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The Positive Impact of Plastic Recycling in the Built Environment, Architecture and the Waters of the World

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ABSTRACT

One of the ever present facts of human existence is the generation of wastes. Collection and disposal of these wastes, which are mostly plastics have always been major concerns of societies for both health and economic reasons. Every hour, Americans use 2.5 million plastic bottles, most of which are thrown away. About 9.1% of plastic production was recycled in the U.S. during 2015 although, varying by product category. Plastic packaging was recycled at 14.6%, plastic durable goods at 6.6%, and other non-durable goods at 2.2%. Currently, 25 percent of plastic waste is recycled in Europe, Americans recycled 3.14 million tons of plastics in 2015, down from 3.17 million in 2014. It is the primary aim of this article to draw attention to the benefits of recycling plastics and how it is helping in keeping the built environment healthy. The instrument of more than two research strategies; quantitative and qualitative research methods and their tactics were used. Secondary data were based on direct observation and relevant documents from previous studies on the related matter. Plastic recycling faces many challenges, ranging from mixed plastics to hard-to-remove residues. The cost-effective and efficient recycling of the mixed plastic stream is perhaps the biggest challenge facing the recycling industry. With the abundance of empty plastic bottles and soil, most poor communities have embarked on taking advantage of the resources in building comfortable houses for themselves and the use of these resources have helped in keeping the built environment clean.

KEYWORDS: *environment, recycling, architecture, road construction, landscape, regeneration*

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INTRODUCTION

The rapid increase in municipal solid waste is a significant global problem. Municipal solid waste is what everyone else calls garbage. It's about bottles, cans, disposables, diapers, uneaten food, scraps of wood and metal, worn-out tires, and used-up batteries, papers and plastic packages, boxes, broken furniture and appliances, clippings from our lawns and shrubs-the varied human refuse of our modern industrial society, Obiadi and Ezezue, (2015) citing Porter (1989). As the Organization for Economic Cooperation and Development stated, population growth and increasing per capital output have led to an increasing generation of goods, and hence of waste. Also increasing per capita income and changing patterns of consumption have resulted in materials previously regarded as useful now being discarded. In short, per capita waste generated has been rising sharply, leading to increased disposal cost; there is no indication that this trend would significantly be reversed in near future unless appropriate measures are taken. Additionally, locational changes such as the continuing migration of people to urban areas, and the concentration of livestock into intensive production units, exacerbate local problems of waste disposal (Obiadi and Ezezue, 2015).

One of the ever present facts of human existence is the generation of wastes. People produce wastes in their homes, work places and leisure area. Collection and disposal of these wastes have always been major concerns of societies, for both health and economic reasons. As global population increases at tremendous rate, waste generation throughout the world has also drastically increased; however, this problem is most acutely felt in the least developed counties (LDCs). In 1996, two thirds of the respondents to the solid waste management research conducted by Obiadi and Ezezue (2015) indicated that, they did not recycle their garbage. However, their field study shows that the people actually recycle without knowing what they were doing. All the cities had what they called "Ndi-onono-nkpo" (used item contractors). These contractors walked around the streets, buying empty bottles, plastics containers, news papers and other valuables. The used items were resold to the merchants in the market or in-front of the hospitals who used them for different needs (resale).

In 2012-2013, 117 out of the 255 (46%) respondents to their research indicated that they recycle their garbage while 54 percent do not. The percentage of the respondents, who indicated that they recycled their garbage in 1996 increased by 9 percent. In 1996, it was 37 percent. The field study shows that more people recycle now than they did in 1996. In the communities today, there is insatiable want for empty water plastic containers used by both petty traders, industries and at homes, in storing different products including, but not limited to, palm oil, palm wine, kerosene, petrol, malaria medicines, fruit juices and endless list of others. Industries now buy large quantities of both plastic containers and metal products and recycle them into other products and most of them either resold or exported. This recycling aspect of municipal solid waste disposal has helped in keeping clean, the communities. In all the three cities studied by the researchers, Lagos, Enugu and Onitsha, Nigeria, selling both plastic bottles and empty sachet water wraps on their streets was a common practice. In 1996, such was not the case. In 2012 – 2-13, their field study shows that most of the sachet water wraps and the empty plastic water containers ended up in gutters (plates 1 and 2) and water ways (Obiadi and Ezezue, 2015).

