

Waste Polyethylene Terephthalate Packaging Materials in Developing Countries – Sources, Adverse Effects, and Management

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ABSTRACT

The ecological issues posed in the land, air and water compartments of the environment by waste polyethylene terephthalate (PET) packaging materials linger to be a significant problem nowadays, strictly linked to the rise in consumption of PET packaging materials by the populations in developing countries. However, little efforts are involved in these parts of the world, in managing sources and impacts of waste PET packaging materials. Although the main raw materials, PET polymers, are not considered lethal, the residual monomers in the raw materials have been proven hazardous to the environment. Moreover, many chemicals used in the production of PET packaging materials, such as additives, are dangerous to the environment, along with some degradation products that may be released during the PET packaging materials life cycle. In view of the potential impacts by waste PET packaging materials in the environment, this paper highlights the sources, impacts and management of waste PET packaging materials. We involved extensive literature review on the waste PET packaging materials. It was concluded that the management of waste PET packaging materials by the sources generating them together with recycling, enlightenment, re-usage, ban, product replacement, and improved collection of waste will mitigate the impacts on the environment.

Keywords: PET packaging materials, wastes, sources, impacts, environments

INTRODUCTION

A waste is a material that is unwanted or unusable to the person or company generating it. A waste is any material that is discarded or is worthless, faulty and useless to the owner after main use. A waste product can become a by-product, joint product or resource through an invention that increases a value above zero for waste products (Hahladakis *et al.*, 2018). Examples include municipal solid waste (household waste), hazardous waste, wastewater (such as human waste (feces and urine) and run-off surfaces, radioactive waste and others (Murat *et al.*, 2019). Table 1 shows five main types of wastes.

PET is used as a raw material to make packaging materials such as bottles and containers for a broad variety of food products and other consumer goods. Soft drinks, alcoholic drinks, detergents, cosmetics, pharmaceutical products and

edible oils are examples. The plastics made from PET are the most frequently used consumer plastics. For instance, polyethylene terephthalate can also be used as the primary material in creating water-resistant paper (Russo *et al.*, 2019). With the aforementioned importance of PET, waste containers generated from polyethylene terephthalate have constituted menace to the environment (United Nations Environment Program, 2016). In many countries, waste PET packaging materials are coded inside the universal recycling symbol with the resin identification code number usually located at the bottom of the container (Birzul *et al.*; 2019). PET packaging materials are not found in isolation but they are brought into being via various sources. More importantly, their wastes cause nuisance to the lands, air and water bodies (Birzul *et al.*; 2019).

This paper focused on the review of the sources, impacts and management of waste PET

Table 1. Types and sources of wastes [Geyer *et al.*, 2017]

Type	Sources
Liquid wastes	Liquid wastes are frequently found both in homes and industries
Solid wastes	Solid wastes may contain a range of products found in households as well as business and industrial sites.
Organic wastes	All food waste, garden waste, manure and meat that is rotten is classified as organic waste. Over time, microorganisms transform organic waste into manure. That does not imply they can be disposed anywhere.
Recyclable wastes	They include all wastes that can be transformed into goods for reuse. It is possible to recycle all solid products such as paper, metals, furniture and organic waste.
Harmful wastes	They include all flammable, poisonous, corrosive and reactive kinds of waste.

packaging materials with a view to make information available to the stakeholders – the users of PET packaging materials, the producers of PET packaging materials, the communities affected by the menace of waste PET packaging materials, the environmental regulatory bodies, investors that are into recycling and astute researchers.

SOURCES OF WASTE PET PACKAGING MATERIALS POLLUTION

Agro-allied industries

The agro-allied industry as we know it, is an industry that relies solely on agriculture for their raw materials so as to convert them into finished products that can be utilized by both humans and animals. It is therefore important to point out the negative impact this industry has on the environment in terms of the waste PET packaging materials pollution (Karayannidis *et al.*, 2006). Virtually every agro-allied industry generates a high amount of effluents and solid wastes, including waste PET packaging materials, which directly and indirectly harm the environment (Glasson *et al.*, 2004).

