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SUSTAINABLE WASTE MANAGEMENT STRATEGY FOR PLASTIC BAG MITIGATION AND REDUCING CARBON FOOTPRINT IN THE EMIRATE OF AJMAN – UAE

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Abstract

The Sustainable Development Goals (SDGs) set by the United Nations anticipated a circular economy to reach zero net waste. This paper presents a case study on reducing the carbon footprint resulting from plastic bags in Ajman, UAE, and recommends mitigation approaches. The main contribution of this paper is the comprehensive analysis of circular waste management practices and the development of recommendations for reducing the carbon footprint caused by plastic bags in Ajman, UAE. The study emphasizes the role of consumers in shaping plastic demand and consumption patterns, highlighting the need for their active involvement in sustainable waste management practices. The important results obtained from the survey and data analyses indicate that implementing an efficient circular industry economy framework, supported by strong public and private partnerships, can significantly reduce plastic pollution. The study proposes two key recommendations that aim to decrease the use of plastic bags per capita by 30% within three years, leading to a substantial reduction of 8,918 tons of CO_2 emissions annually. Furthermore, the study presents a third recommendation advocating a complete ban on plastic bags. Through sustainable implementation, the research demonstrates that zero emissions related to plastic bags can be accomplished within a year. These findings highlight the potential impact of implementing the proposed recommendations in Ajman and as a blueprint for other regions striving to address plastic pollution and advance their circular waste management efforts. In addition to shedding light on the challenges and opportunities associated with circular waste management, this study provides practical recommendations with quantifiable environmental benefits to assist in achieving the Sustainable Development Goals and creating a more sustainable future.

Keywords: Ajman – UAE, Carbon footprint, Environmental sustainability, Plastic bags, Sustainable waste management.

1. Introduction

Environmental sustainability is becoming increasingly important in society. Over the last decade, behavior has shifted significantly, focusing on energy conservation [1]. People's behavior has been demonstrated to be strongly influenced by social norms [2]. Due to its significant environmental impact, plastic pollution has become a critical issue related to waste management. According to Walker and Fequet [3], global plastic production and consumption have rapidly increased over the past few decades, when global plastic production in 1967 was approximately 23 million tons (Mt).

Nevertheless, this figure has risen to more than 500 Mt in recent years. The exponential growth of plastic production and consumption has had severe environmental consequences, including the accumulation of plastic waste in the oceans and its detrimental impact on marine life. Plastics are synthetic organic polymers with a high molecular mass. The plastics we use every day are also finite resources. Most plastics are made from hydrocarbons such as crude oil and natural gas [4].

While it is difficult to predict when raw materials will run out, finite resources will eventually run out. We must, therefore, reduce our reliance on these materials and explore alternative materials and production methods that are more sustainable and environmentally friendly [5]. Waybackmachine [6] categorized plastic into thermoplastic and thermoset. Thermoplastics, such as high and low-density polypropylene (PP), polyvinyl chloride (PVC), polyethylene (PE), polyethylene terephthalate (PET), and polystyrene (PS), can be heated and reshaped multiple times, making them ideal for recycling. They are known as "recyclable plastics."

On the other hand, Ramakrishnan et al. [7] described that thermoplastic plastic, such as some composites and epoxy resins, cannot be heated and reshaped once they have been formed, making them difficult to recycle. Hence, they are known as "non-recyclable plastics." The plastic materials industry is one of the most critical sectors in the modern period. An estimated ten thousand different types of materials are created and used in industries such as agriculture, transportation, medicine, etc. The following are some of the reasons for the widespread use of plastics:

- Low cost of production, and thus cheaper.
- Lightweight and hence easy and affordable to transport.
- Resistance to corrosion and rust.
- Ease of formation and insulation of heat and electricity.
- Their ability to withstand various weather conditions.
- The technology used in their manufacture is simple and uncomplicated.