Plate 1. Randle Street, Surulere, Lagos Water Channel clogged with empty plastic water containers
Source: Obiadi (2012)

Plate 2. Surulere, Lagos Population Census area canal, covered and blocked with millions of empty plastic water containers
Source: Obiadi (2012)

With the global environmental concerns, a Nigerian, Intissar bsahir-Kurfi, based in Abuja, the Federal Capital Territory (FCT) of the Nigeria, channels her energy into converting wastes from sachet water nylons and other recyclable plastics into interlocking tiles (plate 3) in the FCT. Her drive emerged from her hatred for seeing plastics and sachet water nylons litter the streets and eventually washed by erosion to block drainages thereby causing flood in the community and posing danger to the inhabitants. Her passion is to see a clean environment free from litters and also make good use of the wastes by converting them into reusable products. According to her, the interlocking tiles made from plastics and nylons are more durable than regular ones because nylons ordinarily can stay several years in the layers of the earth without decay, hence making a product from such material surely poses longevity of durability. Another good thing is that she already devised a means to make the tiles beautiful by making them in various colours (plate 3). From the tons of wastes the nation generates on a daily basis, if thoroughly harnessed, this business should not fade of any moment soon (My Engineers, 2020).

Plate 3. Colored ties used in building construction and erosion control
Source: Obiadi (2017)

According to the data presented by LeBlanc (2019), every hour, Americans use 2.5 million plastic bottles, most of which are thrown away. About 9.1% of plastic production was recycled in the U.S. during 2015 although, varying by product category. Plastic packaging was recycled at 14.6%, plastic durable goods at 6.6%, and other non-durable goods at 2.2%. Currently, 25 percent of plastic waste is recycled in Europe, Americans recycled 3.14 million tons of plastics in 2015, down from 3.17 million in 2014. Recycling plastic takes 88% less energy than producing plastics from new raw materials. The energy saved from recycling just a single plastic bottle can power a 100 watt light bulb for nearly an hour. Currently, around 50% of plastics we use are thrown away just after a single use and plastics account for 10% of total global waste generation and plastics can take hundreds of years to degrade. The plastics that end up in the oceans, break down into small pieces and every year around 100,000 marine mammals and one million seabirds get killed eating those small pieces of plastics.

The trend in plastic manufacturing is changing and a lot of plastic manufacturers use recycled plastics both in their products and product packaging and a lot of authors have defined plastic recycling differently. According to LeBlanc (2019), plastic recycling refers to the process of recovering waste or scrap plastic and reprocessing the materials into functional and useful products. This activity is known as the plastic recycling process. The goal of recycling plastic is to reduce high rates of plastic pollution while putting less pressure on virgin materials to produce brand new plastic products. This approach helps to conserve resources and diverts plastics from landfills or unintended destinations such as oceans. Plastics are durable, lightweight and inexpensive materials. They can readily be moulded into various products which find uses in a plethora of applications. Every year, more than 100 million tons of plastics are manufactured across the globe. Around 200 billion pounds of new plastic material is thermoformed, foamed, laminated and extruded into millions of packages and products. Consequently, the reuse, recovery and the recycling of plastics are extremely important.

Plastic recycling is the process of recovering scrap or waste plastic and reprocessing the material into useful products. Since the majority of plastic is non-biodegradable, recycling is a part of global efforts to reduce plastic in the waste stream, especially the approximately 8 million metric tons of waste plastic that enters the Earth's ocean every year (Hardesty and Wilcos, 2015, Jambeck, 2015). Compared with lucrative recycling of metal, and similar to the low value of glass recycling, plastic polymers recycling is often more challenging because of low density and low value. There are also numerous technical hurdles to overcome when recycling plastic. Materials recovery facilities are responsible for sorting and processing plastics. As of 2019, due to limitations in their economic viability, these facilities have struggled to make a meaningful contribution to the plastic supply chain (Municipal Sector, 2019). When different types of plastics are melted together, they tend to phase-separate, like oil and water, and set in these layers. The phase boundaries cause structural weakness in the resulting material, meaning that polymer blends are useful in only limited applications.

Nearly all types of plastics can be recycled. However, the extent to which they are recycled depends upon technical, economic and logistic factors. Plastics are a finite and valuable resource, so the best outcome after their initial use is typically to be recycled into a new product. Across the United Kingdom (UK), as part of local authorities waste management, nearly all councils provide plastics recycling collection. This plastic is then 'post-consumer' plastics packaging waste, and is supplied to the recycling sector. The amount which is collected and recycled has increased each year for at least the last twenty-five years (Plastic Recycling, 2020).

