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Assessing the Potential Environmental Risks Associated with Plastic Carrier Bag Usage and Disposal: A case study on Supermarkets in Da Nang City, Central Vietnam

Duong Thi Thanh[1, 2], Duong Cong Chinh[3], Tran Thi Thanh Thuy[4], Nguyen Van Thinh[4], Nguyen Bich Ngoc[5], Doan Thi Oanh[5], Dam Van Ve[6], Tran Thi Thu Huong[4]*

[1]Duong Thi Thanh, Faculty of Environment and Natural Resources, Ho Chi Minh City University of Technology (HCMUT); Ho Chi Minh City, Vietnam
[2]Vietnam National University Ho Chi Minh City, Ho Chi Minh City (VNUHCM), Vietnam duongthanh@hcmut.edu.vn
[3]Duong Cong Chinh, Southern Institute of Water Resources Research (SIWRR). duongchinh73@gmail.com
[4]Tran Thi Thanh Thuy. Hanoi University of Mining and Geology (HUMG), No.18, Vien Street, Dong Ngac Ward, Hanoi, Vietnam. tranthithanhthuy@humg.edu.vn
[4]Tran Anh Quan. Hanoi University of Mining and Geology (HUMG), No.18, Vien Street, Dong Ngac Ward, Hanoi, Vietnam. quantrananh.humg@gmail.com
[4]Nguyen Van Thinh. Hanoi University of Mining and Geology (HUMG), No.18, Vien Street, Dong Ngac Ward, Hanoi, Vietnam. nguyenvanthinh@humg.edu.vn
[5]Nguyen Bich Ngoc. Hanoi University of Natural Resources and Environment, No 41 A Phu Dien Road, Phu Dien Ward, Hanoi, Vietnam. nbngoc@hunre.edu.vn
[5]Doan Thi Oanh. Hanoi University of Natural Resources and Environment, No 41 A Phu Dien Road, Phu Dien Ward, Hanoi, Vietnam. doanoanh158@gmail.com
[6]Dam Van Ve. Northern Center for Environmental Monitoring, 79 Van Tien Dung, Tay Tuu Ward, Hanoi City. damvanve@gmail.com
[4]Tran Thi Thu Huong. Hanoi University of Mining and Geology (HUMG), No.18, Vien Street, Dong Ngac Ward, Hanoi, Vietnam. tranthithuhuong@humg.edu.vn
†Corresponding author: Tran Thi Thu Huong; tranthithuhuong@humg.edu.vn
ORCID IDs of Authors (Not mandatory; Give if available)
1, 2. Duong Thi Thanh. ORCID: 0000-0003-0879-1241
3. Duong Cong Chinh. ORCID: 0000-0001-7862-6802
3. Tran Thi Thanh Thuy. ORCID: 0009-0000-0682-5933
4. Tran Anh Quan. ORCID: 0000-0003-1201-0161
5. Nguyen Van Thinh. ORCID: 0000-0002-6001-4864
6. Nguyen Bich Ngoc. ORCID: 0009-0009-5712-6441.
7. Doan Thi Oanh. ORCID: 0009-0003-7306-3184
8. Dam Van Ve. ORCID: 0009-0001-2493-4292
9. Tran Thi Thu Huong. ORCID: 0000-0002-9272-9362

Abstract

The single-use plastic carrier bags in retail systems is a pressing environmental issue in Vietnam. Although policies aimed at reducing and ultimately eliminating single-use plastic products by 2030 have been introduced, consumption levels remain high due to convenience and consumer habits. This study assessed the potential environmental risks associated with plastic carrier bag usage and disposal. The study employed expert consultation, sociological survey, and ecological risk assessment methods. Polymer Hazard Index (PHI) calculated from three sediment sampling locations (ĐN1-ĐN3) during both the rainy and dry seasons of 2024. Results showed that single-use plastic carrier bags accounted for 95-99% of all bags used, with an average ratio of 2.48 bags/customer/shopping trip. Although 97.5% of respondents were aware of the

negative environmental impact, their consumption behavior had not significantly changed due to the continued free provision of plastic carrier bags. Notably, 92% of consumers were unaware of the regulation banning the distribution of free plastic bags by 2030. The PHI values recorded in the rainy and dry seasons were 37.06 and 69.68 MP/kg, respectively, indicating a low potential environmental risk level. These findings support measures to reduce plastic bag consumption such as restricting the free bags, enhancing communication, and promoting the use of alternative products and providing scientific evidence for plastic waste management policies.

Keywords

Microplastics, Plastic carrier bag, Pollution Hazard Index (PHI), Potential risk, Supermarket

1. INTRODUCTION

The term “supermarket shopping bag” refers to any bag used by customers for the purpose of carrying items purchased or received from supermarkets, including plastic carrier bags. According to UNEP (2018) and ARM (2022), a “plastic carrier bag or nylon carrier bags” are any bag made of plastic materials, including biodegradable or degradable plastics, but excluding reusable plastic bags. The use and disposal of single-use plastic carrier bags within retail systems have become an urgent environmental issue, especially in urban areas and large cities. Despite many policies have been introduced to reduce and eliminate single-use plastic products, consumption levels remain high due to their convenience and consumer habits. This leads to the generation of plastic waste into the environment having emerged as a global environmental challenge, rapidly increasing with economic growth and the expansion of packaging consumption. Plastic carrier bags are a popular single-use plastic product in modern life due to their lightweight, durable, and convenient properties. They are commonly found in grocery stores, retail stores, and households, widely used in packaging, storage, and transportation of goods. These bags are primarily made of polyethylene or nylon (synthetic polymers), they are both light and durable, characteristics that make them convenient for single-use purposes. On the other hand, polyethylene and nylon polymers are a compound which is difficult to decompose, so plastic carrier bags have the potential to persist for a long time, increasing pressure on waste management systems and causing environmental pollution. Morever, large-scale consumption has been causing serious environmental problems globally.

