Pollution of Polyethylene Terephthalate Water Bottles

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According to studies on global plastic manufacturing and the resulting pollution, plastic wastes have been identified as a serious environmental concern. The impact of plastic garbage on marine species, humans, and the environment is a source of public concern, necessitating the need to save ecosystems and the lives that depend on them. Polyethylene terephthalate (PET) water bottles have a significant carbon footprint and represent tremendous waste. In the United Arab Emirates (UAE), PET water bottles are widely utilized, with yearly consumption reaching 450 water bottles per person.

water bottles carbon footprint polyethylene terephthalate (PET)

1. Management of Plastic Wastes

Plastic wastes, primarily containing PE (polyethylene), PP (polypropylene), and PET (polyethylene terephthalate), are processed using a molten paste fusion, extrusion, and cutting process to produce grains of various sizes. In most cases, using these particles in the concrete mix reduces the strength and density of the concrete. As a result, feasible uses may be for non-structural purposes in general. The use of recycled plastics in concrete decreases the bulk density of the concrete. Simultaneously, as compared to concrete made with traditional aggregates, concrete containing flexible aggregates may display more ductile behavior, resulting in enhanced behavior in crack development and propagation. Recycled plastic may repair and overlay damaged cement-based concrete surfaces in pavements, bridges, floors, and dams [1].

Environmental and economic goals motivate product design for recyclability. Similarly, recyclability may be integrated into products through material selection and modularity. As a result, eco-design is critical in developing goods that are easier to handle in post-treatment processes such as sorting and recycling. Chemical characteristics of product composition and recommendations for different materials for various goods are included in eco-design guidance. To attain environmental goals, general awareness of the necessity of recycling, avoiding single-use plastic items, and efficient plastic waste management is crucial [2].

The United Arab Emirates (UAE) has set a goal for the 2021 National Agenda to achieve a perfect balance between economic and social development to ensure sustainable development while maintaining the environment. The agenda focuses on improving air quality, expanding clean energy contributions, conserving water resources, and implementing green growth initiatives in this area [3]. The UAE's garbage production has increased over the last decade because of population expansion and economic activity. The majority of the waste is disposed of in

municipal landfills or dumpsites, where organic waste produces a significant amount of methane, a potent greenhouse gas. Currently, little waste is burned, and municipal waste recycling rates are high [3][4].

Pyrolysis is a crucial chemical recycling alternative. Pyrolysis in a zero-oxygen environment results in a combination of thermal cracking and condensation reactions, resulting in the formation of various liquids, gaseous, and solid fractions. Pyrolysis is often referred to as destructive distillation, even though it is an endothermic process in contrast to other combustion processes, which are exothermic. The significant compounds generated by pyrolysis are functions of the organic attributes of the compounds, which primarily consist of a gas stream composed of carbon dioxide, hydrogen, carbon monoxide, and methane, as well as a liquid fraction consisting of a tar–oil stream composed primarily of acetic acid, acetone, and methanol, and a char composed of almost pure carbon in combination with some inert materials [5].

Burning solid waste in a suitably built and operated incineration process efficiently decreases solid waste. The combusted residue usually chemically reacts with molecular oxygen to produce CO_2 and H_2O during incineration, while the residue produces metallic oxides and minerals [5].

2. Management of Plastic Waste and Water Bottles in the UAE

Residents of the UAE have three apparent alternatives for drinking water: tap water, reusable 5-gallon bottled containers, and single-use bottled water. The tap water in the UAE is safe to drink and meets stringent water quality regulations. According to a survey, the primary concerns of UAE citizens about tap water quality are taste, bacterial contamination, odor, color, temperature, and mineral mix. In the United Arab Emirates, tap water is primarily desalinated saltwater. Impurities may be introduced into the water after it has been treated through the water distribution network or ground or roof water tanks in residential buildings, especially if these tanks are not cleaned regularly. This is most likely the primary reason UAE citizens choose to consume bottled water rather than tap water. Although using reusable bottled containers is better for the environment, single-use bottles are still extensively used. Commercially viable, environmentally friendly packaging is currently unavailable. There are currently no global directives or guidelines for future plastic water packaging; however, a plan should include at least a reduction at the source by limiting manufacture and delivery, promoting alternative solutions by limiting intake, improving the design by promoting eco-design, improving the end-of-life outcome by optimizing collection and recycling, and informing citizens by raising public awareness [5].