According to Plastics Europe (2019), capturing waste plastic and channelling it into efficient recycling and recovery routes is widely recognized as a key way to reduce costs and environmental impact across the construction, manufacturing and retail sectors in particular. The recyclability of plastic is also one of its key strengths as an extremely resource-efficient material and used plastic should ideally be regarded as a valuable resource rather than waste. There is no simple answer to how many times plastic can be recycled. It depends on the type of plastic, how it is being recycled and what it is being recycled for. Polymers do slightly break down as they are recycled, but this minor degradation is easily countered by mixing in calculated amounts of 'virgin' (new) plastic. Once the plastic is collected and sent to a recycling centre, it is typically separated into different polymer types, which are then separately shredded (and impurities like paper are removed), then melted back into polymer pellets. These pellets are then sold on to be used in new products. Recycling and other recovery processing routes help reduce environmental impacts, as well as save costs, across the construction, manufacturing and retail sectors in particular.

Recycling rates in the United Kingdom (UK) have come a long way in recent years and continue to grow year on year. For example, in the year 2000 only 13,000 tons of plastic bottles were recycled (Hardesty and Wilcox, 2015); the UK now recycles over 370,000 tons a year (Jambeck, 2015). The total proportion of plastics being recycled varies by region around the world, with the Europe (EU) coming third overall.

There are six common types of plastics as indicated by LeBlanc (2019),
- PS (Polystyrene) – Example: foam hot drink cups, plastic cutlery, containers, and yogurt.
- PP (Polypropylene**)** – Example: lunch boxes, take-out food containers, ice cream containers.
- LDPE (Low-density polyethylene) **–** Example: garbage bins and bags.
- PVC (Plasticised Polyvinyl chloride or polyvinyl chloride)—Example: cordial, juice or squeeze bottles.
- HDPE (High-density polyethylene) **–** Example: shampoo containers or milk bottles.
- PET (Polyethylene terephthalate) **–** Example: fruit juice and soft drink bottles.

Currently, only PET, HDPE, and PVC plastic products are recycled under curbside recycling programs. PS, PP, and LDPE typically are not recycled because these plastic materials get stuck in the sorting equipment in recycling facilities causing it to break or stop. Lids and bottle tops cannot be recycled as well. To recycle or Not to Recycle is a big question when it comes to plastic recycling. Some plastic types are not recycled because they are not economically feasible to do so (LeBlanc, 2019).

There is no mandatory need to mark plastic in a way that signifies what polymer it is. However, to aid recycling, the British Plastic Federation (BPF) recommends that larger parts and packaging should be marked with an appropriate identification code. The BPF recommends the use of a coding system devised by the Plastics Industry Association as below. Molded plastics items should be marked in accordance with ISO 11469:2016 where possible (British Plastics Federation, 2020).

1 PETE	PET	polyethylene terephthalate	Water bottles, soft and fizzy drink bottles, pots, tubs, oven ready trays, jam jars
2 HDPE	HDPE	high-density polyethylene	Chemical drums, jerricans, carboys, toys, picnic ware, household and kitchenware, cable insulation, carrier bags, food wrapping material.

3 V	PVC	polyvinyl chloride	Window frames, drainage pipe, water service pipe, medical devices, blood storage bags, cable and wire insulation, resilient flooring, roofing membranes, stationery, automotive interiors and seat coverings, fashion and footwear, packaging, cling film, credit cards, synthetic leather and other coated fabrics.
4 LDPE	LDPE	low density polyethylene	Squeeze bottles, toys, carrier bags, high frequency insulation, chemical tank linings, heavy duty sacks, general packaging, gas and water pipes.
5 PP	PP	polypropylene	Buckets, crates, toys, medical components, washing machine drums, bottle caps, and battery cases.
6 PS	PS	polystyrene	Toys and novelties, rigid packaging, refrigerator trays and boxes, cosmetic packs and costume jewellery.
7 OTHER	Other	other types of plastics	

