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Original Article

Assessment of Plastic Waste Generation and Environmental Leakage in Hai An Ward, Nghi Son Town, Thanh Hoa Province

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Abstract: The study estimates plastic waste generation and leakage to the environment and the sea in Hai An ward, Thanh Hoa province. The study uses a material flow analysis model, field samplings (include plastic waste sorting and weighing), and secondary data collection and analysis. The plastic waste generated is estimated to be 77.01 ton/year, of which the plastic waste from domestic sources and other sources, including agriculture and aquaculture (fishing), are 71.17 ton/year and 5.84 ton/year, respectively. Research results show the composition of plastic waste from domestic sources is diverse, with bottles being the highest (28.4%), followed by plastic bags (23.1%). The findings of the study also indicate that the plastic waste leakage to the environment is 9.63 ton/year, of which 6.4 tons are from the uncollected plastic waste and 3.23 tons are the plastic waste lost during the collection, transportation, and treatment process. The research also estimates that the plastic waste leakage to the sea accounts for about 7.24 ton/year, plastic waste retained on land is about 2.16 ton/year, and the plastic waste openly burnt is 0.23 ton/year.

Keywords: Plastic waste, plastic waste leakage, material flow analysis model, Hai An.

1. Introduction

Plastic waste can be generally defined as useless by-products/unwanted plastic substances that are generated mainly during human activities and have negative impacts on the environment and humans [1-3]. Plastic waste includes plastic bags, plastic bottles, plastic

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cups, plastic straws, old plastic toys and so on. These products are characterized by a long decomposition time, which can take up to hundreds or thousands of years.

According to Shen et al., (2020) [4], each year the world releases most of 320 million tons of used plastic products into the environment. Between 4.8 and 12.7 million tons of plastic waste are leaked into aquatic ecosystems annually [5, 6]. Vietnam releases about 1.8 million tons to the environment [5]. In particular, plastic waste is generated from many sources including domestic waste which is from residential areas, markets, and stores, shops, restaurants [7, 8]. The main composition of domestic plastic waste is plastic bags, plastic bottles, toys, diapers, straws, yogurt cups, and toothbrushes. Plastic waste also comes from industrial activities, such as factories, enterprises, and industrial zones. Plastic waste is also generated from agriculture and aquaculture activities. Plastic waste comes from medical sector, which is a fairly large source of plastic waste today due to the specific characteristics of the medical industry that requires the use of a lot of items. Medical plastic is used to minimize the risk of infection and ensure safety in medical examination and treatment. Types of medical plastic waste include plastic bags, medical material packaging, medicine packaging, gloves, and needles. In addition, plastic waste also originates from tourist areas, services, entertainment areas, or schools.

Plastic waste causes harm to the environment and animals such as changing the physical, biological, and chemical properties of water sources, making soil infertile, causing soil erosion, and affecting crops. Plastic waste clogs sewers, causing floods and waterlogging, seriously affecting the environment. Most plastic waste flows into the ocean. According to some studies, plastic waste kills 1.5 million animals each year because they ingest it [9], leading to the risk of extinction or destruction or decline of biodiversity. In addition, it also changes the structure and species composition of the ecosystem due to the transport of organisms through plastic waste from other places.

Plastic waste also affects human health, such as the decomposition process of some types of plastic waste generated from substances harmful to human health. Plastic bags, straws, disposable plastic cups, foam boxes, plastic bottles are mainly recycled from used plastic products, some chemicals contained in these plastic products such as plasticizers, dyes, lead, and cadmium... will leach into food, then be absorbed into the human body during the use of the products. These chemicals accumulate over a long period of time and can cause cancer, adversely affect brain development in children, cause tissue changes, chromosomal changes, miscarriages, birth defects, and hormonal changes. and many other consequences for human health. Plastic waste pollutes water and air sources, affecting the growth and development of animals and plants. It can cause diseases such as diarrhea, fever, coughs and colds, headaches, for people living near the places where plastic waste pollution occurs [1, 12].

Marine plastic waste is plastic waste produced or used by humans, from plastic bags to plastic bottles thrown into the sea or areas near the coast, causing serious consequences for the lives of marine animals and other creatures. Marine plastic waste affects socio-economic activities, the environment, marine ecosystems and human health [10-12, 21].