According to UNEP (United Nations Environment Programme), there are 500 billion plastics bags that are used annually but only a very small percentage are recycled. The majority of the remaining plastic carrier bags become waste that is dispersed into the environment, including soil, rivers, and oceans (UNEP. 2016). As public awareness of the adverse impacts of plastic bags increases, discussions regarding their environmental consequences have become increasingly intense. Example, many marine organisms, such as turtles, fish, and seabirds, may mistakenly ingest plastic carrier bags as their food, leading to digestive blockages, health deterioration, or mortality. Furthermore, during degradation processes driven by sunlight exposure and environmental factors, plastic carrier bags break down to microplastic particles and enter the food chain. Plastic carrier bags also affect coral reefs, aquatic plants, and the marine ecological balance by suffocating coral reefs, entangling marine animals, and obstructing sunlight reaching underwater plants. Consequently, plastic carrier bag pollution is becoming an urgent environmental problem, requiring sustainable management strategies and replacement solutions to minimize the impact on ecosystems and human health. Global plastic production has increased 20-fold in the past 50 years and is projected to reach approximately 1,124 million tons by 2030, leading to the risk of "white pollution" for the environment if appropriate treatment measures are not taken (UNEP. 2018).

The discarded plastic carrier bags and plastic waste in general in Vietnam account for approximately 10-12% of the nation’s municipal solid waste, equivalent to around 2.6-2.8 million tons generated in 2019, large proportion of this waste accumulating in rivers, lakes, estuaries, and coastal areas (Government Report No. 233/BC-CP. 2019). According to statistics, each Vietnamese family uses approximately 10 plastic bags/day, corresponding to nearly 1 kg of plastic/month (MONRE. 2020). By the end of 2025, Vietnam had established

five virgin polypropylene (PP) resin production plants and 2 factories producing polyethylene terephthalate (PET). Currently, there are nearly 5,000 businesses related to plastics nationwide, including 450 packaging manufacturers, generating a large amount of plastic waste daily, including non-biodegradable plastic bags. The amount of plastic packaging and nylon bags is increasing and becoming a burden on the environment, seriously threatening land, water, air, and ocean environments. In urban areas of Vietnam, the total volume of plastic carrier bags used is 10.48-52.4 tons/day, and only about 17% of which is reused (MONRE. 2020). Furthermore, it has from 2,000 to 13,000 tons of floating plastic debris collected annually from major urban canals systems (Kieu-Le et al. 2016).

The sorting and collection of recyclable plastic waste and nylon bags in Vietnam is often spontaneous, carried out at the household level by independent garbage collectors and scavengers. Plastic waste with no or low recycling value (such as foam containers, plastic straws, and especially thin nylon bags) is frequently discharged directly into the environment or disposed of in landfills and incinerators. A large proportion of plastic waste is landfilled in municipal solid waste landfills, with packaging and nylon bag waste accounting for 6-8% of waste disposed (MONRE. 2019a). In the context of rapid economic growth, Vietnam is facing serious plastic pollution. According to estimates by Jambeck et al. (2015), Vietnam ranked fourth among 192 countries studied in terms of marine plastic waste generation. Unmanaged plastic waste amounts to 1.83 million tons/year, equivalent to 0.28-0.73 million tons of plastic released into the sea and accounting for nearly 6% of the total global marine released into the sea worldwide. In Vietnam, 80% of plastic waste originates from land-based sources and the remaining 20% comes from fishing, aquaculture, and ships at sea... (MONRE. 2020). A survey conducted by the World Bank showed that plastic carrier bags and their fragments account for approximately 26% of plastic waste in rivers and seas, primarily originating from takeaway food packaging (44%) and household activities (22%) (Report of Vietnam Environment Administration. 2019). Therefore, this study was conducted to assess the status of use and people's awareness of single-use plastic carrier bags in several supermarkets/grocery stores/retail stores in Da Nang city. The aims of this study are to assess the potential environmental risks from disposing of plastic carrier bags into the environment, contributing scientific data for management the production and disposal of plastic products in consumer goods sector.

This research aims to:

1. Assess the status of use and people's awareness of single-use plastic carrier bags in several supermarkets/ retail stores in Da Nang city

2. Assess the potential environmental risks from disposing of plastic carrier bags into the environment by PHI value

2. MATERIALS AND METHODS

2.1. Characteristics of Survey Study

Da Nang is one of seven cities in Vietnam, located in the South-Central Coast and Central Highlands region. It serves as a major political, economic, and social center of Central Vietnam. Da Nang is also an important coastal urban area, the large number of tourists visiting annually has led to a significant increase in tourism services and consumer activities (Huynh et al. 2010). Consequently, the use of plastic carrier bags for packaging and transporting goods has increased considerably. To assess the status of plastic bags used in supermarkets and retail stores in Da Nang, the research team surveyed 120 questionnaires with customers and 25 questionnaires with supermarket/retail store employees in the city center (Table 1). This survey primarily focuses on determining the level of awareness among supermarkets and customers regarding the impact of plastic carrier bags as well as their willingness to reduce the use of single-use plastic carrier bags on the environment to support the implementation of the planned ban on single-use plastic products by 2030.

Table 1. Survey information.

No.	Subject of survey	Code	Number of survey forms

A	Customer		
1	Go Supermarket	ST1	30
2	MM Mega Market	ST2	12
3	Jolymart	ST3	26
4	VitaMart	ST4	23
5	An Phu Farm	ST5	15
6	Dien Bien Phu Co.op Mart	ST6	15
	Total		**120**
B	**Staff**		
1	Go Supermarket	ST1	5
2	MM Mega Market	ST2	5
3	Jolymart	ST3	5
4	VitaMart	ST4	2
5	An Phu Farm	ST5	3
6	Dien Bien Phu Co.op Mart	ST6	5
	Total		**25**

Following the completion of the survey, three sediment samples were collected from landfill area near Han Market (ĐN1) and two samples from the Han River (ĐN2 and ĐN3). These three sampling locations were chosen because they represent major receiving areas for municipal waste, with ĐN3 location corresponding to the final downstream section of the Han River before its flows into Da Nang Bay. The Han River is approximately 7.2 km long and flows through the urban area of Da Nang City (Huynh et al., 2010). Many restaurants, hotels, and residential communities live along both banks of the river and fishing activities within the estuarine area also generate a significant amount of organic waste to the environment, including plastic debris.