As of 2015, approximately 6.3 billion tons of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated, and 79% was accumulated in landfills or the natural environment (Geyer, 2017). In 2016 only 14% of plastic waste was recycled globally (Ellen, 2016). According to the United State Environmental Protection Agency (EPA), the recycling rate for plastics overall was 9.1% in 2015. Certain products have higher rates, such as PET bottles and jars at 29.9%, and HDPE natural bottles at 30.3%. These rates are lower than certain other materials, like steel cans, that had an estimated recycling rate of 71.3% in 2015 (Ferrous Metals, 2019, Plastic Materials, 2016). Japan's plastic waste utilization rate stood at 39% in 1996, increasing to 73% in 2006, 77% in 2011 (McCurry, 2011), 83% in 2014 and 86% in 2017, according to the nation's Plastic Waste Management Institute. The Ocean Conservancy reported that China, Indonesia, Philippines, Thailand, and Vietnam dump more plastic in the sea than all other countries combined (Hannah, 2018). Scientific American reported that China dumps 30% of all plastics in the ocean, followed by Indonesia, the Philippines, Vietnam, Sri Lanka, Thailand, Egypt, Malaysia, Nigeria and Bangladesh (Will, 2019). The United States, in 2015, produced 34.5 million tons of plastic, which was about 13% of total waste (Olem, 2017). About 9% of that was recycled. Most of the waste stream is biodegradable, but plastic though only 13% of the waste stream is persistent and accumulates (Olem, 2017). British Plastics Federation (BPF) Member, Axion Polymers, analysed its carban footprint. It found that substituting one tone of virgin polypropylene (PP) for one tone of Axpoly rPP would save nearly 1200 kg CO2, which is the equivalent to transporting the materials from London to Milan in a standard lorry. Although this data is specific to Axion Polymers'process, other methods will show similar benefits (Axionpolymers 2017).

As more plastic is recovered and recycled, it provides increasing amounts of raw material for the recycling sector, which can be used for either 'closed loop' or 'open loop' recycling. Closed loop recycling means a product is recycled into another, almost identical product. A simple example of this is recycling a PET drink bottle into a new PET drink bottle. Open loop recycling means a product is turned into a new type of product. For example, recycled plastic packaging could end up in a plastic water pipe, a park bench or even a pair of trainers. Although many environmentalists understandably favour closed loop recycling, open loop recycling is still valuable as products like a park bench have a very long life, using recycled material is often more resource efficient and applications like this provide a market for recycled plastic that is not of sufficient quality or purity for going back into products that will be in contact with food or drink. Broadly, there are two major ways to recycle plastic: (Indorama, 2016) (1) mechanical recycling ("chop and wash", where the plastic is washed, ground into powders and melted, and (2) chemical recycling, where the plastic is broken down into basic components.

Technically, every plastic can be recycled, but the extent to which they are recycled depends upon economic and logistical factors. The most widely recycled plastics are the two used to make soft drinks bottles and milk bottles: PET and HDPE. Traditional recycling is known as 'mechanical recycling'. A technology known as 'chemical recycling' means mixed batches of all types of plastic can be recycled – even back into food-grade packaging. The application of this technology to recycle large amounts of plastic is relatively new and work is underway to scale it up (Plastic Europe, 2019).

An estimated 60 companies are pursuing chemical recycling as of 2019. In 2019, Eastman Chemical Company announced initiatives for methanolysis of polyesters and polymer gasification to syngas designed to handle a greater variety of used material (Siegel, 2019). Chemical recycling' is the broad term used to describe a range of technologies, other than mechanical recycling, that are emerging in the plastic waste recycling sector to recycle plastics streams that are currently sent to landfill or incineration.

In turning plastic waste back into base chemicals and chemical feed stocks, these processes are defined as recycling and contribute to improving recycling rates and enable the petrochemical industry to manufacture new virgin quality and food grade polymers with recycled content. New technologies have been developed for chemical recycling and several pilot plants across Europe are operating and expanding on an industrial scale. Commercial plants will range in size from large-scale centralized plants with 30-200kt annual throughput to much smaller modular, distributed units with capacity from 3-10kt per annum. Although different technologies will operate differently and produce different end-products, the broader category of chemical recycling is a complementary recycling solution to mechanical recycling for residual plastic waste, able to extract further value from polymers that have exhausted their potential for further mechanical processing. Chemical recycling provides an alternative to landfill and incineration for erstwhile hard-to-recycle plastic wastes, such as films, multi-layered and laminated plastics (Plastic Europe, 2019).