The report on the current status of the national marine and island environment for the period 2016-2020 of the Ministry of Natural Resources and Environment, Vietnam estimated that more than 80% of annual ocean plastic waste originates from the mainland. 70% of marine plastic debris will sink to the seabed and destroy life activities on the seabed [13]. Vietnam ranks 4th out of 20 countries with the most plastic waste discharged into the environment and into the sea in the world, with the volume of plastic waste leaked into the environment being 1.83 million tons, and 0.28-0.73 million ton/year, equivalent to 6% of the world's total amount of plastic waste discharged into the sea [5].

According to research by the International Union for Conservation of Nature (IUCN) on assessing the number and volume of plastic waste in 30 beaches and 10 marine protected areas of Vietnam, it shows that on average, over 100m of beach length will have plastic waste quantity of 7,374 pieces and 94.58kg. In plastic waste, the types that account for the largest proportion in quantity are foam buoys, ropes, and small nets. These products account for 47% of the quantity of trash and 46% of the volume of waste. Others are disposable plastic waste types, such as: Styrofoam food containers, plastic bottles, plastic bags [14]. Currently, the assessment of plastic waste is often qualitative and focuses on the amount generated, does not estimate the amount of plastic waste lost to the environment, especially to the sea. Therefore, it is necessary to evaluate the source of generation, propose methods and estimate the amount of plastic waste generated and lost to the environment, and the sea, on that basis, the effective solutions to control plastic waste are proposed.

2. Methodology

2.1. Study Area

The study area is Hai An ward, in Thanh Hoa Province, Figure 1. Hai An Beach is located in Hai An ward, Nghi Son District, Thanh Hoa province, Vietnam. This is a coastal area, located in the northern area of Nghi Son town, about 11 km from the town center [15].

There are 6500 people in the ward. Main economic activities are agriculture and aquaculture (fishing). Tourism activities are mainly for local residents.

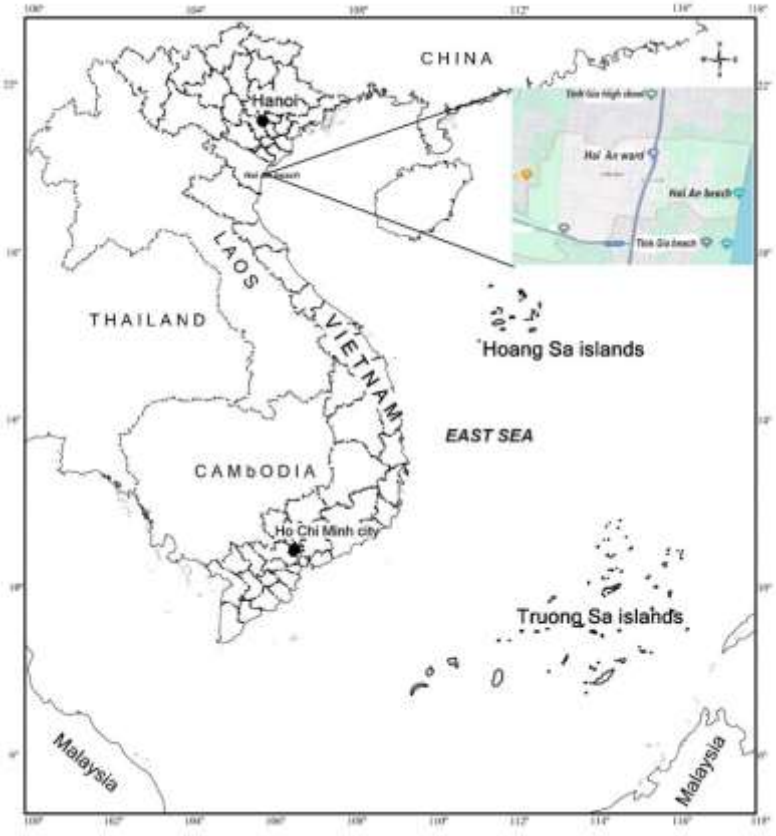

Figure 1. Geographic location of Hai An ward.