Table 2. Characteristics of sampling area.

No.	Sampling Location	Code	Coordinates	Characteristic
1	Landfill near Han market	ĐN1	16°04'5.2"N; 108°13'26.6"E	This is location where waste from the Han market is collected.
2	City Discharge Drain	ĐN2	16°04'47"N; 108°13'34"E	This is location where the city's wastewater is received.
3	Da Nang Bay	ĐN3	16°05'47.3"N; 108°13'13.7"E	This is the mouth of the Han River where it flows into Da Nang Bay.

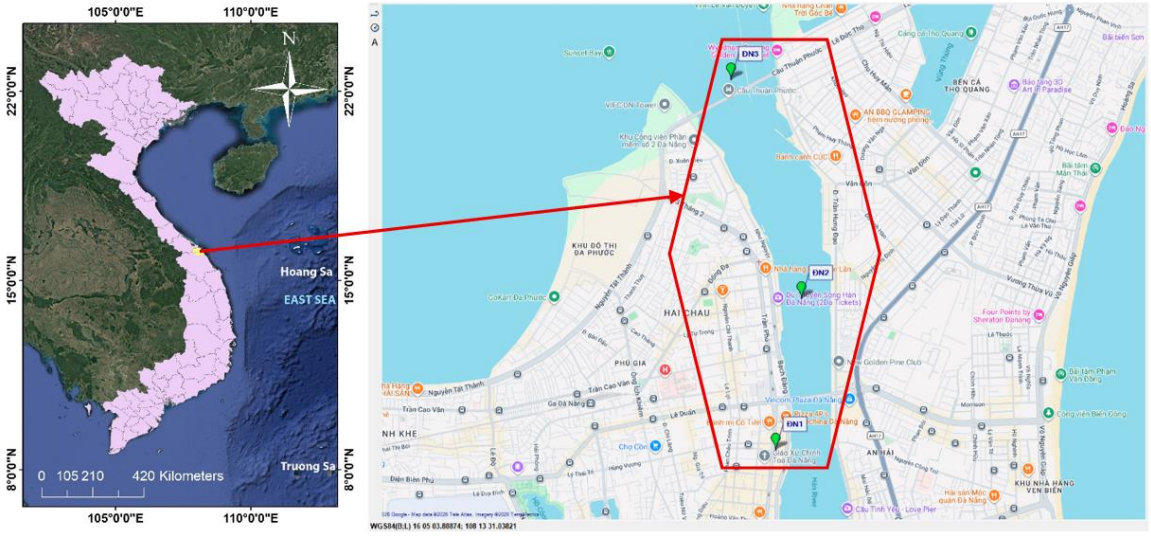

Fig 1. Sampling location area.

2.2. Methods for Analyzing and Evaluating the Effectiveness of Policies

Key information collected includes: (i) experiences in implementing solutions to reduce or ban the use of single-use plastic carrier bags; (ii) Information on the economic, social, and consumption conditions in Da Nang; (iii) Database and documents related to the status of plastic waste management and the distribution of plastic bags in supermarkets and retail stores; (iv) The regulations and policies related to plastic carrier bags. The effectiveness of Vietnam's plastic waste management policies will be analyzed and evaluated to propose actions and solutions for implementing a roadmap to reduce the use of plastic carrier bags in supermarkets and retail stores in Da Nang.

2.3. Methods for Sociological Interview and Survey

A survey was conducted by two target groups, including customers (120 questionnaires) and supermarket staff/managers (25 questionnaires) in order to collect data. Six supermarkets and retail stores in Da Nang city were surveyed: Go, MM Mega Market, Jolymart, VitaMart, An Phu Farm Organic Food, and Co.op Mart Dien Bien Phu. In addition, the Da Nang Department of Natural Resources and Environment and the Da Nang Department of Industry and Trade were also consulted to obtain information on reducing plastic bags and propose a model for minimizing plastic carrier bags in supermarkets/retail stores. The sociological survey method was applied to surveys, interviews with managers, sales staff and customers directly shopping at supermarkets, combined with direct observation. Three types of questionnaires were designed for three groups: customers, staff, and supermarket managers. Survey criteria included the status of plastic carrier bag consumption, people's awareness of the harmful effects of plastic carrier bags, the government's plan to reduce plastic carrier bags, environmental protection plans and habits regarding the use of plastic carrier bags during shopping activities. The views and opinions of stakeholders on the government's policy to reduce the use of plastic carrier bags were also investigated (Table 3).

Table 3. Criteria established in the questionnaire

No.	Customer	Staff	Manager
1	General customer information	General customer information	General supermarket information
2	Information about current purchases	Current bag distribution process at the supermarket	Status of plastic bag usage in supermarkets
3	Awareness of plastic bags and related regulations	Customer feedback assessment	Internal policy on reducing plastic bags
4	Customer attitudes towards plastic bag reduction solutions	Staff's difficulties in encouraging customers to reduce plastic bag use	Difficulties in the process of reducing plastic bags
5	Expected behavior in the future	Staff suggestions	The possibility of participating in a pilot program using green materials as a replacement for plastic bags.
6	Customer suggestions		Managament suggestions and recommendations

2.4. Methodology for Potential Environmental Risk Assessment

2.4.1. Sampling Method

The sediment samples were collected following a published method by Lenaker et al. (2019). The surface sediment layer (0-25 cm) was collected using a standard Ekman-Birge sampling bucket (20 x 20 x 35 cm). The sampling bucket was anchored to a boat at the sampling locations. Three samples were collected at each location during the dry season (May) and the rainy season (October) of 2024. The samples were thoroughly mixed, placed in clean glass bottles, stored in a box, cooled with gel ice, and transported to the laboratory for further analysis.

