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Review

A Revision for the Different Reuses of Polyethylene Terephthalate (PET) Water Bottles

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Abstract: 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. This study aims to review the literature on using PET water bottles in the UAE. A systematic literature search was conducted on journal articles, peer-reviewed journal articles, etc., published in the last 12 months. The main aspects of this systematic literature review include information on how plastic wastes are managed in the UAE and worldwide. In addition, it discusses the public health effects caused by plastic wastes, how the consumers of plastic bottles responded to the environmental policies, and so on. The article selection criteria included studies related to plastic water bottles in the UAE, waste management, environmental consequences, etc. A total of 30 articles were selected by initial screening, and 20 met the selection criteria and were included in the final review. To establish the credibility of this research, we understood that it was necessary to survey the UAE population to see the best approach to deal with PET water bottles.

Keywords: water bottles; carbon footprint; polyethylene terephthalate (PET); environment

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1. Introduction

Plastic contamination is one of the most severe environmental concerns facing today. Plastic is widely employed in various industries because of its long-lasting nature, moldability, low production cost, light weight, and adaptability. The usage of single-use plastic-bottled drinking water has exacerbated the issue of plastic pollution. Despite the negative environmental consequences, there has been a rise in bottled drinking water use. High-temperature and heat-wave-prone areas are projected to be the biggest consumers of bottled water. According to an economic analysis conducted by the Dubai Chambers of Commerce, bottled drinking water consumption in the UAE is estimated to reach 1.153 billion liters in 2025, with an annual growth rate of 1.4 percent by volume from 2020 to 2025 [1].

People also give it free of cost in mosques and other public places because of its ease of access; many cases abuse this resource by taking a bottle, sipping it, ingesting part of it, and then disposing of it at the same place or tossing it in garbage bins. Used and partially used water bottles made of plastics are thrown and discarded in municipal garbage cans, where they are collected and transferred to a municipal disposal site. These water bottles have a large carbon footprint and reflect a massive waste of a valuable water source and mismanagement of our other vulnerable resources. In reality, the UAE has the world's largest per capita consumption of bottled water, up to 285 L per year. Every year, the average UAE citizen uses more than 450 plastic water bottles [1,2].

It is crucial to understand that plastic is derived from petroleum. A billion plastic bottles require 24 million gallons of oil. Plastic takes approximately 700 years to disintegrate. The bottle accounts for 90% of the cost of bottled water. About 80% of plastic bottles produced are not recycled [1]. Globally, the rate of plastic recycling is relatively low, and large amounts of plastic are disposed of in landfills, where they remain for hundreds of years without being organically decomposed [3].

PET stands for polyethylene terephthalate and is a smooth, translucent, and relatively thin plastic. It is also known as stomach plastics. Since PET is anti-inflammatory and liquid, it is often used to produce salad dressing, juice, mouthwash, vegetable oil, cosmetics, soft drinks, margarine, and water bottles that are all disposable. PET is also anti-air, preventing oxygen from entering. Antimony trioxide, an inorganic chemical, is used as a catalyst in the production of PET and rubber vulcanization.

To prevent dangerous compounds such as acetaldehyde, antimony, and phthalates from leaching from PET, polymers must be stored away from high temperatures. Effective, adequately followed, and enforced regulations are required to address and reduce persistent environmental contamination caused by plastics. This should include the need for a global convention on plastic pollution, requiring plastics manufacturers to list all components in their products and warn customers about the possible health impacts of such substances. It is necessary to adopt policies that categorize some of the toxic compounds in plastics. Waste management is crucial in decreasing the damaging impacts of plastic waste on the environment and public health. Improvements of ineffective plastic waste collection, treatment, and disposal are required to reduce global plastic litter and marine pollution [4]. Even though the closed-loop recycling system is modern technology, most countries have not yet developed this system in their recycling methods. In addition, the UAE has been introduced into this new policy, and it is noted that extraordinarily little research has been undertaken on this topic.

The information needed was searched from various journal articles and peer-reviewed journal articles for this literature review. The articles selected for this review included waste management, plastic water bottles in the UAE, and environmental consequences. As part of the initial screening for literature review, 30 articles were selected, of which 20 met the selection criteria and were included in the final review. All articles selected for the literature review were from Scopus Indexed scientific database.

2. Literature Review

2.1. 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 [5].

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 [6].

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 [7]. 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 [7,8].