However, currently the environmental conditions in the Hai An ward is getting polluted by rubbish. The solid waste is gathered into temporary sites, causing pollution and urban aesthetics. Plastic waste, especially plastic bags or unused plastic items, is often openly burnt, causing air pollution.

2.2. Methods

2.2.1. Data Collection and Analysis

Secondary data including documents and reports of socio-economic activities (e.g., agriculture, fishing), population, current state of plastic waste in Hai An ward were collected from different sources [14, 15, 18, 20, 21], including scientific journals and reports on plastic waste, its impacts on the environment, and sea. Methods for estimating plastic waste were also collected and synthesized. In addition, the study conducted surveys and fieldtrips to assess and identify sources of plastic waste in Hai An ward.

2.2.2. Investigation and Survey Methods, Combined with Interviews

The preliminary fieldtrip was conducted in January 2024 to collect information about natural and socio-economic conditions, plastic waste sources, plastic waste recycling shops, and transporting routes, where plastic waste is lost, agricultural and fishing activities and other relevant information.

The more thorough survey was carried out in March 2024 to take sampling of the domestic waste from 15 households, ensuring the representation of the sampling, for 7 consecutive days including two weekend days. The 15 households were chosen randomly from the list of residents. The selection for domestic waste sampling was made representatively in terms of occupation and address.

The amount of plastic waste from daily activities was calculated on average per day (kg/person/day). The plastic waste sampling and composition was also made according to UN-Habitat [24].

The interviews of households, fisherman and junk shop owner and management officials regarding plastic waste were carried out to assess the plastic waste generation and management in the area. The number of interviewees are 30 and the content is about people habits and awareness on plastic use, waste generation and classification, collection, treatment at source, and the ways in which the plastic waste is leaked to the environment.

2.2.3. Estimation of the Amount of Plastic Waste Generation

From the identification of plastic waste sources, the study calculated the amount of plastic waste generation from different sources using the methodology according to the previous studies [7, 16, 17, 22]

Total amount of plastic waste generated M is calculated in formula 1.

$$M = M_{dw} + M_{ndw} \quad (1)$$

M_{dw}: Plastic waste from domestic sources, in which

$$M_{dw} = m \times N \quad (2)$$

m: volume of plastic waste generated/person/day and N: total population.

M_{ndw}: Plastic waste from non-domestic sources, estimated according to generation coefficients referenced from previous documents [17, 22].

For the plastic waste from agriculture, the amount of plastic waste generated is calculated by the areas of the crop and multipled by the co-efficient of that crop [17].

For the plastic waste from fishing, the amount of plastic waste generated is calculated by the amount of plastic waste generated by one fishing boat and multipled by the number of boats [22].

2.2.4. Estimating Plastic Waste Loss to the Environment and Sea Using Material Flow Analysis Model

The material flow analysis model is employed to estimate the plastic waste loss to the environment and to the sea. This method has been used in a number of studies such as the plastic waste leakage into the coastal area of Tam Giang (Nguyen Bac Giang et al., 2023), Ha Tinh

(Do Quynh Nga, 2021), Quy Nhon (Nguyen Thao Huong, 2024), and Nghe An (Mai Van Trinh, 2023; Nguyen Tai Tue et al., 2023) in Vietnam [7, 8, 16-18]. Based on these references mention above, the material flow analysis diagram was made, Figure 2, using the following data and formulas:

$$M=M_{cpw}+ M_{ucpw} + M_{lpw} \quad (3)$$

M is the amount of plastic waste generation, identified in formula 1.

M_{cpw} is the amount of collected plastic waste M_{ucpw} is the amount of uncollected plastic waste.

M_{lpw} is the amount of plastic waste lost during the collection, transportation and transfer process.

The plastic waste leakage to the environment includes the uncollected plastic waste (M_{ucpw}) and the plastic waste lost during the collection, transportation and transfer process (M_{lpw}).

The collected plastic waste and uncollected plastic waste and the plastic waste lost during the collection, transportation and transfer process were estimated during the interviews and fieldtrips.