Beverage industry

The beverage industry includes various drinks, from water to spirits such as whisky. They may be made of cereals, seeds, herbs or vegetable, carbonated, fermented, clarified and distilled. The broad range of raw materials and manufacturing procedures are characteristic for this industry. Drinks (PET plastics, cans or glass), hot or cold and natural or traditional, may be canned, bottled or packaged. Drinking crops, drinking processing and drink packing are innovative features in the drinking sector that are catalyzed by the demands for nonalcoholic beverages (Luo *et al.*, 2018). The beverage industry is very large, involving a lot of products; as a result, it pollutes the atmosphere and environment. As shown in Figure 1, waste PET packaging materials are associated with this industry due to being used in packing such beverages like water, milk, tea, coffee, soft drinks, juices, milkshakes, smoothies, beer, wine, hard alcohol and so on (Kavlock *et al.*, 2002). In disposable packing, PET packaging materials find increasing numbers of applications, primarily for drinks. According to Lasmarias *et al.* (2006), nowadays, PET jug and natural product juice are being utilized by cola companies. PET containers



Figure 1. Waste PET packaging materials from beverage industry, Nigeria

have been recognized by mineral water and alcohol companies for the bundling of their product. The simple PET packaging materials are used at mineral water, smooth drinking water and sodas.

Brewery industry

Brewing consists of steeping beer in a starch source (usually barley grains), and fermenting the resulting sweet liquid with yeast (Awaja and Pavel, 2005). As shown in the work of Achilias and Karayannidis (2004), polyethylene terephthalate bottles are available in a multitude of packages in the brewery industry since injection blowing methods are implemented. One of the applications where this method and material has discovered a niche is the packaging of fluid foods and therefore displaces the products used earlier. Presently, soft drinks, beer, and wine are packaged in PET containers. Every liquid is optimally conserved and is influenced by oxygen, light and temperature exposure in different ways (López-Fonseca *et al.*, 2011).

In the food industry, the brewing sector holds a high economic position in terms of beer production of about 1.34 billion hl as of 2002 (López-Fonseca *et al.*, 2010). Due to the ever increasing population in the world, there is a high tendency for beer consumption to increase which consequently means that more bottles will be sold and thereby the generation of waste PET packaging materials will increase as well. For beer packaging, it is essential that PET bottles do not allow the transfer of gas, especially oxygen and carbon dioxide, between the outside and the inside of the package. While PET has excellent barrier characteristics, they need to be enhanced for beer packaging by raising the base barrier factor of the material (Zhang *et al.*, 2005). For this purpose,

oxygen scavengers are used as PET additives (monolayer bottles), leading to a greater generation of waste PET bottles.

Sugar industry

The manufacturing, processing and marketing of sugars (mostly sucrose and fructose) is part of the sugar sector. Globally, the sugar cane (~80 percent mainly in tropical waters) as well as the sugar beet are mostly extracted the most. Sugar beets are being used for soft beverages, sweetened beverages, convenience foods, fast food, candy, clothing, baked products and other sweetened foods packaged in the containers made from PET (López-Fonseca *et al.*, 2011)

IMPACTS OF WASTE PET PACKAGING MATERIALS ON THE ENVIRONMENT

Environmental degradation

Indiscriminate disposal of PET packaging materials in the environment, will lead to rapid a decrease in the quality of the environment in so many ways, for it cannot degrade biologically, unlike – for instance – sawdust (Elehinafe *et al.*, 2019). During the rainy season, the waste PET packaging materials that have been dropped on the road, as the case in developing countries, are washed by rain into the nearby water reservoirs, canals, and drains, leading to their clogging up and overflow (Figure 2). Moreover, the quality of the water bodies deteriorates due to the addition of these waste PET materials (Collegman *et al.*, 2014). Manufacturing of these PET packaging materials is a serious issue that is faced by the



Figure 2. A scenario of indiscriminate disposal of PET bottles in the environment in Nigeria

environmentalists, researchers and the governments in developing worlds. The manufacturers of these packaging materials are contaminating the environment by disposing of the wastes from the chemicals used in the process of manufacturing the PET packaging materials into nearby water bodies, open spaces and channels, thereby triggering health risks as well as environmental pollution (Dayang *et al.*, 2006).

Breeding room for diseases

Due to the indiscriminate disposal of waste PET packaging material, it is usually noticed that the accumulation of these wastes creates shelter for the breeding of all manners of mosquitoes and other carriers of pathogenic organisms that cause diseases (Krystosik *et al.*, 2020). Moreover, most Polyethylene terephthalate (PET) packaging materials are liable to be breeding room for bacteria when they are to be reused (Gupta and Bashir, 2002).