As shown in Figure 1, China has produced the most significant quantity at 59.08 tons of plastic, followed by the United States (37.83 tons). In addition, India has produced 4.49 million tons of plastic waste annually [9].

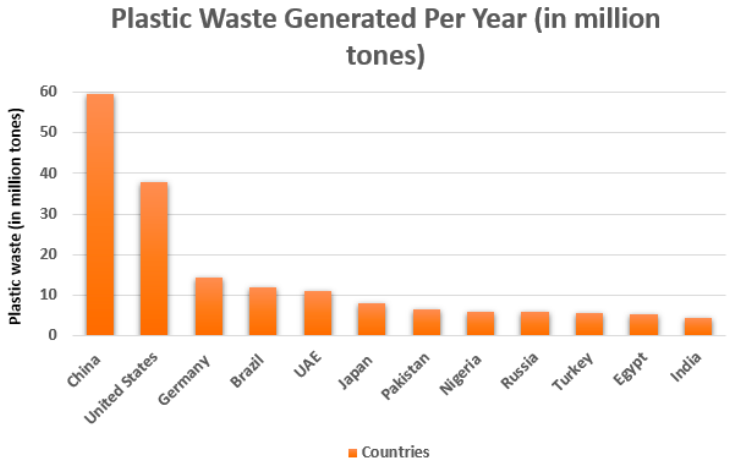

Figure 1. Plastic Waste Generated Per Year [9].

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 [9].

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 [9].

The main advantages of a municipal incinerator are the reduced requirement for land and efficient energy storage. Despite this awareness, waste incineration has several advantages, including volume reduction, quick disposal without delayed biodegradation, reduced land requirements, toxic waste destruction, waste value addition, and electricity generation [9].

2.2. 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 [9].

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 [9].

The Sharjah waste management business that conducted the 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 [10].

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 [7,10].

2.3. 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 [11–13].

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 [12,13].

2.4. Environmental Pollution

Plastics have altered our 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 [14].

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 [1].

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 [15].

The distribution of plastic wastes is linked to human populations. The demand for all plastic products, including plastic water bottles, is increasing continuously proportional to

the increase of the world's population. As shown in Figure 2, China contributes the highest percentage of 28% of the global total mismanaged plastic waste, followed by Indonesia (10%), and both Vietnam and the Philippines (6%). Other contributors include Thailand (3.2%), Egypt (3%), both Nigeria and Turkey (2.7%), and South Africa (2%). However, as per sources in the UAE, there is 0.00% of total plastic waste being mismanaged. Environmental pollution results from poor disposal of plastic-made products in various ways, including deterioration of natural ecological beauty, incoherence, impacts on aquatic organisms, and blocked sewage systems, particularly in Third World countries. That would enhance the breeding of mosquitoes and different kinds of diseases [4].

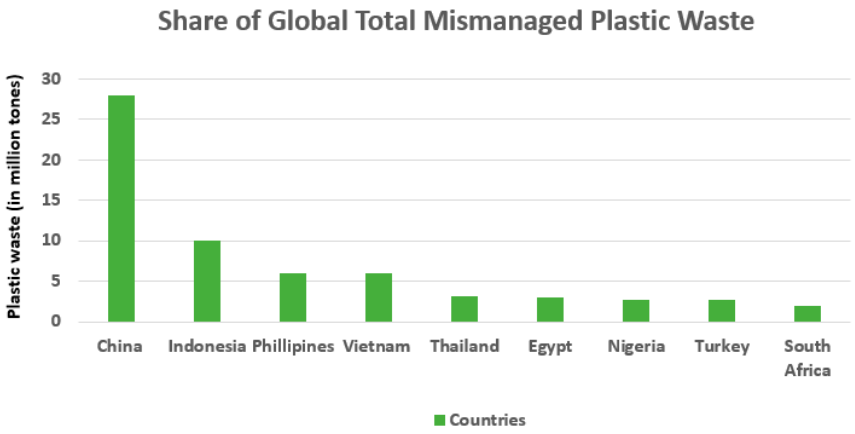

Figure 2. Share of Global Total Mismanaged Plastic Waste [16].

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 [4,16].

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 [17].

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 [18].

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 [18,19]. 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 [20].

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 [8]. 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 [21–23].

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 [23]. 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 [24].

A study [25] 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 [25].

2.5. 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 [4]. As shown in Table 1, wildlife species experience severe impacts, such as slower metabolic rate, reduced growth and development, reduced energy stores, and reduced reproducibility and survival [16].