The fate of the plastic waste in the environment is identified as follows [16].

Plastic waste is retained on land.

Plastic waste leakage to the drain, waterbody system and eventually to the sea.

Plastic waste is openly burnt.

The amount of plastic waste lost to the environment is calculated as follow:

$$M_e= M_{ucpw} + M_{lpw} \quad (4)$$

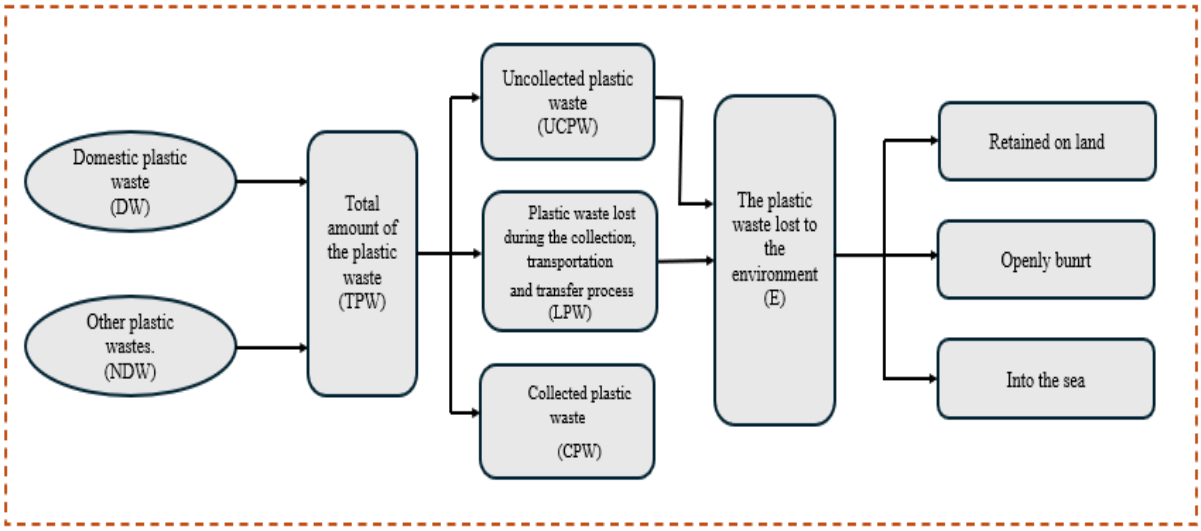

Figure 2. Plastic waste flow analysis diagram.

3. Results and Discussion

3.1. Plastic Waste Sources

Through investigation, the sources of plastic waste in Hai An ward were identified, including plastic waste which is of domestic source and plastic waste from other sources of fishing and agriculture.

The plastic waste from agriculture is from farming and the plastic waste from fishing. At present, there are only local residents visiting the beach and no tourists to the ward therefore no plastic waste generated from tourism. There is no hospital in the ward and no medical plastic waste is generated.

3.2. Plastic Waste Amount

3.2.1. Plastic Waste from Domestic Source

A survey of waste generated from households was conducted in Hai An ward. 15

households of different groups in terms of occupation and address were selected for the survey and sampling for 7 days including 2 weekend days.

From information about occupations, the number of households and the volume of plastic waste collected each day, the study determined the average plastic waste generation index per capita in Hai An ward.

From demographic information of households in different occupations and the volume of waste collected each day by each household, the average volume of plastic waste per capita in Hai An ward was determined statistically [19] from Figure 3 and was 0.03 kg/person/day. Compared to other research results such as that of Duong Thi Phuong Anh et al., (2023), the plastic waste generation coefficient in household activities is 0.04 kg/person/day [20] or by Do Quynh Nga (2021), the plastic waste generation coefficient from households is also 0.04 kg/person/day [7], the findings are quite consistent. The population of Hai An ward is 6,500 people [15], therefore, the amount of plastic waste generated from domestic source is 0.03 kg x 6500 x 365 days = 71,175 kg/year, corresponding to 71.17 tons of plastic waste/year.

