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An Empirical Investigation on Plastic Waste Issues and Plastic Disposal Strategies to Protect the Environment: A UAE Perspective

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Abstract: Due to the rise in waste, both developed and developing countries' municipal solid waste (MSW) disposal systems are overburdened. The increased inflow of used plastic water bottles has rendered the situation difficult. Plastic usage in several forms is becoming indispensable in daily life, despite its harmful effects on humans and animals in general. Government bodies are eager to cut plastic usage in several forms, but the manufacturing costs and selling prices make it difficult to replace plastic with materials that are safe for living bodies. One such problem lies in the form of the water bottle. The use of plastic in water bottles is much more common in Gulf countries because of their geographical position and the scarcity of potable water. The large amount of plastic waste created by used water bottles is a very critical issue, as it has a severe environmental effect and is a hurdle in efforts to foster sustainable development and green initiatives. The present research undertook an empirical investigation on plastic waste issues, environmental concerns, and various mitigating initiatives. It further investigated the waste management system using closed-loop recycling for water bottles as an efficient means of managing MSW and protecting the environment in the UAE. A survey was initiated and distributed among the UAE population to study the feasibility of building such a system. The responses to the plastic waste issue and mitigating solutions were found to be encouraging. The statistical analysis showed a higher mean value of up to 4.47 on the 5-point Likert scale.

Keywords: plastic disposal; municipal solid waste (MSW); sustainable plastic water bottle; waste management system; recycling; environment

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1. Introduction

The disposal systems of municipal solid waste (MSW) in developing countries and developed countries are under stress, and the United Arab Emirates (UAE) is not an exception to this. The growing waste generation rate is influenced by product consumption, the changing needs of the people, the growing population, and socio-economic lifestyles. In the UAE, waste is produced at a rate of 1.76 to 2.3 kg/day per person [1]. The use of plastic has increased the burden on MSW in the UAE.

The increase in waste generation is expected to grow to a level of 5622 tonnes/day in 2030. The predicted trend of MSW generation in Abu Dhabi (UAE) as shown in Figure 1 reveals an increase in garbage production. Hence, the burden on MSW will be growing in the years to come unless a potential mitigating system is devised. The burden on the MSW disposal system may be reduced by cutting down on the input flow of used plastic water bottles [1].

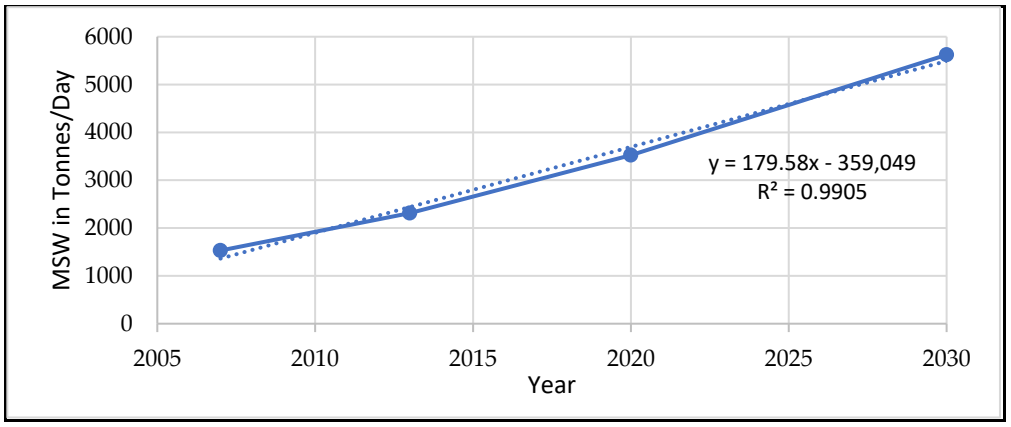

Figure 1. Anticipated trend of MSW produced in Abu Dhabi (UAE).

There is significant ongoing debate about whether plastic is a benefit or a burden. However, plastics have become an integral component of modern life. The vast usage of plastic in modern industries is increasing globally. The long life, considerably low weight, easy manufacturing, and decreased manufacturing cost of plastics mean that it is the first choice for the packaging, construction, and medical equipment manufacturing sectors. Variation in the usage of plastic is witnessed from country to country due to their economic and socioeconomic situations.

Underdeveloped and developing countries find plastic to be a cost-effective replacement. The growing population and industrial expansion are further factors contributing to the greater use of plastics. Due to the rapid growth in its population and GDP per capita, the UAE is also witnessing a surge in the use of plastic. According to EcoMENA data, the average UAE citizen uses 450 plastic water bottles each year. The UAE consumed bottled water at the fourth-highest rate in the world in 2011 [2]. In total, 11 billion plastic bags are used each year according to the United Arab Emirates' Ministry of Environment and Water. This brings the annual total waste to 912.5 kg per capita and the municipal solid waste generation to nearly 2.1 kg/day of, which includes chemicals as well [3]. The shocking rise in municipal solid waste indicates the escalating rise in plastic bag and water bottle usage. Plastics have proven to be more cost-effective replacements for many costly materials, such as glass and metals, due to their high versatility and long life. However, their safe disposal at the end of their lives is a significant and difficult issue.

Due to the UAE's heavy reliance on plastic, managing plastic trash is a difficult task. The UAE government is vigilant about the escalating use of plastic waste and its environmental effects. Many remedial measures have been taken. The UAE will begin to limit the use of non-biodegradable plastic products in the early part of the next year as one such corrective move. Many public awareness campaigns aiming to avoid plastic usage were initiated in the past. To reduce the projected 2.9 billion plastic bags used annually by 20 percent, the "Say No to Plastic Bags" campaign was introduced in May 2013. By increasing consumer knowledge and offering recyclable and reusable alternatives such as jute and paper bags at supermarkets, plastic usage may be reduced. To fulfill the Emirate of Sharjah's goal of 100% rubbish diversion, a public–private partnership (PPP) has been developed with the Sharjah Municipality in Sharjah. Such initiatives may give rise to waste management infrastructure and community awareness regarding the practice of "Reduce, Reuse, and Recycle" (3R). Sustainable waste management may be initiated using the PPP project. One such initiative is the formation of the Waste Management Center (CWM) by the government of Abu Dhabi. Several non-governmental organizations (NGOs) and many different groups in the community are actively collecting plastic waste [2–4].

Because of its geographic position and water availability, the UAE is quite different in terms of its use of water bottles when compared with other global regions. The use of water bottles is also influenced by the culture and habits of UAE citizens. Since the

use of plastic has positive and negative effects on the economy and socioeconomics, it must be monitored [5]. Non-government organizations (NGOs) and various community groups are actively participating in plastic trash collection [2–4]. The culture and customs of UAE nationals have impacts on how often they use water bottles. The increased mass consumption of bottled water contributes to the environmental issue that results in water waste, pollution, and climate change [6]. Public perception in the UK and Portugal was investigated using a cross-national mixed-method approach based on survey (qualitative) and focus group (quantitative) research. It revealed the behavioral involvement of water bottle users [7]. In Qatar, sociodemographic data, behavior related to the consumption of water, environmental consciousness, and water conservation attitudes, as well as the water actual usage, were taken into account while mapping human behavioral components with respect to water consumption [8].

A detailed review of the literature revealed that there has been little research undertaken in the UAE on the management of plastic waste and the use of recycling to save the environment. This gap in the literature is filled by the current investigation. Considering the foregoing premise, a research study was carried out to identify waste generation through water bottle and plastic waste disposal in the UAE and investigate the possibility of using the recycling of water bottles as a tool to protect the environment. The aim of the present study can be summarized as follows: (a) to investigate environmental concerns about plastic water bottles; (b) to examine consumer behavior concerning efforts to decrease the negative effects of the plastics used in a water bottles on the environment; and (c) to carry out a feasibility study regarding the development of a waste management system using the closed-loop recycling of water bottles as an efficient means of protecting the environment.

The research is structured as follows: The paper explores the environmental concerns and initiatives and how the environment can be negatively affected by plastic waste and the effect of the construction of a recycling system to protect the environment. Then, the feasibility of the construction of a closed-loop recycling system for water bottles is studied and analyzed.

2. Literature Review

Karak et al. [9] discussed the global context, focusing on the generation, composition, and management of MSW in the UAE. Arafat and Jijakli [10] carried out a modeling and comparative study of the effects of varying process temperatures on the gasification of MSW in the USA, UAE, and Thailand. They further carried out a comparative study of incineration as an alternative to the gasification of MSW and explored it with respect to energy production. Rizwan et al. [11] developed an optimal method for processing and converting MSW into valuable products and energy. Dabbagh [12] discussed the waste-creating situation and the management practices according to the municipality's plans and strategies. Saif et al. [13] investigated the treatment of MSW and built a dynamic discrete optimization model with the aiming of sustainability.