Most plastic recycling facilities use the following two-step process: **Step One:** Sorting plastics automatically or with a manual sort to make sure all the contaminants are removed from the plastic waste stream. **Step Two:** Melting down plastics directly into a new shape or shredding into flakes then melting down before being finally processed into granulates. Ongoing innovations in recycling technologies have made the plastic recycling process easier and more cost-effective. Such technologies include reliable detectors and sophisticated decision and recognition software that collectively enhance the productivity and accuracy of automatic sorting of plastics. For an example, FT-NIR detectors can run for up to 8,000 hours between faults in the detectors. Another notable innovation in plastic recycling has been in finding higher value applications for recycled polymers in closed-loop recycling processes. Since 2005, for example, PET sheets for thermoforming in the United Kingdom can contain 50 percent to 70 percent recycled PET through the use of A/B/A layer sheets. Recently, some European countries including Germany, Spain, Italy, Norway, and Austria have begun collecting rigid packaging such as pots, tubs, and trays as well as a limited amount of post-consumer flexible packaging. Due to recent improvements in washing and sorting technologies, the recycling of non-bottle plastic packaging has become feasible (LeBlanc, 2019).

The recycling of plastic bottles has been made mandatory in several U.S. states including California, Connecticut, Massachusetts, New Jersy, North Carolina, Pennsylvania, and Wisconsin. Recycling is critical to effective end-of-life plastic management. Increasing recycling rates have resulted from greater public awareness and the increased effectiveness of recycling operations. Recycling of a greater range of post-consumer plastic products and packaging will further boost recycling and divert more end-of-life plastic wastes from landfills (LaBlanc, 2019).

In 2019, Brightmark Energy in the United States began building a facility to convert 100,000 tons of mixed plastic per into diesel, naphtha blend stocks, and wax; (Commercial Plastic, 2019) the company plans to expand into building another plant which can process an additional 800,000 tons of plastic per year (Munucipal Sector, 2019). The company has said that the economics have a significant margin of safety from price declines (Investors Explain Decision, 2019).

Recently, the use of block copolymers as molecular stitches (Creton, 2017), or "macromolecular welding flux" has been proposed (Eagan, J. M. et al (2017), to overcome the difficulties associated with phase separation during recycling (Fleischman, 2017). Certain bioplastics, such as PLA, recycled by breaking down plastic polymers into their chemical building blocks, can be recycled hundreds of times. The use of biodegradable plastics or plastics which can be organically recycled or can be composted in industrial composting is increasing for certain short-lived packaging applications (Hatti, Tornvall, Gustafsson and Borjesson, 2007).

A process has also been developed in which many kinds of plastic can be used as a carbon source (in place of coke) in the recycling of scrap steel (Scientist, 2014). There are also possibilities for better recycling of mixed plastics, avoiding the need for expensive/inefficient separation of the plastic waste stream. One such method is called compatibilization which uses special chemical bridging agents called compatibilizers to maintain the quality of mixed polymers (Ignatyev, Thielemans, Beke, 2014). Post-consumer polyethylene terephthalate (PET or PETE) containers are sorted into different color fractions and baled for onward sale. PET recyclers further sort the baled bottles and they are washed and flaked (or flaked and then washed). Non-PET fractions such as caps and labels are removed during this process. The clean flake is dried. Further treatment can take place e.g. melt filtering and pelletizing or various treatments to produce food-contact-approved recycled PET (RPET). This sorted post-consumer PET waste is crushed, chopped into flakes, pressed into bales, and offered for sale (Idea, 2010).

The recycling of 'post-commercial' industrial and agricultural films is well established in the UK. Products made from recycled films include refuse sacks, damp-proof membranes, fencing and garden furniture. Collection of 'post-consumer' film is still developing, however, and currently few councils collect it. This currently refers to the very thin films that often seal food within a plastic tray, for example. Films are extremely resource efficient from a CO2 and material-use perspective and help to save countless tons of food from going to waste every year. Post-consumer film from packaging can, in fact, be recycled (all plastics can technically be recycled). Chemical recycling technologies are capable of converting mixed batches of all plastics, including plastic films back into oil, which can then be converted back into plastic.