2.4.2. Analysis Method

Microplastics in sediments were treated according to the method published by Masura et al. (2015). The samples were thawed to room temperature for determination of the drying coefficient according to Vietnamese Standard TCVN 6648:2000. The samples were then dried and sieved through mesh size of 0.3-5.0 mm, and 100 g of the dried sample was weighed and transferred into a 500 mL beaker. The samples were then further dried for 20–24 h in a drying oven at 60°C and followed by natural air-drying overnight. Sequently, each sample was weighed again to record the actual weight of the dried sample. The microplastic-impurity mixture was wet-oxidized with peroxide (WPO) and Fe(II) catalyst to degrade biodegradable organic compounds. The microplastic quantity was observed under optical stereomicroscope (MSZ5000-T-IL-TL, Kruss, Germany). In addition, the polymer composition of microplastics was also analyzed using Fourier transform infrared spectroscopy (FTIR) with a Nicolet iN10 MX infrared microscope (Thermo Fisher Scientific, USA).

2.4.3. Risk Assessment by PHI Index

To assess the potential risks associated with microplastics, the Polymer Hazard Index (PHI) was applied to evaluate the health risks posed by microplastic contamination, following the approach proposed by Andreas Lithner et al. (2011). The PHI value was calculated using the following equation:

$$\mathbf{PHI} = \sum \mathbf{P_n S_n}$$

Where:

Pn is the average percentage of each type of microplastic polymer in all samples and

Sn is the risk score assigned to each polymer type.

The risk scores of PP, PET, PE, PS, NY, PVC and other polymers are 1, 10, 11, 30, 150, 11 and 100, respectively. PHI ≤ 100 indicates a low-risk level of microplastic pollution, and conversely, PHI > 100 reflects a high-risk level of microplastic pollution.

2.5. Statistical Data

The questionnaire database is reviewed and the questionaire not meet the requirements are discarded. The data is then coded, entered, and processed using statistical software Excel 2010, GraphPad 6 and Origin 2019. The quantity of microplastics was based on the number of MPs/kg of dry sediment and determined using the following formula (Do et al. 2022):

$$C = \frac{N}{W}$$

where C denotes quantity of microplastics in the dry sediment sample (MPs/kg); N represents the total number of microplastic particles counted and classified (MPs) and W corresponds to the mass of the dry sediment sample dried under standard conditions (kg)

3. RESULTS AND DISCUSSION

3.1. Assessment of the status of use and public awareness regarding single-use plastic bags

3.1.1. Operations of some major supermarkets and retail stores

The survey results showed that the number of customers visiting supermarkets in Da Nang ranges from 1,600 to 5,200 customers/day, while the retail stores have 250-330 customers/day, increasing by 20-40% during holiday vacations compared to normal days. The number of customers shopping at retail stores accounts for a small percentage, approximately 10%. The number of customers visiting supermarkets and stores is presented in Figure 2.

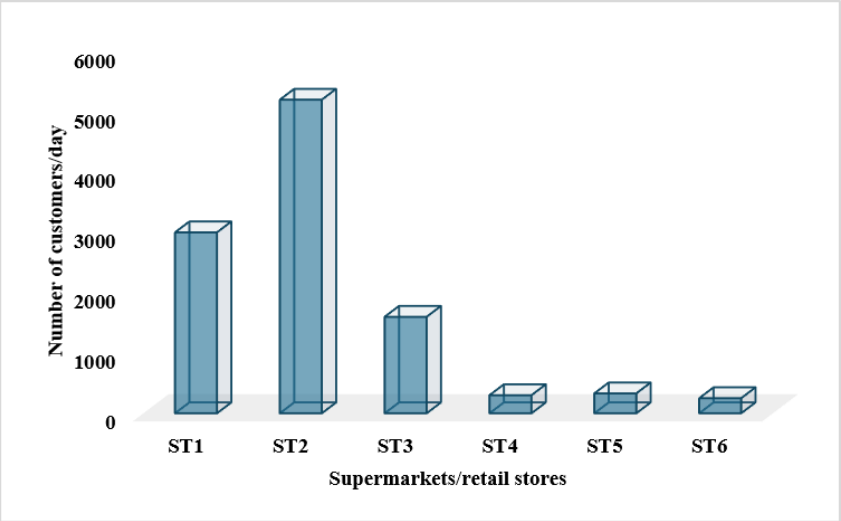

Fig 2. Diagram represents the number of customers at supermarkets and retail stores in Da Nang.

Interviews with supermarket managers regarding the provision and use of plastic carrier bags revealed that approximately 99% of customers use biodegradable plastic carrier bags provided by the supermarket to carry their goods. Only 0.1-1% bring their own bags when shopping, this value could increase to 3-10% when supermarkets offer promotions for eco-friendly shopping. Single-use plastic carrier bags account for 95-99% of packaging, while reusable bags account for 1-5%, depending on the supermarket. Large supermarkets consume 50-100 kg of bags/day, while retail stores consume 1-5 kg/day. The bags used come in various sizes, primarily: 40x70, 30x50, 26x40 and 20x30 cm. The average daily volume of plastic carrier bags provided to shoppers is shown in Figure 3.

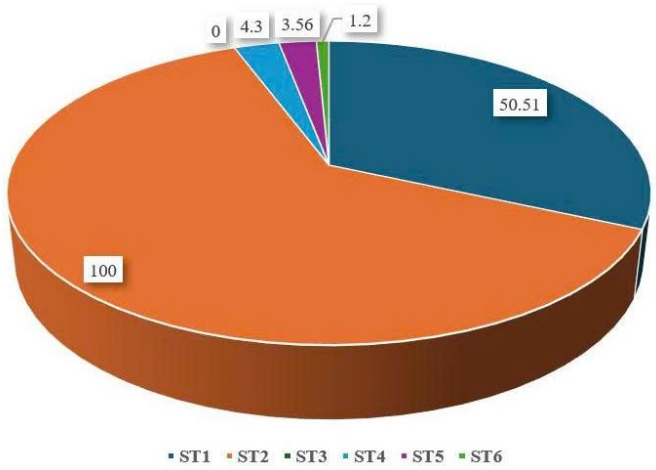

Fig 3. Diagram represents the daily supply of plastic carrier bags at supermarkets and retail stores in Da Nang city (kg/day).