The effects of recycling on the protection of the environment and on sustainability have attracted the attention of many researchers around the world. The recycling of different products has been the subject of much research from different perspectives. One study discussed recycling in the textile industry and how it contributes to cost savings and environmental protection [14]. Other research investigated the factors affecting the willingness of customers to participate in recycling [15]. These factors were: ecological cognition, perceived customer behavioral control, customer attitudes towards recycling, the subject norms, and exemplary norms. Another study [16] investigated the key determinants affecting waste separation behavior and intentions.

The study discovered that insightful future policies that provide waste separation and collection locations, encourage recycling programs and traders, and educate residents could improve recycling habits and protect the environment. To reduce the waste of construction materials, a study discussed the recycling and reuse of construction paints

for other purposes [17]. Another study [18] discussed the recycling of waste circuit boards and analyzed the savings achieved and the protection of the environment. New recycling agents (Rag) were introduced to enhance the use of large amounts of reclaimed asphalt pavement for the construction of new pavements [19]. Other research has focused on recycling as a tool for protecting the environment. One study emphasized the importance of solid waste management for reducing costs and protecting the environment using a life cycle approach [20]. Other research [21] highlighted the importance of recycling in the concrete industry as a way to protect the environment from solid waste. Another research study discussed the impacts of remanufactured industries on the saving of resources, the protection of the environment, and, thus, sustainability [22].

There have been several kinds of research on the effects of recycled materials on consumer purchasing intentions [23]. It has been found that sustainability enhances consumers' intentions to purchase. A review discussed the effects of pro-environmental behavior on resource conservation and recycling. It was found that internal and external factors influence pro-environmental behavior, including psychological and demographic factors [24]. A study [25] investigated differences between age groups in pro-environmental behavior and its relationship to moral judgements and emotions about environmental issues. They found that older adolescents are less involved in recycling activities and, thus, in protecting the environment in Canada. In another study, the environment was protected by reducing the loss of nutrients through the leaching and recycling of nitrogen and phosphorus nutrients from anaerobic digestate [26]. The recycling of plastics and polymer products has also been a subject of a great deal of research. One study [27] evaluated the willingness of consumers who used plastic water bottles to pay for different types of plastic in order to help to protect the environment. Researchers in Kuwait attempted to protect the environment differently by implementing a new prototype for the water box kit that is cost-effective, economical, and, most importantly, environmentally friendly [28].

The authors of another study designed two new punchers to reduce the harmful effects of the film fragments generated by the punching of holes into the plastic films. The two new designs had a higher recycling success percentage and a shorter punching time [29]. A review [30] proposed various methods based on the reaction mechanism of bottle recycling for poly (ethylene terephthalate) (PET). This review concluded that we need to understand the PET recycling reaction mechanism in detail in order to make the right waste management decisions [30]. Sustainable packaging and its rules for the protection of the environment were discussed in detail in [31]. Sustainable packaging means the recycling of packaging materials and, therefore, the reduction in packaging waste during the production and processing of raw materials. Another study discussed the importance of recycling for protecting the environment and recovering more than 95% of the energy used in the manufacturing of plastic products [32]. Another study explored how ethylene-vinyl acetate copolymers (EVA) and polyethylene-graft-maleic anhydride (PE-g-MA) compatibilizers could be employed to enhance PET processing and mechanical characteristics [33]. Issues related to PET recycling—whether the physical (mechanical), chemical, or thermochemical recycling of PET is used—are discussed and illustrated in [34]. In Malaysia, most plastic waste is not recycled. Thus, one study [35] suggested using plastic waste in the mixture of concrete. This could save the environment and reduce the cost of concrete. The researchers discussed the use of recycled PET in injection moldings. The major problem, in this case, was the low impact strength of the recycled PET. In this research, the authors found an effective modifier of R-PET so as to resolve this problem and increase the impact strength [36]. On the other hand, other researchers [37] suggested regulating the process of the recycling of plastic wastes, as this might lead to the pollution of the environment, as these plastic wastes usually contain brominated flame retardants.

Plastic has become an indispensable part of daily activities. Plastic material is used as a packaging material in water bottles, thus creating a large amount of plastic waste after its use. Plastic waste in the form of plastic debris is endangering human life, as well as wildlife [38–41]. The effects of recycling on the protection of the environment and on

sustainability have attracted the attention of many research projects around the world. Plastic disposal through the landfill process and incineration may lead to an environmental setback in regard to plastic disposal [42].

The closed-loop recycling system is depicted in Figure 2. The used water bottles from consumers may be fed back into the system for recycling in order to convert them into new products, thus generating zero waste. The unusable water bottle may be thrown out for further disposal as per environmental guidelines. The closed-loop recycling system is suitable for plastic bottles, glass bottles, aluminum cans, etc., without affecting the end-product quality.

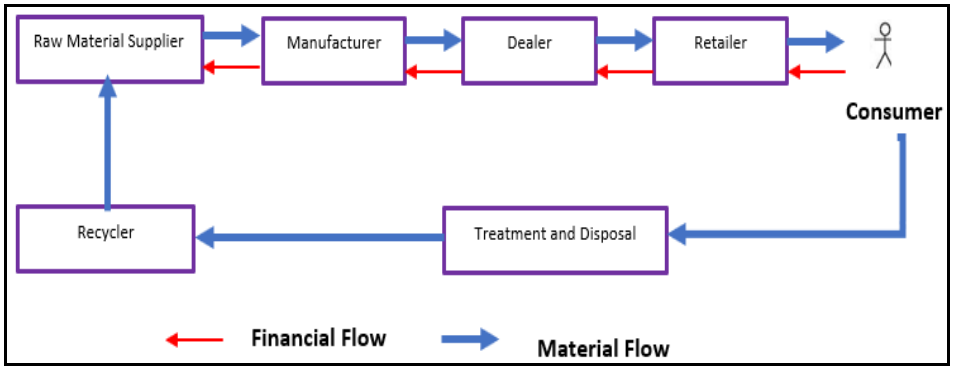

Figure 2. The closed-loop recycling system.

A large quantity of waste may soon be converted into energy due to the pressures of the high costs of energy resources and existing resources. Shareefdeen et al. [1] investigated waste-to-energy (WtE) technologies in the UAE. Paleologos et al. [43] studied Abu Dhabi's potential for a new industrial typology. Al-Dabbagh [12] examined Ajman's waste management development and plan. Al Naimi et al. [44] examined the use of industrial waste in the UAE as a high-temperature material for applications requiring thermal energy storage. In the UAE, AlMallahi et al. [45] studied the rapid pyrolysis method for the production of bio-oil from coffee waste. Pyrolysis is one of the most effective and widely adopted methods for the recycling of plastic water bottles. In pyrolysis, the thermal degradation of solid waste yields pyrolytic oil and gas at elevated temperatures. This provides a great opportunity to mitigate MSW.

A study carried out and reported in [46] led to plastic bottle cap recycling, contributing to a circular economy of plastics. PET is recycled in many countries due to their policies on waste management. The recycled PET may be termed "rPET". Biodegradable materials such as polylactic acid (PLA) and polyethylene furanoate (PEF) have been developed in the last few years.

As per the study by Gere and Czigany [47], the increase in compatibilizers reduces the particle size depending on the amount of PLA. Furthermore, the authors concluded that PLA proportions of less than 50% resulted in a PET matrix, and PLA proportions of 50% or larger than 50% resulted in a PLA matrix with a 0.1 m to 1 µm blend (Figure 3). The compatibilized blend may be suitable for the packaging industry, specifically for food packaging. Furthermore, PLA has a better influence on the environment than PET [48]. The recyclability of used water bottles can be increased by utilizing mixed PET and poly (lactic acid) (PLA) bottle waste in varying ratios [47]. A study examined customers' willingness to pay for alternatives to plastic water bottle packaging materials [27]. Waste PET materials may be used in bituminous mixtures as polymer additives to combat pavement problems [49]. Assemblage waste accumulated from plastic bottles may also be utilized in concrete [50]. It was further established by Eerhart et al. [51] that PEF provides a lower carbon footprint than PET by 50–70%. Truelove et al. [52] carried out a study involving 283 university students in the U.S. to evaluate the effects of guilt, environmental identification, and environmental worry. The study used three different activities, including recycling a

water bottle, tossing a bottle into the garbage, and acting as a control condition. Kristina et al. [53] studied the feasibility and hurdles of the recycling of plastic bottle waste in Indonesia.