Plastic packaging is widely used all over the world. Polyethylene terephthalate, abbreviated PET (also abbreviated PETE), is one of the most used plastics. This plastic is solid, durable, and thermally and chemically stable. In addition, it has low gas permeability and is quickly processed and handled. This unique combination of properties makes PET desirable for many applications, including food and beverage packaging, mostly water bottles, at a very cost-effective price. 389 billion PET bottles were produced in 2010, 46% for water packaging [8]. However, this stability leads PET to be highly resistant to environmental biodegradation. As a result, the biodegradation of one PET bottle left in nature can last around 500 years. Thus, this causes many environmental concerns for terrestrial and marine areas. Its

accumulation is particularly damaging in the world's oceans, comprising approximately 10% of global plastic production yearly [9].

Out of all plastic resins, 44.8% were used for packaging purposes, consisting of similar amounts each of Low-density polyethylene (LDPE), polypropylene (PP), and PET, with another 18.8% being used by the building and construction industry, mainly in the form of PVC [10]. The total primary production of plastics consumed by each sector is shown in Table 1 [11], which clearly shows the most important use is for packaging and continues to be increasing.

Table 1. Plastic production according to the sector of use [11].

Type of Plastic use	Production in millions of tons
Packaging	146
Building and Construction	65
Textiles	59
Consumer and institutional products	42
Transportation	27
Electrical/electronic	18

Humans, ocean seabirds, and marine animal deaths increase yearly due to plastic pollution. Therefore, the world faces a challenge to act quickly against this severe crisis, develop solutions that look at plastic accumulative problems, and theoretically and practically model effective solutions. Countries are experiencing an accumulating number of plastic debris as plastic marine debris and dispersal, a growing global problem affecting all marine environments [12]. The UAE has experienced a significant increase in population and GDP per capita, which has nearly doubled and resulted in higher consumer spending and higher demand for plastics in packaging and shopping for convenience and hygienic shopping [13].

A typical UAE resident uses 450 plastic water bottles annually, equivalent to 43 gallons per person in 2011. The United Arab Emirates had the fourth-highest level of bottled water consumption globally [14]. This paper examines some practical examples of plastic products used in different countries. The paper examines society's awareness of this issue by identifying primary responsibilities and public contributions to mitigate the harm caused by plastic use to the environment and related health risks. The paper is also to identify factors that look at the main drivers. To promote sustainable waste management practices, public-private partnerships must be investigated.

Its novelty lies in its integrated approach to addressing circular waste management and reducing the carbon footprint associated with plastic bags. This study provides a case study specifically focused on Ajman, UAE, as well as tailored recommendations for sustainable practices in relation to waste management and plastic pollution. Previous studies have covered aspects of waste management and plastic pollution, but this study goes beyond that by focusing on waste management in Ajman, UAE. The findings of this study are expected to apply to other cities in the United Arab Emirates and beyond, providing guidance in the implementation of sustainable circular waste management solutions. Moreover, this study could be used as a model for other cities to follow when addressing plastic pollution and waste management.

2. Marine Debris and Plastic

Marine debris, defined by Diem et al. [12] as any manufactured or processed solid waste imported into the marine environment, is proven to have a widespread negative impact on marine wildlife. However, plastic debris (synthetic organic polymers) comprise most marine litter worldwide. Litter from ships, fishing and pleasure boats, and waste thrown into the water from land-based industrialized and densely inhabited areas are the main contributors to marine debris [15]. Plastic waste results in 100 million types of marine animals dying each year. 100,000 marine animals also get entangled with plastic every year. Unfortunately, many fish now contain plastic debris or fibrous material, resulting in toxins that consumers of seafood digest. In addition, 86% of turtle species and 44% of marine mammals are estimated to have plastic in their guts. Around 8 million tons of land plastic go to the oceans each year, equivalent to covering 5% of the earth's entire surface by 2025 [16]. Plastic has recently become more prominent in the UAE as it has started affecting camels' health, with many deaths [17].

3. National Strategy for Integrated Plastic Waste Management in the UAE

The UAE has set up targets for waste management and established key performance indicators (KPIs) to measure progress toward achieving these targets. For instance, Improving the percentage of treated waste of total waste generated is one of these (KPIs) [18].