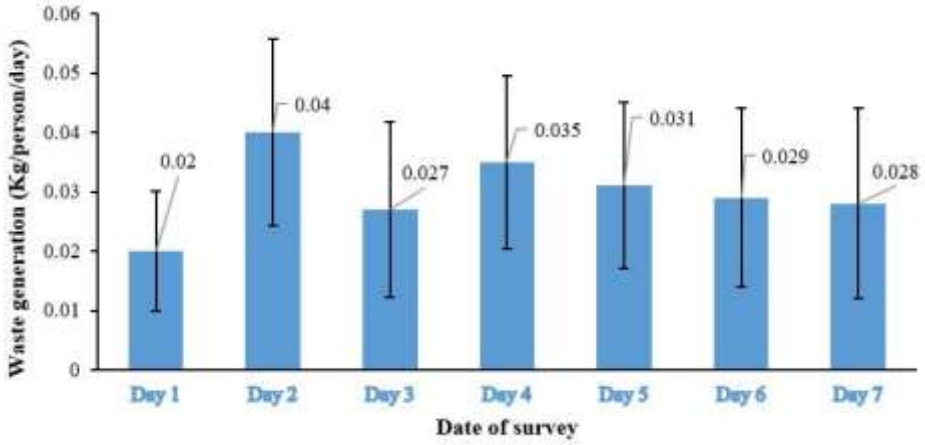

Figure 3. Amount of plastic waste generated per day per capita. Error bars represent standard deviation.

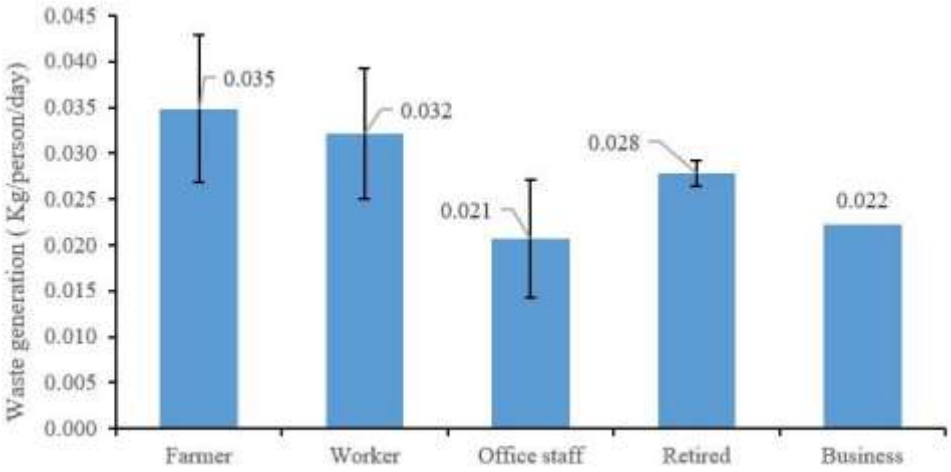

Figure 4. Amount of plastic waste by different occupations. Error bars represent standard deviation.

The amount of waste generated per capita on weekdays did not differ significantly over the 7 days of the survey.

In addition, from the ratio of plastic waste generated per day in Figure 3, the index of plastic waste generation by occupation can be determined in Figure 4.

Regarding the amount of plastic waste by occupation, the index of household plastic waste generation from households by occupation also shows the influence of occupation on the use of plastic and plastic waste generation. In particular, the average group of farmer and worker households consumes and disposes of more plastic waste than the group of office worker and retired households. It can be seen that occupation also has a considerable influence on the plastic consumption habits and lifestyle of people.