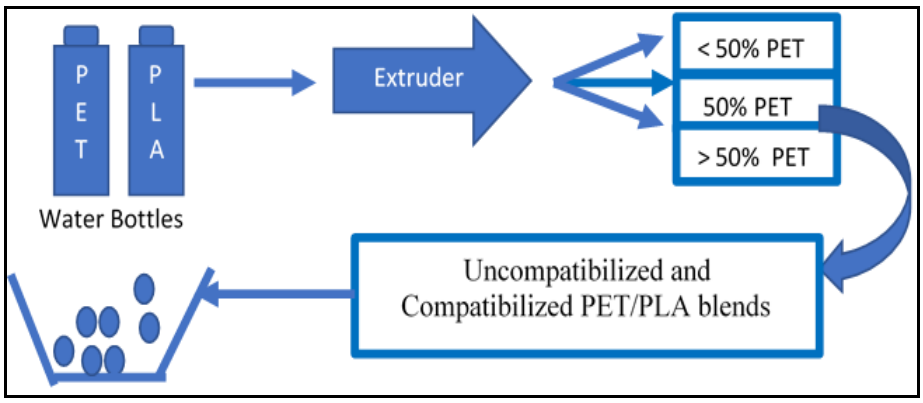

Figure 3. The recycling process of PET/PLA water bottles.

Based on the research that has been conducted, this research attempts to investigate the effects of plastic waste on the environment and lives of people in UAE and study the feasibility of the construction of a recycling system that can be accepted by the population and is efficient in handling the disposed plastic water bottles.

3. Environmental Concerns and Initiatives

3.1. Environmental Pollution by Plastic Wastes

In USA, the landfills were found to be clogged with around 2 million tons of used water bottles. It can take up to a thousand of years for each water bottle to degrade. When a single water bottle decomposes, it produces chemicals which are dangerous to our environment. Research studies have reported that the toxins that are released into the air when water bottles break down can cause several health problems, including reproductive disorders and cancer [54].

According to recent research [55], wasted water bottles made of plastic might require more than 400 years to biodegrade. The major concern is that the very small plastic particles of those bottles (Microplastics) might become embedded in human food when they degrade, especially when they are consumed by marine life, thus forming a serious danger for the life and health of human beings. It is agreed that using plastic bottles for drinking water is very convenient and healthy, but the lack of appropriate regulations produced by governments has resulted in the propagation of plastic disposables. In the last six decades, the industrial sector has produced more than 8 billion of metric tons of plastics, which has resulted in more than 6 billion tons of plastic waste.

The distribution of plastic trash is very diverse because of specific factors, such as wind and ocean currents, urban areas, and trade routes. Since plastics can act as carriers of chemical pollutants, such as heavy metals, and persistent organic pollutants, the human population can have a significant impact on this issue in some areas. The use of plastics in the manufacturing of chemicals that are harmful for both people and animals is another major factor contributing to their negative environmental impact. Many of the chemicals used to create plastic are neurotoxic and carcinogenic and interfere with hormones. These substances inevitably contaminate the water, land, and air, which allows them to enter our ecosystem. Some of the more well-known substances include vinyl chloride (found in PVC), dioxins (also found in PVC), benzene (found in polystyrene), phthalates and other plasticizers (found in PVC and other materials), formaldehyde, and bisphenol A, or BPA (found in polycarbonate). Many of these are persistent organic pollutants (POPs), which are among the most harmful poisons on Earth due to the great amount of time in which they remain in the environment and the fact that they are dangerous. They have

effects on all the terrestrial and aquatic creatures they come into contact with due to their unrestricted discharge into the ecosystem. Hazardous gases such as carbon monoxide, dioxin, and hydrogen cyanide are released into the atmosphere during the production of plastic products. These gases seriously contaminate the air. High levels of these gases in the atmosphere have negative impacts on both human and animal health. They can cause breathing problems, problems with the nervous system, and lower resistance to disease. There is a chance that chlorinated plastics can release harmful chemicals into the soil around them. These chemicals can then seep into nearby water sources, such as groundwater or other bodies of water, harming the environment and rendering the water unsafe to drink. As a result, the species that consume the water might experience serious consequences. There are many different kinds of plastics and the landfills contain them. These landfills contain many bacteria that accelerate the biodegradation of plastics. Bacteria such as Flavobacteria, bacteria that eat nylon, and pseudomonas are among the microbes. These bacteria degrade nylon using the nylonase enzyme. When biodegradable plastics break down, they release methane, which is a strong greenhouse gas that exacerbates global warming [56].

3.2. Public Health Effects of Plastic Wastes

When children use plastic toys and food packages made of plastic, they are subjected to harmful chemicals, as in cases where children chew plastic toys, and these chemicals might leach into food stored in plastic packages, which may result in risky effects on children's health, cancer, the lowering of the immune system, birth defects, and other health consequences. These risky threats to children's health must be addressed. Whereas plastic replacements can offer a solution, another more efficient solution is to dispose of those plastic items in convenient way, with appropriate arrangements [57].

It was mostly believed that plastic would have no or little effect on human health, as it is inert. This might be accurate, as several plastic monomers and other additives presumably come from polymers and are expected to be health threats. Endocrine disruptors and carcinogens form most of these plastic additives. Exposure to these chemicals in humans might occur through skin contact, ingestion, or inhalation. Dermatitis is linked to skin contact with some of the compounds found in plastics. Another risk to public health is microplastics, which are significant contaminants consumed by marine and freshwater creatures, thus entering the food chain. If animals are exposed to plastic additives and to microplastics for long periods of time, they might be harmful for humans as well. Studies on environmental pollutant assessment and the investigation of the biomonitoring of tissues in humans concluded that plastics can live and survive in human beings [58,59].

3.3. Disposal of Plastic Wastes

Burning, burying, or recycling are the three options for disposing of plastic garbage. About 16 percent of all municipal waste is burned by incineration in developing countries. Waste-to-energy facilities the use of burn waste to produce steam or electricity using heat energy [43,60]. Plastics, which are frequently made from gas or oil, can produce fuel-like levels of energy. Hydrogen chloride, dioxin, cadmium, and fine particle matter are examples of potentially dangerous pollutants derived from the incineration of plastics. Even though new air pollution laws have been put in place, the public is still strongly against incineration. As plastics are chemically inert, landfilling is generally a safe practice. Due to their potential to migrate from the polymers into the leachate, some plastic additives raise concerns. Plasticizers known as phthalates are dangerous compounds that have been detected at varying concentrations in several leachate analyses [61]. The process of recycling involves the stages of collecting the used plastic products, classifying them into six categories, converting the collected plastics chemically and physically into flakes or pellets, and then using those pellets or flakes to produce the new plastic products. It takes a great deal of time and money to separate plastic from glass or metal. Thus, it is not recycled as often as other materials [57,62].

In the USA, although very few states and local governments have implemented measures and enhanced the collection of used water bottles for the purpose of recycling, the recycling of plastic water bottles has recently gained policy significance. There are two reasons why plastic water bottles are receiving more attention. Firstly, plastic water bottles account for a substantial and growing portion of the garbage created, rising from 12 billion in 2000 to 36 billion in 2006. Each year, PET-made water bottles produce hundreds of millions of pounds of waste that is either burned or dumped in landfills. Secondly, whereas the laws regulating the disposal of bottles have been in place for a long time in many places, those related to plastic water bottles have only recently been introduced. Six states have been added to the list of states with bottle deposit regulations, and others might be added in the future as well [63].

There are programs for the recycling of the collected waste of consumers among communities and organizations around the world, including plastics, metals, and papers. The public's interest in collecting waste is far from the financial profit of employing a large amount of recycled materials. Landfills are regularly used to dispose of additional recyclable materials. Additionally, recycled plastics will be advantageous by enabling the use of less expanded polystyrene in lightweight geotechnical fill applications. The production of expanded polystyrene blocks is worse for the environment than the recycling of plastic bottles. Plastic bottles work well for petroleum-based substances and do not break down in the case of an oil or gasoline spill. These advantages have prompted the use of plastic bottles in an environmentally friendly fill [64,65].