The following objectives characterize the national strategy:

- **Promote sustainable plastic consumption**. In this respect, the percentage of reduced-produced plastic products with one-time use will increase by 75% in 2021 [19]. It could be achieved with the rationalization of consumption and reuse.
- **Boosting the economy by recycling plastic waste**. This strategy is intended to boost the economy of recycling plastic waste, which will gradually increase the recycling percentage with a target to reach 25% in 2021. This is to be practiced by encouraging recycling and energy recovery.
- **Reducing plastic waste in landfills by 2021**. This strategy supports all activities that enhance behavior and achievements to minimize waste to landfill with a ratio of 50% for a short period. Increasing public awareness of behavior change and intelligent technology can strongly support this strategy.

4. Plastic Recycling in the UAE

With plastic recycling and waste management becoming a key challenge in the Gulf Cooperation Council (GCC), the association intends to understand the overall ecosystem to implement sustainable practices for post-consumer plastic waste. Plastic waste accounts for around 15% of total waste, as shown in Figs. 1 and 2, with the waste generation quantities in the UAE [20].

The plastic market volume in the UAE is shown in Fig. 3. Only 30% of plastics produced in the UAE are consumed domestically, Fig. 4, with LDPE and high-density polyethylene (HDPE) accounting for nearly 45% of consumption [20].

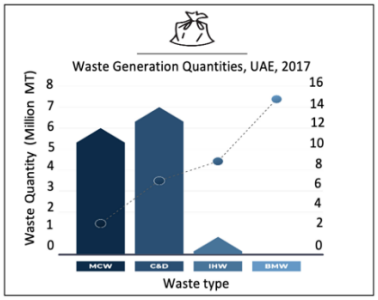

Fig. 1. Waste generation quantities in UAE [20].

Fig. 2. Percentage of plastic waste within waste generation quantities in the UAE [20].

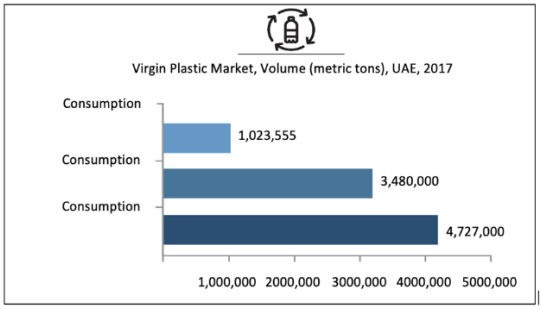

Fig. 3. Plastic market volume in the UAE 2017 [20].

Figure 4 shows the types of recycled plastic granules/flakes produced in the UAE, and Fig. 5 shows waste generation quantities (data adopted from the study by [20]. The figure also illustrates the types of plastic waste recycling in the UAE, which contributes to promoting sustainable waste management practices and developing strategies to address plastic pollution.

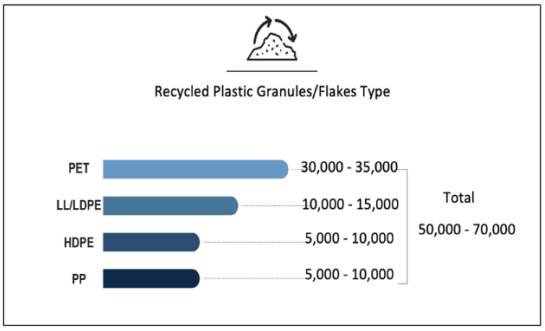

Fig. 4. Recycled plastic activity (Produced by authors).

Less than 5% of plastic waste was recycled in the UAE in 2017. However, installing advanced MRFs (Material Recovery Facilities) can improve recycling, as shown in Fig. 5, which shows how 15% of plastic is treated, 2-3% is processed by mechanical recycling, 1-2% is considered plastic scrap exports and less than 3% is energy recovery/incineration;95-97% ends up in dump sites/landfills.

