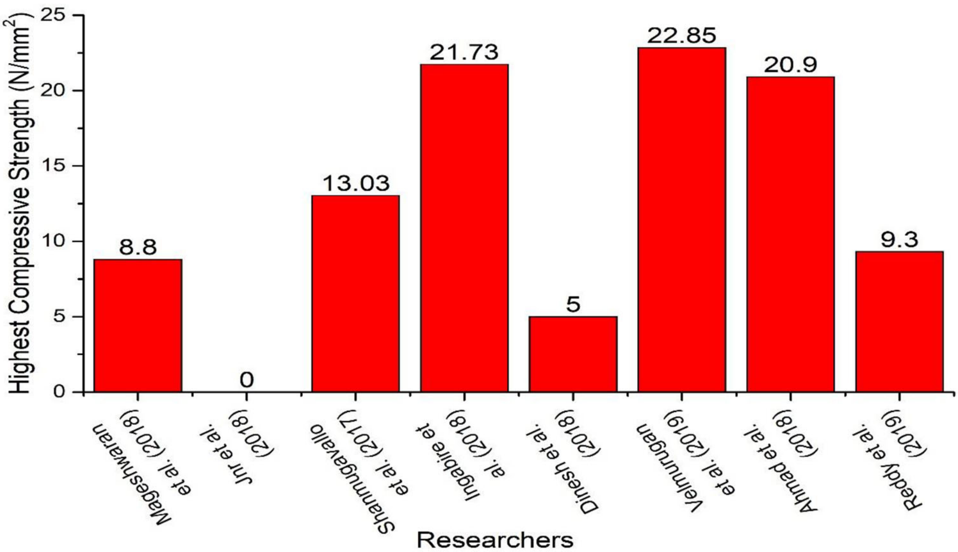

Figure 7. Highest compressive strength of paving block utilised plastic waste as aggregate based on previous studies.

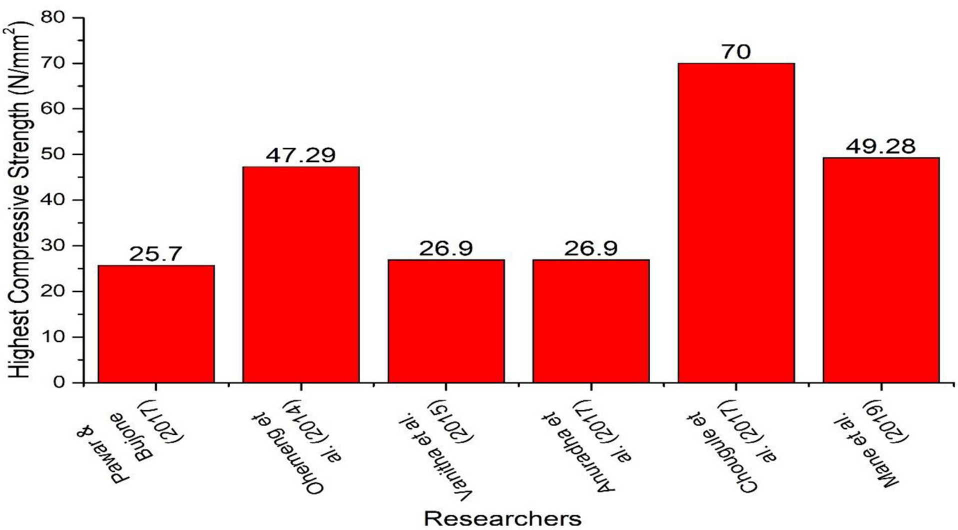

Figure 8. Highest compressive strength of paving block incorporated with plastic waste aggregate.

PW increases. Meanwhile Harikrishna et al. (2018), highlighted that out the compressive strength increases up to a certain percentage of PW and subsequently decreases.

The shape and size of plastic waste also play a role in terms of the compressive strength of bricks. Binici et al. (2005) demonstrated that plastic fibers have better compressive strength of 6.5 N/mm^2 than plastic straw and polystyrene fabric. In a similar study, Al-Shathr and Al-Ebrahimy (2018) proved that size of plastic aggregate affects the compressive strength of bricks. The highest compressive strength was recorded at 11.66 N/mm^2 for 1.18 mm PET and 11.03 N/mm^2 for 2.36 mm PET. The decrease in compressive strength might be due to the presence of voids from the firing process.

Despite the properties of plastic aggregate, the preparation of bricks also influence the compressive strength of the bricks. The unbaked bricks showed higher compressive strength as compared to the bricks baked at 100 °C irrespective to the different types of plastic (Mondal et al., 2019). Another factor which affect the compressive strength of the bricks is the water-cement ratio. Ali et al. (2018) exhibited that bricks with 3% of HDPE using 0.40 water-cement ratio recorded higher compressive strength

Table 1 PESTLE analysis on the utilisation of plastic waste.

PESTLE	Factors
Political (P)	• Government initiatives towards zero PW • The "No plastic bag" campaigns • Banning of the single use plastic materials • Aligned with the United Nation's Sustainable Development Goals (SDGs)
Economical (E)	• Provide subsidies and incentives • Decrease the demand and cost of conventional raw materials • Circular economy • Urban-industrial symbiotic relationships
Social (S)	• Active participation from all stakeholders • Increase awareness on plastic recycling • Changing consumer's plastic consumption behaviour • Feasible recycling facilities at the household level
Technological (T)	• Alternative usage and function of PW • Research and development (R&D) on environmentally friendly products
Legal (L)	• Levies on plastic products • Introduce effective environmental laws and regulations
Environmental (E)	• Reduce bioaccumulation of plastic in the environment • Prevent over-exploitation of the natural resources

(15.9 N/mm^2) than the control bricks with 0.40 water-cement ratio (14.4 N/mm^2). Figure 5 shows highest compressive strength of bricks utilised plastic waste as raw material based on previous studies.

5.3. Studies on the use of plastic waste in the production of paving blocks

Paving blocks or paving bricks are commonly used as the decorative purpose for pavement. Most of the paving blocks can be lifted individually and replaced which allows remedial work to take place. Generally, paving blocks are made of up concrete or clay along with other additives. In recent times, PW is added to paving blocks as raw material, aggregate and additives to reduce PW and enhance durability. Apart from that, PW also serves as an alternative raw material for paving block production.

5.3.1. Plastic waste as raw materials

5.3.1.1. Water absorption rate. Little attention has been given on the water absorption rate in plastic paving block. A study conducted by Dinesh et al. (2018) showed that the highest water absorption rate (2.2%) was recorded as the amount of PW increases. However, some studies reported that the increasing amount of LDPE, decreases the porosity thus decreases the water absorption rate (Jnr et al., 2018). Besides porosity, Ingabire et al. (2018) suggested that the poor water absorption ability of HDPE and compaction of paving block could decrease the water absorption rate. Similarly, an increasing amount of PW causes the paving block to become pulverised which affects the water absorption rate. Apart from that, Velmurugan et al. (2019) found that PE waste included as paving blocks can be used in seashore as PE do not absorb and react with the sea water. Figure 6 shows the summarised previous studies on the water absorption rate of plastic paving block.

5.3.1.2. Compressive strength. Mageshwaran et al. (2018) examined the utilisation of nylon grid, PE bags and M-sand in the production paving block. The results indicated that the compressive strength of the paving block depend on the amount of PW, whereas the compressive strength increases with the amount of PW. Paving block produced using LDPE (Jnr et al., 2018; Shanmugavalli et al., 2017) and HDPE waste (Ingabire et al., 2018) also found that the compressive strength increases as the PW increases. In addition, plastic paving block also found to have higher compressive strength than the conventional bricks. Dinesh et al. (2018) demonstrated that plastic paving block recorded higher compressive strength of 5 N/mm^2 as compared with the control paver block (1 N/mm^2). Similarly, Velmurugan et al. (2019) reported that paving block produced using 30% PE waste and 70% fly ash recorded the highest compressive strength of 22.85 N/mm^2 as compared to the concrete paving block (17 N/mm^2).

On the other hand, increasing PW as raw material in paving block production reported decreasing the compressive strength. Ahmad et al. (2018) showed control paver block with 0% replacement of PET recorded the highest compressive strength of 21.4 N/mm^2, followed by 20.9 N/mm^2, 12.2 N/mm^2 and 10.9 N/mm^2 for 5%, 10% and 15% of PET respectively. These findings suggested that lack of adhesion between PET wastes and cement paste could decrease the compressive strength. Similar results were also shared by Reddy et al. (2019) where increasing the amount of PW will cause paving block with pulverised and liquid conditions. Figure 7 shows the summarised previous studies on the compressive strength of plastic paving blocks.

5.3.2. Plastic waste as additive and aggregate

5.3.2.1. Water absorption rate. Increasing the amount of LDPE as PW aggregate reported to influence the water absorption rate of paving block and produced light weighted paving blocks (Ohemeng et al., 2014).

5.3.2.2. Compressive strength. **The** utilisation of PW as alternate aggregate influences the compressive strength of the paving block. Pawar and Bujone (2017) mentioned that the increasing amount of PE bags aggregate increases the compressive strength up to 25.7 N/mm^2 at 30% replacement of PE waste. But, in contrast, the compressive strength was found decreasing when with the increasing amount of LDPE (Ohemeng et al., 2014), HDPE (Anuradha et al., 2017; Vanitha et al., 2015) and PP (Chougule et al., 2017) aggregate content due to the reduced adhesion strength. Simultaneously, the study also recorded compressive strength increases as the curing age increases regardless of the amount of plastic used due to the hydration reaction in the cement paste. Apart from that, Mane et al. (2019) showed that the compressive strength of paving block increases with HDPE content up to a certain level and subsequently dropped as the plastic content increases. Figure 8 shows the highest compressive strength of paving block incorporated with PW aggregate in the previous studies.

6. Pestle analysis on plastic waste utilisation

PESTLE analysis is referred to as an analytical tool used to evaluate the impacts of political, economic, social, technological, legal and environmental factors on a study project (Islam & Mamun, 2017; Maliki et al., 2012; Racz et al., 2018; Rastogi & Trivedi, 2016). The PESTLE analysis is also used to evaluate the influence of external surroundings on an issue (Christodoulou & Cullinane, 2019; Srdjevic et al., 2012). Henceforth, the PESTLE analysis is applied in this study to analyse various external factors to ensure the effectiveness of reusing PW in order to solve emerging environmental issues (Fozer et al., 2017a, 2017b; Sridhar et al., 2016).

6.1. Political perspectives of plastic waste utilization

The political initiatives provided by the governments have a huge impact on the outlook of PW management. For instance, the Ministry of Housing and Local Government (KPKT) in Malaysia reported that about 38000 tonnes of waste were discarded daily where a huge portion from it is plastics (Harun et al., 2019; Kalianan et al., 2020). As a surplus to advocate the efforts of the Solid Waste Management and Public Cleansing Corporation (SWCorps) in Malaysia to resolve increasing PW issue, the Ministry of Science, Technology and Innovation (MOSTI) in Malaysia, formally known as Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC) has introduced the Malaysia's Roadmap Towards Zero Single-Use Plastics 2018-2030 (Ministry of Energy, Science, Technology, Environment and Climate (MESTECC), 2018). This roadmap is aimed to emulate a sustainable natural cycle, where all single-use plastics will be replaced through various phases. Besides, this framework includes all stakeholders such as federal and state governments, manufacturers, suppliers and the general public through the unified and collection approach towards a more sustainable pathway for a cleaner and healthier environment by 2030. The Phase 1 of this roadmap creates an opportunity to embrace and innovate new eco-friendly alternative. As consequences, reusing PW as construction materials could be a positive move towards redesigning products and processes to address plastic pollution.

On the global perspectives, similar initiatives have also be taken in other countries like New Zealand, India, Taiwan, European Union and ASEAN nations to address the PW pollution issue aligned with the

United Nations Sustainable Development Goals (SDGs) where single-use plastics were banned (Godfrey, 2019; Ma et al., 2020; Quoquab & Mohammad, 2020; The ASEAN Post, 2019).