Exposure to toxins during recycling

Due to the chemical composition of waste PET packaging materials, there are chances that these compositions can come in contact with the handlers and thereby affect them negatively. Burning waste PET packaging materials leads to the degradation of the air quality, due to the release of noxious chemicals, leading to air pollution. Recycling of waste PET packaging materials requires workers, who are at the risk of developing respiratory problems and skin infections due to the inhalation of poisonous gaseous emissions (Rinku *et al.*, 2016).

Incinerating waste PET packaging materials releases emissions

A common means of disposing refuse in low income nation is open burning. Incineration of plastic waste PET packaging materials in an open field is a major source of air pollution. Most of the times, the municipal solid waste containing about 12% of plastics is burnt, releasing toxic gases like dioxins, furans, mercury and polychlorinated biphenyls into the atmosphere. Further, burning of polyvinyl chloride releases hazardous halogens and pollutes air, the impact of which is climate change. The toxic substances thus released pose a threat to vegetation, human and animal health and environment as a whole (Rinku *et al.*, 2016).

In developing countries, the emissions from open burning of solid wastes made from fossil raw materials are similar to those from vehicular activities (Odunlami *et al.*, 2018).

Millions of tons of PET packaging materials end up in landfills

Consumers pass through millions of tons of PET packaging materials. These packaging materials are simple to recycle and they will be taken back by just about every municipal recycling facility (Sharma *et al.*, 2019). However, using them is far from being accountable for the environment. The Berkeley Ecology Center discovered that the manufacturing of PET packaging materials not only utilizes huge quantities of electricity and resources, but also produces poisonous emissions and pollutants that add to global warming. While PET packaging materials can be recycled, in the developing countries alone, tons of these wastes find their way into wastewater every day (Geyer, *et al.*, 2017).

Migration of chemicals into the environment from waste PET packaging materials

Chemicals such as PET monomers and additives in PET packaging materials move to the soil and water bodies if their wastes are disposed of indiscriminately. Trace amounts of antimony can move into the environment due to long period of dumping, for heavy metals are used for producing the PET packaging materials. These additives contained in all PET products for enhancing the polymer properties and prolonging their life can be released from waste PET packaging materials during the various recycling and recovery processes and from the products produced from recyclates. Thus, sound recycling has to be performed in such a way as to prevent the that emission of substances of high concern and contamination of recycled products, ensuring environmental and human health protection, at all times (Hahladakis *et al.*, 2018).

MANAGEMENT OF WASTE PET PACKAGING MATERIALS

Recycling

This is by far the most economical way to handle the waste PET packaging materials pollution as it relates to the environment and the living

organisms living in it. Studies discovered that plastic waste is very toxic and non-biodegradable. This affects the health of the living creatures in the environment, including the marine life. Recycling has proven to be a better way to access the amount of waste generated by this indiscriminate disposal of waste PET bottles (Kuijpers, 2004). Recently, a research was carried out to turn the waste PET packaging materials into ultralight soft, flexible, durable polyethylene terephthalate aerogels that are exceedingly light in weight and easy to handle. They are also known to exhibit excellent thermal insulation and strong capacity in absorption. These attributes make these aerogels applicable in various aspects like acoustic and thermal insulation in buildings, oil spill scrubbing and also as a lightweight insulation for firefighter coats, CO₂ absorption masks for fire escape and fire rescue operations (Kuijpers, 2004).

Re-usage

This should not be mistaken for recycling as recycling is just reprocessing a material into something different. Reusing, on the other hand, is using that same material for the same purpose. For example, when a person buys a soft drink and finishes drinking it, instead of disposing of the bottle, it can be reused as a water bottle. It still serves the purpose for drinking. Another example could be when a person goes to an eatery and buys a food in a take away pack, after eating it does not have to be thrown away. It can be turned into one of containers at home, in which extra food can be stored and placed in the fridge (Wagner *et al.*, 1991). Reuse plays an important role as an ‘inner loop’ to enhance material productivity in a circular economy. In the case of plastics, it can create value in both business-to business (B2B) and business-to-consumer (B2C) applications. In the B2B segment, different types of reuse systems, from those adopted by individual companies to shared-asset systems like the Physical Internet (to transform the way physical objects are moved, stored, realized, supplied and used, by pursuing global logistics efficiency and sustainability), can unlock significant value with benefits that go beyond direct material savings (World Economic Forum *et al.* 2016).