3.4. Why Does Recycling Help to Reduce the Pollution Caused by Plastics?

Recycling waste is the best way to handle trash, but it can also be seen as a contemporary illustration of the concept of ecological sustainability, because there are not any wastes in a natural ecosystem, but only products. The recycling of plastics is one way to reduce the damage they do to the environment, prevent resources from depleting, and reduce the amount of energy and materials required to produce one unit of plastic. Thus, plastic is more environmentally friendly. Recently, researchers have been focusing on creating plans for the recycling and reuse of plastic waste in ways that are good for the environment and the economy. According to some research, the long polymeric chain can be broken down in a fire to create new products from recycled plastic. Using plastic waste as a fine aggregate in concrete can provide it with the same compressive and flexural strength and mechanical resistance as regular concrete [66].

Bitumen plays a crucial role in the construction of roads because it holds everything in place. Researchers and engineers have discovered a way to improve its properties by coating it with waste plastic, because it does not effectively resist water. The construction of flexible road pavements has made extensive use of this technique. The innovation increases the quality of the road's construction, extending its useful life. Researchers have also looked into the use of plastic waste as a source of carbon for the synthesis of carbon nanotubes (CNTs) [67].

Recycling prevents plastics from ending up in landfills. Plastic recycling saves 7.4 cubic yards of landfill space per tonne. This is not to mention the waste plastic that directly pollutes our soil and water, breaks down into tiny pieces (called "microplastics"), and adds to the great garbage patches in the oceans. The energy and resources (such as water, oil, coal, and gas) required to produce plastic are reduced when plastic is recycled.

Nowadays, it is easier than ever to recycle plastic. More than 60% of Americans have simple access to a municipal curbside recycling program, whether they participate in it or live close to a drop-off location. According to the American Plastics Council, more than 1800 businesses in the country handle or recycle consumer-used plastics.

The current state of the plastic recycling industry is worsening the issue regarding where plastic can be discarded by creating more plastic waste. The most environmentally friendly way to recycle plastic is to transform it into building tiles, which also takes advantage of the greatest drawback of plastic.

3.5. Rewards for Recycling

In Abu Dhabi, a mobile application called RECAPP was initiated to guarantee that recyclable trash is collected from homes free of charge. Using a single click, one can use the app to order recycling pickup from their location. Moreover, those recycled plastics that are collected translate points which can be replaced with gifts. The main purpose of this application is to enhance recycling among the people and show them how easy the process is so that less waste ends up in landfills. Coca-Cola Uganda is a beverage company. Thus, it generates plastic trash in the process. The firm deliberately established a recycling factory in Nakawa, named Plastic Recycling Industries, to address its beverage consumers' massive volume of plastic trash. This project sought to develop the Coca-Cola green rewards mobile web application, which contributes to the increase in the number of people who collect plastic waste. The Coca-Cola green rewards app is a mobile web application designed for Coca-Cola recycling plants and all plastic bottle collectors and agents. The app allows bottle collectors to quickly inform agents about accumulating garbage that needs to be picked up, which encourages more individuals to join in plastic bottle collection because it is a simple and successful technique [68–70].

3.6. Implementation of a Closed-Loop System in Countries

In many nations around the world, the water infrastructure is a linear system managed by centralized water firms and water agencies. This linear system is also commonly used in industry to regulate the water supply and wastewater discharge. From the initial process of converting groundwater into tap or industrial water to its final conversion back into wastewater, the system, comprised of kilometers of pipelines, guarantees that everyone receives the appropriate amount of water [3].

Currently, longer periods of drought are being caused by climate change. Severe rainfall is causing flooding, and entire ecosystems are collapsing. Providing clean and safe water to a growing global population with the current linear water infrastructure will thus become increasingly problematic in the future. A project, which will include features of the closed-loop water system, will be delivered to a new-build residential neighborhood in the eastern part of the Netherlands, called "Heuvelstraat", in Silvolde. Nijhuis Saur Industries and Semilla Sanitation are collaborating closely with the town, water authorities, and other partners to develop this novel concept as one of the solutions to the local drought. Such a project will play a significant role in lowering home drinking water use and releasing clean water into the earth. Furthermore, the removal of medical leftovers will reduce environmental pollution. Finally, this system will allow green minerals, such as fertilizer and compost, to be recovered from water so as to prevent the loss of these precious resources [3].

4. Methodology for Solving the Problem of the Disposal of Plastic Water Bottles

4.1. Suggested Solution

According to the literature and the research investigations conducted previously, the best solution for the disposal of plastic water bottles is to recycle them by building a closed-loop recycling system. Such a system can only be successful if it is approved and adopted by the consumers of those plastic water bottles. Therefore, this research attempted to investigate the awareness of the population in UAE regarding the harmful effects of disposed plastic water bottles on the environment and, thus, on lives. We then tested and investigated their willingness to adopt and use a closed-loop recycling system for the used plastic water bottles. The study used a survey to detect this information and collect the customers' responses, indicating their realization of the problem, and the customer intentions with respect to the suggested solution.

4.2. Target Population and Sample Size

For the survey, the population targeted in the present research were UAE residents. The UAE's population consists of both UAE citizens and expatriates. The target population

was estimated to include approximately 250,000 bottled water users. The sample size plays a significant role in imitating the true characteristics of targeted populations. If the sample size under consideration is too small, neither the results obtained nor the realities of the target population under investigation will be sufficiently reflected. Hence, to determine the sample size for the present study, Fisher's formula was used, which is shown in Equation (1):

$$n = \frac{Z^2 p(q)}{d^2} \quad (1)$$

where n = the sample size; Z = 1.96 (standard deviation for the 95% confidence level); p = 0.5 (prevalence of the attribute, i.e., 50%); d = the acceptable difference, so that if the value is 5%, d = 0.05; and q = (1–p). Various values may be used to calculate the sample size, as shown in Equation (2), yielding the sample size of 384.16:

$$n = \frac{Z^2 p(q)}{d^2} = \frac{1.96^2 (0.50)(0.50)}{0.05^2} = 384.16 \quad (2)$$

Furthermore, the sample size was verified using Raosoft, a sample size open-source calculator, considering a sample population of 250,000. Thus, in the present study, a sample size of 388 was found to be acceptable in order to derive the required results.

4.3. Questionnaire Design Process

The current study used a descriptive cross-sectional technique which attempts to precisely and methodically describe the population. The study primarily focused on factors affecting UAE individual behavior regarding the disposal of bottled water. Through a series of questionnaires, many characteristics of the respondents' comprehension regarding the handling of water bottles, their behaviors, and courses of action were examined. The study's primary objective was to cover a spectrum of issues surrounding the waste disposal of water bottles, the respondents' awareness of waste disposal techniques, their attitude toward waste disposal habits, etc. Thus, the objective of the study's design was to gather secondary quantitative data that could later be utilized to assess various variables and draw logical conclusions. Before carrying out the pilot study, the preliminary drafted questionnaire was sent to the three consultants experienced in environmental management systems (EMS). Based on their feedback, the questionnaire was simplified to help the respondents. After the formal approval of these three consultants was obtained, the questionnaire was further tested through its pilot testing. The pilot testing of the questionnaire was performed among colleagues and students to ensure that it was reliable and valid. Based on the pilot testing, two questions were discarded, as they were found to be redundant. Additionally, we ensured that the questionnaire's layout made it simple for the respondents to grasp the purpose of each item. Additionally, we ensured that each question's meaning was clear to the respondents according to the questionnaire's layout. Before distributing the survey, formal clearance from the IRB and the participants' consent were sought. The consultants and respondents agreed to participate voluntarily, without receiving any compensation. It was also agreed upon by both parties that there would be no penalties for abandoning the study at any stage.

4.4. Study Design and Data Collection

The current study used a survey approach that produced an empirical study. A homogenous sampling method of purposive sampling was undertaken to identify the identical traits of the users of water bottles. To help the survey participants to understand the questions, the questionnaire was written in both Arabic and English. The "Google Forms" program was then used to administer the questionnaire. The collected data were tested for internal consistency. Internal consistency was ensured using Cronbach's alpha (α) value. An α = 0.7 or higher is the acceptable limit for testing internal consistency. The results of the analyses showed an $\alpha > 0.7$; hence, the internal consistency was maintained. For the data analysis, IBM SPSS Statistics 27.0 software was used.

5. Results and Discussion

Figure 4 shows that the majority of the survey respondents firmly agreed that plastic bottles are environmentally detrimental. Whereas 63% strongly agreed with this statement, 32% only just agreed with it, and 5% had a neutral opinion on this statement.