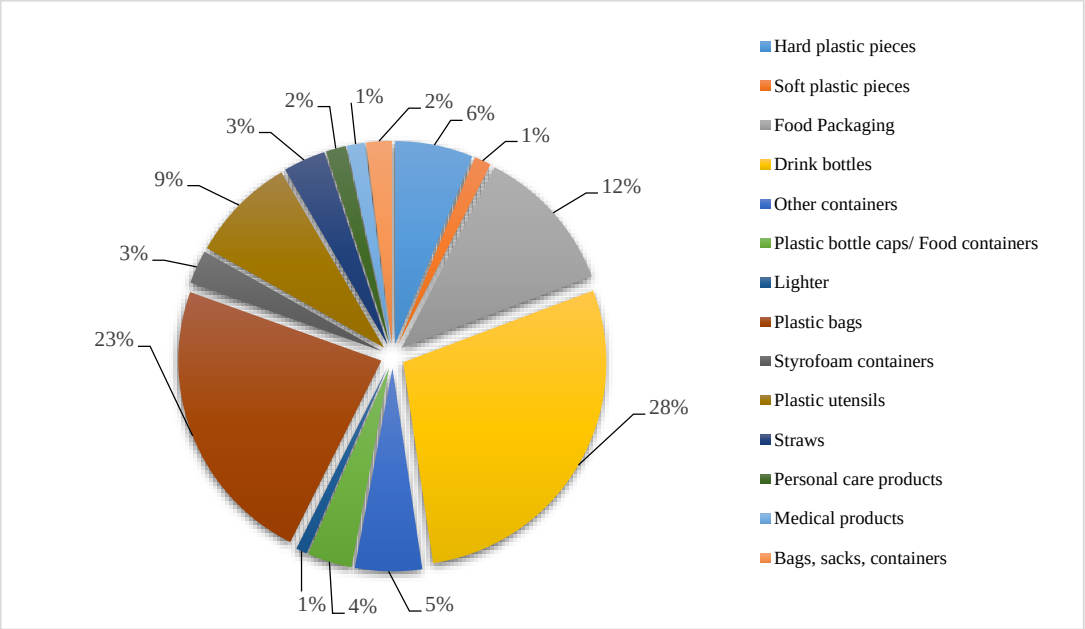

Figure 5. Composition of household plastic waste by weight.

Composition of household plastic waste

The study has classified the composition of household plastic waste using the method of made according to UN-Habitat [24] in Figure 5.

The collected plastic waste was poured on a flat concrete floor. The waste was then mixed thoroughly and divided into four parts, discarded the opposite two quarters, combined the remaining two quarters and took the waste to be classified by weight.

After collecting, synthesizing and analyzing the survey and sample results, the proportion (%) of plastic waste from households are presented in Figure 5. In the composition of plastic waste from domestic source, the largest proportions are beverage bottles (28.4%) and plastic bags (23.1%), followed by food packaging (11.7%). The remaining components have lower proportions, but still contribute to the diversity of plastic waste composition.

The findings are fairly aligned to other studies such as Duong Thi Phuong Anh et al., (2023) which has the largest component of plastic waste is food packaging with 37%, followed by plastic bags with 29% [20] or Do Quynh Nga (2021) the largest proportion of plastic waste is plastic bags with 46.4%, followed by bottles (21.4%) and food packaging (17.6%) [7].

In general, bottles, plastic bags and food packaging are identified as the main components of plastic waste from households. This indicates

that everyday consumer products such as bottled beverages, plastic bags and food wrappers play an important role in generating plastic waste, and their management can be an important part of waste reduction and environmental protection strategies.

3.2.2. Plastic Waste from Other Sources

i) Plastic waste from agriculture

According to the report from Hai An ward, the total agricultural land area in Hai An ward is 253.48 hectares [15]. The estimation of the amount of plastic waste from agricultural activities is calculated by the cultivated area multiplied by the plastic generation coefficient per unit area according to the research by Mai Van Trinh (2023) [17]. The coefficients in that study have been used in research areas in Vietnam such as Nghe An province. Our study is in Thanh Hoa province which is neighouring to Nghe An province, therefore it can be applicable;

The cultivation area is 253.48 hectares (rice: 184.33 hectares and other annual crops such as potatoes, peanuts: 69.15 hectares) [15], the total amount of plastic waste generated from cultivation each year is estimated to be 4.36 ton/year;

ii) Plastic waste from fishing

The amount of plastic waste from fishing boats is calculated based on the report of Quang Ninh DONRE (2021) and calculated with data for the assumed type of fishing boat [22].