6.2. Economical perspectives of plastic waste utilisation

The political and legal pressures have influenced the economic factors to solve PW issues by providing appropriate subsidies and incentives. However, funding is one of the major obstacles in preparing and implementing programmes and initiatives to tackle the PW problems (Achinas et al., 2019; Sridhar et al., 2016). Reusing PW as a construction material will indirectly boost the Malaysia's economic sectors as a huge amount in about 143.37 billion MYR was spent solely on construction work in 2019 (Hirschmann, 2020). Meanwhile, the cost of raw materials such as cement is expected to be increased in Malaysia in the upcoming years due to the high demand (The Business Times, 2019). As a result, PW could be used as a part of the construction material since it is readily available in enormous quantity yet it provides a new purpose in its life-cycle. Moreover, Cestari (2020), Taaffe et al., 2014, Shiri et al. (2015), Harikrishna et al. (2018), and Pawar and Bujone (2017) highlighted that plastics are robust, durable, waterproof, lightweight and easy to mould are the ideal properties for a construction material. Nevertheless, PW is also available at a more affordable price in comparison with the conventional construction, thus it could reduce the overall production and operational cost.

In addition, the circular economy is an alternative method that aims to keep resources in use as long as possible. The recovered PW is used to the remanufacture new product is widely demonstrated recently, such as bricks, road construction, furniture, and clothes and footwear (Barra et al., 2018). Besides, the circular economy also helps to improve the collaboration between businesses and consumers where it enhanced the public awareness of plastic recycling and increases the value of plastic products. For example, the relevant stakeholders of the urban-industrial symbiosis model in China actively exchange resources between the residential and industrial areas. Through this symbiotic relationship, it managed to reduces up to 78000 tonnes of carbon dioxide emission and 25000 tonnes of PW annually from being dumped into the environment (Sun et al., 2017).

6.3. Social perspectives of plastic waste utilisation

Active participation from all the stakeholders are required to seek appropriate solutions to the globally increasing plastic pollution. Non-governmental organisations (NGOs) and civil societies have to join their hands to increase the awareness on problems related with PW that aligned with the global and regional initiatives such as by European Union's Plastic Strategy in Malta and banning single-use plastic (United Nations Environment Programme (UNEP), 2016). Moreover, many efforts and initiatives were being implemented to reduce the coastal plastic pollution by various organisations such as Clean Blue Lagoon and KwaZulu-Natal (KZN) through beach cleanup activities in the developing countries (Rensburg et al., 2020).

Besides, the willingness of consumers to change their consumption patterns and behaviour is crucial as it has a direct impact on the demand for plastic product. This signifies the importance to understand the consumer's perception in solving problems associated with PW (Lebreton et al., 2017). In spite of that, most Malaysians showed a positive attitude and efforts to reduce the PW leading to the necessity of more recycling system facilities which could assist the plastic recycling process at the household level (Afroz et al., 2017).

6.4. Technological perspectives on plastic waste utilisation

The technological development and innovation in the industry will influence the PW utilisation in the local market. Previously, raw materials such as cement, sand, clay and mud are used as the raw materials for concrete, bricks and paving blocks. However, over-exploitation of these raw materials has resulted in resource depletion (Lawrence et al., 2020; Luangchroenrat et al., 2019). Recently, many studies are conducted on reusing PW as an alternate construction raw materials such as (1) cement, clay and mud where the PW was melted and incorporated with other materials and (2) sand and stone chips where the plastic aggregates are used in the production of bricks, pavers, mortars and concrete. The studies conducted by Ohemeng et al. (2014) Vanitha et al. (2015) and Mane et al. (2019) highlighted that PW can be used as a replacement for natural aggregate meanwhile, Sarkar and Pal (2016), Saxena et al. (2018) and Hameed and Ahmed (2019) indicated PW could be the raw resource in the production of construction materials.

6.5. Legal perspectives on plastic waste utilisation

The legal perspectives also play an important role in determining the roots and solutions for PW. The compulsory levies on plastic products is an important measure to reduce the production of excessive PW. For example, Denmark was the first country to introduce levies on plastic manufactures, as it reduces the usage of plastic products by 66% (Afroz et al., 2017). Subsequently, other countries such as Mexico, China, Nepal, India and Malaysia also introduced similar taxes and tariffs on PW. Nevertheless, Nyathi and Togo (2020) highlighted that the legislation implementation remains a great challenge in many countries, especially in the African continent due to stkeholder resistance and weak enforcement. Therefore, a feasible and effective enactments must be put in practiced in order to ensure harmonisation in the environmental legislation system (Bhagat et al., 2016).

6.6. Environmental perspectives on plastic waste utilisation

The influence of environmental factor plays an important role in creating awareness of PW pollution. Many studies have been conducted by reusing plastic in construction material to reduce the accumulation of PW in the environment as well as to lower the risk of over-exploitation in natural resources (Al-Shathr & Al-Ebrahimy, 2018; Binici et al., 2005; Hameed & Ahmed 2019; Junaid & Jan, 2016;; Rai et al., 2012). Moreover, PW utilisation in the construction sector is a more favourable and effective option than landfilling and incineration (Awasthi et al., 2017; Schmaltz et al., 2020). Table 1 represents the PESTLE factors affecting the reuse of PW as construction material.

7. Conclusions and recommendations

Reusing PW in construction material has proven to be an alternative method instead of recycling or landfilling 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 especially bricks and paving block:

- The durable properties of PW enable them to be an ideal material to be used in the construction where the addition of PW enhances the overall strength. However, the smooth and low adhesion property of PW prevents them from binding with other components, thus result in lower compressive 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.
- Both PET and LDPE are the most commonly used PW as raw materials, aggregate and additives in the production of construction materials.
- Most studies only focused solely on the compressive strength and rate of water absorption to evaluate 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, leaching properties and skid resistance.
- PESTLE analysis indicated that there are many initiatives taken to reduce the bioaccumulation of PW through various methods. Plastic products in many countries are subjected to levies on both manufacturers and consumers through law enactments which have significantly lower down the demand. Apart from that, incentives are also commonly provided to boost plastic recycling.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abdelaal, M. Y., Sobahi, T. R., & Makki, M. S. I. (2011). Chemical transformation of pet waste through glycolysis. *Construction and Building Materials*, *25*(8), 3267–3271. https://doi.org/10.1016/j.conbuildmat.2011.03.013

Abdul-Latif, N. I. S., Ong, M. Y., Nomanbhay, S., Salman, B., & Show, P. L. (2020). Estimation of carbon dioxide (CO2) reduction by utilization of algal biomass bioplastic in Malaysia using carbon emission pinch analysis (CEPA). *Bioengineered*, *11*(1), 154–164. https://doi.org/10.1080/21655979.2020.1718471

Achinas, S., Horjus, J., Achinas, V., & Euverink, G. J. W. (2019). A PESTLE analysis of biofuels energy industry in Europe. *Sustainability*, *11*(21), 5981. https://doi.org/10.3390/su11215981

Afroz, R., Rahman, A., Masud, M. M., & Akhtar, R. (2017). The knowledge, awareness, attitude and motivational analysis of plastic waste and household perspective in Malaysia. *Environmental Science and Pollution Research International*, *24*(3), 2304–2315. https://doi.org/10.1007/s11356-016-7942-0

Agyeman, S., Obeng-Ahenkora, N. K., Assiamah, S., & Twumasi, G. (2019). Exploiting recycled plastic waste as an alternative binder for paving blocks production. *Case Studies in Construction Materials*, *11*, e00246. https://doi.org/10.1016/j.cscm.2019.e00246

Ahmad, N. F. A., Razali, S. N. M., Sahat, S., & Kaamin, M. (2018). September). PET concrete as paver block. In *AIP Conference Proceedings* (Vol. 2016, No. 1, p. 020015). AIP Publishing LLC.

Aiswaria, K., Abdulla, K., Akhil, E. B., Lashmi, H. G., & Timmy, J. (2018). Manufacturing and experimental investigation of bricks with plastic and M-sand. *International Journal of Innovative Research in Science, Engineering and Technology*, *7*(6), 6558–6562.

Akinyele, J. O., & Toriola, I. O. (2018). The effect of crushed plastics waste on the structural properties of sandcrete blocks. *African Journal of Science. Technology, Innovation and Development*, *10*(6), 709–713.

Alabi, O. A., Ologbonjaye, K. I., Awosolu, O., & Alalade, O. E. (2019). Public and environmental health effects of plastic wastes disposal: a review. *Journal of Toxicology and Risk Assessment*, *5*(21), 1–13.

Ali, N., Yusuf, N. M., Khalid, F. S., Shahidan, S., & Abdullah, S. R. (2018). The effect of ater cment ratio on cement brick containing high density polyethylene (HDPE) as sand replacement. In *MATEC Web of Conferences* (vol. *150*, pp. 1–5). EDP Sciences. https://doi.org/10.1051

Alighiri, D., Yasin, M. N., Rohmawati, B., & Drastisianti, A. (2019). Processing of recycled waste PET (polyethylene terephthalate) plastics bottle into for the lightweight and reinforcement bricks. *Journal of Physics: Conference Series*, *1321*(2), 022023.

Alomar, C., Estarellas, F., & Deudero, S. (2016). Microplastics in the Mediterranean Sea: deposition in coastal shallow sediments, spatial variation and preferential grain size. *Marine Environmental Research*, *115*, 1–10. https://doi.org/10.1016/j.marenvres.2016.01.005

Al-Shathr, B. S., & Al-Ebrahimy, S. N. (2018). Production of lightweight clay bricks using polymer wastes. *Engineering and Technology Journal*, *36*(8 Part (A) Engineering), 823–831.

Andrady, A. L. (1994). Assessment of environmental biodegradation of synthetic polymers. *Journal of Macromolecular Science, Part C: Polymer Reviews*, *34*(1), 25–76. https://doi.org/10.1080/15321799408009632

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Andrews, G. (2012). *Plastics in the Ocean Affecting Human Health*. Retrieved September 15, 2020, from Geology and Human Health: https://serc.carleton.edu/NAGTWorkshops/health/case_studies/plastics.html

Anuradha, R., Panimayam, A., Chinnadurai, P., Pradeesh, K., & Jaffer, A. U. (2017). Utilisation of waste plastics as a replacement of coarse aggregate in paver blocks. *International Journal of ChemTech Research*, *10*, 211–218.

Araghi, H. J., Nikbin, I. M., Reskati, S. R., Rahmani, E., & Allahyari, H. (2015). An experimental investigation on the erosion resistance of concrete containing various PET particles percentages against sulfuric acid attack. *Construction and Building Materials*, *77*, 461–471. https://doi.org/10.1016/j.conbuildmat.2014.12.037

Arhant, M., & Davies, P. (2019). 2- Thermoplastic matrix composites for marine applications. In R. Pemberton, J. Summerscales, & J. Grahan-Jones (Eds.), *Woodhead publishing series in composites science* *and engineering, marine composites* (pp. 31–53). Woodhead Publishing. Retrieved from https: doi.org/ https://doi.org/10.1016/B978-0-08-102264-1.00002.9

Assamoi, B., & Lawryshyn, Y. (2012). The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. *Waste Management (New York, NY)*, *32*(5), 1019–1030. https://doi.org/10.1016/j.wasman.2011.10.023

Auta, H. S., Emenike, C. U., & Fauziah, S. H. (2017). Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. *Environment International*, *102*, 165–176. https://doi.org/10.1016/j.envint.2017.02.013

Avio, C. G., Gorbi, S., & Regoli, F. (2015). Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. *Marine Environmental Research*, *111*, 18–26. https://doi.org/10.1016/j.marenvres.2015.06.014

Awasthi, A. K., Shivashankar, M., & Majumder, S. (2017). Plastic solid waste utilization technologies: A Review. In *IOP conference series: Materials science and engineering* (Vol. 263, No. 2, p. 022024). IOP Publishing.