Locals prioritize availability, quality, brand, and price when purchasing bottled drinking water. Concerns about the environment were also shown to differ considerably across male and female respondents. The locals were unfamiliar with the distinctions between 100 percent biodegradable and recyclable plastic items. To encourage households to recycle plastic, knowledge of successful recycling and its accompanying environmental benefits must be disseminated through awareness campaigns and segregation programs. More recycling containers should be placed in public spaces to encourage plastic recycling by providing greater access and convenience.

Furthermore, an incentive system might be implemented to incentivize recycling. Residents of the United Arab Emirates showed little interest in eco-friendly plastic items, owing to a lack of expertise and a high price. As a result, efforts should raise awareness of available eco-friendly plastic goods and their long-term environmental advantages. Government officials should also impose strict recycling standards and assess the country's capabilities to deal with the rising problem of plastic pollution [5].

The Sharjah waste management business that conducted a study recovered 3342 tons of plastic last year and estimates that the total amount thrown is likely six times that. According to their findings, only one-third of Sharjah residents recycle their plastic waste. According to the Beverage Marketing Corporation, a US consultant, the UAE's per capita consumption of bottled water is among the highest globally, with 259.7 L in 2007. According to Bee'ah, each inhabitant uses up to 450 plastic water bottles every year, just a tiny percentage recycled. The bottles are made of polyethylene terephthalate or PET. Bee'ah collected 1649 tons of PET last year. Granules, exported for further processing into other items and plastic film and containers, are the end products. Bee'ah recovers most of its plastic garbage at a plant in Al Saj'ah, where mixed household waste is separated into plastics, metal, glass, and other recyclable items using mechanical equipment and by hand. They are then subdivided further and sold to companies that convert them into valuable materials [6].

In 2008, the Abu Dhabi government set up the Tadweer Waste Management Centre. The company is in charge of the emirate's waste management policy, strategy, and contractual systems. The Department of Garbage Management in Dubai Municipality could develop a master plan for waste management in 2012. The purpose of this plan is to have zero waste in the landfills within 20 years. That can be done using an innovative and integrated strategy. Their plans included building a giant plant in the Middle East to convert all solid wastes to electricity in the Warsan area for AED 2 billion. The decision also aligns with the National Agenda's goal of reducing landfills by 75% by 2021 and safeguarding the environment from methane gas emitted by landfills [3][6].

3. Disposal of Plastic Bottles

Only a few states and municipal governments in the USA have established policies to encourage recycling water bottles made out of plastics. On the other hand, plastic water bottle recycling has lately gained policy significance. The growing attention to plastic water bottles is due to two factors. First, the amount of garbage generated by plastic water bottles is significant and growing, increasing from 12 billion in 2000 to 36 billion in 2006. Every year, bottled water bottles manufactured out of polyethylene terephthalate generate hundreds of millions of pounds of waste, either burned or buried in landfills. Second, while many states have had bottle deposit programs for cans and other beverage containers for a long time, plastic water bottle deposit regulations have just recently arisen. Six states have expanded their bottle deposit laws to include plastic water bottles, and several more are contemplating doing so [7][8][9].

Recycling programs gather post-consumer waste such as paper, metal, glass, and plastic from communities and organizations worldwide. Unfortunately, the excitement shown by the public during collecting does not equal the economic advantage derived from using much of the recycled material. Excess recyclable material is frequently

dumped in landfills. The novel recycled plastic bottle fill can utilize a considerable amount of recycled plastic, decreasing the need for expanded polystyrene in lightweight geotechnical fill applications. Reusing plastic bottles is better for the environment than making expanded polystyrene blocks. Instead of melting and processing waste plastic, recycling bottles in their original post-consumer state saves energy and landfill space. Because repurposed bottles make up most of this novel geo-material, the only material expense of creating this lightweight fill comes from the adhesive binding agent that holds the bottles together. Plastic bottles are also suitable for petroleum compounds and will not disintegrate in the event of a gasoline or oil spill. These benefits have encouraged plastic bottles as a lightweight, ecologically sustainable fill [8][9].