Table 1. Impact of microplastics on wildlife [16].

Wildlife Species	Impacts
Asian green mussels	Slower metabolic rate
Copepods	Reduced reproducibility and survival
Daphnia	Reduced growth and development
Langoustine	Reduced growth and development
Shore crabs and lugworms	Reduced energy stores

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 [26].

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 [27].

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 [4].

A research study [27] opposed the idea of the harmful effect plastics have on the environment. They also think polymer plays a vital role in protecting humanity from coronavirus infections, where most high-quality masks are made of polymers. So, this research highlighted the importance of polymers in sustainable development.

2.6. Rewards for Recycling

Punishment for disobeying a law, rule, or contract is a penalty. Penalties are economic instruments in policy that aim to achieve a specific behavior target. Anything presented in appreciation of service, effort, or achievement is a reward. In policy, rewards are economical devices that help people achieve a specific behavioral goal. So far, the most significant experiences in terms of incentive programs aiming at inspiring residents to recycle more and better have been adopted at the government level in the United Kingdom. According to Eunomia and Serco, authorities who aim to improve the efficacy of their waste collection service, increase recycling participation, increase recycling tonnages collected, or minimize residual waste might utilize awards. In addition, incentives must be of significant value to the householder and should only be used where there is effective service delivery, costly to deliver, and depend on communicating effectively. At the same time, endless rewards are often complex, finding it challenging to isolate the effects of the constituent parts [28].

The European Commission issued an EU Action Plan for a Circular Economy in December 2015, naming plastics as a top priority and promising to develop a strategy to address the issues posed by plastics across the value chain, taking into consideration their whole life cycle. The commission reaffirmed in 2017 that it would concentrate on plastics production and consumption, to make all plastic packaging recyclable by 2030. The European Strategy for Plastics in a Circular Economy, established in January 2018, will change the way plastic goods are designed, manufactured, and recycled in the EU [28].

Waste management has been a significant concern in recent years. Society is confronting environmental contamination issues from inappropriate garbage disposal and management, which has a direct impact on humans. Separating garbage is often a challenging duty for workers. People are unaware of these issues and do not properly dispose of rubbish, resulting in garbage accumulation in public areas. So, to encourage people to dispose of garbage properly, this article discusses an idea that will provide a platform for individuals to dispose of waste in a more scientific and user-friendly manner. They will be rewarded in a cashless manner through digital payments, free vouchers, and other means. The kind (wet or dry) and weight of waste dumped in the machine will be detected, divid-

ing it into two halves. The user will be compensated based on the amount of waste they produce. The Arduino Uno microcontroller, sensors, and GSM technology program the operation flow. This system allows for garbage collection and segregation in one location, allowing for effective recycling and environmental reduction. This would also significantly contribute to the government of India's Swachh Bharat Abhiyaan initiative [29].

In the south of England, the Bracknell Forest Council is responsible for the trash of 118,000 residents. The council opted to launch a trial, self-funded incentive plan because of their poor recycling rate and the rising cost of landfill tax in the region (up to GBP 80 per ton). The program's primary goals were to raise curbside recycling participation from 75% to 82% in 2 years and lower the recycling rate in residual fractions from 13% to at least 8%. Citizens can opt out of the incentive system, and participation is not required. Every citizen who opts in is issued an "e+ card" to earn points. Points are awarded for each of these designated containers being picked up and emptied by the garbage truck's employees if they are eligible. No weight system is required in the residual waste bin administration, and no charge reduction is available. Users of the system are given no cashable value, although they are granted a maximum total value of GBP 26 in credits (points) every year. The significant incentives were leisure incentives, such as discounts or direct access to sporting facilities, and membership in local clubs, gyms, pools, etc. The municipality of Bracknell Forest deemed the implementation a success because at least 11,000 homes signed up for the project (a quarter of the total number of households). A total of 1000 tons of residual trash were eliminated, resulting in a savings of GBP 90,000. The system has been fully implemented [30–32].