Awoyera, P. O., & Adesina, A. (2020). Plastic wastes to construction products: Status, limitations and future perspective. *Case Studies in Construction Materials*, *12*, e00330. https://doi.org/10.1016/j.cscm.2020.e00330

Awuchi, C. G., & Awuchi, C. G. (2019). Impacts of plastic pollution on the sustainability of seafood value chain and human health. *International Journal of Advanced Academic Research*, *5*(11), 46–138.

Azoulay, D., Villa, P., Moon, D., Lloyd-Smith, M., Moore, L., & Hernandez, V. (2019). *Report: Plastic Threatens Human Health at a Global Scale*. Retrieved September 15, 2020, from Plastic Pollution Coalition: https://www.plasticpollutioncoalition.org/blog/2019/2/20/report-plastic-threatens-human-health-at-a-global-scale

Bakir, A., Rowland, S. J., & Thompson, R. C. (2014). Transport of persistent organic pollutants by microplastics in estuarine conditions. *Estuarine, Coastal and Shelf Science*, *140*, 14–21. https://doi.org/10.1016/j.ecss.2014.01.004

Balakrishnan, A. A. M. N. F. R., & Flora, R. M. N. (2017). The environmental impact of plastics and recycling of plastic waste. *International Journal of Engineering Research and Reviews (Online)*, *5*(3), 14–20.

Barboza, L. G. A., & Gimenez, B. C. G. (2015). Microplastics in the marine environment: current trends and future perspectives. *Marine Pollution Bulletin*, *97*(1–2), 5–12. https://doi.org/10.1016/j.marpolbul.2015.06.008

Barboza, L. G. A., Lopes, C., Oliveira, P., Bessa, F., Otero, V., Henriques, B., Raimundo, J., Caetano, M., Vale, C., & Guilhermino, L. (2020). Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *The Science of the Total Environment*, *717*, 134625. https://doi.org/10.1016/j.scitotenv.2019.134625

Barnes, D. K., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Barra, R., Leonard, S. A., Whaley, C., Bierbaum, W. R., Gonzalez, P., Hartikainen, E., Hoogzaad, J., … .Zuin, V. G. (2018). Plastics and the circular economy. *Scientific and Technical Advisory Panel*, 1–28.

Begum, S. A., Rane, A. V., & Kanny, K. (2020). Applications of compatiblized polymer blends in automobile industry. In *Compatibilization of polymer blends* (pp. 563–593). Elsevier.

Bellasi, A., Binda, G., Pozzi, A., Galafassi, S., Volta, P., & Bettinetti, R. (2020). Microplastic contamination in freshwater environments: A review, focusing on interactions with sediments and benthic organisms. *Environments*, *7*(4), 30. https://doi.org/10.3390/environments7040030

Beltrán-Sanahuja, A., Casado-Coy, N., Simó-Cabrera, L., & Sanz-Lázaro, C. (2020). Monitoring polymer degradation under different conditions in the marine environment. *Environmental Pollution (Barking, Essex: 1987)*, *259*, 113836. https://doi.org/10.1016/j.envpol.2019.113836

Bhagat, S., Bhardawaj, A., Mittal, P., Chandak, P., Akhtar, M., & Sharma, P. (2016). Evaluating plastic waste disposal options in Delhi using multi criteria decision analysis. *Institute of Integrative Omics and Applied Biotechnology*, *7*(11), 25–35.

Binici, H., Aksogan, O., & Shah, T. (2005). Investigation of fibre reinforced mud brick as a building material. *Construction and Building Materials*, *19*(4), 313–318. https://doi.org/10.1016/j.conbuildmat.2004.07.013

Boerger, C. M., Lattin, G. L., Moore, S. L., & Moore, C. J. (2010). Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine Pollution Bulletin*, *60*(12), 2275–2278. https://doi.org/10.1016/j.marpolbul.2010.08.007

Bolden, J., Abu-Lebdeh, T., & Fini, E. (2013). Utilization of recycled and waste materials in various construction applications. *American Journal of Environmental Science*, *9*(1), 14–24.

Borrelle, S. B., Ringma, J., Law, K. L., Monnahan, C. C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G. H., Hilleary, M. A., Eriksen, M., Possingham, H. P., De Frond, H., Gerber, L. R., Polidoro, B., Tahir, A., Bernard, M., Mallos, N., Barnes, M., & Rochman, C. M. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science (New York, NY)*, *369*(6510), 1515–1518. https://doi.org/10.1126/science.aba3656

Briassoulis, D., Hiskakis, M., & Babou, E. (2013). Technical specifications for mechanical recycling of agricultural plastic waste. *Waste management*, *33*(6), 1516–1530. https://doi.org/10.1016/j.wasman.2013.03.004

British Plastic Federation. (2008). *Oil Consumption*. Retrieved May 5, 2020, from British Plastic Federation: http://www.bpf.co.uk/Oil-Consumption.aspx.

Brouwer, M. T., van Velzen, E. U. T., Augustinus, A., Soethoudt, H., De Meester, S., & Ragaert, K. (2018). Predictive model for the Dutch post-consumer plastic packaging recycling system and implications for the circular economy. *Waste Management*, *71*, 62–85. https://doi.org/10.1016/j.wasman.2017.10.034

Bruvoll, A. (2001). Factors influence solid waste generation and management. *Journal of Solid Waste Technology and Management*, *27*(3), 156–162.

Cantonwine, D. E., Hauser, R., & Meeker, J. D. (2013). Bisphenol A and human reproductive health. *Expert Review of Obstetrics & Gynecology*, *8*(4), 329–335. https://doi.org/10.1586/17474108.2013.811939

Caporossi, L., Alteri, A., Campo, G., Paci, E., Tranfo, G., Capanna, S., Papaleo, E., Pigini, D., Viganò, P., & Papaleo, B. (2020). Cross sectional study on exposure to BPA and phthalates and semen parameters in men attending a fertility center. *International Journal of Environmental Research and Public Health*, *17*(2), 489. https://doi.org/10.3390/ijerph17020489

Carlsson, R. M. (2005). Economic assessment of municipal waste management system: case studies using a combination of life cycle assessment (LCA) and life cycle costing (LCC). *Journal of Cleaner Production*, *13*, 253–263.

Carr, S. A., Liu, J., & Tesoro, A. G. (2016). Transport and fate of microplastic particles in wastewater treatment plants. *Water Research*, *91*, 174–182. https://doi.org/10.1016/j.watres.2016.01.002

Carson, S. H., Colbert, S. L., Kaylor, M. J., & McDermid, K. J. (2011). Small plastic debris changes water movement and heat transfer through beach sediments. *Marine Pollution Bulletin*, *62*(8), 1708–1713.

Cestari, S. (2020). Why plastic waste is an ideal building material. Retrieved on December 11, 2020, from BBC: https://www.bbc/future/article/20200819-why-plastic-waste-is-an-ideal-building-material.

Chandegera, V. K., Cholera, S. P., Nandasana, J. N., Kumpavat, M. T., & Patel, K. C. (2015). Plastic packaging waste impacts on climate change and its mitigation. In R. Subbaiah, & G. V. Prajapathi, *Adaptation of climate resilient water management and agriculture* (Vol. 3, pp. 404–415). Gyan Publishing House.

Chougule, R. S., Yamgar, S., Salunkhe, S., Patil, P., Saitawadekar, A., & Kapase, M. (2017). Use of plastic waste in civil construction. *International Journal of Engineering Technology, Management and Applied Sciences*, *5*(4), 186–190.

Choy, C. A., & Drazen, J. C. (2013). Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific. *Marine Ecology Progress Series*, *485*, 155–163. https://doi.org/10.3354/meps10342

Chris, T., & Dan, M. (2017). *Invisibles: the plastics inside us*. Retrieved May 5, 2020, from Orbmedia.org: https://orbmedia.org/stories/invisibles_plastics

Christodoulou, A., & Cullinane, K. (2019). Identifying the main opportunities and challenges from the implementation of a port energy management system: A SWOT/PESTLE Analysis. *Sustainability*, *11*(21), 6046. https://doi.org/10.3390/su11216046

Cincinelli, A., Scopetani, C., Chelazzi, D., Lombardini, E., Martellini, T., Katsoyiannis, A., Fossi, M. C., & Corsolini, S. (2017). Microplastic in the surface waters of the Ross Sea (Antarctica): occurrence, distribution and characterization by FTIR. *Chemosphere*, *175*, 391–400. https://doi.org/10.1016/j.chemosphere.2017.02.024

Coates, G. W., & Getzler, Y. D. (2020). Chemical recycling to monomer for an ideal, circular polymer economy. *Nature Reviews Materials*, 5, 1–16.

Corinaldesi, V., Donnini, J., & Nardinocchi, A. (2015). Lightweight plasters containing plastic waste for sustainable and energy-efficient building. *Construction and Building Materials*, *94*, 337–345. https://doi.org/10.1016/j.conbuildmat.2015.07.069

Corvellec, H., & Bramryd, T. (2012). The multiple market-exposure of waste management companies: A case study of two Swedish municipally owned companies. *Waste Management (New York, NY)*, *32*(9), 1722–1727. https://doi.org/10.1016/j.wasman.2012.04.005

Corvellec, H., Campos, M. J. Z., & Zapata, P. (2013). Infrastructures, lock-in, and sustainable urban development: the case of waste incineration in the Göteborg Metropolitan Area. *Journal of Cleaner Production*, *50*, 32–39. https://doi.org/10.1016/j.jclepro.2012.12.009

Creton, C. (2017). Molecular stitches for enhanced recycling of packaging. *Science (New York, NY)*, *355*(6327), 797–798. https://doi.org/10.1126/science.aam5803

Cudjoe, D., & Acquah, P. M. (2020). Environmental impact analysis of municipal solid waste incineration in African countries. *Chemosphere*, *265*, 129186.

Cunningham, E. M., Kiriakoulakis, K., Dick, J. T., Kregting, L., Schuchert, P., & Sigwart, J. D. (2020). Driven by speculation, not by impact-the effects of plastic on fish species. *Journal of Fish Biology*, *96*(6), 1294–1297. https://doi.org/10.1111/jfb.14303

Cunningham, E. M., & Sigwart, J. D. (2019). Environmentally accurate microplastic levels and their absence from exposure studies. *Integrative and Comparative Biology*, *59*(6), 1485–1496. https://doi.org/10.1093/icb/icz068

d'Ambrières, W. (2019). Plastics recycling worldwide: current overview and desirable changes. *Field Actions Science Reports*. *The Journal of Field Actions, (Special Issue 19)*, 12–21.

da Costa, J. P., Santos, P. S. M., Duarte, A. C., & Rocha-Santos, T. (2016). (Nano)plastics in the environment-sources, fates and effects. *Science of the Total Environment*, *566*, 15–26.

Daftardar, A., Shah, R., Gandhi, P., & Garg, H. (2017). Use of waste plastic as a construction material. *International Journal of Engineering and Applied Sciences*, *4*(11), 148–151.

Datta, J., & Kopczyńska, P. (2016). From polymer waste to potential main industrial products: Actual state of recycling and recovering. *Critical Reviews in Environmental Science and Technology*, *46*(10), 905–946. https://doi.org/10.1080/10643389.2016.1180227

de Camargo, R. V., & Saron, C. (2020). Mechanical–chemical recycling of low-density polyethylene waste with polypropylene. *Journal of Polymers and the Environment*, *28*(3), 794–802. https://doi.org/10.1007/s10924-019-01642-5

de Weerdt, L., Sasao, T., Compernolle, T., Van Passel, S., & De Jaeger, S. (2020). The effect of waste incineration taxation on industrial plastic waste generation: A panel analysis. *Resources, Conservation and Recycling*, *157*, 104717. https://doi.org/10.1016/j.resconrec.2020.104717

Devasahayam, S., Raju, G. B., & Hussain, C. M. (2019). Utilization and recycling of end of life plastics for sustainable and clean industrial processes including the iron and steel industry. *Materials Science for Energy Technologies*, *2*(3), 634–646. https://doi.org/10.1016/j.mset.2019.08.002

Devezas, T. C., Vaz, A. M., & Magee, C. L. (2017). Global Pattern in Materials Consumption: an empirical study. In T. Devezas, J. Leitao, & A. Sarygulov (Ed.), *Industry 4.0*. (pp. 263–292). Springer. https://doi.org/10.1007/978-3-319-49604-7_14

Dinesh, S., Parishee, M. K., Sriram, J., & Bashith, M. M. (2018). Effective use of waste plastic as manufacturing of paver block. *International Journal of Advanced Research in Basic Engineering Sciences and Technology*, *4*, 231–235.