4. Environmental Pollution

Plastics have altered lives since their inception in the 20th century, providing numerous benefits and causing significant environmental damage. The main issue with plastics is that many are incredibly durable and can take hundreds of years to degrade. This produces severe issues, such as the accumulation of plastic waste on land and the seas. Each year, between 1.15 and 2.41 million tons of plastic are projected to reach the ocean, accumulating in vast offshore zones. The Great Pacific Garbage Patch, with an estimated surface size of 1.6 million square kilometers, is the most significant [10].

Plastic waste is one of the most severe environmental concerns confronting today. Plastic is widely employed in various industries because of its long-lasting nature, mouldability, low manufacturing cost, light weight, and adaptability. Plastic has been mass-produced on a vast scale because of its enormous demand, and its manufacturing has expanded tremendously. Plastic manufacturing expanded from 1.5 million metric tons in the 1950s to over 367 million metric tons in 2020, intending to triple by 2050. Plastic pollutes land and water and adds to financial burdens and waste management complexity because of its widespread usage and manufacture [11].

Plastic contamination in rural water supplies has received little attention and is frequently neglected. Despite having a lower population density, rural regions suffer from macroplastic and microplastic contamination that is due to a lack of official or informal waste infrastructure. Solid waste dumping on land and in water bodies, a frequent source of microplastics in the environment, and the open burning of plastic garbage, are expected outcomes. Plastic trash can affect the quality and stability of water supplies both directly and indirectly. Plastic pollution, including macro- and microplastics, can carry endogenous and exogenously related chemicals and act as surfaces for microbial “Plastisphere” formation. Floatable plastics can also impact water quality by raising the risk of regional floods. Microplastic contamination is quite common in rural areas, especially in agricultural soil. Agroecosystems are critical for food security and biodiversity and have been under increasing stress from climate change and population growth. Microplastics in soils may generate extra stress, which must be understood to assess their influence on rural populations, global food supply, and the environment. Because rural communities and agricultural regions rely on the soil, contaminants like microplastics can potentially harm individuals who live and work in these places [12].

Plastic items may be found in considerable quantities in the workplace and the home. Plastic and plastic product pollution may harm and pollute the terrestrial environment, which can then be transported to the aquatic environment. Even though roughly 80% of plastic garbage at sea comes from land-based sources, there is a scarcity of data on the volume of plastic waste on land compared to the vast amount of data available on plastic debris in marine ecosystems. Additives to plastic might leak and then infiltrate different environmental elements, resulting in soil and water contamination when plastics are dumped on land or landfilled. According to reports, microplastics and synthetic polymer fibers have remained detectable in sewage sludge and soils 5 years after they were applied. Chlorinated plastics can leach harmful chemicals into the soil and leak into underground water or the neighboring aquatic system, contaminating the ecosystem. During microbial biodegradation of plastics, methane is produced, a hazardous greenhouse gas contributing considerably to global warming [13][14].

In recent years, microplastics have become a significant cause of marine plastic pollution. Microplastics are tiny fragments of plastic (less than 5 mm) that come from two sources: (1) microbeads, which are manufactured microplastics commonly made from polyethylene and polypropylene and found in many facial cleansers, toothpaste, and hand scrubs, and (2) plastic debris degraded by a variety of biological, physical, and chemical factors. Microplastic contamination has an ecological impact because of its capacity to absorb toxic hydrophobic chemicals and escape wastewater treatment in fresh water and the potential danger it poses to sea creatures and ocean life [15].

Sharjah is the third-largest city in the United Arab Emirates (UAE). It is also the third most significant garbage producer, accounting for 9.9% of the UAE's total waste production in 2012. Bee'ah, a Sharjah-based environmental management organization, has invested more than USD 1 billion in recycling facilities to make Sharjah the first Arab city to achieve zero landfill trash through 100% recycling and conversion. Despite the advantages of recycling programs, their implementation has been limited by a lack of public awareness and poor recycling participation. Identifying and measuring people's knowledge, attitudes, and behavior should be the first step toward achieving integrated MSW management [16].