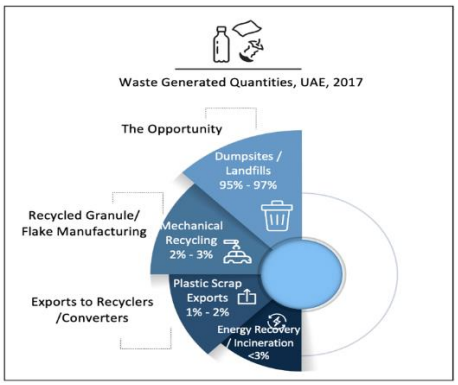

Fig. 5. Waste generated quantities, UAE, 2017 [20].

5. Plastics and Carbon Footprint

Plastic (LDPE or PET, polyethylene) creates a carbon footprint of about 6 kg CO_2 per kg of plastic. A plastic bag weighs 5.5 grams; thus, 180 bags may accumulate 1 kilogram of plastic. Consequently, one bag generates about 33 grams of CO_2. Therefore, a household may contribute 8.25 Kg of CO_2 annually when consuming around 250 bags yearly [21]. Figure 6 categorizes conventional plastics' global life cycle GHG emissions in 2015 by life cycle stage and plastic type [22]. The carbon credits gained when recycling is not included in this figure. The conventional (fossil fuel-based) plastics produced in 2015 emitted 1.8 Gt CO_2e over their life cycle. Also, the resin-production stage generated the most emissions (61%), followed by the conversion stage (30%) [23]. The polyolefin family (polypropylene, PP; low-density/linear low-density polyethylene, L/LLDPE; and high-density polyethylene, HDPE) accounts for nearly 50% of the world's plastics consumption. It was also a significant contributor to GHG emissions from bio-based plastics not considered for 2015, given their negligible market share (<1%) [22].

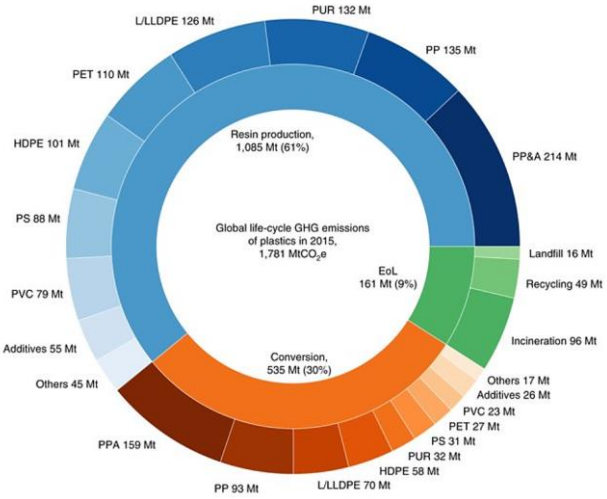

Fig. 6. Global life cycle GHG emissions of conventional plastics in 2015 by life-cycle stage and plastic type [22].

6. Policies Adopted in the UAE

It is estimated that 11 billion plastic bags are used annually in the UAE. This is about 1,182 bags per capita per year and is considered high compared to other countries. Globally, 307 bags per capita per year and 200 bags per capita per year for Europe [24]. Efforts worldwide were put forward to adopt policies to limit single-use plastic bags increased sharply.

6.1. Single-use plastic policy – Abu Dhabi

Policies adopted by the UAE to reduce the environmental effects of plastic have been widened, and many practices show significant results. Some practical examples are illustrated in the following sections. Abu Dhabi has adopted the single-use plastic Policy 2020 to make Abu Dhabi free of single-use plastic bags by the end of 2021 [24]. It has also implemented a policy that establishes a general framework for dealing with single-use plastic materials, which the Environment Agency manages – Abu Dhabi (EAD) on behalf of the Abu Dhabi Government through consultation, coordination, and cooperation with governmental and private stakeholders as well as impact analysis based on systematic and structured procedures. The policy is aligned with the country's national policies, plans, and strategies and the UAE 2021 vision for waste management. It was performed with the vision of "ensuring sustainable production and consumption of plastics" [24]. Table 2 shows the indicators and targets set up by this policy.