Dormer, A., Finn, D. P., Ward, P., & Cullen, J. (2013). Carbon footprint analysis in plastics manufacturing. *Journal of Cleaner Production*, *51*, 133–141. https://doi.org/10.1016/j.jclepro.2013.01.014

dos Santos, I. F. S., Mensah, J. H. R., Gonçalves, A. T. T., & Barros, R. M. (2020). Incineration of municipal solid waste in Brazil: An analysis of the economically viable energy potential. *Renewable Energy.*, *149*, 1386–1394.

Dubaish, F., & Liebezeit, G. (2013). Suspended microplastics and black carbon particles in the Jade system, southern North Sea. *Water, Air, & Soil Pollution*, *224*(2), 1352. https://doi.org/10.1007/s11270-012-1352-9

Eerkes-Medrano, D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*, *75*, 63–82. https://doi.org/10.1016/j.watres.2015.02.012

Energy Information Administration (EIA). (2020). *How much oil used to make plastics*. Retrieved August 15, 2020, from Eneygy Information Administration: https://www.eia.gov/tools/faqs/faq.php?id=34&t=6

Environmental Protection Department. (2019). *Hong Kong Waste treatment and disposal*. Retrieved December 9, 2020 from Environmental Protection Department: https://www.epd.gov.hk/epd/english/environmentinhk/waste/data/stat_treat.html

Eriksen, M. K., Christiansen, J. D., Daugaard, A. E., & Astrup, T. F. (2019). Closing the loop for PET, PE and PP waste from households: Influence of material properties and product design for plastic recycling. *Waste Management*, *96*, 75–85. https://doi.org/10.1016/j.wasman.2019.07.005

Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., Galgani, F., Ryan, P. G., & Reisser, J. (2014). Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PloS One*, *9*(12), e111913. https://doi.org/10.1371/journal.pone.0111913

Eriksson, C., Burton, H., Fitch, S., Schulz, M., & van den Hoff, J. (2013). Daily accumulation rates of marine debris on sub-Antarctic island beaches. *Marine Pollution Bulletin*, *66*(1–2), 199–208. https://doi.org/10.1016/j.marpolbul.2012.08.026

Erren, T., Zeuß, D., Steffany, F., & Meyer-Rochow, B. (2009). Increase of wildlife cancer: an echo of plastic pollution? *Nature Reviews Cancer*, *9*(11), 842–842. https://doi.org/10.1038/nrc2665-c1

Escamilla-García, P. E., Camarillo-López, R. H., Carrasco-Hernández, R., Fernández-Rodríguez, E., & Legal-Hernández, J. M. (2020). Technical and economic analysis of energy generation from waste incineration in Mexico. *Energy Strategy Reviews*, *31*, 100542. https://doi.org/10.1016/j.esr.2020.100542

Estahbanati, S., & Fahrenfeld, N. L. (2016). Influence of wastewater treatment plant discharges on microplastic concentrations in surface water. *Chemosphere*, *162*, 277–284. https://doi.org/10.1016/j.chemosphere.2016.07.083

Eureka Recycling. (n.d.). *Recycling plastics: complications & limitations*. Retrieved May 5, 2020, from Eureka Recycling: http://www.eurekarecyling.org

European Commision. (2018). *An European strategy for plastics in a circular economy*. COM (2018) 28 FInal, European Commison.

Eweed, K. M., Ebrahim, Y. K., & Ali, R. S. (2018). Effecting the addition of the Plastic waste and Rubber on the constructions materials properties. *IOP Conference Series: Materials Science and Engineering*, *454*(1), p. 012151.

Federation, B. P. (2008). *Oil consumption*. Retrieved May 10, 2020, from Oil consumption: http://www.bpf.co.uk/Oil_Consumption.aspx.

Ferreira, L., de Brito, J., & Saikia, N. (2012). Influence of curing conditions on the mechanical performance of concrete containing recycled plastic aggregate. *Construction and Building Materials*, *36*, 196–204. https://doi.org/10.1016/j.conbuildmat.2012.02.098

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health*, *16*(6), 1060. https://doi.org/10.3390/ijerph16061060

Fielding, K. S., van Kasteren, Y., Louis, W., McKenna, B., Russell, S., & Spinks, A. (2016). Using individual householder survey responses to predict household environmental outcomes: The cases of recycling and water conservation. *Resources, Conservation and Recycling*, *106*, 90–97. https://doi.org/10.1016/j.resconrec.2015.11.009

Filella, M. (2015). Questions of size and numbers in environmental research on microplastics: methodological and conceptual aspects. *Environmental Chemistry*, *12*(5), 527–538. https://doi.org/10.1071/EN15012

Fozer, D., Sziraky, F. Z., Racz, L., Nagy, T., Tarjani, A. J., Toth, A. J., Haaz, E., Benko, T., & Mizsey, P. (2017a). Life cycle, PESTLE and multi-criteria decision analysis of CCS process alternatives. *Journal of Cleaner Production*, *147*, 75–85. https://doi.org/10.1016/j.jclepro.2017.01.056

Fozer, D., Valentinyi, N., Racz, L., & Mizsey, P. (2017b). Evaluation of microalgae-based biorefinery alternatives. *Clean Technologies and Environmental Policy*, *19*(2), 501–515. https://doi.org/10.1007/s10098-016-1242-8

Francis, R. (Ed.). (2016). *Recycling of polymers: methods, characterization and applications*. John Wiley & Sons.

Gabbatiss, J. (2018). *Plastic chemicals changing marine animals behaviour and leaving them vulnerable to attack study suggest*. Retrieved March 3, 2020, from Independent: https://www.independent.co.uk/environment/plastic-pollution-ocean-animal-behaviour-microplastics-chemicals-study-research-a8654541.html

Gall, S. C., & Thompson, R. C. (2015). The impact of debris on marine life. *Marine Pollution Bulletin*, *92*(1-2), 170–179. https://doi.org/10.1016/j.marpolbul.2014.12.041

Galloway, T. S. (2015). Micro-and nano-plastics and human health. In *Marine anthropogenic litter* (pp. 343–366). Springer.

Garcia, J. M., & Robertson, M. L. (2017). The future of plastics recycling. *Science (New York, NY)*, *358*(6365), 870–872. https://doi.org/10.1126/science.aaq0324

Gawande, A., Zamare, G., Renge, V. C., Tayde, S., & Bharsakale, G. (2012). An overview on waste plastic utilization in asphalting of roads. *Journal of Engineering Research and Studies*, *3*(2), 1–5.

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Ghanem, S. Y., Bowling, J., & Sun, Z., fiber reinforced self-consolidating concrete. (2021). Mechanical properties of hybrid syntehthic. *Composites Part C: Open Access*, *5*, 100154.

Gilbert, M., (Ed). (2016). Chapter 1- Plastics materials: Introduction and historical development. In M. Gilbert (Ed.), *Brydson's plastics materials* (8th ed., pp. 1–18). Butterworth-Heinemann. Retrieved from http://www.sciencedirect.com/article/pii/B9780323358248000013.

Godfrey, L. (2019). Waste plastic, the challenge facing developing countries—ban it, change it, collect it? *Recycling*, *4*(1), 3. https://doi.org/10.3390/recycling4010003

Gouin, T., Avalos, J., Brunning, I., Brzuska, K., De Graaf, J., Kaumanns, J., … Thomas, J. (2015). Use of micro-plastic beads in cosmetic products in Europe and their estimated emissions to the North Sea environment. *SOFW J*, *141*(4), 40–46.

Gray, H., Lattin, G. L., & Moore, C. J. (2012). Incidence, mass and variety of plastics ingested by Laysan (Phoebastria immutabilis) and Black-footed Albatrosses (P. nigripes) recovered as by-catch in the North Pacific Ocean. *Marine Pollution Bulletin*, *64*(10), 2190–2192. https://doi.org/10.1016/j.marpolbul.2012.07.053

Gu, L., & Ozbakkaloglu, T. (2016). Use of recycled plastics in concrete: A critical review. *Waste Management*, *51*, 19–42. https://doi.org/10.1016/j.wasman.2016.03.005

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. (2018). An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal and recycling. *Journal of Hazardous Materials*, *344*, 179–199. https://doi.org/10.1016/j.jhazmat.2017.10.014

Hale, R. C. (2017). Analytical challenges associated with the determination of microplastics in the environment. *Analytical Methods*, *9*(9), 1326–1327. https://doi.org/10.1039/C7AY90015E

Hameed, A. M., & Ahmed, B. A. F. (2019). Employment the plastic waste to produce the light weight concrete. *Energy Procedia*, *157*, 30–38. https://doi.org/10.1016/j.egypro.2018.11.160

Hamilton, L., Fiet, S., Kelso, M., Rubright, S., Bernhardt, C., Schaeffer, …. Muffett, C. (2020). *Plastic & climate* (p. 108). Center for International Environmental Law. Retrieved from http://www.ciel.org/plasticandclimate

Hamlet, C., Matte, T., & Mehta, S. (2020). *Combating plastic and air pollution on earth day*. Retrieved May 5, 2020, from Vital Strategies: https://medium.com/vital-strategies/combating-plastic-and-air-pollution-on-earth-day-d9c06f1ca219

Hammer, J., Kraak, M. H., & Parsons, J. R. (2012). Plastics in the marine environment: the dark side of a modern gift. In *Reviews of environmental contamination and toxicology* (pp. 1–44). Springer.

Hardesty, B. D., Good, T. P., & Wilcox, C. (2015). Novel methods, new results and science-based solutions to tackle marine debris impacts on wildlife. *Ocean & Coastal Management*, *115*, 4–9. https://doi.org/10.1016/j.ocecoaman.2015.04.004

Harikrishna, K. S., Harikrishnan, M., Jai Ganesh, N., Jothi Kumar, S., & Sundari, M. (2018). Experimental study on partial replacement of plastic waste in bricks. *International Journal for Scientific Research & Development*, *6*, 819–825.

Harun, H. A., Yunus, N. M., Rasul, R., Zainudin, A. Z., Zakaria, S. R. A., & Mohsin, A. (2019). Challenges in the implementation of zero waste concept in Johor Bahru city council. *International Journal of Real Estate Studies*, *13*(1), 80–88.

Harvey, F. (2019). *Animals and birds under increasing threat from plastic waste*. Retrieved May 5, 2020, from The Guardian: https://www.theguardian.com/environment/2019/feb/04/animals-birds-plastic-waste-rspca.

Herberz, T., Barlow, C. Y., & Finkbeiner, M. (2020). Sustainability assessment of a single-use plastics ban. *Sustainability*, *12*(9), 3746. https://doi.org/10.3390/su12093746

Hernandez, E. B., Nowack, B., & Mitrano, D. M. (2017). Polyester textiles as a source of microplastics from households: A mechanistic study to understand microfiber release during washing. *Environmental Science & Technology*, *51*(12), 7036–7046. https://doi.org/10.1021/acs.est.7b01750

Hidalgo-Ruz, V., Gutow, L., Thompson, R. C., & Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. *Environmental Science & Technology*, *46*(6), 3060–3075. https://doi.org/10.1021/es2031505

Hiremath, P. M., & Shetty, S. (2014). Utilization of waste plastic in manufacturing of plastic soil bricks. *International Journal of Technology Enhancements and Emerging Engineering Research*, *2*, 102–107.

Hirschmann, R. (2020). Value of construction work in Malaysia 2011-2019. Retrieved on December 9, 2020, from the Statistia: https:www.statista.com/statistics/665028/value-of-construction-work-malaysia/#:∼:text=In%202019%2c%20the%20value%20of,a%20bid%20to%20decrease%20debt.