Plastic pollution is visible and deadly in the Arabian Peninsula's deserts, as evidenced by research findings that sent an alarm that the most emblematic ecosystem of the desert species, camels, are mostly affected by the problem of plastic. A veterinary microbiologist, Ulrich Wernery, and environmental scientist Marcus Eriksen investigated more than 30,000 dead camels in the United Arab Emirates in areas around Dubai. They found that 1% of the camels perished because of consumption that was due to the accumulation of plastics in their digestive tracts. Camel's bones show compacted tangles of plastic goods, primarily plastic bags, which the duo termed "polybezoars", which kill camels slowly by clogging their intestines and ripping at internal organs, allowing bacteria to infect them [16][17]. Plastic waste is unattractive, but it also risks marine operations such as fishing and tourism. Ghost fishing occurs when fishing nets are discarded, resulting in commercial fisheries losses. Since floating plastic waste may remain at the sea surface for long periods, it can quickly become colonized by marine life [18].

Over 165 million tons of plastic trash are believed to be present in the world's seas, with an average of 8 million tons of plastic dumped into the ocean each year and approximately 5 trillion plastic fragments floating on the

surface. Plastics in the oceans often dissolve within a year, but not entirely. Toxic compounds like polystyrene and BPA can be released into the water during the plastic breakdown, resulting in water contamination. Plastic makes up roughly 80% of the waste found in the seas. Marine creatures may quickly colonize plastic waste floating in the water because its long-term persistence on the ocean surface may facilitate the migration of 'alien' or non-native species.

Microplastic contaminants are bioavailable to much marine life because of their abundance in benthic and pelagic habitats and their tiny size. Plastics have been observed to concentrate and sorb pollutants existing in seawater from many other sources within the marine ecosystem. Persistent organic pollutants such as nonylphenol, PCBs, dichlorodiphenyldichloroethylene (DDE), and phenanthrene are contaminants that accumulate many times more in plastic trash than plastic trash in the surrounding ocean. More than 260 marine species, including turtles, invertebrates, seabirds, fish, and mammals, have swallowed or become entangled in or with plastic waste, resulting in decreased mobility, feeding, reproductive output, ulcers, lacerations, and death [4]. Through the "Together, We Make a Difference" campaign, the Abu Dhabi International Marine Sports Club (ADIMSC) and the Abu Dhabi Environment Agency (EAD) staged the seventh initiative of its type in 2018 [19][20][21].

One hundred and fifty-five volunteers from various environmental protection organizations cleaned 4700 kilos of marine litter from Abu Dhabi's waterways over the last few days of 2018, including 3400 kg of abandoned and prohibited fishing nets and 1300 kg of garbage gathered from the bottom. Ropes, fishing nets, iron, and plastic pipes made up most of the trash [21]. Another type of pollution is air pollution; when landfilled plastic garbage decomposes, methane and carbon dioxide are released. In 2008, an estimated 20 million tons of CO_2 equivalent ($eqCO_2$) was emitted into the atmosphere through the breakdown of solid waste in landfills. CO_2 is also released into the atmosphere when plastics and plastic goods are burned, and this CO_2 can retain radiant heat and prevent it from exiting the planet, resulting in global warming. Air pollution is one of the most severe environmental hazards to human health, and it is responsible for more than 6 million fatalities worldwide. When plastics and plastic goods are burned openly, pollutants such as heavy metals, dioxins, PCBs, and furans are released, posing health concerns, particularly respiratory problems. Plastics' involvement in air pollution in emerging and underdeveloped nations cannot be overstated, and the consequences for future generations might be devastating [22].

A study [23] investigated the recyclability of weathered and non weathered PET. The model of the marine environment was modeled artificially by an accelerated weathering procedure. The quantitative comparison was performed between three types of plastic products manufactured with the same technology. The objective was to compare the qualities of products made from original PET with products made from PET waste but non-weathered as an example of classical PET recycling, and the third type is the weathered PET. It has been found that minor mechanical properties were changed in the weathered PET. As a consequence, it was concluded that mechanical-wise weathered plastic material could be successfully recycled and used to manufacture plastic products [23].

