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Plastic Waste Generation and Management in Thoi Lai District, Can Tho City, Vietnam

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ABSTRACT The objective of this study was to assess the current situation of generation and management of plastic waste in Thoi Lai district, Can Tho city, Vietnam through collecting domestic solid waste samples from 30 households and interviewing 150 households using questionaires. The results showed that the average amount of domestic solid waste was 0.3 kg/person/day, in which the plastic waste accounted for 11.7% with generation rate of 0.035 kg/person/day. Shopping bags were dominant accounting for 34.7%, single-use plastic products accounting for 18.5% and food packaging plastic bags accounting for 9.51%. The generation rates of domestic solid waste and plastic waste had positive correlation with household's size and income. In addition, the rate of plastic waste generation also appeared to have a relationship with the characteristics of the study area. Plastic waste has not been classified but it is mixed with other domestic solid waste. Knowledge of plastic waste impact has not been widely propagated in the community. Therefore, appropriate measures should be implemented to reduce municipal waste and plastic wastes.

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Over the past decade, plastic waste has become one of the major challenges facing many countries around the world, as well as on land and at sea (Letcher, 2020; Vietnam Environment Administration, 2020). It is estimated that the annual global demand for plastic is very large with about 300 million tons (Anderson *et al.*, 2016). And the amount of plastic waste released by humans on a global scale is enough to cover four times the area of the Earth's surface, of which 13 million tons of plastic waste are dumped into the ocean, negatively impacting the environment, ecosystem and national sustainable development (Vietnam Environment Administration, 2020). Without stopping, if solid waste management is not improved, an estimated 20-53 million tons of plastic waste may enter the aquatic environment by 2030 (Borrellel *et al.*, 2020). In Vietnam alone, it is estimated that the amount of plastic waste lost to the environment is about 5 kg/person/year, equivalent to 0.3 - 0.7 million tons/year, making it one of the leading countries in plastic emissions (Huong, 2019). According to the Ministry of Natural Resources and Environment (2020), in Vietnam, 80% of plastic waste comes from the mainland, that is, from production and human activities, the remaining 20% comes from activities of fishing, aquaculture, ships at sea. Currently, plastic is widely used in all fields such as used as raw materials for manufacturing machinery, equipment, construction works, packaging, clothing and household tools, etc. Plastic is inexpensive and durable. As a result, the level of plastic production for human consumption has increased, in which packaging is the largest plastic sector in the world (Kibria, 2007). Six common plastics on the market

today are Polyethylene (PE), Polypropylene (PP), Polyvinul chloride (PVC), Polystyrene (PS), Polyurethane (PUR) and Polyethylene terephthalate (PET) (Kibria, 2007). Most of the chemicals used to make plastics are derived from crude oil and some other hazardous chemicals (Lithner *et al.,* 2011). And they are not easily biodegradable and persist in the natural environment for a long time (Kibria, 2017). As an example, each plastic bag or piece of plastic takes an average of 200-300 years to decompose (Vietnam Environment Administration, 2020). Therefore, when plastic waste persists in the environment for a long time, it will cause environmental pollution and seriously affect human health (Thompson *et al.,* 2009). Plastic waste problems are common today such as clogging sewers, breeding grounds for mosquitoes and disease-causing species, killing many animals when they are eaten or entangled, leaking toxic materials harmful and enter the human food chain (UNEP, 2018). In particular, microplastics are found in many different animal species such as corals, polychaetes, zooplankton, microcrustaceans, mollusks, fish, etc. and lead to death; Not only that, microplastics can cause cancer, reproductive damage, immunodeficiency and deformities in animals including humans (Auta *et al.,* 2017). Thoi Lai is a district of Can Tho city, currently being invested in construction and strongly developed. Thoi Lai District People's Committee said that in 2019, all 12 communes in Thoi Lai district met the New Rural Commune standard, by the end of 2020 there were 2 communes that met the New Advanced Rural standard, agricultural economy of Thoi Lai district to develop in the direction of sustainability and diversity of plants and animals. That is one of the reasons for the increasing volume of MSW in the district. However, at present, the pollution of plastic waste has not been deeply concerned in the locality, and people still lack understanding about this issue. The current status of plastic waste pollution in daily life and the proposed management solutions have been concerned by many authors around the world and a few domestic authors have also mentioned in research works (Bhattacharya *et al.,* 2018; Thanh, 2011; Dung *et al.,* 2020), even microplastic pollution affects the environment, ecology and human health (Dung *et al.,* 2019). This study was to assess the current status and management of plastic waste in Thoi Lai district, Can Tho city and to propose effective management measures for minimizing the pollution caused by plastic wastes.