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1526), 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Hunter, B. (2018). How a shortage of bricks could impact the construction industry. Retrieved 9 December, 2020, from Bricks Hunter: https://brickhunter.com/blog/how-a-shortage-of-bricks-could-impact-the-construction-industry

Hurley, R., Woodward, J., & Rothwell, J. J. (2018). Microplastic contamination of river beds significantly reduced by catchment-wide flooding. *Nature Geoscience*, *11*(4), 251–257. https://doi.org/10.1038/s41561-018-0080-1

Ihesiulor, O. K., & Ugoamadi, C. C. (2011). Optimization of the development of a plastic recycling machine. *Nigerian Journal of Technology*, *30*, 67–81.

Ingabire, D., Ntihemuka, F., Mugabo, G., Isabane, R. S., & Turatimana, T. (2018). Recycling High-Density Polyethylene (HDPE) into construction materials as a key step in plastic waste reduction: case of Kigali City. *Rwanda Journal of Engineering*. *Science, Technology and Environment*, *1*(1).

Intan, S. K., & Santosa, S. (2019). Utilization of PTE and LDPE plastic waste and building material waste as bricks. *Korean Journal of Materials Research*, *29*(10), 603–608. https://doi.org/10.3740/MRSK.2019.29.10.603

Isangedighi, I. A., David, G. S., & Obot, O. I. (2018). Plastic waste in the aquatic environment: impacts and management. *Environment*, *2*, 1–31.

Islam, F. R., & Mamun, K. A. (2017). Possibilities and challenges of implementing renewable energy in the light of PESTLE & SWOT analyses for island countries. In *Smart energy grid design for island countries* (pp. 1–19). Springer.

Istrate, I. R., Galvez-Martos, J. L., & Dufour, J. (2021). The impact of incineration phase-out on municipal solid waste landfilling and life cycle environmental performance. *Science of the Total Environment*, *755*, 142537. https://doi.org/10.1016/j.scitotenv.2020.142537

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Marine pollution. Plastic waste inputs from land into the ocean. *Science (New York, NY)*, *347*(6223), 768–771. https://doi.org/10.1126/science.1260352

Jambeck, J., Hardesty, B. D., Brooks, A. L., Friend, T., Teleki, K., Fabres, J., Beaudoin, Y., Bamba, A., Francis, J., Ribbink, A. J., Baleta, T., Bouwman, H., Knox, J., & Wilcox, C. (2018). Challenges and emerging solutions to the land-based plastic waste issue in Africa. *Marine Policy*, *96*, 256–263. https://doi.org/10.1016/j.marpol.2017.10.041

Jeswani, H., Krüger, C., Russ, M., Horlacher, M., Antony, F., Hann, S., & Azapagic, A. (2021). Life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery. *Science of the Total Environment*, *769*, 144483. https://doi.org/10.1016/j.scitotenv.2020.144483

Jia, L., Evans, S., & van der Linden, S. (2019). Motivating actions to mitigate plastic pollution. *Nature Communications*, *10*(1), 1–3. https://doi.org/10.1038/s41467-019-12666-9

Jnr, A. K. L., Yunana, D., Kamsouloum, P., Webster, M., Wilson, D. C., & Cheeseman, C. (2018). Recycling waste plastics in developing countries: Use of low-density polyethylene water sachets to form plastic bonded sand blocks. *Waste Management*, *80*, 112–118.

Junaid, A., & Jan, A. (2016). Effectiveness of waste polyethylene bags modified bitumen mixes and their comparative economical analysis. *International Journal of Science and Engineering Research*, *7*, 1171–1177.

Kabir, E., Kaur, R., Lee, J., Kim, K. H., & Kwon, E. E. (2020). Prospects of biopolymer technology as an alternative option for non-degradable plastics and sustainable management of plastic wastes. *Journal of Cleaner Production*, *258*, 120536. https://doi.org/10.1016/j.jclepro.2020.120536

Kaiser, J. (2010). The dirt on the ocean garbage patches. *Science (New York, NY)*, *328*(5985), 1506–1506. https://doi.org/10.1126/science.328.5985.1506

Kalianan, T., Fang, Y. X., & Abidin, Z. A. Z. (2020). Efforts towards zero single-use plastic in a private institution. *Journal of Social Science Advanced Research*, *1*(2), 87–96.

Kamaruddin, M., Abdullah, M. M. A., Zawawi, M. H., & Zainol, M. R. R. A. (2017). Potential use of plastic waste as construction materials: recent progress and future prospect. In *IOP Conference Series: Materials Science and Engineering* (Vol. 267, No. 1, p. 012011). IOP Publishing Ltd.

Karleskint, G., Turner, R., & Small, J. (2012). *Introduction to marine biology*. Cengage Learning.

Kathe, V., Gangurde, A., & Pawar, A. (2015). Green concrete using plastic waste. *Third International Conference on Sustainable Construction Materials and Technologies*, *19*, 214–216.

Khan, F., Ahmed, W., & Najmi, A. (2019). Understanding consumers' behavior intentions towards dealing with the plastic waste: Perspective of a developing country. *Resources, Conservation and Recycling*, *142*, 49–58. https://doi.org/10.1016/j.resconrec.2018.11.020

Khoonkari, M., Haghighi, A. H., Sefidbakht, Y., Shekoohi, K., & Ghaderian, A. (2015). Chemical recycling of PET wastes with different catalysts. *International Journal of Polymer Science*, *2015*, 1–11. https://doi.org/10.1155/2015/124524

Klemeš, J. J., Fan, Y. V., & Jiang, P. (2020). Plastics: friends or foes? The circularity and plastic waste footprint. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*,43, 1549–1565 .

Kosuth, M., Mason, S., Wattenberg, E., Tyree, C., & Morrison, D. (2017). Synthethic polymer contamination of global drinking water. *Orb Media*. Retrieved May 5, 2020, from https://orbmedia.org/stories/Invisibles_final_report

Laville, S. (2019). *Single-use plastics a serious climate change hazard, study warns*. Retrieved September 2020, 2020, from The Guardian: https://www.theguardian.com/environment/2019/may/15/single-use-plastics-a-serious-climate-change-hazard-study-warns

Law, K. L. (2017). Plastics in the marine environment. *Annual Review of Marine Science*, *9*, 205–229. https://doi.org/10.1146/annurev-marine-010816-060409

Lawrence, M., Kiberu, F., Kyakula, M., & Batambuze, A. O. (2020). An assessment of impact construction activities on the environment in Uganda: A case study of Iganga Municipality. *Journal of Construction Engineering and Project Management*, *2*(4) 20–24.

Lazarevic, D., Aoustin, E., Buclet, N., & Brandt, N. (2010). Plastic waste management in the context of a European recycling society: comparing results and uncertainties in a life cycle perspective. *Resources, Conservation and Recycling*, *55*(2), 246–259. https://doi.org/10.1016/j.resconrec.2010.09.014

Leal Filho, W., Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M., & Voronova, V. (2019). An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. *Journal of Cleaner Production*, *214*, 550–558. https://doi.org/10.1016/j.jclepro.2018.12.256

Lebreton, L. C., Van Der Zwet, J., Damsteeg, J. W., Slat, B., Andrady, A., & Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications*, *8*(1), 1–10. https://doi.org/10.1038/ncomms15611

Lee, A., & Liew, M. S. (2020). Tertiary recycling of plastics waste: an analysis of feedstock, chemical and biological degradation methods. *Journal of Material Cycles and Waste Management*, *22*(1), 1–12. https://doi.org/10.1007/s10163-019-00931-4

Lelchat, F., Dussauze, M., Lemaire, P., Theron, M., Toffin, L., & Le Floch, S. (2020). Measuring the biological impact of drilling waste on the deep seafloor: an experimental challenge. *Journal of Hazardous Materials*, *389*, 122132. https://doi.org/10.1016/j.jhazmat.2020.122132

Liang, Y., Tan, Q., Song, Q., & Li, J. (2021). An analysis of the plastic waste trade and management in Asia. *Waste Management*, *119*, 242–253. https://doi.org/10.1016/j.wasman.2020.09.049

Ling, Y. F., Zhang, P., Wang, J., & Shi, Y. (2020). Effect of sand size on mechanical performance of cement-based composite containing PVA fibers and nano-SiO2. *Materials*, *13*(2), 325. https://doi.org/10.3390/ma13020325

Li, J., Qu, X., Su, L., Zhang, W., Yang, D., Kolandhasamy, P., Li, D., & Shi, H. (2016). Microplastics in mussels along the coastal waters of China. *Environmental Pollution (Barking, Essex: 1987)*, *214*, 177–184. https://doi.org/10.1016/j.envpol.2016.04.012

Li, J., Wu, G., & Xu, Z. (2015). Tribo-charging properties of waste plastic granules in process of tribo-electrostatic separation. *Waste Management (New York, NY)*, *35*, 36–41. https://doi.org/10.1016/j.wasman.2014.10.001

Long, R., Yang, J., Chen, H., Li, Q., Fang, W., & Wang, L. (2019). Co-evolutionary simulation study of multiple stakeholders in the take-out waste recycling industry chain. *Journal of Environmental Management*, *231*, 701–713. https://doi.org/10.1016/j.jenvman.2018.10.061

Luangchroenrat, C., Intrachooto, S., Peansupap, V., & Sutthinarakorn, W. (2019). Factors influencing construction waste generation in building construction. *Sustainability*, *11*, 2638.

Lusher, A. (2015). Microplastocs in the marine environment: distribution, interactions and effects. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine anthropogenic Litter* (pp. 245–307). Springer.

MPMA. Malaysian Plastic Manufacturers Assosiation. (2018). Last retrieved on 5 December 2020 from the https://mpma.org.my/M

Mageshwaran, A., Vino, S., Satish Kumar, C., Vijayakumar, M., & Praveen Kumar, T. (2018). Effective utilization of waste plastic with sand in addition with nylon grids in paver stones. *International Journal of Current Engineering and Scientific Research*, *5*, 14–17.

Mahajan, P., Girase, D., & Lokhande, A. R. (2018). Plastic soil bricks substituiting traditional bricks. *International Journal for Research in Applied Science and Engineering Technology*, *6*(1), 3380–3386. https://doi.org/10.22214/ijraset.2018.1470

Ma, Y., Huang, A., Cao, S., Sun, F., Wang, L., Guo, H., & Ji, R. (2016). Effects of nanoplastics and microplastics on toxicity, bioaccumulation, and environmental fate of phenanthrene in fresh water. *Environmental Pollution (Barking, Essex : 1987)*, *219*, 166–173. https://doi.org/10.1016/j.envpol.2016.10.061

Ma, Z. F., Ibrahim, Y. S., & Lee, Y. Y. (2020). Microplastic pollution and health and relevance to the Malaysia's roadmap to zero single-use plastics 2018-2030. *The Malaysian Journal of Medical Sciences: MJMS*, *27*(3), 1–6. https://doi.org/10.21315/mjms2020.27.3.1

Maio, G., Olson, J., & Cheung, I. (2013). Attitudes in social behaviour. *Personality and Social Psychology*, *5*, 275–304.

Maliki, A. B., Jahrin, M. E. B., Kamarulzaman, N. S. B., Ali, N. B. M., Azhar, N. I. B. M., & Chew, B. C. (2012). PESTLE analysis on Beichi technology- technology which turns plastic waste into fuels. At International Conference on Technology Management and Technopreneurship.

Mane, R., Rayewar, S., Katageri, S., & Patil, N. K. (2019). Use of plastic waste as partial replacement of aggregate in paver block. *International Research Journal of Engineering and Technology*, *6*, 102–105.

Manjarekar, A. S., Gulpatil, D., Patil, V. P., Nikam, R. S., & Jeur, C. M. (2017). Utilization of plastic waste in foundry sand bricks. *International Journal Research Applied Science Engineering Technology (IJRASET)*, *5*(3), 977–982.

Manju, R., Sathya, S., & Sheema, K. (2017). Use of plastic waste in bituminous pavement. *International Journal of ChemTech Research*, *10*(8), 804–811.