Figures 2 and 3 show a correlation between the daily quantity of plastic carrier bags and the number of customers shopping, except for Mega Mart supermarket does not provide plastic bags to customers. Based on the average price of plastic carrier bags in the Vietnam market at approximately 38,500 VND/kg, the cost of providing plastic carrier bags to customers is about 2-4 million VND/day for large supermarkets, and 50,000-200,000 VND/day for smaller stores. These costs remain relatively insignificant compared with total sales revenue and are therefore incorporated into the overall pricing structure of commercial goods. According to brand management, consumers are increasingly concerned about health, safety, and sustainability factors when choosing products. Therefore, minimizing plastic waste is the most common form of environmental protection through not using single-use plastic carrier bags for packaging. At MM Mega Market Da Nang, the number of distributed goods reaches 17,000 product codes, and since 2019, the supermarket has stopped providing single-use plastic carrier bags and switched to reusable bags and cardboard boxes for packaging goods.

3.1.2. Status of Plastic Bag Usage by Customers

The survey results on the number of plastic carrier bags customers take home showed that 95/120 customers use plastic carrier bags to carry their purchased goods home, 12/120 customers shopping do not use plastic carrier bags for their goods, and the remaining 13/120 customers participated in the interview while selecting goods. 95 customers used 1-12 bags depending on the amount of goods purchased, with an average value of 2.48 bags/customer. The highest percentage (41%) used 2 bags/shopping trip, followed by 1 bag (27%), and only 5.3% used 5 bags/trip, and 4.3% used more than 5 bags to carry goods (Figure 4).

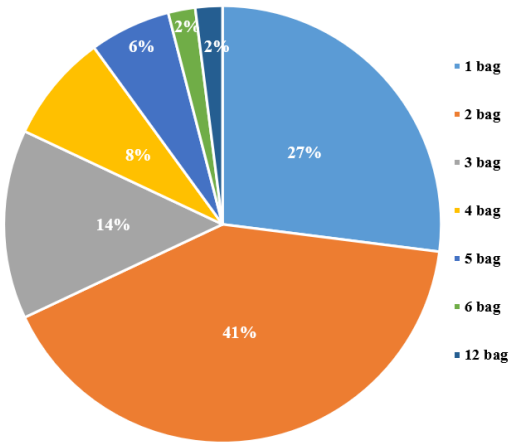

Fig 4. Percentage of customers using plastic carrier bags during a single shopping trip.

3.1.3. Investigation into Consumer Awareness of Plastic Bag Use and Its Environmental Impact

Analysis of consumer awareness regarding plastic carrier bags showed that 85% of customers recognized that the plastic bags distributed in supermarkets were intended for single-use purposes. However, 15% of customers were still unable to identify them as single-use plastic carrier bags (Figure 5a). Among the customers who were aware that these bags are designed for one-time use, as many as 52% of customers believe that these bags cannot be recycled (Figure 5b). Some customers believed that the non-recyclability of plastic carrier bags was the absence of waste collectors, whereas some customers believe that plastic carrier bags are recyclable. According to customers, plastic is a recyclable material, and recycling activities are dependent on collectors and recycling factories. The results suggest that consumers generally recognize the materials used to produce plastic carrier bags. However, a significant proportion of customers are still not fully aware of the characteristics of plastic carrier bags, so it is necessary to strengthen public communication and

awareness programs concerning the properties, composition, and harmful effects of plastic carrier bags on the environment (Figures 5).

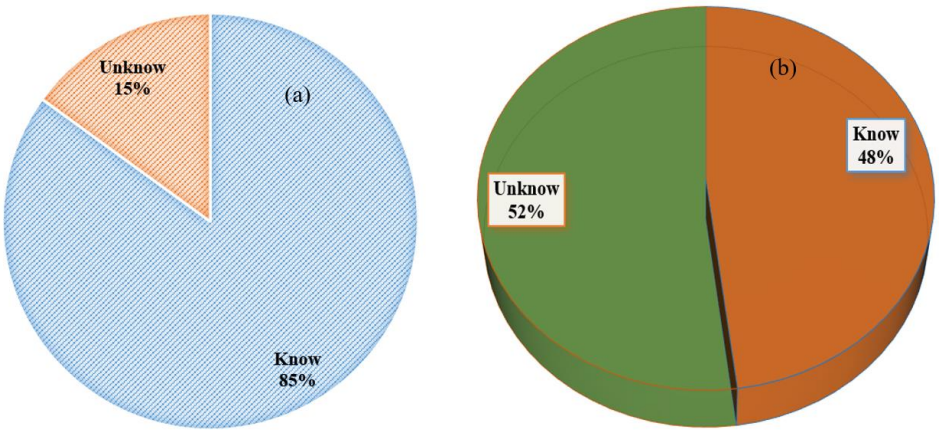

Fig 5. Customer awareness regarding: (a) the plastic carrier bag is single-use bag; (b) the recyclability of plastic carrier bag.

The interview results showed that almost of customers are aware of the environmental impact of plastic carrier bags such as effects on rivers, lakes, soil, and the sea, harm to plants and animals, and effects on human health. Figure 6 indicated that major customers recognize that plastic carrier bags are difficult to decompose and persist in the environment for a long time. 35.3% of customers know that plastic carrier bags take more than 100 years to decompose in the environment, and 16.8% believe they require many more years to be needed for their degradation.