Reduce

Plastics do not have to be used at all times, especially when there are better alternatives to

it. For a more efficient use of our environment, there has to be a balance in the usage of PET packaging materials. PET packaging materials should be only used only when there are no other options to try out. This is to curb the excessive usage of PET packaging materials (Green Education Foundation 2018). Resources, including energy, water and fabrication stocks, can be conserved by minimizing the use of PET packaging materials, especially disposable ones. Consumers have a major role in reducing the use of PET packaging materials in general shopping packaging, food and beverage packaging and bathroom products (Hunter, 2017).

Enlightenment

Most people do not know the importance of these PET packaging materials in the environment. Thousands of plastic factories produce tons of PET packaging materials which are commonly used by the people for shopping purposes because of the ease, cheapness and convenience of use, but their very hazardous negative impact is never highlighted or, at the very least, openly discussed in a more serious tone. The situation is worsened in the economically disadvantaged countries (Moharam and Maqtari, 2014). If people are made to know how delicate this issue of pollution is in terms of the hazards it causes to both the lives of human beings, marine lives and even the environment, then there would be a conscious effort to control the use of PET packaging materials and their disposal rate (Imran *et al.*, 2010).

Ban

One of the ways to alleviate pollution in terms of waste PET packaging materials is to place a ban on the chemicals used in making those plastics that can serve as toxins to animals when swallowed or to humans when they come into contact with them. Many countries are now considering the ban of PET packaging materials due to the public concern over the serious negative impact on the environment and agriculture, especially, in agricultural countries, such as Yemen, Bangladesh, India, Pakistan, South Africa, etc. (Moharam and Maqtari, 2014). The legal action characteristically implemented by governments, especially in the advanced nations, where it is difficult to improve the waste collection services and where they have little or no control over the design of industrial

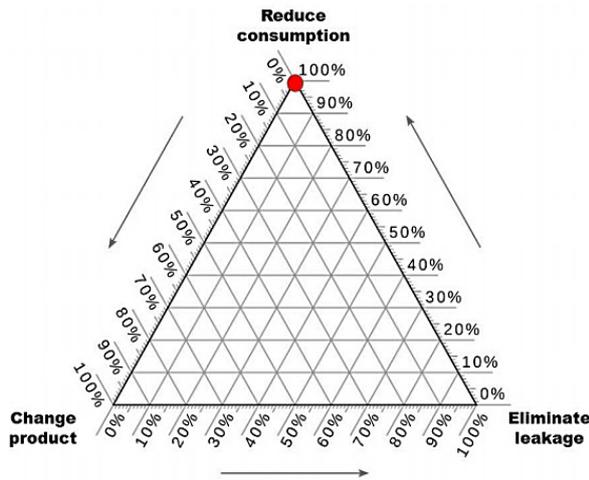


Figure 3. Driving solely a product ban approach (Godfrey, 2019)

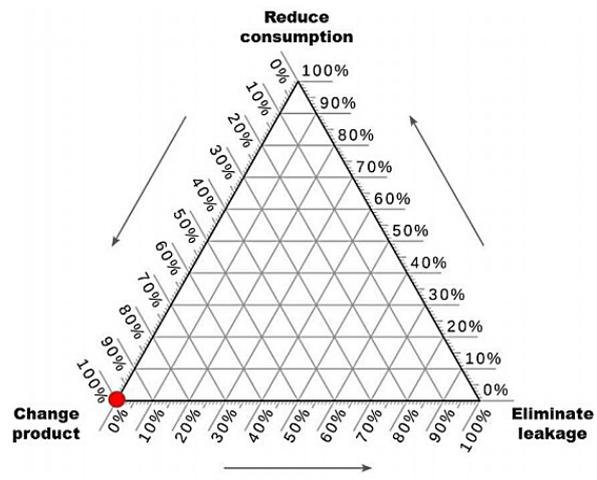


Figure 4. Driving solely a product replacement approach (Godfrey, 2019)

products in circulation, is to ban the products out of the market (Figure 3). Such measures are carefully taken while hypothetically giving a close to quick answer to the issue viewed as a danger to business, especially the domestic PET packaging industry which engenders the job losses potential that can be expected as a result. If ineffectively actualized and implemented by government, such bans can have drastic unintended outcomes (European Commission, 2018).