MATERIALS AND METHODS

Study area: Thoi Lai district has a total area of 266.93 km^2 in Can Tho city. The population of the district is 124,818 thousand people with an average density of 468 people/km^2. The whole district has 29,375 households, of which about 4,402 people are ethnic minorities. Criteria for selecting the study area are urban and rural areas. In Thoi Lai district, Thoi Thanh commune, Truong Thanh commune and Thoi Lai town were selected to survey the current status of plastic waste management in daily life. The first selected study area is Thoi Lai town in the urban area, with an area of 9.72 km^2. This is the central area of the district, also the only town with the highest population and density of 11,043 people and 1,136 people/km^2, respectively. The second selected area is Thoi Thanh commune in the new rural area, with an area of 14.68 km^2, a population of 11,799 people and a population density of 804 people/km^2. The remaining area of Truong Thanh commune belongs to the newly enhanced rural area, with an area of 19.49 km^2, a population of 11,953 people and a population density of 613 people/km^2.

Domestic solid waste sampling: Domestic solid waste of the households was collected continuously within 7 days from March 8-14, 2021 following the methods of the previous studies (Trung, 2011; Trang, 2014; Giao, 2020). Thirty households in Thoi Thanh commune, Truong Thanh commune and Thoi Lai town were randomly selected sample collection. Plastic bags for domestic solid waste containing were provided for each household during consecutive seven days. In addition, interviewing households have been conducted to collect information of number of family members, income and occupation.

Domestic solid waste separation: After the sample was collected, it was placed on a plastic sheet spread on the ground where the wasts could be separated and weighed. The solid waste sample was weighed using the balance with an accuracy of 0.01 kg. Total volume of the sample was also recorded for percentage calculation. Furthermore, plastic wastes were classified into 22 sub-categories (Thanh *et al.,* 2010) including plastic beverage bottles, food plastic bottles, non-food/beverage plastic bottles, PET bottles for drinking water, PET bottles for containers food, food/beverage-free PET bottles, styrofoam trays, other trays, plastic food containers, food-free plastic containers, food-grade plastic tubes, non-food-grade plastic tubes, plastic packaging food, non-food packaging plastic packaging, plastic packaging for unspecified purposes, plastic shopping bags, cushioning materials, plastic straps, other containers and packaging, durable products (multipurpose) use), consumer products (disposable), other plastics.

Households interviewing: The study conducted random interviews with 150 households in the survey

areas, which were Thoi Lai town, Thoi Thanh commune and Truong Thanh commune about the form of solid waste management and people's knowledge, attitudes and behaviors about solid waste management. Each area would have 50 households selected for interview. The structure of the interview question consists of three parts. The first part includes general family information and personal information of the interviewee (name, age, gender, occupation, education level, number of family members, address). The second part deals with the current state of household waste management. The third part includes the content of knowledge, attitude and behavior of the people on plastic waste management. This approach has been used in a few previous studies in MSW management (Babaei *et al.*, 2015; Suma *et al.*, 2019).

Data analysis: The collected data were synthesized and processed by Microsoft Excel software to determine values such as generated volume, percentage of solid waste, plastic waste. The results were presented in the form of simple tables and graphs. In addition, the study also conducted one-way ANOVA analysis of variance (95% confidence level) using SPSS software (IBM SPSS Statistics 2015, IBM, USA) to analyze the statistically significant difference between survey areas.