According to surveys and data from Hai An Ward People's Committee, the number of boats in the ward is 7, all of which are less than 15 m in length. Therefore, according to a study conducted by scientists from VNU-HUS in collaboration with the Department of Natural Resources and Environment of Quang Ninh the amount of plastic waste generated by a fishing boat per a year is 211 kg. Our study is in Thanh Hoa province, a coastal province in North Vietnam, therefore the previous study in Quang Ninh province can be used [22].

The amount of plastic waste from aquatic products of 7 boats per year is 7 x 211 kg = 1.48 ton/year.

Thus, the total amount of plastic waste generated in Hai An ward according to formula 1 is $M = M_{dw} + M_{ndw} = 71.175 + (4.36 + 1.48) = 77.01$ ton/year. Of which, the domestic waste generated is 71.175 ton/year and the plastic waste from agriculture is 4.36 ton/year, followed by fishing at 1.48 ton/year. It shows that the amount of waste coming from daily activities is the largest (92%), followed by waste from agriculture (6%) and fishing (2%), Figure 6.

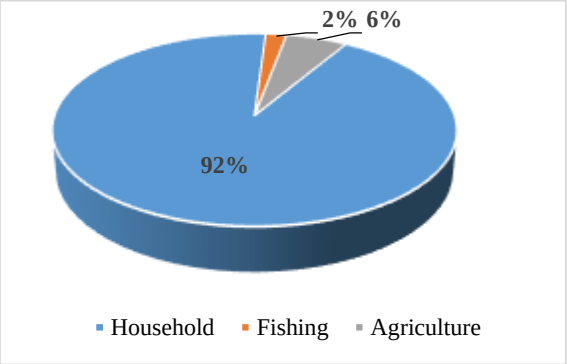

Figure 6. Sources of plastic waste in Hai An ward.

3.3. Estimation of Plastic Waste Leakage to the Environment and into the Sea

Based on the survey results and the principles of material balance, waste flow analysis, and plastic waste generated, combined with the interviews and fieldtrips and used the previous studies [7, 8, 16, 23], the study has estimated the amount of plastic waste released into the environment and the amount of plastic waste leakage into the sea. The amount of plastic waste generated is 77.01 ton/year, of which, the amount of domestic plastic waste is 71.17 ton/year, accounting for 92% and the amount of other plastic waste is 5.84 ton/year, accounting for the remaining 8%.

The plastic waste released into the environment is due to the uncollected plastic waste and the plastic waste lost during collection, transportation and junk shops. The results are comparable to those reported by Nguyen Bac Giang et al., (2023) [16] and Tran Thu Huong (2020) [23].

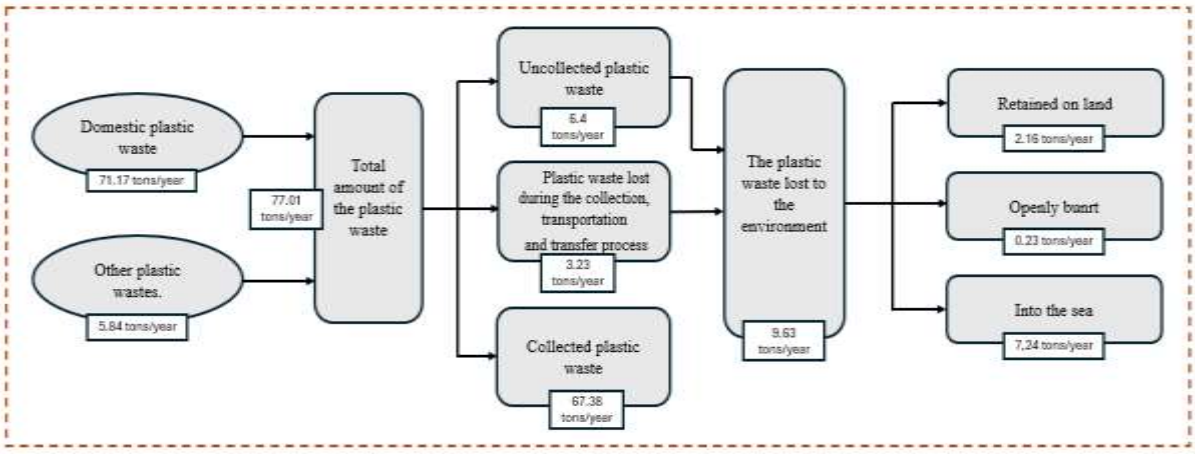

Figure 7. Plastic waste flow analysis diagram of the area.