Product replacement

The reaction normally embraced by enterprises (e.g., trademark owners and merchants), where they have slight influence on improving the waste collection services, and no passion for decreasing the product consumption, is to change to substitute product designs or materials in an attempt to diminish the potential recognition damage from their products leaking into the environment (Figure 4). With inadequate worldwide accomplishment in plastic recycling – only about 9% of all plastic manufactured has been recycled (Geyer *et al.*, 2017) – design of product and raw material replacement increasingly accounted for in business enterprises for accountable product controlling at end-of-life. Such reduction processes, while hypothetically supplanting a hazardous item with an ecologically considerate other option, are additionally observed as a danger by business, especially those that are reluctant or incapable to expand into alternative raw materials. Notwithstanding, great consideration must be taken when actualizing such item substitution measures. Examples of changing

from carrier bags made of plastic to bags made from biodegradable raw materials, have indicated that a significant number of these items are not actually biodegradable, or only biodegradable under very definite situations, often unachievable under ordinary environmental conditions. The changes to substitute, bio-benign raw materials should be supported by a life cycle sustainable evaluation, to guarantee that net affirmative environmental, economic, and social benefits are attained.

Improved collection of waste PET packaging materials

About two billion individuals have no access to solid waste collection services, with numerous communities in developing and underdeveloped countries having only a 30–60% waste collection reportage (UNEP, 2018) (Figure 5). While the Global Waste Management Outlook defines the objective of expanding “reasonable collection services to all in the communities, independent of level of development”, there are numerous people who contend that a 100% assortment rate is unattainable – monetarily and operationally – due to poor governance and limitations in terms of the capacity facing neighborhood districts (Qian, 2006). In any case, while boycotts may make an obvious distinction in PET packaging materials litter, they do not tackle the ecological issues brought about by poor waste management. Without appropriate assortment frameworks, lingering waste streams, for examples: glass, metal, and paper, household wastes, building rubble, continue polluting the spheres of the environment.

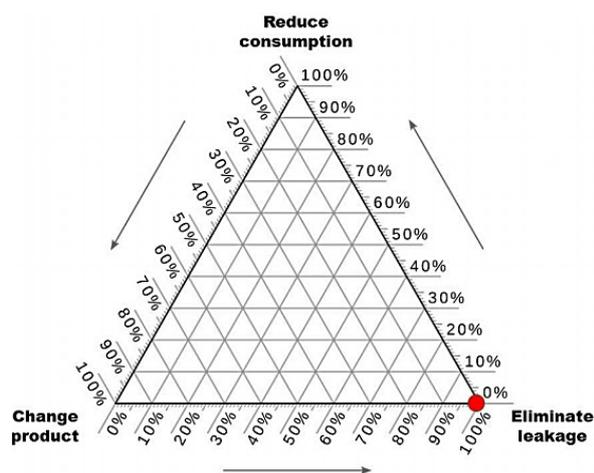


Figure 5. Driving solely a product replacement approach (Godfrey, 2019)

Improving the collection of waste schemes must be a main concern in developing countries as a result of challenges arising from expansive waste management. Improved collection of wastes additionally affords the prospects to develop local recycling, recovery, and reuse economies, which are impractical with high levels of indiscriminate dumping. All things considered, business needs to investigate the methods of cooperating with municipalities in low income nations to improve the waste collection systems (Godfrey, 2019).

CONCLUSIONS

For a better ecosystem, the need for better enlightenment and awareness about waste PET packaging materials cannot be over-emphasized. Sources, footprints, adverse effects and management of these wastes require the appropriate education. Coordinated efforts from industry are needed to disseminate the information about the chemicals used in producing PET packaging materials, together with public training about the raw chemicals. Identification of the waste hotspots is useful in addressing the existing problems with waste PET packaging materials. This can be achieved by monitoring and modeling. The solution lies in a combination of: better-quality waste collection system, product replacement involving the use of biodegradables and regulatory intervention. Recycling is one approach for PET product end-of-life waste management. It allows improving the economy as well as environment and recent developments show a significant rise in the pace of plastic waste regeneration.

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