RESULTS AND DISCUSSION

Current status of plastic waste generation in Thoi Lai district

Volume of plastic waste generation: Solid waste generation often depends on socio-economic development characteristics and living standards of people in each area (Lan & Lieu, 2018). Through the analysis results, the volume of MSW and plastic waste generated in the three study areas is detailed in Table 1.

Table 1. Volume of MSW and plastic waste generated in each area (kg/person/day)

No.	Study area	Volume of total wastes	Volume of plastic waste
1	Thoi Thanh	0.29±0.21a	0.031±0.03b
2	Truong Thanh	0.28±0.18a	0.028±0.02b
3	Thoi Lai	0.32±0.24a	0.044±0.03a

Notes: Values in the same column with the same letter (a, b) are not significantly different at the α = 5% level and vice versa.

In terms of solid waste, the average coefficient of MSW generation in the whole district was about 0.3 kg/person/day. Specifically, the volume of MSW at three survey sites including Thoi Thanh commune, Truong Thanh commune and Thoi Lai town was 0.29±0.21 kg/person/day, 0.28±0.18 kg/person/day and 0.32±0.24 kg/person/day, respectively (Table 1). Statistical results showed that the volume of MSW generation between the three sites was not statistically significant ($p>0.05$) (Table 1). In other words, this result indicated that there was no difference in the amount of waste disposed of per household in urban and rural areas within the same district. Compared with some other studies on domestic waste generation in Can Tho city (0.28 kg/person/day), in rural areas of Vinh Long province (0.24 kg/person/day) (Thanh, 2011; Trang, 2014), the current study's result was relatively higher. However, this result was still lower than those found in Can Tho city of 0.47 kg/person/day in 2018 and 0.49 kg/person/day in 2019 (Ministry of Natural Resources and Environment, 2020) and Dong Ha city of 0.66 kg/person/day, Tien Hai district of 0.5-0.8 kg/person/day and Vu Quang district of 0.38-0.69 kg/person/day (Lan and Lieu, 2018; Huan *et al.*, 2020; Oanh, 2021). For plastic waste, it accounted for about 11.7% of the total MSW composition with an average weight of 0.035 kg/person/day. The current status of plastic waste generation in the study area was still very low compared to the survey on the current status of plastic waste in Vietnam (0.167 kg/person/day) (Huong, 2019) and in Ward 7, Soc Trang city (0.178 kg/person/day) (Giao, 2020). The proportion of plastic waste in the MSW stream was lower than that in the tourist service area, plastic waste accounts for about 15.67% (Widyarsana *et al.*, 2020). In the area of Thoi Thanh commune, the volume of plastic waste generated was 0.031±0.03 kg/person/day, Truong Thanh commune was 0.028±0.02 kg/person/day and Thoi Lai town was 0.045±0.03 kg/person/day (Table 1). Statistical analysis showed that Thoi Lai town had the highest amount of plastic waste generated and had a statistically significant difference compared with the other two communes ($p<0.05$) (Table 1). This may be because there are some economic, occupational and usage differences between urban and rural areas. The area of Thoi Lai had the highest population density in Thoi Lai district, had many markets, trading households where people need to use more types of drinking water, ready-made or packaged food than cooking at home, which gave rise to a variety of packaging, straws, bottles, single-use products, as well as nylon bag. The volume of plastic waste generated in Thoi Thanh and Truong Thanh communes was not statistically significant ($p>0.05$), because the two communes are located in rural areas. The composition of plastic waste was relatively diverse and abundant, from 22 types of plastic waste, the initial classification, the results showed that 19/22 types of plastic waste appeared in the study area (Table 2). In which, plastic packaging containing food, consumer products (disposable) and plastic shopping bags accounted for the highest proportions of 9.51%, 18.54% and 34.69%, respectively. There ere three

types of plastic ingredients that do not appear in the study area including PET bottles that were PET do not contain food/beverage, foam trays and plastic food containers (Table 2).