Biodegradability is an area of growing interest and is often viewed as a solution to litter. There is concern that the mistaken idea that this material will necessarily break down in the natural environment could lead to an increase in littering. Often, plastics that are referred to as 'biodegradable' or 'compostable' require industrial composting facilities to decompose and they will not break down in the natural environment. There is also very limited information and no standards available about how biodegradable or oxodegradable material will perform in the marine environment. The only standards available are for industrial composting. The impact of degradable materials on the recycling of conventional plastics is also a major concern for many recyclers. Even the perceived risk of recycled material containing degradable plastic can prevent a batch of recycled plastic from being used. This is especially true for recycled plastic used in long-term applications, such as in plastic pipes. Manufacturers do not want to risk their products starting to biodegrade or for the quality to decline unpredictably over time (Plastic Europe, 2019). The fact is that, it is very hard to distinguish between a conventional and a biodegradable or oxodegradable plastic means they may contaminate existing recycling streams. If they were to be more widely adopted, it is generally accepted that they would need a separate collection system.

Aim of the Article

The aim of this article is to draw attention to the benefits of recycling used plastics and how it is helping in keeping, the built environment healthy, the products reused in the architecture of the built environment.

Research Methodology

The instrument of more than two research strategies; quantitative and qualitative research methods and their tactics were used. Secondary data were based on direct observation and relevant documents from previous studies on the related matter.

Findings

Plastic recycling faces many challenges, ranging from mixed plastics to hard-to-remove residues. The cost-effective and efficient recycling of the mixed plastic stream is perhaps the biggest challenge facing the recycling industry. Experts believe that designing plastic packaging and other plastic products with recycling in mind can play a significant role in facing this challenge. The recovery and recycling of post-consumer flexible packaging is a recycling problem. Most material recovery facilities and local authorities do not actively collect it due to a lack of equipment that can efficiently and easily separate them (LeBlanc, 2019).

Recycling empty plastic containers (wastes) has a lot of advantages and the importance can never be overemphasized. The advantages would include, but not limited to:

- Provision of sustainable source of raw materials to the industries
- Greatly reduces the environmental (especially the CO2) impact of plastic-rich products
- Minimizes the amount of plastic being sent to the landfill sites
- Avoids the consumption of the Earth's oil stocks
- Consumes less energy than producing new, virgin polymers
- Embeds the right values and behaviour to reduce human impact on the environment (Axionpolymers, 2017)

Oceanic plastic pollution has become a recent flashpoint for public concern. Ocean plastic is expected to triple in the next decade, and public concern has prompted leading organizations around the world to take action towards better plastic resource management and pollution prevention (LeBlanc, 2019).

One use for this recycled PET is to create fabrics to be used in the clothing industry (PT, 2009) The fabrics are created by spinning the PET flakes into thread and yarn (Idea, 2010). This is done just as easily as creating polyester from brand new PET (Reware's 2010). The recycled PET thread or yarn can be used either alone or together with other fibers to create a very wide variety of fabrics. Traditionally these fabrics are used to create strong, durable, rough products, such as jackets, coats, shoes, bags, hats, and accessories since they are usually too rough for direct skin contact and can cause irritation. However, these types of fabrics have become more popular as a result of the public's growing awareness of environmental issues. Numerous fabric and clothing manufacturers have capitalized on this trend (Billabong, 2008).

In the United States, the recycling rate for PET packaging was 31% in 2013, according to a report from The National Association for PET Container Resources (NAPCOR) and The Association of Postconsumer Plastic Recyclers (APR). A total of 1.798 billion pounds was collected and 475 million pounds of recycled PET used out of a total of 5.764 billion pounds of PET bottles (Recycling for PET, 2016).

Scientists have estimated that the potential commodity value of waste plastic may be in excess of $300 per ton when used in process pathways yielding high-value chemical products or to produce electricity in efficient IGCC (Integrated Gasification Combined Cycle) processes (Fox, Stacy, 2019).

High-density polyethylene (HDPE) is a commonly recycled plastic. HDPE's highly crystalline structure makes it a strong, high density, moderately stiff plastic. HDPE Thermoplastic materials become liquid at their melting point—around 130 °C. A major benefit of thermoplastics is that they can be heated to melting point, cooled, and reheated again without significant degradation. Instead of burning, thermoplastics like PE (Polyethylene) liquefy, allowing them to be easily extruded or injection molded and turned into brand new HDPE pipe. Often it is typically downcycled into plastic lumber, tables, roadside curbs, benches, truck cargo liners, trash receptacles, stationery (e.g. rulers) and other durable plastic products and is usually in demand (Polystyrene, 2017).