Table 2. Single-use plastic bags policy indicators and targets [24].

Indicator	Target	Rationale
The percentage of reduction in the single use of plastic bags for each customer consumed in the Emirate of Abu Dhabi	100% reduction of these bags from the baseline of 2019.	This indicator is a proxy indicator for other types of target material in this policy.
The percentage of the amount of plastic waste collected through a plastic bottle return scheme to the total consumption of these materials.	50% collection of this material in 2021 from the baseline of 2019.	This indicator measures the amount of plastic waste collected through the return scheme.
The percentage of government entities that ban single-use plastics in their operations in the Emirate of Abu Dhabi	100% of government entities in the Emirate of Abu Dhabi	This indicator measures government entities in the Emirate of Abu Dhabi that have banned single-use materials in their operations.

6.2. A Day without plastic bags

As a means of promoting sustainable waste management and environmental protection, the Ajman Municipality and Planning Department distributed 25,000 paper bags in ten shopping malls and supermarkets across the Emirate as part of its green environment campaign, dubbed "The Day Without Plastic Bags," which has been held on the 16th of May every year since 2012 and is still going strong [25, 26]. Figure 7 shows the target and achieved reduction in plastic bags on the 16th of May, 2012-2022, in the Emirate of Ajman – UAE.

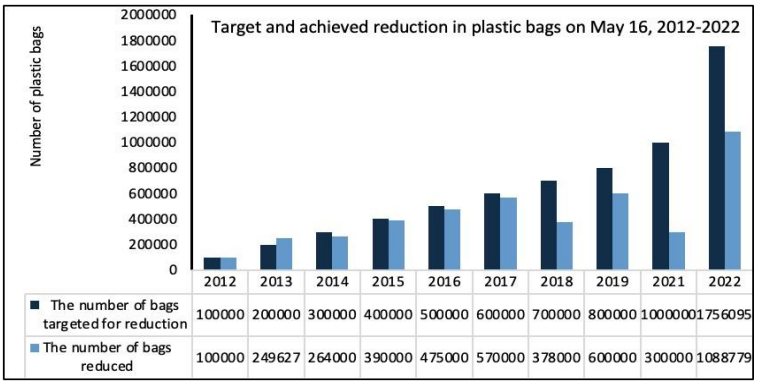

Fig. 7. Target and achieved reduction in plastic bags [27].

The campaign is held in ten shopping centres throughout the Emirate every year. In 2017, this program successfully reduced plastic bag usage by 5,900,000 units, the largest reduction rate since the initiative began. The Emirate of Ajman was the first in the UAE to ban non-biodegradable plastic bags and test degradable plastic bags [26].

6.3. Plastic bags' possible zero carbon footprint in Ajman - UAE

Although plastic has a substantial carbon footprint, replacing plastic is a challenging issue due to the lack of a clear solution despite the availability of several alternatives. By 2050, plastic production and incineration emissions are expected to account for 15% of the global carbon budget [28]. In addition, plastic bags contribute significantly to the accumulated plastic-associated impact on carbon footprints. Figure 8 shows the Volume of CO_2 reduced compared to the weight of plastic bags reduced on the 16th of May 2012- 2022.

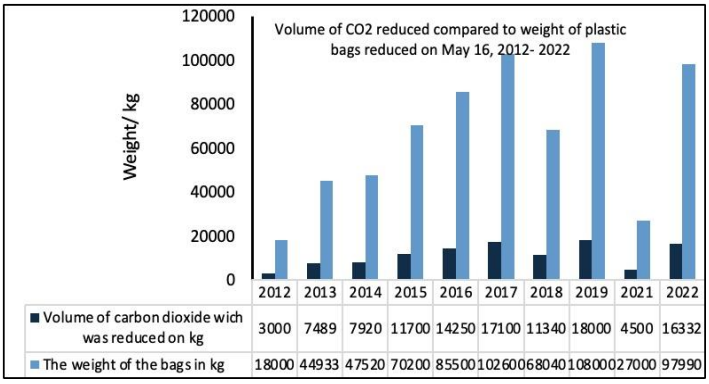

Fig. 8. The volume of CO_2 reduced compared to the weight of plastic bags reduced [27].