Table 2. Plastic waste composition in the study area

No.	Composition	Mean weight (kg)	Ratio (%)
1	Plastic bottles for drinks	0.00068	1.80
2	Plastic bottles for food	0.00022	0.6
3	Plastic bottles do not contain food/beverages	0.00017	0.46
4	PET bottles for drinking water	0.00157	4.21
5	PET bottles containing food	0.00039	1.03
6	PET bottles do not contain food/beverages	0	0
7	Styrofoam tray	0	0
8	Other tray	0.00053	1.41
9	Plastic food containers	0.00023	0.62
10	Plastic containers do not contain food	0.00094	2.51
11	Plastic tubes for food	0	0
12	Food-free plastic tubes	0.00113	3.03
13	Food packaging plastic	0.00355	9.51
14	Food-free plastic packaging	0.00240	6.43
15	Plastic packaging for unspecified purposes	0.00160	4.29
16	Plastic shopping bags	0.01296	34.69
17	Cushion material	0.00067	1.79
18	Plastic rope	0.00016	0.44
19	Other containers and packaging	0.00076	2.05
20	Durable product (multi-use)	0.00195	5.23
21	Consumer products (disposable)	0.00693	18.54
22	Other plastic	0.00051	1.37

Domestic solid waste and plastic waste generated within a week: Depending on the needs of use, each household daily generate different amounts of waste. The results in Table 3 compared the difference in the volume of MSW and plastic waste generated on weekdays.

Table 3. Volume of MSW and plastic waste generated between days of the week (kg/person/day)

No.	Day	Amount of solid waste	Amount of plastic waste
1	Monday	0.298±0.23a	0.045±0.04a
2	Tuesday	0.288±0.18a	0.042±0.03a
3	Wednesday	0.31±0.18a	0.029±0.02a
4	Thursday	0.282±0.25a	0.031±0.03a
5	Friday	0.342±0.23a	0.031±0.03a
6	Saturday	0.247±0.19a	0.03±0.02a
7	Sunday	0.325±0.21a	0.035±0.03a

Notes: Values in the same column with the same letter (a, b) are not significantly different at the α = 5% level and vice versa.

Statistical analysis showed no significant difference in overall waste volume between weekdays ($p>0.05$). This is also consistent with the results of previous studies in the provinces of the Mekong Delta and the town of Gulberg (Pakistan) (Thanh *et al.,* 2010; Jadoon *et al.,* 2014). Specifically, from Monday to Sunday, the generated solid waste volumes were 0.298±0.23, 0.288±0.18, 0.31±0.18, 0.282±0.25, 0.342±0.23, 0.247±0.19, 0.325±0.21 kg/person/day, respectively. Similarly, for plastic waste, the analysis results showed that the volume of plastic waste generated between the days of the week was not statistically significant ($p>0.05$). This indicated that the amount of plastic waste emitted had no effect on the days of the week. From Monday to Sunday, the volume of plastic waste generated is 0.045±0.04, 0.042±0.03, 0.029±0.02, 0.031±0.03, 0.031±0.03, 0.03±0.02, 0.035±0.03 kg/person/day, respectively.

Solid waste and plastic waste arising between household sizes: There were three types of household sizes including 3 people (12 households), 4 people (13 households) and 5 people (5 households). The households in the study were randomly selected. The results of comparison of MSW and plastic waste at three household sizes are detailed in Table 4.

Table 4. Volume of MSW and plastic waste generated by household size (kg/person/day)

No.	Members in family	Amount of solid waste	Amount of plastic weight
1	3 persons	0.36±0.25a	0.04±0.03a
2	4 persons	0.29±0.17a	0.035±0.03a
3	5 persons	0.18±0.17b	0.023±0.03b

Notes: Values in the same column with the same letter (a, b) are not significantly different at the α = 5% level and vice versa.