Mansour, A. M. H., & Ali, S. A. (2015). Reusing waste plastic bottles as an alternative sustainable building material. *Energy for Sustainable Development*, *24*, 79–85. https://doi.org/10.1016/j.esd.2014.11.001

Marn, N., Jusup, M., Kooijman, S. A., & Klanjscek, T. (2020). Quantifying impacts of plastic debris on marine wildlife identifies ecological breakpoints. *Ecology Letters*, *23*(10), 1479–1487. https://doi.org/10.1111/ele.13574

Marques, R. C., Simões, P., & Pinto, F. S. (2018). Tariff regulation in the waste sector: An unavoidable future. *Waste Management (New York, NY)*, *78*, 292–300. https://doi.org/10.1016/j.wasman.2018.05.028

Mastali, M., Dalvand, A., Sattarifard, A. R., Abdollahnejad, Z., & Illikainen, M. (2018). Characterisation and optimisation of hardened properties of self-consolidating concrete incorporating recycled steel, industrial steel, polypropylene and hybrid fibers. *Composites Part B Engineering*, *151*, 186–200. https://doi.org/10.1016/j.compositesb.2018.06.021

Matuszczak, E., Komarowska, M. D., Debek, W., & Hermanowicz, A. (2019). The impact of bisphenol A on fertility, reproductive system, and development: a review of the literature. *International Journal of Endocrinology*, *2019*, 4068717. https://doi.org/10.1155/2019/4068717

Merrington, A. (2017). Recycling of plastics. In *Applied plastics engineering handbook* (pp. 167–189). William Andrew Publishing.

Meys, R., Frick, F., Westhues, S., Sternberg, A., Klankermayer, J., & Bardow, A. (2020). Towards a circular economy for plastic packaging wastes–the environmental potential of chemical recycling. *Resources, Conservation and Recycling*, *162*, 105010. https://doi.org/10.1016/j.resconrec.2020.105010

Michielssen, M. R., Michielssen, E. R., Ni, J., & Duhaime, M. B. (2016). Fate of microplastics and other small anthropogenic litter (SAL) in wastewater treatment plants depends on unit processes employed. *Environmental Science: Water Research & Technology*, *2*(6), 1064–1073.

Milios, L., Christensen, L. H., McKinnon, D., Christensen, C., Rasch, M. K., & Eriksen, M. H. (2018). Plastic recycling in the Nordics: A value chain market analysis. *Waste Management (New York, NY)*, *76*, 180–189. https://doi.org/10.1016/j.wasman.2018.03.034

Milios, L., Esmailzadeh Davani, A., & Yu, Y. (2018). Sustainability impact assessment of increased plastic recycling and future pathways of plastic waste management in Sweden. *Recycling*, *3*(3), 33. https://doi.org/10.3390/recycling3030033

Min, K., Cuiffi, J. D., & Mathers, R. T. (2020). Ranking environmental degradation trends of plastic marine debris based on physical properties and molecular structure. *Nature Communications*, *11*(1), 1–11. https://doi.org/10.1038/s41467-020-14538-z

Ministry of Energy, Science, Technology, Environment and Climate (MESTECC). (2018). https://www.mestecc.gov.my/web/wp-content/uploads/2019/03/Malaysia-Roadmap-Towards-Zero-Single Use-Plastics-2018-20302.pdf

Mintenig, S. M., Int-Veen, I., Löder, M. G., Primpke, S., & Gerdts, G. (2017). Identification of microplastic in effluents of waste water treatment plants using focal plane array-based micro-Fourier-transform infrared imaging. *Water Research*, *108*, 365–372. https://doi.org/10.1016/j.watres.2016.11.015

Mir, A. H. (2015). Use of plastic waste in pavement construction: An example of creative waste management. *International Organization of Scientific Research*, *5*(2), 57–67.

Misal, K. S., Zambani, S. S., Gawande, D. S., & Malekar, O. (2019). Use of PET plastic waste in manufacturing and testing of plastic sand bricks. *International Journal for Research in Applied Science and Engineering Technology*, *7*(5), 1001–1006. https://doi.org/10.22214/ijraset.2019.5167

Mohammadinia, A., Wong, Y. C., Arulrajah, A., & Horpibulsuk, S. (2019). Strength evaluation of utilizing recycled plastic waste and recycled crushed glass in concrete footpaths. *Construction and Building Materials*, *197*, 489–496. https://doi.org/10.1016/j.conbuildmat.2018.11.192

Mohan, C. G., Mathew, J., Kurian, J. N., Moolayil, J. T., & Sreekumar, C. (2016). Fabrication of plastic brick manufacturing machine and bricks analysis. *International Journal for Innovative Research in Science and Technology*, *2*, 455–462.

Moharir, R. V., & Kumar, S. (2019). Challenges associated with plastic waste disposal and allied microbial routes for its effective degradation: a comprehensive review. *Journal of Cleaner Production*, *208*, 65–76. https://doi.org/10.1016/j.jclepro.2018.10.059

Mondal, M. K., Bose, B. P., & Bansal, P. (2019). Recycling waste thermoplastic for energy efficient construction materials: An experimental investigation. *Journal of Environmental Management*, *240*, 119–125. https://doi.org/10.1016/j.jenvman.2019.03.016

Mourshed, M., Masud, M. H., Rashid, F., & Joardder, M. U. H. (2017). Towards the effective plastic waste management in Bangladesh: a review. *Environmental Science and Pollution Research International*, *24*(35), 27021–27046. https://doi.org/10.1007/s11356-017-0429-9

Mrowiec, B. (2017). Plastic pollutants in water environment. *Ochrona Srodowiska i Zasobów Naturalnych*, *28*(4), 51–55. https://doi.org/10.1515/oszn-2017-0030

Nagy, A., & Kuti, R. (2016). The environmental Impact of plastic waste incineration. *Academic and Applied Research in Military Science*, *15*, 231–237.

Nakatani, J., Konno, K., & Moriguchi, Y. (2017). Variability-based optimal design for robust plastic recycling systems. *Resources, Conservation and Recycling*, *116*, 53–60. https://doi.org/10.1016/j.resconrec.2016.09.020

Nkwachukwu, O. I., Chima, C. H., Ikenna, A. O., & Albert, L. (2013). Focus on potential environmental issues on plastic world towards a sustainable plastic recycling in developing countries. *International Journal of Industrial Chemistry*, *4*(1), 34. https://doi.org/10.1186/2228-5547-4-34

Nodoushani, O., Stewart, C., & Kaur, M. (2016). Recycling and its effects on the environment. In *Competition forum* (Vol. 14, No. 1, p. 65). American Society for Competitiveness.

North, E. J., & Halden, R. U. (2013). Plastics and environmental health: the road ahead. *Reviews on Environmental Health*, *28*(1), 1–8. https://doi.org/10.1515/reveh-2012-0030

Nursyamsi, N., Indrawan, I., & Ramadhan, P. (2019). *The influence of the usage of ldpe plastic waste as fine aggregate in light concrete bricks [Paper presentation]*. MATEC Web of Conferences (Vol. 258, p. 01006). EDP Sciences.

Nyathi, B., & Togo, C. A. (2020). Overview of legal and policy framework approaches for plastic bag waste management in African Countries. *Journal of Environmental and Public Health*, *2020*, 1–8. https://doi.org/10.1155/2020/8892773

Ocean Crusaders. (n.d.). *Plastics Ain't So Fantastic*. Retrieved 10 December, 2020, from the Ocean Crusaders: https://oceancrusaders.org/plastic-crusades/plastic-statistics/#:~:text+Shoppers%20world-wide%20are%20using%20approximately,circumnavigate%20the%globe%204%2C200%20times.ide%

Oever, M., Molenveld, K., Zee, M., & Bos, H. (2017). *Bio-based and biodegradable plastics-facts and figures*. Wageningen Food & Biobased Research. https://doi.org/10.18174/408350

Ohemeng, E. A., & Ekolu, S. O. (2019). Strength prediction model for cement mortar made with waste LDPE plastic as fine aggregate. *Journal of Sustainable Cement-Based Materials*, *8*(4), 228–243. https://doi.org/10.1080/21650373.2019.1625826

Ohemeng, E. A., Yalley, P. P., Dadzie, J., & Djokoto, S. D. (2014). Utilization of waste low density polyethylene in high strengths concrete pavement blocks production. *Civil and Environmental Research*, *6*(5), 126–135.

Pacheco, E. B., Ronchetti, L. M., & Masanet, E. (2012). An overview of plastic recycling in Rio de Janeiro. *Resources, Conservation and Recycling*, *60*, 140–146. https://doi.org/10.1016/j.resconrec.2011.12.010

Padanyi, J., & Foldi, L. (2014). Environmental responsibilities of military soldiers on have to be "Greener Berets. *Ecology Management*, *2*, 48–55.

Palansooriya, K. N., Wijesekara, H., Bradney, L., Kumarathilaka, P., Bundschuh, J., Bolan, N. S., … Ok, Y. S. (2020). Characteristics of particulate plastics in terrestrial ecocystem. In N. S. Bolan, M. Kirkham, C. Halsband, D. Nugegoda, & Y. S. Ok (Eds.), *Particulate plastics in terrestrial and aquatic environment* (1st ed., pp. 107–124). CRC Press.

Palm, E., & Myrin, S. E. (2018). *Mapping the plastics system and its sustainability challenges*. Lund University.

Pan, D., Su, F., Liu, C., & Guo, Z. (2020). Research progress for plastic waste management and manufacture of value-added products. *Advanced Composites and Hybrid Materials*, *3*(4), 443–461. https://doi.org/10.1007/s42114-020-00190-0

Panyakapo, P., & Panyakapo, M. (2008). Reuse of thermosetting plastic waste for lightweight concrete. *Waste Management (New York, NY)*, *28*(9), 1581–1588. https://doi.org/10.1016/j.wasman.2007.08.006

Pawar, S. S., & Bujone, S. A. (2017). Use of fly ash and plastic in paver block. *International Journal of Engineering and Technology*, *4*, 1542–1547.

Pinto Da Costa, J., Rocha-Santos, T., & Duarte, A. C. (2020). *The environmental impacts of plastics and micro-plastics use, waste and pollution: EU and national measures. Policy Department for Citizens' Rights and Constitutional Affairs*. European Parliament's Committee on Petitions. Retrieved from https://www.europarl.europa.eu/RegData/etudes/STUD/2020/658279/IPOL_STU(2020)658279_EN.pdf

Plastic Insight. (2014). *World per-capita consumption of PE, PP & PVC resins*. Retrieved May 28, 2020, from Plastic Insight: http://www.plasticsinsight.com/world-per-capita-consumption-pe-pp-pvc-resins-2014/

Pocket Guide to Marine Debris. (2003). *The ocean conservancy*. Retrieved May 10, 2020, from Pocket Guide to Marine Debris: http://www.windowsonourwaters.org/biotimeline

Post, W., Susa, A., Blaauw, R., Molenveld, K., & Knoop, R. J. (2020). A review on the potential and limitations of recyclable thermosets for structural applications. *Polymer Reviews*, *60*(2), 359–388. https://doi.org/10.1080/15583724.2019.1673406

Prem, K. K., & Gomathi, M. (2017). Production of construction bricks by partial replacement of waste plastics. *IOSR Journal of Mechanical and Civil Engineerin*, *14*, 9–12.

Quoquab, F., & Mohammad, J. (2020). Striving for obtaining sustainability: Toil to adopt 'no plastic bag use'behaviour. In *CSR in an age of Isolationism*. Emerald Publishing Limited.