7. Data Segregation and Analysis

Data collection contributes to developing an evidence-based research approach, allowing researchers to arrive at conclusions based on the gathered information.

The authors adopted an evidence-based practice by employing data analysis techniques and leveraging the gathered facts to draw meaningful conclusions based on the comments of Battisto et al. [29]. Insights derived from data analysis are crucial to guiding decision-making and developing policy initiatives. For example, policymakers could develop effective strategies to mitigate the proliferation of plastic bag usage by utilizing the information obtained from the study [30]. Data could also be used to identify patterns and trends that can aid in formulating decisions. Data analysis allows researchers to draw conclusions and answer questions by identifying correlations between variables. In addition to identifying patterns that may not be visible to the naked eye, data can also be used to identify long-term trends and Behavioral changes. The information gathered from this study can then be used to inform decision-making and shape policy.

In the UAE, a questionnaire has been conducted to determine the reasons for the increasing use of plastic bags. Moreover, data can be used to identify patterns and trends, which can be used to inform decision-making. Using data analysis to draw conclusions and answer questions, researchers can identify correlations between different variables. It is also possible to use data to identify patterns that may be difficult to detect with the naked eye, such as long-term trends or changes in behavior. Information such as this can then be used to inform decision-making and shape policy. Study participants will be drawn from all Emirate of Ajman case study area populations. Considering the key actors responsible for the consumption of plastic bags in this region. A sample size of 397 measurements or surveys is needed for a 95% confidence level. Using SurveyMonkey's Sample size calculator, the measured or surveyed value must be within 5% and the margin of error 9.38% of the calculated value.

7.1. Statistics of bag types

Figure 9 shows the number of participants and how many bags others consumed. It can be altered that a high level of awareness is reflected in the number of respondents with significant knowledge, supporting any future initiatives the authority introduced.

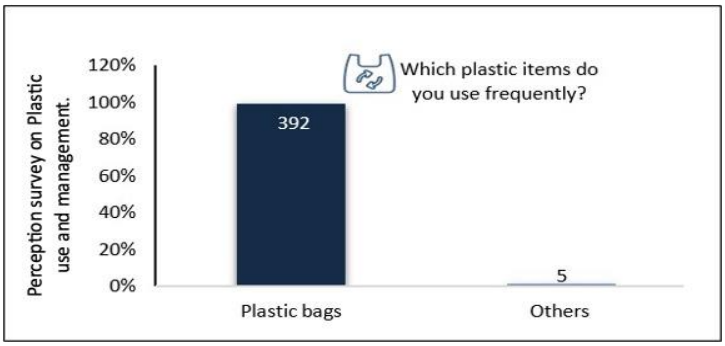

Fig. 9. The number of participants and how many bags others consumed (Author's survey).

7.2. Statistics of plastic bags usage

A valuable insight into the dynamics of bag usage within the studied population is provided by Fig. 10, which provides data on the number of participants and the

corresponding bag consumption per participant per week. According to the figure, there is a significant difference in bag consumption among users. Different bags are available on the market, which may account for this variation.

The disparity in the number of users can be attributed to the diverse range of bag options participants can access. The various sizes, materials, and functionalities of bags cater to various consumer preferences, needs, and contexts. For example, some individuals may opt for smaller bags for convenience and portability, whereas others may choose larger bags to accommodate larger quantities or specific items. Additionally, differences in bag consumption may be due to differences in personality, lifestyle, and shopping habits.

It is essential to identify the specific types of bags used most by participants to effectively address the issue of excessive bag usage and move towards sustainable alternatives. Decision-makers can devise targeted strategies to eliminate or reduce the use of bags with the highest environmental impact when familiar with the characteristics and prevalence of various bag types.