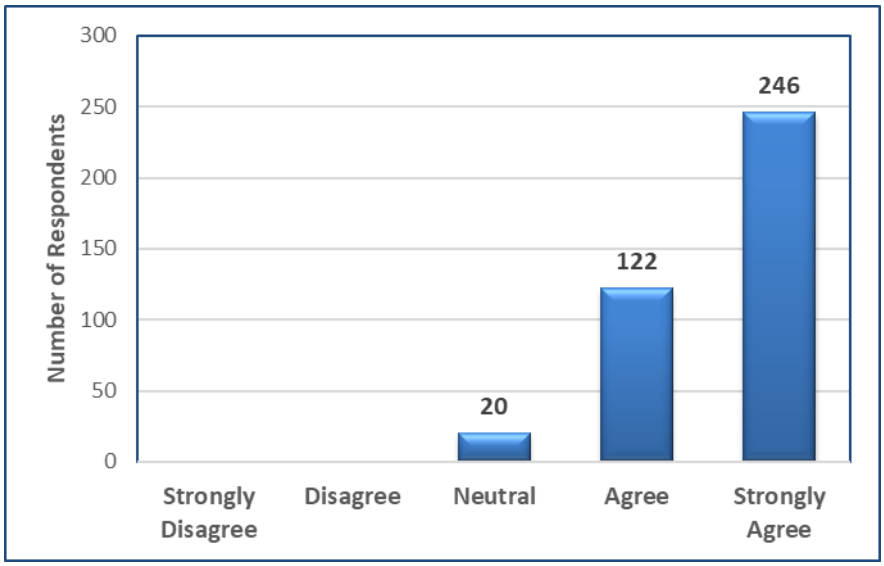

Figure 4. Response analysis of the participants' feedback on the question about whether plastic bottles are considered harmful to the environment.

Next, as shown in Figure 5, 37% of the participants answered that they realized how many years are needed for a water bottle to be thoroughly analyzed. In addition, 33% strongly agreed with this statement, while 16% disagreed, 9% had a neutral opinion, and 5% strongly disagreed.

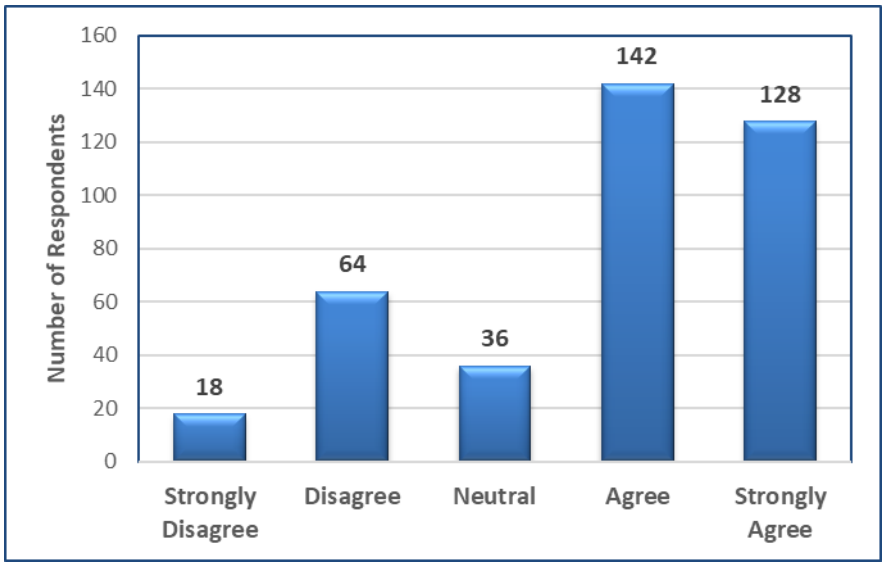

Figure 5. Response analysis of the question asking the participants whether they realize how many years are required for a water bottle to be thoroughly analyzed.

When the participants were asked whether throwing used water bottles into trash cans is a perfect way to dispose of them, as indicated by the results shown in Figure 6, 38% of the participants disagreed with this statement, 28% of them strongly disagreed with this

statement, 16% of them had a neutral opinion, 8% strongly agreed with this statement, and 10% agreed with it.

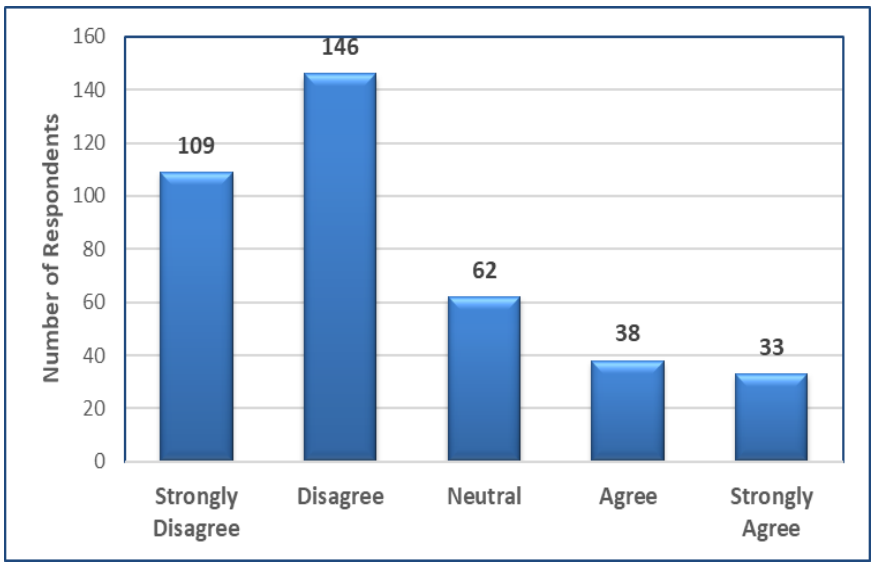

Figure 6. Response analysis of the question asking participants whether throwing used water bottles into trash cans is a perfect way to dispose of them.

Out of the 388 participants, as indicated by the results shown in Figure 7, 40% of the participants reported that they disagreed with the opinion that the easiest way to dispose of used bottles is by throwing them into collecting containers. In contrast, 11% agreed with this opinion, 10% had a neutral opinion, 16% strongly agreed, and 23% strongly disagreed.

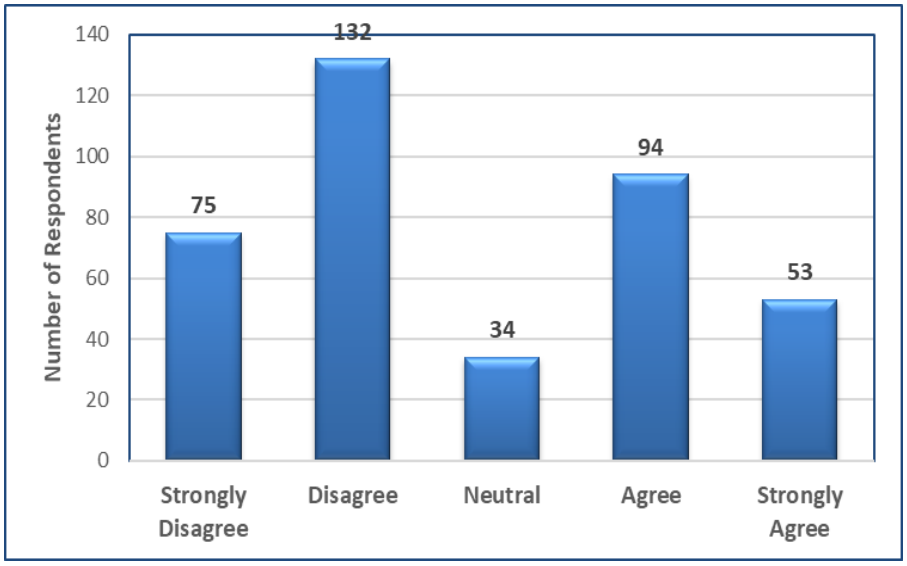

Figure 7. Response analysis of the question asking participants whether the easiest way to dispose of used bottles is by throwing them in collecting containers.

As shown in Figure 8, 49% of the respondents reported that they strongly agreed with the statement that throwing used water bottles into trash cans can cause harmful effects on the environment. In addition, 35% disagreed with this statement, 12% had a neutral opinion on this statement, 3% disagreed, and 1% agreed.