After sorting, for mechanical recycling the plastic recyclables are then shredded. These shredded fragments then undergo processes to eliminate impurities like paper labels. This material is melted and often extruded into the form of pellets which are then used to manufacture other products. The highest quality purification may be referred to as "regeneration" (Understanding Recycling, 2019).

Each time plastic is recycled, additional virgin materials must be added to help improve the integrity of the material. So, even recycled plastic has new plastic material added in. The same piece of plastic can only be recycled about 2–3 times before its quality decreases to the point where it can no longer be used (National Geography, 2019).

Most polystyrene products are not recycled due to the lack of incentive to invest in the compactors and logistical systems required. As a result, manufacturers cannot obtain sufficient scrap. Expanded polystyrene (EPS) scrap can easily be added to products such as EPS insulation sheets and other EPS materials for construction applications. When it is not used to make more EPS, foam scrap can be turned into clothes hangers, park benches, flower pots, toys, rulers, stapler bodies, seedling containers, picture frames, and architectural molding from recycled PS. Recycled EPS is also used in many metal casting operations. Rastra is made from EPS that is combined with cement to be used as an insulating amendment in the making of concrete foundations and walls. Since 1993, American manufacturers have produced insulating concrete forms made with approximately 80% recycled EPS (Polystyrene, 2017).

Successful trials in Israel have shown that plastic films recovered from mixed municipal waste streams can be recycled into useful household products such as buckets (Plastic Trial Procedure, 206). Similarly, agricultural plastics such as mulch film, drip tape and silage bags are being diverted from the waste stream and successfully recycled (Agricultural Plastic, 2008) into much larger products for industrial applications such as plastic composite railroad ties (Plastic Composite Railroad Tie Facts, 2008). Historically, these agricultural plastics have primarily been either landfilled or burned on-site in the fields of individual farms (Garthe, Kowal, 2017).

CNN reports that Dr. S. Madhu of the Kerala Highway Research Institute, India, has formulated a road surface that includes recycled plastic: aggregate, bitumen (asphalt) with plastic that has been shredded and melted at a temperature below 220 °C (428 °F) to avoid pollution. This road surface is claimed to be very durable and monsoon rain resistant. The test road used 60 kg of plastic for an approximately 500-meter-long, 8-meter-wide, two-lane road. The process chops thin-film road-waste into a light fluff of tiny flakes that hot-mix plants can uniformly introduce into viscous bitumen with a customized dosing machine. Tests at both Bangalore and the Indian Road Research Centre indicate that roads built using this 'KK process' will have longer useful lives and better resistance to cold, heat, cracking, and rutting, by a factor of 3 (Patel, 2003).

The quantity of post-consumer plastics recycled has increased every year since at least 1990, but rates lag far behind those of other items, such as newspaper (about 80%) and corrugated fiberboard (about 70%) (Alan, 2007). Overall, U.S. post-consumer plastic waste for 2008 was estimated at 33.6 million tons; 2.2 million tons (6.5%) were recycled and 2.6 million tons (8%) were burned for energy; 28.9 million tons, or 86%, were discarded in landfills (Journalist's Resources.org, Retrieved May 2020).

As applied in India's road construction works, the use of recycled plastic products is equally gaining attention in the architecture of the built environment, buildings and in landscaping works. Plate 4 is a picture of recycled plastic melted and used in building palets.

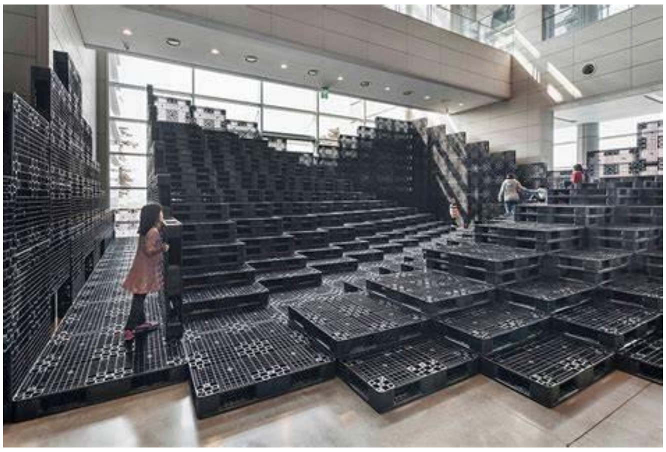

Plate 4. Live components built tectonic Landscape
Source: Designboom

Plate 5 is a pavilion built with recycled plastic materials. Plate 6 is a chair, made of plastic bottles held in place with fabricated metal frame.