Fig. 10. Number of participants and bags consumed per week (Author's survey).

The type of bags used in Ajman were HDPE, LDPE, LLDPE, PET and PP. In Fig. 11, the percentages of the use of these bags are shown.

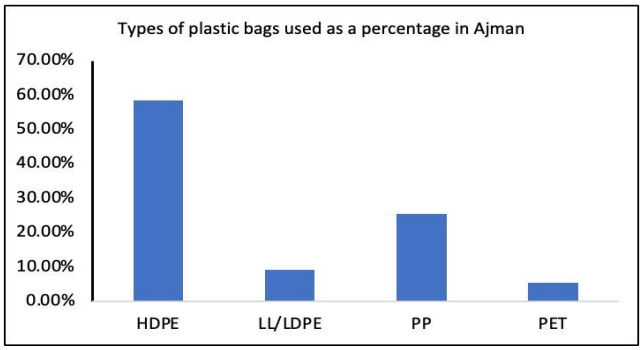

Fig. 11. Types of plastic bags used as a percentage in Ajman.

7.3. Statistics on public usage of plastic bags

The questioner considered the reason that encourages people to use plastic bags. In this respect, the survey asked why participants used plastic bags; the segregation of results and statistics is shown in Fig. 12. Looking at the results of this question, 41.84% of the participants pointed out that because of being easy to get and available. Moreover, the second percentage is 23.47%, reflecting another critical issue: the lack of alternative materials.

Fig. 12. Participants' answers regarding the reason for using plastic bags (Author's survey).

7.4. Plastic bags net-zero carbon emission

Within the survey, the research looked at the possibility of eliminating CO_2 emission (Net-Zero) associated with plastic bags in the UAE. The carbon footprint associated with bags was estimated for the Emirate of Ajman, shown in Table 3. Three recommendations were proposed that provide an argument for options that may be followed to achieve significant reductions.

Table 3. Calculated carbon footprint for Ajman due to plastic bags and possible reductions.

Argument	Quantity
One plastic bag equal	32.5 grams
CO_2 generated by one bag	200 grams
CO_2 generated by 1 kg of plastic	6.15 kilos
Table 2 shows the average number of bags consumed per capita	6.25 per week
Assuming the Emirate of Ajman population is	505,000
Number of adults are	200,000
Total average use is 98% of 200,000	196,000
Total average use of bags per week	1,225,000
Total average use of bags per capita per year	63,700,000
Total CO_2 generated in Ajman per year, grams	12,740,000,000 grams
Total CO_2 generated in Ajman per year, tons	12,740

8. Mitigation Recommendations

After analysing and quantifying the survey, the authors developed three recommendations to mitigate the plastic bag problems in Ajman. Based on the findings of this study, it is evident that these recommendations must be followed carefully to achieve the zero use of single bags target.

8.1. Recommendation 1

At this stage, relying on the participants' answers, it is recommended that reducing the average use of bags per capita by 30% in 3 years will reduce CO_2 /year by 3,822 tons. The number of bags per capita after reduction is 230 bags/year. Therefore, the result was a reduction of CO_2 by 8,918 tons reductions, as shown in Table 4.

8.2. Recommendation 2

Table 3 shows the calculated arguments to the participants' responses concerning the reason for using plastic bags. Having the Ajman Authority initiate a policy to sort the two reasons mentioned in Table 3 (i.e., lack of alternative materials to plastic bags and readily available) can reduce 78% of the present use. In addition, considering the results in Table 3, it can also lead to net-zero emissions due to the use of bags if the first and the second recommendations are implemented.

8.3. Recommendation 3

Considering the expected population growth, the value of the reduction in CO_2 mentioned in Table 4 may increase due to unforeseen situations. As a result, the research proposes to Municipality and Planning Departments a plan to eliminate the use of plastic bags for one year to a minimum, with data to be collected to assess the impact of such a proposition. For example, the Ajman Municipality in the UAE has responded to this recommendation and announced the ban on plastic bags from January 2023 [26]. In this respect, this research is conducting an ongoing action that will monitor this activity and collect data to test the effectiveness of such action.