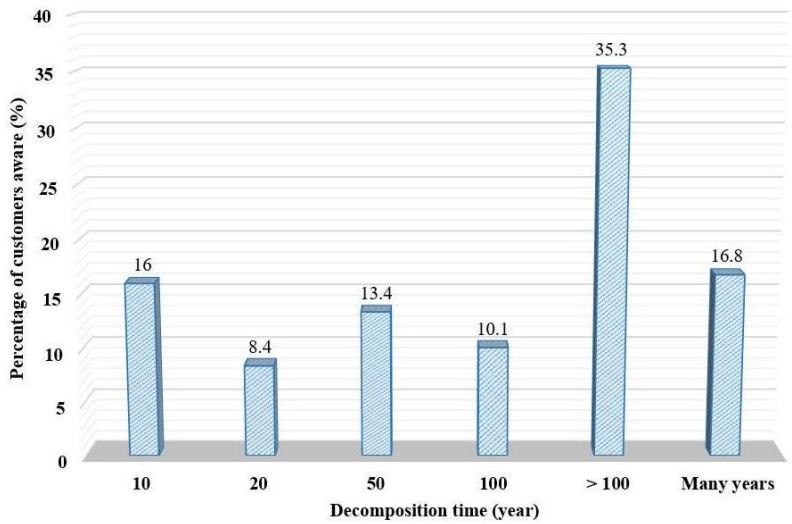

Fig 6. Customers are awareness of the decomposition time of plastic carrier bags when discarded into the environment.

The interview results regarding the regulation prohibiting supermarkets from providing free plastic carrier bags to customers by 2030 indicated that 92% of customers were unaware of this policy. Only 8% of customers reported having prior knowledge of the regulation, and among these customers share that they learned about it from the interview itself (Figure 7). These findings demonstrate that people are unaware of the prohibit from

providing free distribution of single-use plastic carrier bags during shopping and this will be a significant barrier to the effective implementation of policies for reducing plastic emission.

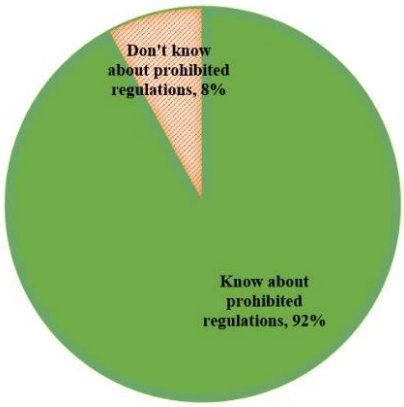

Fig 7. Customer understanding of the regulation prohibiting supermarkets from providing free plastic carrier bags by 2030.

3.2. Potential Environmental Risk Assessment by PHI Value

Based on status of plastic carrier bag usage in several supermarkets and retail stores and assesses the potential risks associated with disposing of plastic carrier bags into the environment in Da Nang city, sediment samples were subsequently collected from three locations receiving municipal solid waste and wastewater. These experiments took place to examine whether the degradation and accumulation of microplastics were associated with plastic carrier bag disposal activities. The results obtained were evaluated according to the threshold values of the Polymer Hazard Index (PHI) for health risk assessment.

3.2.1. Quantity of Microplastics

The analysis results in Table 3 showed that the quantity of microplastics ranged from 400 to 744 (MPs/kg) in the rainy season and from 194 to 489 (MPs/kg) in the dry season. Microplastics were observed at all three sampling locations, with the lowest values recorded at ĐN3 in both seasons. The presence of microplastics tended to decrease towards the estuarine mouth, which is consistent with the geographical characteristics along both riverbanks, where residential areas and service-related activities become increasingly sparse toward the river mouth. In addition, field observations indicated that sediment at site ĐN3 consisted predominantly of sand with minimal sludge content, thereby reducing the capacity for the accumulation and retention of particulate materials.

Table 3. Quantity of microplastics in sediment samples were analyzed in rainr and dry seasons.

No.	Code	Quantity of microplastic (MPs/kg)	
		Rainy season	Dry season
1	ĐN1	744	489
2	ĐN2	447.3	396
3	ĐN3	400	194
	Total	**1591.3**	**1079**

3.2.2. Components of Microplastic Polymers

The analysis results in Figure 8 indicated that 10 types of polymers, total quantity of 1591.3 MPs/kg, were identified in the three sediment samples in the rainy season. All three sampling locations recorded a significantly higher presence of PET and nylon polymers compared to the other polymers, with quantity of

695.5 and 298.7 MPs/kg respectively. The remaining microplastic polymers, including Polyester, Polyethylene, Polypropylene, Cellophane, Polyvinyl chloride, Polystyrene, Polytetrafluoroethylene, and Perfluoroalkoxy (PFA), were found in lower quantities. Similarly, during the dry season, the number of polymers decreased to only six types in the dry season including PET, Nylon, Olefin, Polyacrylamide, Polyethylene Low Density, and Polytetrafluoroethylene. The total quantity of microplastics also decreased significantly to only 1079 MPs/kg. However, PET and nylon still accounted for the highest proportions with value of 197 and 488 MPs/kg respectively.

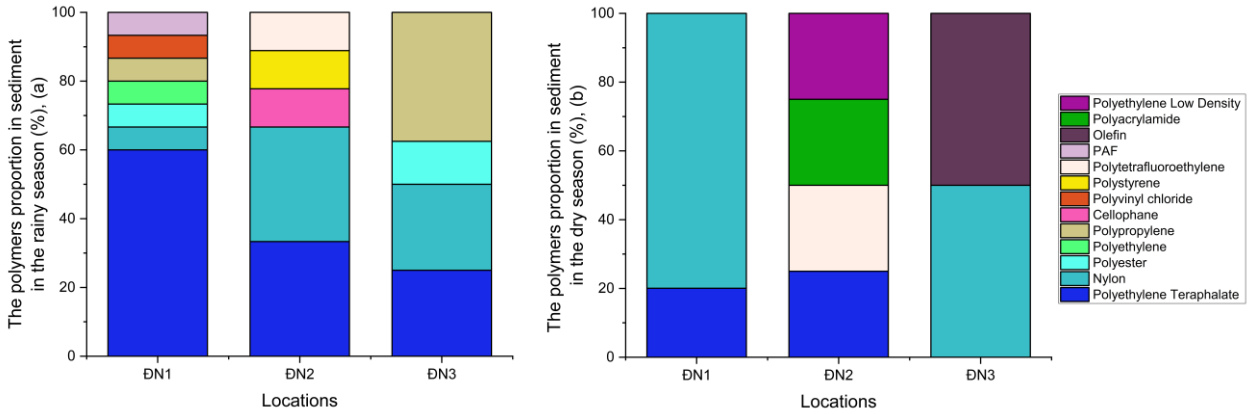

Fig 8. The polymer ratio in sediment samples in Han River (Da Nang): (a) rainy season; (b) dry season.