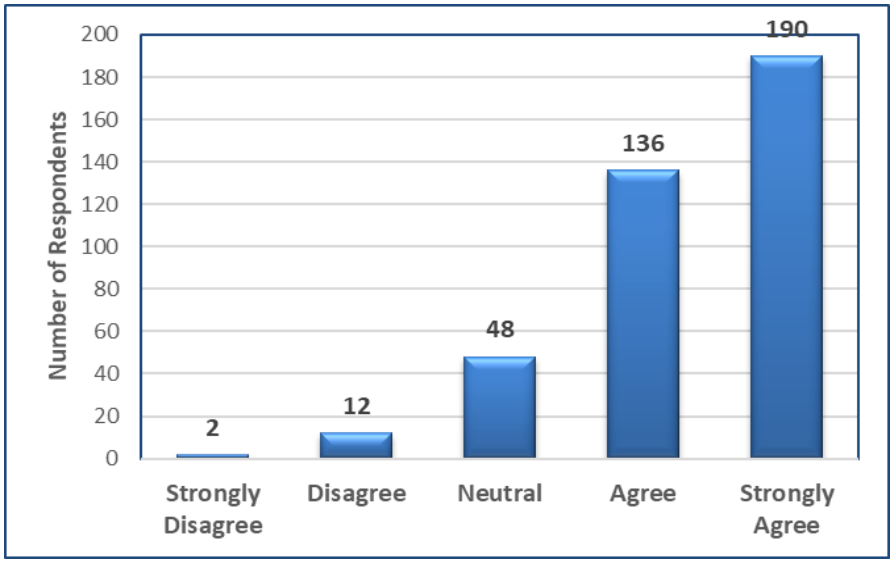

Figure 8. Response analysis of the question regarding the participants' feedback about the fact that throwing used water bottles into trash cans can cause harmful effects on the environment.

The participants' feedback results show that, in their opinion, throwing used water bottles into trash cans causes a significant increase in the trash size, making it harder to dispose of it. This is shown in Figure 9. Out of all the participants, 50% strongly agreed that throwing used water bottles into trash cans causes a significant increase in the trash size, making their disposal harder. In comparison, 38% agreed with this statement, 2% disagreed, and 10% had a neutral opinion on this statement.

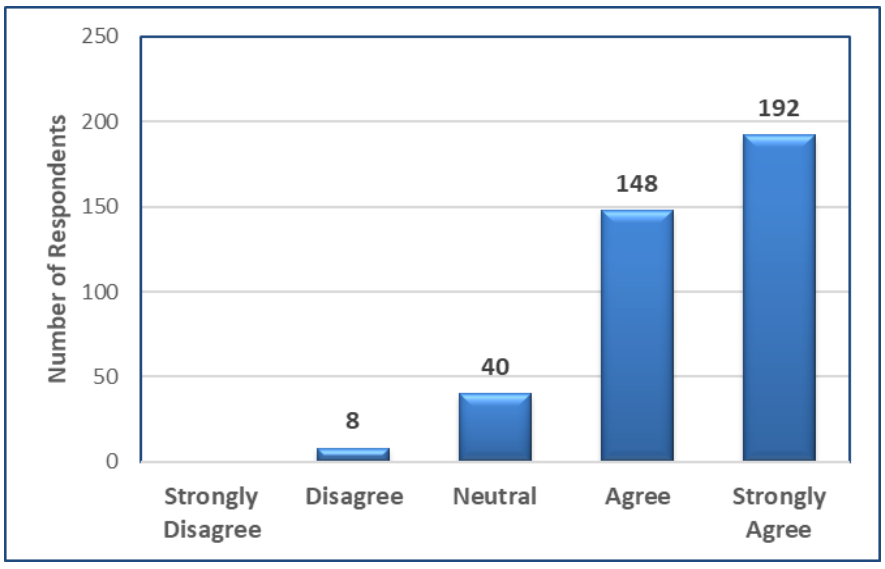

Figure 9. Response analysis of the question on participants' feedback about the fact that throwing used water bottles into trash cans causes a significant increase in the trash size, making their disposal harder.

Of the 388 participants, 60% strongly agreed that other methods should be identified in order to dispose of those used water bottles without negatively affecting the environment. Additionally, 35% of the participants agreed with this statement, 3% had a neutral opinion, and 2% disagreed, as shown in Figure 10.

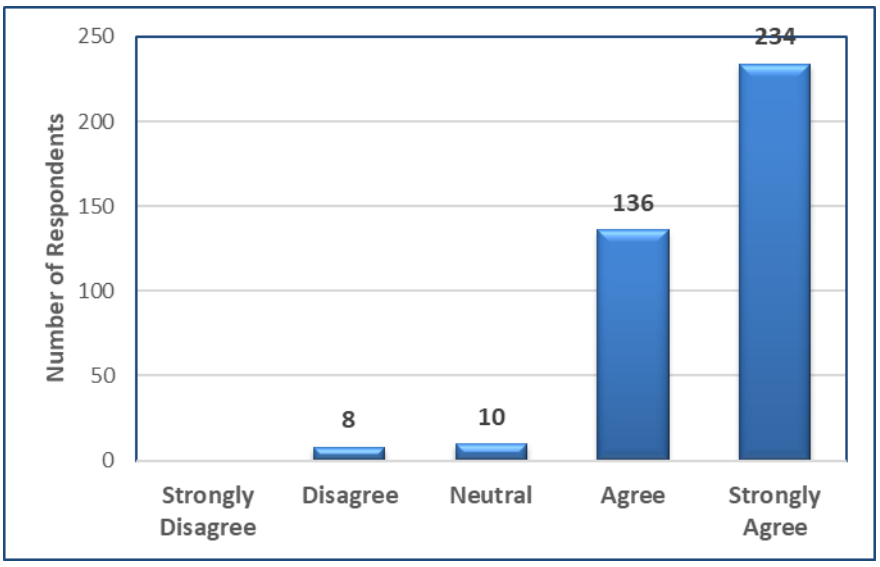

Figure 10. Response analysis of the question regarding participants' feedback about the fact that it is so necessary to identify other methods to dispose of those used water bottles without negatively affecting the environment.

As shown in Figure 11, when the participants were asked if they had little knowledge about the amount and kinds of harmful effects that plastics have on the environment, 31% of the participants disagreed with this statement, 26% agreed with this statement, 19% had a neutral opinion, 10% strongly agreed, and 14% strongly disagreed.

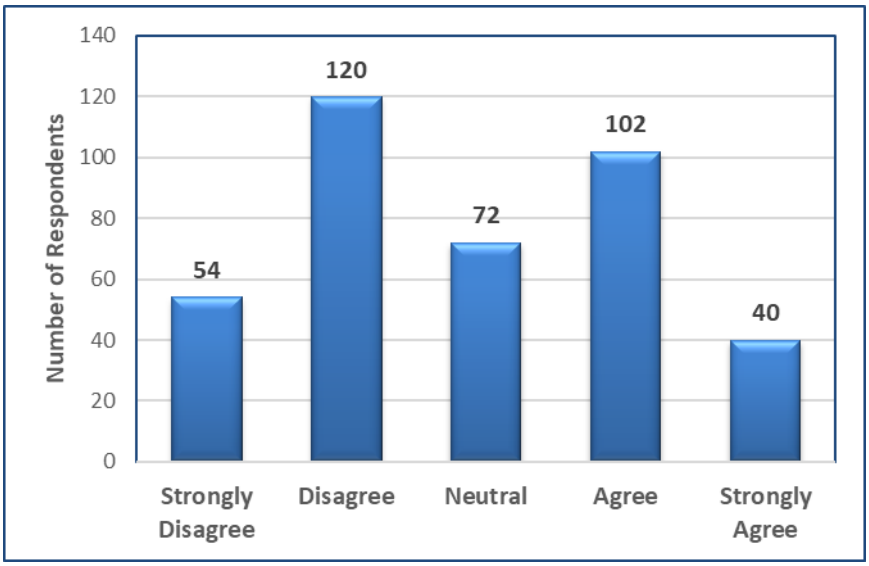

Figure 11. Response analysis of the question on participants' feedback about whether they had little knowledge about the amount and kinds of harmful effects that plastics have on the environment.

Out of all the participants, Figure 12 shows that 46% agreed that they would make it their rule to protect the environment by sending used water bottles for recycling, while 40% strongly agreed with this statement, 11% had a neutral opinion, 2% disagreed, and 1% strongly disagreed.