It was found that there was a difference in MSW generation between household sizes ($p<0.05$). A family of 5 people generated an average waste volume of 0.18±0.17 kg/person/day, which was lower than the other two household sizes of 4 people (0.29±0.17 kg/person/day) and 3 people (0.26±0.25 kg/person/day). This result indicated that households with more people would have a lower rate of MSW generation than households with few people. It could be explained that when many people eat and drink together resulted in reducing the amount of waste generated every day. However, the results of this study were not consistent with the study conducted in Thu Dau Mot and Dehradun area (India), with household size with many members would generate a larger amount of solid waste (Suthar and Singh, 2015; Trang *et al.,* 2017). Further study with large sample size should be conducted to elaborate this difference. Similarly, the results also showed that there was a significant difference in the mean volume of plastic waste between the three household sizes ($p<0.05$). Household size of 5 people had a lower emission of plastic waste (0.023±0.03 kg/person/day) than the remaining 2 household sizes of 4 people (0.036±0.03 kg/person/day) and 3 people (0.04±0.03 kg/person/day). The results were similar to the study of Thanh (2011), the generation rate of plastic waste

would be lower when the household size is larger. This indicated that, when many people use the same plastic products/packaging in family activities, the rate of waste generation would be reduced. People in the same family tend to share a variety of utensils such as baskets, pots, soap bottles, toothpaste bottles, plastic seasoning bottles, etc. In addition, they would buy products with large capacity that can be used longer, thereby reducing the rate of plastic waste generation. The variation in the amount of plastic waste generated is very largely depending on the volume and time of disposal of the product or packaging. Besides, plastic waste can actually limit emissions every day by reusing or refusing to use behaviors.

Comparing the volume of MSW and plastic waste generated across income levels: The income level was determined into four categories based on quartile analysis of the survey samples as below 2 million/person/day (9 households), 2 to 3 million/person/day (7 households), 3 up to 4 million/person/day (7 households) and over 4 million/person/day (7 households). The results of comparing the rates of MSW and plastic waste generation among income levels are shown in Table 5.

Table 5. Volume of MSW and plastic waste generated between income levels (kg/person/day)

No.	Income	Amount of solid waste	Amount of plastic weight
1	<2 million	0.195±0.18b	0.021±0.02b
2	2-3 million	0.364±0.20a	0.034±0.02b
3	3-4 million	0.289±0.17b	0.038±0.03a
4	>4 million	0.395±0.25a	0.052±0.03a

Notes: Values in the same column with the same letter (a, b) are not significantly different at the α = 5% level and vice versa.

The results showed that there was a statistical difference in the generation of MSW among income levels ($p<0.05$). The lowest income households under 2 million/person/day had a smaller amount of waste compared to the two higher income levels of 2 to 3 million/person/day and 4 million/person/day. The households with an income of over 4 million/person/day had higher emissions than the households with lower income of 3 to 4 million/person/day and less than 2 million/person/day. The results showed that the households with higher average income with high ability to pay for goods and high consumption would create a higher amount of MSW generated, consistent with some previous research results of Ogola *et al.* (2011) and Kumar *et al.* (2018). In other words, household income had a strong relationship with the rate of household waste generation (Thanh *et al.,* 2011). However, there are also studies that showing that households with high incomes are generating less waste, because households with higher economic status often go out more often than cooking at home (Trang *et al.,* 2017).