3.2.3. PHI Value

The risk levels, expressed as percentages and corresponding hazard scores for the polymer types identified in the sediment samples, are presented in Table 4. The total PHI values recorded in the rainy season and dry season were 37.06 and 69.86, respectively. PHI values were below 100, indicating a low-risk level of microplastic pollution according to the PHI classification criteria. At this level, the environment is generally considered not to be significantly affected by microplastic pollution.

Table 4. Risk levels based on polymer composition (PHI) were determined in the study area.

No.	Polymers	Sn	Pn (%)		PHI values	
			Rainy season	Dry season	Rainy season	Dry season
1	Polyethylene Terephthalate (PET)	10	43.72	18.27	4.37	1.83
2	Nylon	150	18.78	45.23	28.17	67.85
3	Polyester	-	6.26	-	-	-
4	Polyethylene (PE)	11	3.12	-	0.34	-
5	Polypropylene (PP)	1	12.54	-	0.12	-
6	Cellophane	-	3.12	-	-	-
7	Polyvinyl chloride (PVC)	100	3.12	-	3.12	-
8	Polystyrene (PS)	30	3.12	-	0.94	-

9	Polytetrafluoroethylene (PTFE)	-	3.11	9.17	-	-
10	Perfluoroalkoxy (PFA)	-	3.11	-	-	-
11	Olefin	-	-	8.99	-	-
12	Polyacrylamide (PA)	-	-	9.17	-	-
13	Polyethylene Low Density (LDPE)	-	-	9.17	-	-
	Total PHI				**37.06**	**69.68**

3.3. Discussion

Directive 33/CT-TTg (Vietnamese Gorverment) on strengthening the management, reuse, recycling, treatment, and reduction of plastic waste to achieve the goal of using 100% environmentally friendly plastic carrier bags in shopping supermarkets/retail stores, replacing non-biodegradable plastic carrier bags by 2030, still facing many difficulties and challenges. Plastic waste in general, and discarded plastic carrier bags in particular, pose significant potential risks to the environment and requires a roadmap for reduction and using green sustainable alternative materials in the future. Further investigation is needed into the willingness to pay for eco-friendly bags for supermarket purchases and the status of plastic carrier bag reuse among customers to comprehensively assess the process for developing and implementing a roadmap to reduce plastic carrier bags. Simultaneously, restricting the supply of free bags, enhancing communication, and promoting the use of alternative products are necessary to ensure a feasible and effective roadmap for reducing plastic carrier bags.

In this study, we did not focus on analyzing the detailed characteristics of microplastics identified in the sediment samples, but the primarily identified the polymer components related to the use and disposal of plastic carrier bags by local residents into the environment. The results revealed that nylon and polyethylene terephthalate (PET) polymers were present at all sampling locations. These locations included a waste collection area (ĐN1), a municipal wastewater receiving area (ĐN2), and the Han River estuary (ĐN3). The main pathway of microplastic pollution entering the marine environment is through the river system and their distribution influenced by water depth, wind direction, flow velocity, and human activities. The coastal waters of Da Nang are affected by a semidiurnal tidal regime with an amplitude of approximately 0.6 m (Huynh et al. 2010). The Han River uniquely flows from south to north before discharging into Da Nang Bay. It is characterized by a short channel length, steep gradient, high flow variability, and relatively low sediment load. During the rainy season, flooding occurs rapidly for only a few days. Conversely, water levels in the dry season decrease due to reduced upstream discharge, leading promotes saltwater intrusion. Numerous residential areas, restaurants, hotels, supermarkets, local markets along both riverbanks and a fishing port are distributed near the estuary. Large amounts of waste from the land are transported into the river during flood events, explaining the higher levels of microplastics during the rainy season compared to the dry season. Although not all plastic bags used by consumers are directly discarded into the three sampling areas investigated and PHI vaues is lower than permissible limits, the analytical results indicate potential environmental risks as the two primary polymers commonly used in plastic carrier bag production were present at all surveyed locations.

Plastic waste is a collection of various types of plastics with different densities, ranging from lighter than water such as polyethylene (PE; 0.91-0.97 g/cm³), polypropylene (PP; 0.94 g/cm³) to heavier than water such as polystyrene (PS; 1.06 g/cm³), nylon (1.14 g/cm³) and polyvinyl chloride (PVC; 1.40-1.58 g/cm³) (Masura et al. 2015; Li et al. 2018). Plastic waste can be distributed throughout the aquatic environment (Thushari et al. 2020), occurring in floating form on the water surface, suspended within the water column (Stephanie et al. 2025) or finally settling to the sediment layer (Rellán et al. 2023). This environmental situation results in widespread exposure of aquatic ecosystems, where organisms inhabiting surface waters such as *Daphnia magna* (Kelpsiene et al. 2020; Kaur et al. 2023), organisms living within the water column (fish and shrimp) (Alberghini et al. 2022), and finally benthic organisms in sediments (oysters and mussels) (Irnidayanti et al.

2025) may all become contaminated by microplastics and associated chemical compounds. Therefore, inadequate awareness regarding the use and disposal of plastic carrier bags continues to pose a significant risk of increasing “white pollution” in the environment.