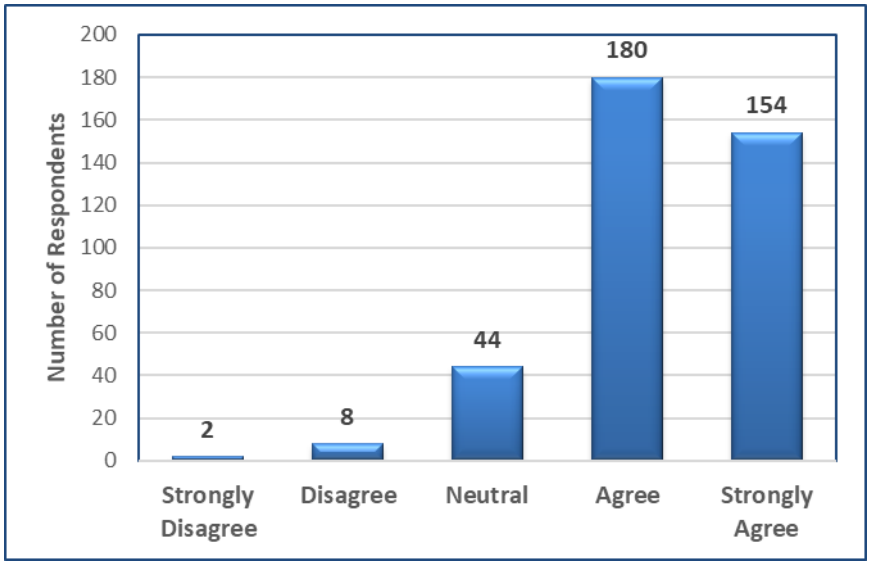

Figure 12. Response analysis of the question on participants' feedback about whether they would make it their rule to protect the environment by sending used water bottles for recycling.

Out of the 388 participants, 37% disagreed that good community members do not think that they have to send used water bottles to recycling vending machines and encourage and support everyone to do so. However, 25% strongly disagreed with this statement, 15% strongly agreed, 14% had a neutral opinion, and 9% agreed, as shown in Figure 13.

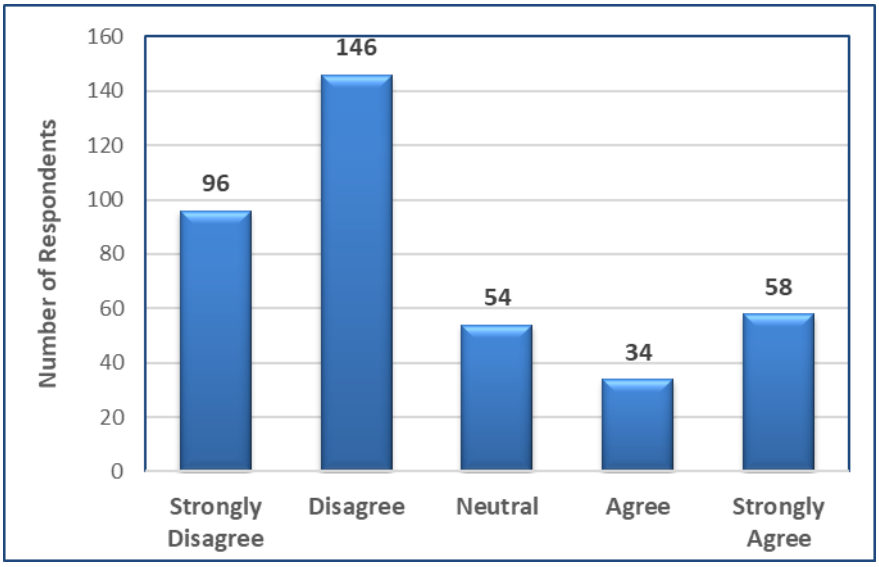

Figure 13. Response analysis of the question on participants' feedback about the belief that being a good community member does not necessarily mean that they have to send used water bottles to recycling vending machines and encourage and support everyone to do so.

The results shown in Figure 14 indicate that a majority of 62% of the participants strongly agreed that the recycling of water bottles protects the environment and protects all community members. However, 34% agreed with this statement, and 4% had a neutral opinion on this.

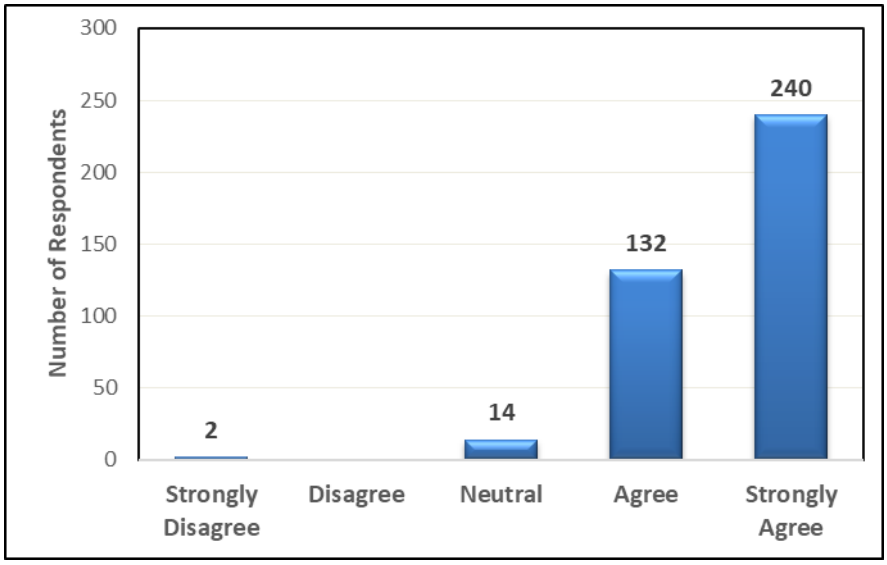

Figure 14. Response analysis of the question on the participants' feedback about whether they believe that the recycling of water bottles protects the environment and protects all community members.

6. Statistical Analysis Results

Based on the respondents' valid responses, a descriptive analysis was performed. The outcomes are displayed in Table 1.

Table 1. Descriptive Statistics.

Construct	N	Minimum	Maximum	Mean (μ)	Std. Deviation (σ)
The easiest way to get rid of those used bottles is by throwing them into trash cans	388	1	5	2.57	1.373
Throwing used water bottles into trash cans is perfect	388	1	5	2.33	1.222
Plastic water bottles are a problem and considered harmful to the environment	388	3	5	4.58	0.589
I ultimately realize how many years are needed for a water bottle to be thoroughly analyzed	388	1	5	3.77	1.204
Throwing used water bottles into trash cans causes harmful effects on the environment	388	1	5	4.29	0.838
Throwing used water bottles into trash cans causes a significant increase in the trash size, which makes their disposal harder	388	2	5	4.35	0.748
Other methods should be identified in order to dispose of those used water bottles without having a negative effect on the environment	388	2	5	4.54	0.652
I do not know very well the amount and kind of harmful effect that kind of plastics cause on the environment	388	1	5	2.88	1.237
I will make it my rule to protect my environment by sending used water bottles for recycling	388	1	5	4.23	0.768
As a good community member, I do not think that I have to send used water bottles for recycling vending machines and encourage and support everyone to do so	388	1	5	2.52	1.350
Recycling water bottles protects the environment and protect all community members	388	1	5	4.57	0.617

An interval scale of a five-point Likert scale was selected. It was used to measure the respondents' attitudes towards a particular question or statement. The mean was very significant. On this scale, a response from 1 to 1.8, as indicated in Table 2, denotes strongly disagree. A response from 1.81 to 2.60 means disagree. A response from 2.61 to 3.40 means neutral, while 3.41 to 4.20 means agree and 4.21 to 5 means strongly agree.

Table 2. Likert Scale Interval.

Level	Scale	Interval Length	Lower Limit	Upper Limit
Strongly Disagree	1	0.8	1	1.8
Disagree	2	0.8	1.8	2.6
Neutral	3	0.8	2.6	3.4
Agree	4	0.8	3.4	4.2
Strongly Agree	5	0.8	4.2	5

In the case of the first statement, the mean was 2.57 (σ = 1.373). This indicates that the majority of the participants disagreed that the easiest way to dispose of used water bottles is by throwing them into trash cans. For the next statement, the mean is 2.33 (SD = 2.33), which also means that out of the 388 participants, the majority of them disagreed that throwing used water bottles into trash cans is the perfect way to dispose of them.