Racz, L., Fozer, D., Nagy, T., Toth, A. J., Haaz, E., Tarjani, J. A., Andre, A., Selim, A., Valentinyi, N., Mika, L. T., Deak, C., & Mizsey, P. (2018). Extensive comparison of biodiesel production alternatives with life cycle, PESTLE and multi-criteria decision analyses. *Clean Technologies and Environmental Policy*, *20*(9), 2013–2024. https://doi.org/10.1007/s10098-018-1527-1

Ragaert, K., Delva, L., & Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. *Waste Management*, *69*, 24–58. https://doi.org/10.1016/j.wasman.2017.07.044

Rahmani, E., Dehestani, M., Beygi, M. H. A., Allahyari, H., & Nikbin, I. M. (2013). On the mechanical properties of concrete containing waste PET particles. *Construction and Building Materials*, *47*, 1302–1308. https://doi.org/10.1016/j.conbuildmat.2013.06.041

Rai, B., Rushad, T., Kr, B., & Duggal, S. K. (2012). Study of waste plastic mix concrete with plasticizer. *ISRN Civil Engineering*, *2012*, 1–5. https://doi.org/10.5402/2012/469272

Rainieri, S., & Barranco, A. (2019). Microplastics, a food safety issue? *Trends in Food Science & Technology*, *84*, 55–57. https://doi.org/10.1016/j.tifs.2018.12.009

Rajmohan, K. V. S., Ramya, C., Viswanathan, M. R., & Varjani, S. (2019). Plastic pollutants: effective waste management for pollution control and abatement. *Current Opinion in Environmental Science & Health*, *12*, 72–84. https://doi.org/10.1016/j.coesh.2019.08.006

Rajput, P. S., & Yadav, R. K. (2016). Use of plastic waste in bituminous road construction. *IJSTE-International Journal of Science Technology & Engineering*, *2*(10), 509–513.

Rastogi, N., & Trivedi, M. K. (2016). PESTLE technique–a tool to identify external risks in construction projects. *International Research Journal of Engineering and Technology (IRJET)*, *3*(1), 384–388.

Reddy, S. K., Kumar, B. C., & Asadi, S. S. (2019). Utilization of low density polyethylene waste in the manufacturing of paver brick. *International Journal of Recent Technology and Engineering*, *7*, 62–67.

Reddy, S. (2018). *Plastic pollution affects sea life throughout the ocean*. Retrieved May 11, 2020, from Pewtrusts: https://www.pewtrusts.org/en/research-and-analysis/articles/2018/09/24/plastic-pollution-affects-sea-life-throughout-the-ocean

Rensburg, M. L., Nkomo, S., & Dube, T. (2020). The 'plastic waste era'; social perceptions towards single-use plastic consumption and impacts on the marine environment in Durban, South Africa. *Applied Geography Journal*, *114*(1), 102132.

Richards, Z. T., & Beger, M. (2011). A quantification of the standing stock of macro-debris in Majuro lagoon and its effect on hard coral communities. *Marine Pollution Bulletin*, *62*(8), 1693–1701. https://doi.org/10.1016/j.marpolbul.2011.06.003

Ritchie, H., & Roser, M. (2018). *Plastic pollution*. Retrieved June 7, 2019, from Our World in Data: https://ourworldindata.org/plastic-pollution

Rochman, C. M. (2015). The complex mixture, fate and toxicity of chemicals associated with plastic debris in the marine environment. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine anthropogenic litter* (pp. 117–140). Springer.

Rochman, C. M., Browne, M. A., Halpern, B. S., Hentschel, B. T., Hoh, E., Karapanagioti, H. K., Rios-Mendoza, L. M., Takada, H., Teh, S., & Thompson, R. C. (2013). Policy: Classify plastic waste as hazardous. *Nature*, *494*(7436), 169–171. https://doi.org/10.1038/494169a

Rochman, C. M., Hentschel, B. T., & Teh, S. J. (2014). Long-term sorption of metals is similar among plastic types: implications for plastic debris in aquatic environments. *PLOS One*, *9*(1), e85433. https://doi.org/10.1371/journal.pone.0085433

Rochman, C. M., Hoh, E., Hentschel, B. T., & Kaye, S. (2013). Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. *Environmental Science & Technology*, *47*(3), 1646–1654. https://doi.org/10.1021/es303700s

Rodrigues, M. O., Abrantes, N., Gonçalves, F. J. M., Nogueira, H., Marques, J. C., & Gonçalves, A. M., M. (2019). Impacts of plastic products used in daily life on the environment and human health: What is known? *Environmental Toxicology and Pharmacology*, *72*, 103239. https://doi.org/10.1016/j.etap.2019.103239

Rodríguez, A., Rodríguez, B., & Carrasco, M. N. (2012). High prevalence of parental delivery of plastic debris in Cory's shearwaters (Calonectris diomedea). *Marine Pollution Bulletin*, *64*(10), 2219–2223. https://doi.org/10.1016/j.marpolbul.2012.06.011

Rokdey, S. N., Naktode, P. L., & Nikhar, M. R. (2015). Use of plastic waste in road construction. *International Journal of Computer Applications*, *7*, 27–29.

Saikia, N., & de Brito, J. (2014). Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate. *Construction and Building Materials*, *52*, 236–244. https://doi.org/10.1016/j.conbuildmat.2013.11.049

Sarkar, D., & Pal, M. (2016). A laboratory study involving use of brick aggregate along with plastic modified bitumen in preparation of bituminous concrete for the roads of Tripura. *ARPN Journal of Engineering and Applied Sciences*, *11*, 570–576.

Saxena, R., Siddique, S., Gupta, T., Sharma, R. K., & Chaudhary, S. (2018). Impact resistance and energy absorption capacity of concrete containing plastic waste. *Construction and Building Materials*, *176*, 415–421. https://doi.org/10.1016/j.conbuildmat.2018.05.019

Schmaltz, E., Melvin, E. C., Diana, Z., Gunady, E. F., Rittschof, D., Somarelli, J. A., Virdin, J., & Dunphy-Daly, M. M. (2020). Plastic pollution solutions: emerging technologies to prevent and collectmarineplastic pollution. *Environment International*, *144*, 106067. https://doi.org/10.1016/j.envint.2020.106067

Schyns, Z. O., & Shaver, M. P. (2021). Mechanical recycling of packaging plastics: A review. *Macromolecular Rapid Communications*, *42*(3), e2000415. https://doi.org/10.1002/marc.202000415

Science for Environmental Policy. (2011). Plastic waste: ecological and human health impact. in depth report. *Science for Environmental Policy, 1, 1-44*.

Seuront, L. (2018). Microplastic leachates impair behavioural vigilance and predator avoidance in a temperate intertidal gastropod. *Biology Letters*, *14*(11), 20180453. https://doi.org/10.1098/rsbl.2018.0453

Shah, R., Garg, H., Gandhi, P., Patel, R., & Daftardar, A. (2017). Study of plastic dust bricks made from plastic waste. *International Journal of Mechanical and Production Engineering*, *5*, 120–123.

Shanmugavalli, B., Gowtham, K., Nalwin, P. J., & Moorthy, B. E. (2017). Reuse of plastic waste in paver blocks. *International Journal of Engineering & Technology*, *6*(02), 313–316.

Sharuddin, S. D. A., Abnisa, F., Daud, W. M. A. W., & Aroua, M. K. (2018). Pyrolysis of plastic waste for liquid fuel production as prospective energy resource. *In IOP Conference Series: Materials Science and Engineering*, *334*, 012001.

Shen, M., Huang, W., Chen, M., Song, B., Zeng, G., & Zhang, Y. (2020). (Micro) plastic crisis: Un-ignorable contribution to global greenhouse gas emissions and climate change. *Journal of Cleaner Production*, *254*, 120138. https://doi.org/10.1016/j.jclepro.2020.120138

Shen, L., & Worrell, E. (2014). Plastic recycling. In *Handbook of recycling* (pp. 179–190). Elsevier.

Shiri, N. D., Kajava, P. V., Ranjan, H. V., Pais, N. L., & Naik, V. M. (2015). Processing of waste plastics into building materials using a plastic extruder and compression testing of plastic bricks. *Journal of Mechanical Engineering and Automation*, *5*(3B), 39–42.

Shruti, V. C., Jonathan, M. P., Rodriguez-Espinosa, P. F., & Rodríguez-González, F. (2019). Microplastics in freshwater sediments of atoyac river basin, puebla city, Mexico. *Science of the Total Environment*, *654*, 154–163. https://doi.org/10.1016/j.scitotenv.2018.11.054

Sidique, S. F., Lupi, F., & Joshi, S. V. (2010). The effects of behavior and attitudes on drop-off recycling activities. *Resources, Conservation and Recycling*, *54*(3), 163–170. https://doi.org/10.1016/j.resconrec.2009.07.012

Simsek, B., Uygunoglu, T., Korucu, H., & Koxakerim, M. M. (2019). Performance of dioctly terephthalate conccrete. In *Use of recycled plastics in eco-efficient concrete* (pp. 249–267). Woodhead Publishing.

Singhal, A., & Netula, O. (2018). Utilization of plastic waste in manufacturing of plastic sand bricks. *3rd International Conference on New Frontiers of Engineering, Science, Management and Humanitie* (pp. 206–210).

Singh, N., Hui, D., Singh, R., Ahuja, I. P. S., Feo, L., & Fraternali, F. (2017). Recycling of plastic solid waste: A state of art review and future applications. *Composites Part B: Engineering*, *115*, 409–422. https://doi.org/10.1016/j.compositesb.2016.09.013

Singh, P., & Sharma, V. P. (2016). Integrated plastic waste management: environmental and improved health approaches. *Procedia Environmental Sciences*, *35*, 692–700. https://doi.org/10.1016/j.proenv.2016.07.068

Singh, L. B., Singh, L. G., Singh, P. B., & Thokchom, S. (2017). Manufacturing bricks from sand and waste plastics. *International Journal of Engineering Technology, Management and Applied Sciences*, *5*, 426–428.

Sinha, V., Patel, M. R., & Patel, J. V. (2010). PET waste management by chemical recycling: a review. *Journal of Polymers and the Environment*, *18*(1), 8–25. https://doi.org/10.1007/s10924-008-0106-7

Sobek, A., & Gustafsson, O. (2014). Deep water masses and sediments are main compartments for polychlorinated biphenyls in the Arctic Ocean. *Environmental Science & Technology*, *48*(12), 6719–6725. https://doi.org/10.1021/es500736q

Solis, M., & Silveira, S. (2020). Technologies for chemical recycling of household plastics–A technical review and TRL assessment. *Waste Management*, *105*, 128–138. https://doi.org/10.1016/j.wasman.2020.01.038

Sommerhuber, P. F., Welling, J., & Krause, A. (2015). Substitution potentials of recycled HDPE and wood particles from post-consumer packaging waste in Wood-Plastic Composites. *Waste Management (New York, NY)*, *46*, 76–85. https://doi.org/10.1016/j.wasman.2015.09.011

Srdjevic, Z., Bajcetic, R., & Srdjevic, B. (2012). Identifying the criteria set for multicriteria decision making based on SWOT/PESTLE analysis: a case study of reconstructing a water intake structure. *Water Resources Management*, *26*(12), 3379–3393. https://doi.org/10.1007/s11269-012-0077-2

Sridhar, R., Sachithanandam, V., Mageswaran, T., Purvaja, R., Ramesh, R., Senthil Vel, A., & Thirunavukkarasu, E. (2016). A Political, Economic, Social, Technological, Legal and Environmental

(PESTLE) approach for assessment of coastal zone management practice in India. *International Review of Public Administration*, *21*(3), 216–232. https://doi.org/10.1080/12294659.2016.1237091

Sultan, M., Jaiswal, R., Jaiswal, R., Sahu, F. R., Devannand, A., & Sahu, M. (2020). Utilization of waste plastic in manufacturing of plastic sand bricks. *International Journal of Innovations in Engineering and Science*, *5*, 38–42.

Sultana, A. K., & Prasad, K. B. (2012). Utilization of waste plastic as a strength modifier in surface course of flexible and rigid pavements. *International Journal of Engineering Research and Application*, *2*, 1185–1191.

Sun, L., Hong, L., Dong, L., Fang, K., Ren, J., Geng, Y., … Liu, Z. (2017). Eco-benefits assessment on urban industrial symbiosis based on material flows analysis and emergy evaluation approach: A case of Liuzhou city, China. *Resources, Conversation and Recycling*, *119*, 78–88.