Figure 8 illustrates that the majority of respondents recognized that plastic carrier bags are highly resistant to degradation and can persist in the environment for prolonged periods. 35.3% of customers knew that plastic carrier bags take more than 100 years to decompose in the environment, and 16.8% believed that it takes many years for plastic bags to decompose. These findings suggest that although most consumers are aware of the harmful effects of plastic carrier bags on the environment, their usage remains highly popular. The findings of this study are consistent with previous results by Thang et al. (2025) in Ninh Binh and Quang Nam provinces (Vietnam) and Liu et al. (2023) where the use of single-use plastic carrier bags in tourism activities and household waste remains prevalent and awareness of existing legal regulations among stakeholders is still relatively low. Thang et al. (2025) reported that plastic carrier bags are still widely used in the tourism industry with an average consumption of approximately 3.64 plastic bottles and 1.48 plastic bags per day, each 4–5-star hotel room was estimated to consume approximately 240 plastic bottles annually. Domestic tourists tend to use plastic carrier bags 1.93 times more frequently, plastic cups, containers, and plates 2.17 times more frequently, and wet wipes 2.73 times more frequently than international tourists. A survey of stakeholders’ awareness and behavior found that 75% of tourists support limiting the use of single-use plastics, while more than over 60% of accommodation establishments had sorted plastic waste segregation and were willing to choose environmentally responsible suppliers. In addition, 75% of travel agents have sorted waste and plastic waste. Nevertheless, reducing the use of single-use plastic remains challenging, with around 60% of tourism businesses reporting a lack of financial and human resources, and 30% stating they do not have access to alternative single-use plastic products.

Another study on single-use plastic bags from daily household waste, through surveys and assessments of existing policy gaps, offered recommendations for improving management along the supply chain in Vietnam (Liu et al., 2023). The results showed that plastic carrier bags were the most commonly item used, averaging nearly 27 bags/week, followed by food wrapping film, straws, coffee cups, cutlery, takeout food containers, food packaging, party cups, water and beverage bottles, and other items. Plastic carrier bags and food packaging were used more frequently in rural areas than in urban areas. These bags also had a high rate of temporary reuse (68.65%) as kitchen waste bags, a habit difficult to change in the short period. Surveys indicated that a large amount of plastic waste is generated in Hanoi, it is not being managed adequately. Some policies such as taxes on plastic bags and waste sorting at source had applied but their implementation remains inconsistent. The surveys also found that consumers are willing to take action to reduce plastic waste, and the detail regulations are needed to enable people to do.

A comprehensive review by Pham et al. (2025), which examined 900 studies on single-use plastics (SUPs), assessed and categorized behavioral change interventions aimed at reducing SUP consumption into individual-level (I-level) and system-level (S-level) approaches. The results showed that I-level interventions focus on educational campaigns, produced inconsistent results with limited of sustainable behavior change. Conversely, S-level interventions focus on prohibitions and market-based mechanisms (e.g., fees and charges), demonstrated greater effectiveness, especially when strictly enforced. Notably, none of the studies reviewed combined both individual-level (I-level) and systemic-level (S-level) approaches. In fact, bans on the use of plastic carrier bags and other SUP have proven relatively effective in several countries such as Chile (Frey et al., 2024), China (He et al., 2021), Australia (Macintosh et al., 2020) and Nepal (Bharadwaj et al., 2021). For example, the plastic carrier bag ban introduced in 2011 resulted in a net reduction of 275 tonnes of plastic over a seven-year period in Australia (Macintosh et al., 2020). However, SUP bags continue to be used by some small retailers who continue to offer SUP bags in areas lacking enforcement, such as farmers' markets, smaller shops or street markets [45]. Some countries have adopted other S-level interventions including fees or taxes (tax rates) primarily focused on plastic shopping bags (He et al., 2021), and not taxing other SUP packaging (Canada (Rivers et al., 2017), China (He et al., 2021), Malaysia (Asmuni et al., 2015), Portugal Martinho et al., 2017), United Kingdom (Chandra et al., 2023), United States (Homonoff, 2018) and

Israel (Shahrabani, 2025). Government-imposed taxes on single-use plastic packaging generally target manufacturers, importers, or or seller, which can lead to higher prices for consumers.

Studies have shown that although plastic carrier bag charges are effective in reducing SUP consumption, their success depends on effective enforcement and consumer attitudes. This finding is consistent with the results observed in the present study, which highlighted that environmental awareness alone has not yet been sufficient to change consumer behavior. Further imply that the continued free provision of plastic carrier bags remains one of the key factors driving their widespread consumption among customers. In addition, providing alternatives to SUP and recycling SUP is also a preferred solution (Novoradovskaya et al., 2021). Novoradovskaya et al. (2021) found that providing free reusable cups and sending reminders via app significantly increased the use of reusable cups immediately after the intervention and after six weeks of follow-up. The overall assessment results show the urgent need for a multi-faceted combination of measures while engaging stakeholders to enhance the effectiveness of the intervention.

4. CONCLUSIONS

This study investigated the status of plastic carrier bag usage and distribution in several supermarkets and retail stores in Da Nang city (Vietnam). The findings indicated that plastic carrier bag consumption was strongly correlated with the number of customers. The average plastic carrier bag usage was recorded at 2.48 bags/customer/shopping trip, indicating a significant dependence of consumer behavior on the free provision of plastic carrier bags by retailers or supermarkets. Although consumer awareness regarding the negative environmental impacts of plastic carrier bags was relatively high (97.5% of customers acknowledged their harmful effects), this awareness had not yet translated into actual consumer behavior. The main reasons identified were convenience habits and the continued widespread provision of free plastic carrier bags. Furthermore, public understanding of the recyclability, characteristics, and degradation lifecycle of plastic carrier bags remained incomplete. Simultaneously, awareness of management policies, especially the roadmap for banning the free distribution of plastic carrier bags by 2030, was also found to be very limited, with only 8% of customers reporting prior knowledge of the policy.

In addition, the study also assessed potential risks associated with disposing of plastic carrier bags into the environment at three locations receiving municipal wastewater and solid waste using the Polymer Hazard Index (PHI). The result recorded PHI values in the rainy and dry seasons were 37.69 and 69.68, respectively, corresponding to a low-risk level. However, nylon polymer quantity in all samples were consistently detected at relatively high level, indicating potential environmental risks. These findings provide important scientific evidence for environmental managers to pay attention to when planning and developing policies and regulations related to plastics and plastic waste.

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7. BACKGROUND INFORMATION FOR RECORD (NOT TO BE PRINTED)

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