Plate 5. Plastic Pavilion
Source:https://i.pinimg.com/736x/bd/d7/f7/bdd7f7357a6b069b818831dea891bd08.jpg

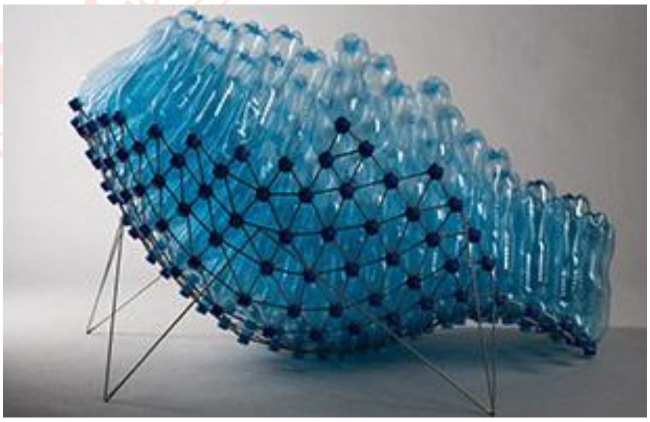

Plate 6. Chair made of upcycled plastic bottles
Source: Powel Grunert, designwillsavetheworld.net

With the abundance of empty plastic bottles and soil, most poor communities have embarked on taking advantage of the resources in building comfortable houses for themselves (plates 7, 8 and 9). Plate 7 shows a collection of empty plastic bottles been filled with sand and used in building walls in plates 8 and9.

Plate 7. Plastic bottles been filled with sand, to be used in urban poor shelter
Source: Duchung (retrieved September 26, 2017).

Plate 8. Typical urban poor shelter made of plastic bottles filled with sand.
Source: Duchung (retrieved September 26, 2017).

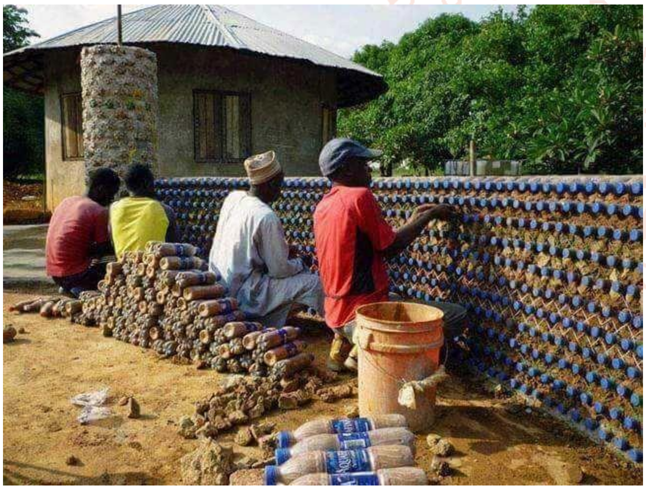

Plate 9. Typical urban poor shelter made of plastic bottles filled with sand.
Source: Duchung (retrieved September 26, 2017).

In some cities around the world, finding empty plastic water bottles for these low income housing is becoming difficult. Collecting and selling empty plastic containers is becoming lucrative for both the rural and urban poor and this has helped in keeping the environment clean.

Recommendations

Every government should and needs to encourage their manufacturing industries to reassess, how they use plastic products in packaging their products and equally, encourage the use of recycled plastic products. These products are already in use in the architecture of the built environment both in housing and landscaping and in road construction work is the case in India. With the trend in both the rural and urban areas especially, in the poor communities, where the poor are creating jobs for themselves by picking, collecting and selling empty plastic wastes for money, the government should promote and encourage established collection and sorting centers for the enablement and growth of plastic recycling programmes in their areas.

Conclusion

With the global environmental concerns and covering of both the built environment and the waters of the world with wastes and especially, empty plastic containers, researchers and innovators are resourcefully, looking for ways to put in use, the empty plastic containers resulting in recycling programmes. This has resulted in mass recycling practices of empty plastic containers all over the world. Virtually every country now, has a plastic recycling association, with interest in organizing used plastic collection and recycling programmes, that would enable reestablishment of product packaging and recycling of packaging materials by using recycled plastic products. These are all geared towards keeping both the built environment and the waters of the world clean at the same time, creating job opportunities for the people.

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