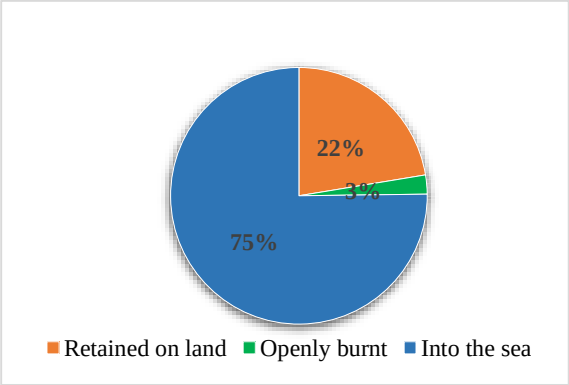

Figure 8. Percentage of plastic waste lost to the environment.

According to the survey, there is one recyclable waste collection shop (junk shop), with an annual purchasing volume of about 1 ton of plastic waste/year in Hai An Ward. This amount of recycled plastic waste is purchased not only in Hai An ward but also in other nearby areas (personal communication) at a price of 4,000 VND/kg. In Hai An ward, there is no landfill and the solid waste is collected and transported to the landfill in the neighboring ward. According to the results of the research from the interviews and fieldtrips, the uncollected plastic waste is about 6.4 ton/year (8.3% of the amount of the plastic waste generated) and from the plastic waste lost during the collection, transportation and transfer process is 3.23 ton/year (about 4.2% of the plastic waste generated). The findings are similar to that of other studies [16, 23]. The plastic waste flow analysis diagram is presented in Figure 7. According to the diagram, once the plastic waste is lost to the environment, it will go to the sea, 7.24 ton/year, accounting for 75% of the total waste % of the total amount of plastic waste released into the environment, Figure 8. The amount of plastic waste lost to the environment but retained on land is 2.16 ton/year, accounting for 22% of the amount of plastic waste lost to the environment. Last but not least, the remaining plastic waste, which is openly burnt, is estimated to be about 0.23 ton/year, accounting for 3% of the total amount of plastic waste released into the environment. Although this rate is lower than the other two sources, it still needs to be paid attention to and minimized to reduce negative impacts on the environment and public health.

4. Conclusions

Research results show that the sources of plastic waste in Hai An ward are from domestic source, agriculture, and fishing. The average plastic waste generation index per capita in Hai An ward is 0.03 kg/person/day. In terms of occupation, the plastic waste generation from the group of farmer and worker households is more

than that of the office worker and retiree households.

The total volume of plastic waste generated is 77.01 ton/year, of which the plastic waste from domestic source is 71.17 ton/year, accounting for 92%, the plastic waste from agriculture is 4.36 ton/year, accounting for 6%, and the plastic waste from fishing is 1.48 ton/year, accounting for 2%.

The composition of household plastic waste is very diverse, with beverage bottles being the highest (accounting for 28.4%), followed by plastic bags (accounting for 23.1%).

Using the material flow analysis model, the study has estimated that the plastic waste leakage to the environment is from the uncollected waste, which is about 6.4 ton/year, 8.3% of the amount of the plastic waste generated and from the plastic waste lost during the collection, transportation and transfer process, which is 3.23 ton/year, about 4.2% of the plastic waste generated. The plastic waste lost to the environment is 9.63 ton/year, of which the largest amount of plastic waste released into the sea is 7.24 ton/year, accounting for 75% of the total amount of plastic released into the environment. The amount of plastic waste retained on land is 2.16 ton/year, accounting for 22% of the amount of plastic lost to the environment. The plastic waste which is openly burnt is about 0.23 ton/year, accounting for 3% of the total amount of the plastic waste released into the environment. Although this rate is lower than the other two sources, it still needs to be paid attention to and minimized to reduce negative impacts on the environment and public health. Based on the findings of the research, more comprehensive studies of plastic waste leakage to environment and sea measures should be conducted for other areas.

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