In Abu Dhabi, RECAPP, a new recycling mobile app, was initiated to ensure that recyclable garbage is collected from households at no cost. RECAPP was found to be the first free-of-charge mobile application in the UAE that is a digital door-to-door service for helping to collect recyclables and encouraging its users toward responsible behavior, which Veolia Middle East introduced in November 2020. The goal is to make recycling easier for consumers and, as a result, minimize the quantity of the garbage that ends up in landfills. RECAPP encourages the citizens of Abu Dhabi to adopt a more sustainable lifestyle by making the process of recycling as straightforward as possible and by rewarding recycling users. All customers need to have the application downloaded, create a new account that clarifies their location, and send a request to collect the recyclable garbage using that application. Through that application, one may request the pickup of recyclables from their doorstep with a single click and earn points that can be used for presents. The RECAPP crew will visit their home to collect recyclables, including plastic bottles and aluminum cans. People have to leave the recyclables outside their doorstep at the collection location, where the staff picks them up, as RECAPP is a contactless service [30,31].

Users may also earn points for collecting recyclable items and exchanging presents from other partners of RECAPP through the marketplace of the online rewards. Based on the overall weight of the recyclables collected by the user, the user then collects a proportional number of points. The importance of the bag of recyclables is put into the system and turned into points. For every 1000 g (1 kg) gathered, users receive 1000 points. Five thousand points may be exchanged for vouchers of AED 20 from the partners of RECAPP, like Al Ain Water and even Carrefour. As a result, for every 5 kg of recyclables collected, an equivalent point of AED 20 will be rewarded by RECAPP [32].

2.7. Environmental Policies in UAE

Solar energy is a typical example of renewable energy use; however, most sources were published in "temperature-appropriate" nations like Ghana, Croatia, and Turkey; nonetheless, it would be acceptable for a hot climate country like the UAE. Another UAE-specific approach is utilizing native plants that are tolerant to the local soil and lack of rainfall, reducing the need for continual watering and groundwater leaching [33].

2.8. Response of Consumers to Environmental Policies

To fight increasing plastic waste, the concept of reducing and reusing appears to be popular among the general public. Most responders claim to recycle as much plastic as possible, while the rest entirely oppose recycling. Surprisingly, more people in their mid-30s claim to be reusing plastic than those in any other age group. Reusing plastic bags was noted by the majority of respondents, with a sizable percentage also mentioning reusing plastic bottles and take-out containers. On the other hand, women are better at adjusting to these changes than males, and we can observe that they are not just lowering their usage of plastics in their everyday lives. A more significant percentage of females also indicates that they are generally reusing plastics [16].

The Directive 94/62/EC of Packaging and Packaging Waste was published by the European Commission on 2 July 2014, which applies to plastic bags. However, because plastic bottles, like plastic bags, are a blatant waste of plastics, that directive might be expanded to include bottles made out of plastics. Suppliers are also attempting to reduce plastic waste. The considerable environmental disadvantages of disposal of plastics via landfills and burning off are driving forces in the techniques of recycling plastics. Portions of the world adopting particular new policies for managing waste are currently recycling PET. The recycled PET is referred to as r-PET. This approach has been utilized in France for over 20 years. France could collect about 310,000 tons of bottles made from PET in 2010, representing a more than a 50% recycling rate. Whereas around 30% of the PET can be used to make food-grade r-PET quality, another option is to develop new plastics that have a lower environmental impact, such as bio-based plastics derived from plants. The two most well-known biopolymers (PEF) are polyethylene-furoate (PEF) and polylactic acid (PLA). Their sources are renewable biomass. PLA is biodegradable and made from glucose. It has been demonstrated that PLA has much less environmental impact than PET [34,35].

Although the UAE government and ministry made many calls for an anti-plastic campaign earlier in 2014, it has been found that only 40% of the people realized those governmental laws prohibiting the use of plastic. The younger generation appears to have the lowest level of knowledge, with just approximately a third aware of such laws, highlighting the critical need to raise awareness about this issue, particularly among this group [36].

2.9. Implementation of Closed-Loop System in Countries

With the significant increase in public awareness, there is a rising understanding of reverse logistics systems and other closed-loop system problems. Several organizations view creating a reverse logistic system as an opportunity for businesses and making money since it delivers income and other long-term plans advantages rather than costs. Reverse logistics allows goods to be certified for repairs, modifications, and distribution of components before being recycled as raw material for future use. It minimizes waste sites by incorporating collecting, disassembly, and processing of used items, materials, and packaging to provide an ecologically safe way of recovery [37].

Due to the variety of trash created, effective and efficient waste management programs are challenging. Technological advancement has made it feasible to reuse and remanufacture items to balance the environment, economy, and society. Sustainable or green supply chain management and closed-loop supply chain or reverse logistics are two significant disciplines for managing the supply chain, which work on integrating the social, environmental, and economic problems. Green logistics is one of the advantages of sustainable reverse logistics operations. To become more environmentally conscious, reverse logistics is considered one of the best techniques for individuals and businesses. It decreases the waste that harms the environment and provides long-term solutions [38].