Taaffe, J., O'Sullivan, S., Rahman, M. E., & Pakrashi, V. (2014). Experimental characterisation of Polyethylene Terephthalate (PET) bottle Eco-bricks. *Materials & Design*, *60*, 50–56. https://doi.org/10.1016/j.matdes.2014.03.045

Talvitie, J., Heinonen, M., Pääkkönen, J. P., Vahtera, E., Mikola, A., Setälä, O., & Vahala, R. (2015). Do wastewater treatment plants act as a potential point source of microplastics? Preliminary study in the coastal Gulf of Finland, Baltic Sea. *Water Science and Technology: A Journal of the International Association on Water Pollution Research*, *72*(9), 1495–1504. https://doi.org/10.2166/wst.2015.360

Tam, V. W. (2011). Rate of reusable and recyclable waste in construction. *The Open Waste Management Journal*, *4*(1), 28–32.

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., … Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2027–2045. https://doi.org/10.1098/rstb.2008.0284

The ASEAN Post. (2019). Will ASEAN ban single-use plastic? Retrieved February 7, 2020, from https://theaseanpost.com/article/will-asean-ban-single-use-plastic.

The Business Times. (2019). Malaysia building materials to cost more by end-2019: Report. Retrieved December 11, 2020, from The Business Times: https://www.businesstimes.sg/asean-business/malaysian-building-materials-to-cost-more-by-end-2019-report.

The Freedom Group Incorporation Press Release. (2014). US demand for bricks, blocks, pavers on the rise. Retrieved December 9, 2020, from Concrete Construction: https://www.concreteconstruction.net/producers/us-demand-for-bricks-blocks-pavers-on-the-rise_o.

Thiounn, T., & Smith, R. C. (2020). Advances and approaches for chemical recycling of plastic waste. *Journal of Polymer Science*, *58*(10), 1347–1364. https://doi.org/10.1002/pol.20190261

Thirugnanasambantham, N., Kumar, P. T., Sujithra, R., Selvaraman, R., & Bharathi, P. (2017). Manufacturing and testing of plastic sand bricks. *International Journal of Science and Engineering Research*, *5*, 1150–1155.

Thompson, R. C., Moore, C. J., Vom Saal, F. S., & Swan, S. H. (2009b). Plastics, the environment and human health: current consensus and future trends. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2153–2166. https://doi.org/10.1098/rstb.2009.0053

Thompson, R. C., Swan, S. H., Moore, C. J., & Vom Saal, F. S. (2009a). Our plastic age. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1526), 1973–1976. https://doi.org/10.1098/rstb.2009.0054

Tokyo Institute of Technology. (2020). Saving marine life: Novel method quantifies the effects of plastic on marine wildlife. Retrieved September 15, 2020, from Eurek Alert!: https://eurekalert.org/pub_releases/2020-08/tiot-sml083120.php

Torretta, V., Ferronato, N., Katsoyiannis, I. A., Tolkou, A. K., & Airoldi, M. (2016). Novel and conventional technologies for landfill leachates treatment: A review. *Sustainability*, *9*(1), 9. https://doi.org/10.3390/su9010009

Union for Conservation for Nature (IUCN). (2018). *Marine plastics*. Retrieved May 5, 2020, from IUCN: https://www.iucn.org/sites/dev/files/marine_plastics_issues_brief_final_0.pdf.

United Nations Environment Programme (UNEP). (2015). Plastic debris in the oceans. In *UNEP Yearbook 2014- Emerging issues in our global environment*. United Nations Environment Programme.

United Nations Environment Programme (UNEP). (2016). G. Arendal: Marine Litter Vital Graphics. Nairobi and Arendal: United Nations Environment Programme and GRID-Arendal.

Van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J., & Janssen, C. R. (2015). Microplastics in sediments: a review of techniques, occurrence and effects. *Marine Environmental Research*, *111*, 5–17. https://doi.org/10.1016/j.marenvres.2015.06.007

van Sebille, E., Wilcox, C., Lebreton, L., Maximenko, N., Hardesty, B. D., van Franeker, J. A., Eriksen, M., Siegel, D., Galgani, F., & Law, K. L. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*, *10*(12), 124006. https://doi.org/10.1088/1748-9326/10/12/124006

Vanitha, S., Natarajan, V., & Praba, M. (2015). Utilisation of waste plastics as a partial replacement of course aggregate in concrete blocks. *Indian Journal of Science and Technology*, *8*(12), 1–6. https://doi.org/10.17485/ijst/2015/v8i12/54462

Vaverková, M. D. (2019). Landfill Impacts on the Environment. *Geosciences*, *9*(10), 431.

Vegter, A. C., Barletta, M., Beck, C., Borrero, J., Burton, H., Campbell, M. L., Costa, M. F., Eriksen, M., Eriksson, C., Estrades, A., Gilardi, K. V. K., Hardesty, B. D., Ivar do Sul, J. A., Lavers, J. L., Lazar, B., Lebreton, L., Nichols, W. J., Ribic, C. A., Ryan, P. G., … Hamann, M. (2014). Global research priorities to mitigate plastic pollution impacts on marine wildlife. *Endangered Species Research*, *25*(3), 225–247. https://doi.org/10.3354/esr00623

Velmurugan, V., Gokul Raj, R., & Harinisree, A. (2019). Rebuilding of plastic waste to pavement bricks. *International Journal for Research in Applied Science and Engineering Technology*, *7*(4), 927–931. https://doi.org/10.22214/ijraset.2019.4165

Vishwakarma, A. (2020). Unsustainable management of plastic wastes in India: A threat to global warming and climate change. In *Contemporary environmental issues and challenges in era of climate change* (pp. 235–244). Springer.

Vollmer, I., Jenks, M. J. F., Roelands, M. C. P., White, R. J., Harmelen, T., Wild, P., Laan, G. P., Meirer, F., Keurentjes, J. T. F., & Weckhuysen, B. M. (2020). Beyond mechanical recycling: Giving new life to plastic waste. *Angewandte Chemie International Edition*, *59*(36), 15402–15423. https://doi.org/10.1002/anie.201915651

Wahab, D. A., Abidin, A., & Azhari, C. H. (2007). Recycling trends in the plastics manufacturing and recycling companies in Malaysia. *JAPSc*, *7*(7), 1030–1035.

Wahid, S. A., Rawi, S. M., & Desa, N. M. (2015). Utilization of plastic bottle waste in sand bricks. *Journal of Basic and Applied Scientific Research*, *5*(1), 35–44.

Wang, Z., Huo, J., & Duan, Y. (2020). The impact of government incentives and penalties on willingness to recycle plastic waste: An evolutionary game theory perspective. *Frontiers of Environmental Science & Engineering*, *14*(2), 1–12. https://doi.org/10.1007/s11783-019-1208-2

Wang, W., Themelis, N. J., Sun, K., Bourtsalas, A. C., Huang, Q., Zhang, Y., & Wu, Z. (2019). Current influence of China's ban on plastic waste imports. *Waste Disposal & Sustainable Energy*, *1*(1), 67–78. https://doi.org/10.1007/s42768-019-00005-z

Wanner, P. (2020). Plastic in agricultural soils–A global risk for groundwater systems and drinking water supplies?–A review. *Chemosphere*, 264, 128453.

Webb, H. K., Arnott, J., Crawford, R. J., & Ivanova, E. P. (2012). Plastic degradation and its environmental implications with special reference to poly (ethylene terephthalate). *Polymers*, *5*(1), 1–18. https://doi.org/10.3390/polym5010001

Weinstein, J. E., Crocker, B. K., & Gray, A. D. (2016). From macroplastic to microplastic: Degradation of high-density polyethylene, polypropylene, and polystyrene in a salt marsh habitat. *Environmental Toxicology and Chemistry*, *35*(7), 1632–1640. https://doi.org/10.1002/etc.3432

Wilcox, C., Van Sebille, E., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences*, *112*(38), 11899–11904. https://doi.org/10.1073/pnas.1502108112

Willis, K., Maureaud, C., Wilcox, C., & Hardesty, B. D. (2018). How successful are waste abatement campaigns and government policies at reducing plastic waste into the marine environment? *Marine Policy*, *96*, 243–249. https://doi.org/10.1016/j.marpol.2017.11.037

Winton, D. J., Anderson, L. G., Rocliffe, S., & Loiselle, S. (2020). Macroplastic pollution in freshwater environments: Focusing public and policy action. *Science of the Total Environment*, *704*, 135242. https://doi.org/10.1016/j.scitotenv.2019.135242

Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L. J., Coppock, R., Sleight, V., Calafat, A., Rogers, A. D., Narayanaswamy, B. E., & Thompson, R. C. (2014). The deep sea is a major sink for microplastic debris. *Royal Society Open Science*, *1*(4), 140317. https://doi.org/10.1098/rsos.140317

World Economic Forum. (2016). The new plastic economy: rethinking the future of plastics. In *Industry Agenda REF 080116*. World Economic Forum.

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., & Jambeck, J. (2017). Plastic as a persistent marine pollutant. *Annual Review of Environment and Resources*, *42*(1), 1–26. https://doi.org/10.1146/annurev-environ-102016-060700

Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: a micro issue? *Environmental Science & Technology*, *51*(12), 6634–6647. https://doi.org/10.1021/acs.est.7b00423

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. *Environmental Pollution (Barking, Essex : 1987)*, *178*, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

Yadav, V., Sherly, M. A., Ranjan, P., Tinoco, R. O., Boldrin, A., Damgaard, A., & Laurent, A. (2020). Framework for quantifying environmental losses of plastics from landfills. *Resources, Conservation and Recycling*, *161*, 104914. https://doi.org/10.1016/j.resconrec.2020.104914

Yang, Z., Lü, F., Zhang, H., Wang, W., Shao, L., Ye, J., & He, P. (2021). Is incineration the terminator of plastics and microplastics? *Journal of Hazardous Materials*, *401*, 123429. https://doi.org/10.1016/j.jhazmat.2020.123429

Yin, S., Tuladhar, R., Shi, F., Combe, M., Collister, T., & Sivakugan, N. (2015). Use of macro plastic fibres in concrete: A review. *Construction and Building Materials*, *93*, 180–188. https://doi.org/10.1016/j.conbuildmat.2015.05.105

Zaman, A. U. (2013). Identification of waste management development drivers and potential emerging waste treatment technologies. *International Journal of Environmental Science and Technology*, *10*(3), 455–464. https://doi.org/10.1007/s13762-013-0187-2

Zander, N. E., Gillan, M., & Lambeth, R. H. (2018). Recycled polyethylene terephthalate as a new FFF feedstock material. *Additive Manufacturing*, *21*, 174–182. https://doi.org/10.1016/j.addma.2018.03.007

Zaroudi, M., Madandoust, R., & Kamran, A. (2020). Fresh and hardened properties of eco-friendly fiber reinforced self-consolidated concrete composed of polyolefin fiber and natural zeolite. *Construction and Building Materials*, *241*, 118064. https://doi.org/10.1016/j.conbuildmat.2020.118064

Zhao, Y. B., Lv, X. D., & Ni, H. G. (2018). Solvent-based separation and recycling of waste plastics: A review. *Chemosphere*, *209*, 707–720. https://doi.org/10.1016/j.chemosphere.2018.06.095

Zhou, A., Zhang, Y., Xie, S., Chen, Y., Li, X., Wang, J., & Zou, J. (2021). Microplastics and their potential effects on the aquaculture systems: a critical review. *Reviews in Aquaculture*, *13*(1), 719–733. https://doi.org/10.1111/raq.12496

Ziajahromi, S., Neale, P. A., Rintoul, L., & Leusch, F. D. (2017). Wastewater treatment plants as a pathway for microplastics: development of a new approach to sample wastewater-based microplastics. *Water Research*, *112*, 93–99. https://doi.org/10.1016/j.watres.2017.01.042

Ziv-Gal, A., & Flaws, J. A. (2016). Evidence for bisphenol A-induced female infertility: a review (2007-2016). *Fertility and Sterility*, *106*(4), 827–856. https://doi.org/10.1016/j.fertnstert.2016.06.027