5. Public Health Effects Caused by Plastic Wastes

Plastic polymers are usually thought to be inert and of little concern to public health; nevertheless, different additives and residual monomers presumably retained from these polymers are hypothesized to be the source of the health concerns. The majority of plastic additives are known carcinogens and endocrine disruptors. Humans are exposed to these chemicals primarily by ingestion, skin contact, and inhalation. Skin contact with certain compounds included in plastics has been linked to dermatitis. Microplastics are significant contaminants that can enter the food chain after being consumed by various freshwater and marine creatures, providing a public health risk. Animals exposed to microplastics and plastic additives can be harmful to humans if finished. By assessing environmental pollutants, biomonitoring investigations on human tissues have revealed that plastic components survive in the human population [13].

Different additives are used in the manufacture of plastics and they have been linked to a variety of health problems in people and are as follows:

First, bisphenol A (BPA) is used to make the inner surface of food cans, reusable water bottles, and infant bottles. In 2003, the global output of BPA was projected to be more than 2.2 million metric tons per year. BPA molecules can leak from the plastics into beverages and food because of the frequent use of beverages and food containers. BPA is an endocrine disruptor that mimics the feminine hormone estrogen. Obesity, repeated miscarriages, endometrial hyperplasia, sterility, and polycyclic ovarian syndrome have been linked to BPA exposure in women. BPA changes the gene expression of the thyroid hormone axis, affecting biological processes such as metabolism and development. Thyroid hormone receptor transcriptional corepressor activity is also increased by BPA, resulting in a decrease in thyroid hormone receptor activity. A change in the thyroid axis causes hypothyroidism. Because children and developing fetuses are more vulnerable to BPA than adults exposed to similar concentrations, exposure of children and women of reproductive age to increased concentrations of BPA is a considerable public health concern. Studies show a tangible link between urine BPA levels and cardiovascular illness, liver enzyme abnormalities, and type 2 diabetes. BPA has also been linked to neurobehavioral problems (e.g., autism), aberrant urethra/penile development in males, early sexual maturation in females, and a rise in hormonally mediated malignancies such as breast and prostate cancers [24].

In addition, high molecular weight phthalates are frequently utilized in industrial applications, such as food packaging, raincoats, medical equipment, toys, hoses, vinyl floors, and shower curtains. Low molecular weight phthalates, particularly dibutyl phthalate (DBP) and diethyl phthalate (DEP), are employed as solvents in lacquers, coatings, varnishes, and personal-care products. Because there is no chemical bond between phthalates and the plastic matrix, phthalates can easily leak out and pollute the environment. Phthalates are hormone disruptors that have antiandrogenic properties. Children and babies are the most vulnerable to phthalates because they frequently put items in their mouths, such as plastic toys and fingers, and experience direct skin contact with phthalate-contaminated substances. Breastfeeding babies are most likely to be exposed to phthalates through breast milk, cow milk, or food packaging materials. Regularly applying personal-care items can increase the rate of exposure to low-molecular-weight phthalates. Studies have shown that males who recently used aftershave and perfume had increased phthalate exposure, as did babies who used shampoos, lotions, and powders. High phthalate concentrations in rats exposed to specific phthalate change hormone levels, resulting in birth abnormalities [25].

In addition, brominated flame retardants are utilized as essential ingredients in the manufacture of polymers for safety reasons. The most commonly used brominated flame retardants in plastic manufacture are tetrabromobisphenol A (TBBPA) and polybrominated diphenyl ethers (PBDEs). These may be found in many plastic goods, including electronic thermoplastics such as computers, phones, televisions, and textiles. Thyroid hormones and estrogen are disrupted by PBDEs and TBBPA, resulting in altered neurological and reproductive system development. TBBPA-containing plastics have been observed to leak TBBPA into sewage sludge, fish, birds, sediments, soils, and the atmosphere. PBDEs have been found at high concentrations in exposed people's blood, breast milk, and adipose tissue. Children are more likely than adults to be exposed to PBDEs per kilogram [13].

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