Deposit-refund systems can effectively shift streams of wastes from ultimate disposal and garbage to reuse through recycling, ensuring the ethical responsibility of the producer. It improves the impacts of treating dispersed and solid waste, which are challenging to regulate, much more than conventional collecting methods. Because of its enormous

volume, scattered consumption, and high pollution intensity, beverage packaging has become a significant application in the deposit-refund system (DRS). The mode of operation, essential process parameters, and the trend of development of the beverage packaging deposit-refund system are described via inquiry and research to promote the system [39].

The deposit-fee system has already been implemented in several nations worldwide, resulting in improved recycling and pollution reduction. Furthermore, much research on the outcomes of the systems built in each country has been undertaken, and there are multiple review articles in the literature comparing the individual systems. Finland has a long history of refillable bottle deposit systems, and the technology was established in 2005 for one-way glass beverage bottles and in 2008 for plastic beverage bottles. Thanks to a well-chosen deposit charge, the redemption percentage in both situations was above 90% by 2015. In Germany, the redemption system has been in place since the early 2000s, and it applies to metal and glass drinking bottles and plastic (PET) products. However, beginning on 1 May 2006, shops (except smaller retail locations) must accept single-use beverage packaging, regardless of where it was purchased. Because of the regulation, the redemption value for PET bottles has reached nearly 100%. According to the standard solution, the deposit-fee system consists of two concurrent incentives. First, the deposit charge is included in the product price at the time of purchase, showing the financial burden connected with the reuse of packaging trash. Second, a charge is paid to users upon redemption to encourage them to use the service. If the end customer recovers his garbage under this approach, he receives a deposit included in the price of the goods; therefore, he has no negative economic impact. A suitably high deposit charge improves collection efficiency, but it can reduce consumption by exceeding a specific threshold. The ideal deposit quantity is critical to the system's survival [40].

2.10. Emerging and Future Prospects

While only a few studies have looked at a single or a few of the issues in this publication, ours is unique. It is an integrated review that looks at many important aspects of plastic waste management, resulting in an encyclopedia on which future researchers may expand. The following gaps have been detected in the list of references included in our analysis, even though it is not exhaustive [41]:

- More peer-reviewed research on the socioeconomic of substituting plastics and the effectiveness of plastic bans are needed [41];
- More research on the closed-loop recycling system for PET water bottles should be undertaken [41].

As a result, a complete cost-benefit analysis of the proposed system is recommended to determine whether the advantages outweigh the costs. Other aspects, such as societal ones, should also be considered when assessing the UAE population's readiness to participate in the DRS and closed-loop recycling. This will help estimate the recycling rate before it is implemented.

2.11. The Initiation of Recycling Plastic Bottles in the United Arab Emirates

The Simply Bottles project was initiated by a manufacturer of eco-friendly clothes called DGrade. The main objective of that project was to enhance plastic-bottle collecting and recycling in the United Arab Emirates (UAE). As part of that program, DGrade was trying to build the first factory in the world that converts bottles to yarn. Moreover, they were willing to educate organizations, institutions, and people and provide them with tools and equipment. They needed infrastructure for reducing the pollution of plastic and raising the rates of plastic-bottle recycling. Although only about 6% of plastic is recycled there, the country of the UAE is considered one of the most significant users of single-use plastic in the world. DGrade stated that organizations might play an essential part in avoiding plastic pollution and contributing to a circular economy by recycling plastic bottles. Plastic is recycled to generate new products such as clothing and accessories. The company has asked organizations of all sizes to become sponsors, members, or supporters of the Simply

Bottles program. Joining organizations will be given a viable method for recycling plastic bottles, a solution that benefits members by providing a return on bottles collected, assisting organizations in lowering waste management expenses while complying with their CSR aims and the Dubai Plan 2021 [42].

3. Conclusions

To conclude, it was understood that the success of such a waste disposal system would minimize trash, protect the environment, make it cleaner, lower manufacturing costs, and bring financial benefits to the end user. As a result, a complete cost-benefit analysis of the proposed system is recommended to determine whether the advantages outweigh the costs. Other aspects, such as societal ones, should also be considered when assessing the UAE population's readiness to participate in the DRS and closed-loop recycling since this will help estimate the recycling rate before it is implemented.

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