Table 4. The recommendations and related statistics.

Recommendation 1	
Reducing the average use of bags per capita by 30% in 3 years will result in a reduction of CO_2 of /year (tons)	3,822
The number of bags per capita per year after	367500
CO_2 generated after reduction (tons)	8,918
Recommendation 2 (eliminate 90%)	891.8
Recommendation 3 (is a result of the above recommendation)	Zero

9. Deviation of the Current Results and Published Data

Comparing the results of the present study with similar cases that are looking for alternatives to plastic bags [31]. Both studies address distinct research objectives and focus on distinct geographical contexts, as can be observed by comparing them. According to published research, plastic pollution adversely impacts the environment, agriculture, health, and sanitation. Regulatory initiatives and the prohibition of plastic bags have reduced plastic bag littering, resulting in a cleaner

and healthier environment. To reduce plastic pollution, the study highlights how research findings can be applied to policy management.

In contrast, the current study examines the plastic waste problem in the UAE, specifically in the Emirate of Ajman. Through recommendations derived from a survey, the research aims to eliminate the carbon footprint of plastic bags. Within three years, the study proposes reducing average bag use per capita by 30%, significantly reducing CO_2 emissions.

Additionally, the study advocates for a ban on plastic bags, aiming for zero emissions within a year. Research objectives, geographical contexts, and methodologies differ between the two studies, which the differences between them can justify. Current research focuses on the broader plastic waste problem in the UAE. It offers specific recommendations for the Emirate of Ajman, in contrast to published research focusing on local challenges and regulatory initiatives. Both studies contribute to understanding and mitigating plastic pollution by providing insights specific to their respective locations and emphasizing the effectiveness of different approaches to addressing plastic pollution.

10. Conclusions

It is imperative that urgent action be taken to address the plastic waste problem in the UAE. As a result of this study, it is apparent that the UAE produces and consumes an alarming amount of plastic, with various products contributing to its carbon footprint.

A method is presented in the paper for eliminating the carbon footprint of plastics in the UAE. On the other hand, the plastic waste problem in the UAE is critical, and urgent action is needed.

Various products contribute to the UAE's carbon footprint, with the amount of plastic produced and consumed in the country alarming. Plastic has a large carbon footprint, which can be eliminated by a method presented in this paper.

This practical case study aims to reduce carbon emissions from plastic bags in Ajman, United Arab Emirates. Two key recommendations were derived from a survey. First, it is possible to reduce CO_2 emissions by 3,627 tons annually by reducing the average use of bags per capita by 30% over the next three years. As a result, 230 bags would be used per person per year, reducing 8,918 tons of CO_2 from the total emissions.

In addition, it is recommended that alternatives be explored and the reasons for using plastic bags addressed. It is the responsibility of the authorities in Ajman to provide sustainable options. A reduction in plastic bag usage of 65% would result in zero emissions within a year if this were undertaken.

To develop a more comprehensive understanding of bag preferences, usage patterns, and environmental impacts, conducting surveys among participants, retailers, and manufacturers will provide valuable information for future research.

As a result of this information, evidence-based decisions can be made, and specific bag types can be prioritized for elimination or reduction according to the data. Interventions and initiatives should be tailored to address the most used or impactful categories of bags to maximize their effectiveness.

By precisely targeting resources, efforts, and awareness campaigns, total bag consumption can be reduced, and a smooth transition to sustainable alternatives can be expedited. This approach is believed to increase the likelihood of success in combating the UAE's plastic waste problem.

Acknowledgment

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Abbreviations

HDPE	high-density polyethylene
L/LLDPE	low-density/linear low-density polyethylene
LDPE	Low-density polyethylene
Mt	Million tons
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
SDGs	Sustainable Development Goals
UN	United Nations

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