For plastic waste, the results of analysis of the volume of plastic waste generation showed statistical difference between the income levels of households ($p<0.05$). The households with income of 4 million/person/day or more generated the highest amount of plastic waste of 0.052±0.03 kg/person/day compared to the other 3 income levels. At the lowest income level of less than 2 million/person/day, the rate of plastic waste discharge was 0.0211±0.02 kg/person/day. Although this result produces the same amount of plastic waste of 2 to 3 million/person/day, it is lower than the higher income levels of 3 to 4 million/person/day and above 4 million/ person/day. It can be seen that households with a higher income level generated a larger amount of plastic waste, because they had more spending activities through buying a variety of plastic packaged products. This result was similar to the other studies on plastic waste (Thanh *et al.,* 2011; Ngan, 2012). In addition, the study by Monavari *et al.* (2012) also showed that the households with higher incomes generated a greater amount of organic waste per day, as well as an increased production of plastic waste. This was due to changes in household consumption patterns and differences in socioeconomic levels. In other words, households with low income and economic conditions had generated more organic waste because they use more homemade foods. While households with higher income and economic conditions use industrially packaged foods. In addition, people with lower incomes tend to save more through the reuse of plastic waste and storing it for sale.

Current status of domestic solid waste and plastic waste management in Thoi Lai district: In Thoi Lai district, people do not classify domestic solid waste at source. Through interviews, 100% of people used garbage collection service but did not sort at source before collecting. Solid waste containing non-burnable waste, combustible waste and even hazardous solid waste is dumped together and collected, without separation, and transported to the incineration plant for treatment. As a result, the processing is time consuming and costly for classification. The implementation of garbage separation is not maintained and implemented well locally because many people are not aware of its consequence. Besides, this activity is also encouraging, not obligatory. The form of classification of plastic waste is not applied in the domestic waste management policy in the study area because the waste treatment technology being applied locally is incineration to generate electricity. This classification

is not necessary because plastic is a highly flammable material. Therefore, improving the people's knowledge, behavior and attitudes towards the issue of reducing plastic use has not been interested by local managers. The classification of plastic waste before treatment is still done by many households because of the benefits that plastic waste brings such as selling and reusing. Thoi Lai district has about 18 plastic waste collectors and no plastic waste recycling facility. They collect all kinds of plastic waste except pesticide bottles.

In the communes of Thoi Lai district, the domestic waste collection agency is selected through bidding. Currently, the collection and transportation of solid waste from households and organizations, business and service units of the district are carried out by Can Tho City Urban Construction Company. After that, the waste is transported to the treatment site, which is the Can Tho Waste Incineration Plant. According to the results of interviews with managers, the percentage of households receiving domestic waste collection in the whole district is relatively high, accounting for 82%. Truong Thanh commune had a low collection rate of only 50% and the highest is in town of Thoi Lai. This difference is due to the limitation of traffic conditions in each area. Regarding solid waste treatment technology, management officials said that at present, it is not really an urgent matter to popularize people to classify or reduce the use of plastic. Because plastic waste can be burned and is a very good burning material, especially plastic bags. In places where there are not yet favorable conditions to collect domestic waste, the Can Tho Department of Natural Resources and Environment directs communes and hamlets to encourage people not to discharge waste into the environment and treat it by burying and burning at home. Currently, the local environmental managers support people to build pits to burn at home. Only collection and treatment is not really a good solution to the problem of plastic waste pollution, because at present, each individual's awareness of environmental protection is still limited, the behavior of littering the environment still exists. Plastic often appears everywhere in the environment. According to Huong (2019), the amount of plastic waste lost to the environment in Vietnam is about 0.35-0.78 million tons/year and the rate of return to the recycling market only accounts for 13-27% of the solid waste stream. About 50-80% of the world's plastic waste ends up on beaches, stays on the seafloor and floats on the ocean's surface (Ryan *et al.*, 2009). Therefore, it is necessary to combine many measures to raise public awareness on the issue of plastic waste pollution.

Conclusion: The results showed that the major types of plastic waste generated in the study area are plastic shopping bags, single-use plastic products and bags plastic food packaging. The factors such as household size, income and days in a week, the rate of generation of domestic solid waste and plastic waste had positive correlation with locations of the study area, the family size and income of households. Most local people do not separate solid wastes at source. The community is also not fully aware of impact of plastic waste on environment. Raising local people's awareness of solid waste separation, reuse, recycle is still limited in the study areas.

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