In the environmental section of the survey, the third statement was about whether plastic water bottles are considered a problem. Most of the participants strongly agreed with this statement, and some students had a neutral opinion of this statement. Out of all the participants, a mean of 3.77 (SD = 1.204) agreed that they realize several years are needed for a water bottle to be thoroughly analyzed. In the case of the next statement, a mean of 4.29 (SD = 0.838) showed that the participants strongly agreed that throwing used water bottles into trash cans can cause harmful effects on the environment. The next statement reported a mean of 4.35 (SD = 0.748), which indicated that the participants strongly agreed that throwing used water bottles into trash cans causes a significant increase in the trash size, which makes their disposal harder. Similarly, a mean of 4.54 (SD = 0.652) was observed when the participants were asked whether other methods should be identified in order to dispose of those used water bottles without having a negative effect on the environment. Out of all the 388 participants, the majority, with a mean of 2.88 (SD = 1.237), reported that they have a neutral opinion on how little they know about the amount and kinds of harmful effects plastics can have on the environment. A mean of 4.33 (SD = 0.768) strongly agreed that they would make it their rule to protect the environment by sending used water bottles for recycling. The next statement reported a mean of 2.52 (SD = 1.350), which means that the majority of the participants disagreed with the statement that, as a good community members, they must send used water bottles for recycling and encourage everyone to do so. Lastly, a mean of 4.57 (SD = 0.617) indicated that the majority reported that the recycling of water bottles protects the environment and protects all the community members, as shown in Table 2.

Based on the means of all the responses, they can be compared based on their mean values. Thus, they can be further grouped into two categories: the low-mean group and the high-mean group. Figure 15 illustrates the comparison of the respondents' responses with respect to the mean values.

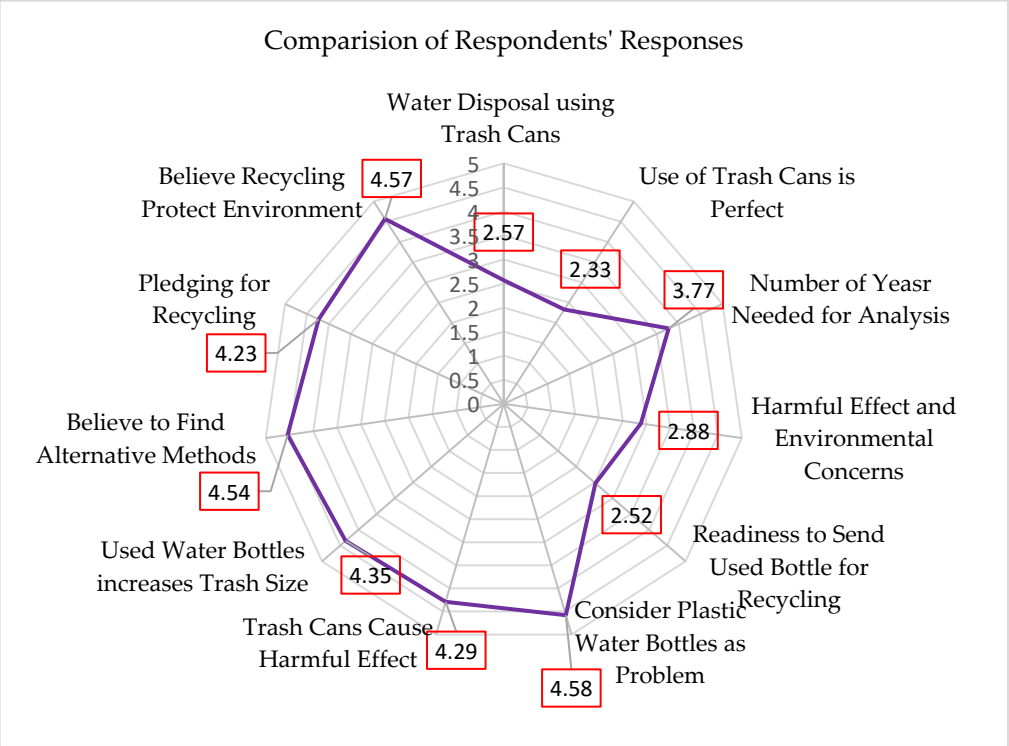

Figure 15. Comparison of the respondents' responses.

7. Conclusions

Various mitigating solutions to the problem of MSW management systems in the UAE have been explored through this review of the literature. The survey carried out provides useful insight into plastic waste issues and the prevailing disposal strategies in the UAE. The responses to the questions were very encouraging and ranged from 4.23 to 4.47. The in-depth analysis of the high-mean responses can be interpreted as follows:

- Plastic water bottles are a problem and are considered harmful to the environment (μ = 4.58). The responses received indicate that a plastic water bottle is considered to be a problem affecting the environment.
- Throwing used water bottles into trash cans causes harmful effects on the environment (μ = 4.29). The responses received indicate that water bottle issues cannot be solved by throwing them into trash cans.
- Throwing used water bottles into trash cans causes a significant increase in the trash size, which makes their disposal harder (μ = 4.35). The responses received indicate that the increasing trash size exacerbates the problem, and another solution to the plastic issue needs to be found.
- Other methods should be identified in order to dispose of used water bottles without having a negative effect on the environment (μ = 4.54). The responses received indicate that, to resolve the problem, another disposal method with no negative effect on the environment has to be explored.
- Individuals are willing to make it their rule to protect the environment by sending used water bottles for recycling (μ = 4.23). The responses received indicate a high level of personal commitment to identifying an environmental mitigating solution.
- Recycling water bottles protects the environment and protects all the community members (μ = 4.57). The responses received indicate the acceptance of the recycling of water bottles as the correct solution for the community.

The present study explored concerns regarding the SWM management system and the readiness and active participation of people in solving environmental problems.

The respondents' responses may be classified into two categories: low-mean-value responses and high-mean-value responses. The low-mean response category covers the "Water Disposal using Trash Cans", "Use of Trash Cans is Perfect", "Number of Years Needed for Analysis", "Harmful Effect and Environmental Concerns", and "Readiness to Send Used Bottle for Recycling" questions, whereas the high- mean-value category covers the "Consider Plastic Water Bottles as a Problem", "Trash Cans Cause Harmful Effects", "Using Water Bottles Increases Trash Size", "Belief in the Need to Find Alternative Methods", "Pledging to Recycle", and "Belief in Recycling to Protect the Environment" questions.

In summary, based on the analysis of the population responses and feedback and intentions of the participants towards the environment, it can be concluded that creating a closed-loop system for PET bottle returns would be the right strategy for the disposal of water bottles and protecting the environment in the UAE. Considering the evaluation of the feedback, it can be said that it would be beneficial to introduce a system so as to improve PET bottle collection and recycling in the UAE, in order to improve the country's economic infrastructure, as well as its environmental sustainability. The implementation of this project design will aid in the expansion of recycling activities in the food industry, plastics industry, and automobile industry, in which recycling strategies are still in their nascent stage in the country.

8. Limitations of the Present Research and Future Research

The current study provided a balanced understanding of the various approaches used to handle PET bottles. Furthermore, the UAE population's recycling knowledge and awareness level were researched. The level of access to the environmental policies of the UAE government must be enhanced to boost environmental protection attitudes and promote recycling habits. The present research also envisaged PET bottle recycling in the UAE. However, the same is true in the proposal stage. The scope of the present study is narrow and focused on "used water bottle collection" only.

Considering the fact that the novel concept of building environmental concerns and attitudes toward safe environmental practices needs further studies in the UAE environment, future research should be conducted to determine how the recycling of PET will affect the economy. It is possible to investigate how PET recycling affects environmental sustainability. This will also allow for the study of PET recycling in developing and less developed countries in order to determine how different countries are attempting to be more environmentally friendly. The realization of the water bottle recycling drive requires further exploration in each area of water bottle recycling.

Author Contributions: Conceptualization, W.A.J., M.R.N.M.Q. and R.A.; Methodology, W.A.J., M.R.N.M.Q. and R.A.; Validation, W.A.J., M.R.N.M.Q. and R.A.; Formal analysis, W.A.J., R.A., M.R.N.M.Q., H.A., G.S., E.A. and S.A.; Investigation, H.A., E.A., G.S. and S.A.; Resources, H.A., E.A., G.S. and S.A.; Data curation, E.A., H.A., G.S. and S.A.; Writing—original draft, W.A.J. and M.R.N.M.Q., R.A.; Writing—review & editing, M.R.N.M.Q., W.A.J. and R.A.; Visualization, W.A.J., R.A., E.A., S.A.; Supervision, W.A.J.; Project administration, W.A.J. All authors have read and agreed to the published version of the manuscript.

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