Potential For Recycling Single-Use Plastic Waste - Case Study in Can Tho City, Vietnam

Nguyen Truong Thanh[1], Kim Lavane[2], Nguyen Vo Chau Ngan[3*]

[1,2,3]*College of Environment and Natural Resources, Can Tho University, 3/2 street, Xuan Khanh, Ninh Kieu, Can Tho 90000, Vietnam; E-mail: nvcngan@ctu.edu.vn*

Abstracts: Circular economy is an economic ideal that has been concretized by the Vietnamese Government in the Law on Environmental Protection 2020. As a part of this model, plastic waste reuse and recycling are encouraged to extend the product life cycle. This study investigates the composition of recyclable plastic waste within the domestic waste sources in Can Tho city. The wastes were collected at waste gathering places, residential areas, markets, bus stations, and schools in the urban district of Ninh Kieu and suburban district of Cai Rang in Can Tho city. The results show that disposable plastic items are very diverse such as grocery bags, plastic bags, foam boxes, straws, drinking water bottles, etc. Plastic components accounted from 6.82 % in Cai Rang district to 14.89 % in Ninh Kieu district of the total waste. In which, LDPE plastic was the highest with 38.17 %, HDPE plastic and PETE plastic accounted for 20.81% and 4.89 %, respectively. Particularly, PETE is less found than other plastics as it is collected by scrap person at the disposal sources or by sanitation worker at the waste gathering place. PETE and HDPE plastics are completely recyclable, accounting for 25.70 %. In addition, LDPE plastic is also recyclable (38.17%) compared to other components. Thus, the recyclable plastic ratio of PETE, HDPE, and LDPE reaches 63.88 %. Meanwhile, non-recyclable plastics, accounted for 36.12 %, such as PS plastic (14.18 %), PP plastic (9.83 %) and other plastics (12.12 %). From the results, the amount of recyclable plastic discarded into the environment is nearly twice that of non-recyclable plastic. The potential to utilize recyclable plastics will most likely fit the circular economy model, which will both extend the product life cycle while limiting waste generation and minimizing adverse environmental impacts.

Keywords: Can Tho City, Circular Economy, Non-recyclable Plastics, Plastic Waste, Recyclable Plastics.

1. INTRODUCTION

In recent society, plastics have been widely used due to their convenient assets and the varied range of products they can produce. The plastic production and consumption are at 45.0 kg/person/year in 2015 in the world scale [1], while the average plastic consumption of 35.0 kg/person/year were recorded in Vietnam [2]. The common use of plastics and their durability have caused persistent pollution to all kind of received environments of soil, water, and air [3, 4, 5, 6, 7]. It is estimated about 80.0 % litter from mismanaged or poorly landfills accessed into the marine by different pathways of sewage outfalls, streams, rivers, or wind-blown [8, 9, 10, 11]. Due to human activities, litter pollution seems to be higher in coastal areas [12].

In Vietnam, the plastic composition takes in account of 10.0 % in domestic solid waste flow [2] and increased from 5.5 % in 2009 to 13.9 % in 2017 [13]. The types of plastic waste are in many forms of bags, bottles, single-use by-products, hard to recovery and recycle by-products, etc. The sources of plastic waste come from (i) daily life activities; (ii) socio-economic activities; (iii) agriculture cultivation, construction works, tourism consumption and plastic recycling activities [14]. For the total amount of plastic waste, only a part is recovered and recycled, and a part is treated by landfill or incineration [14]. However, burning plastic in the uncontrol incinerator release toxic substances that causes of pollution [15]. As of year 2015, approximately 6,300 Mt of plastic waste had been generated, around 9.0 % of which had been recycled, 12.0 % was incinerated, and 79.0 % was accumulated in landfills or discharged to the open sources [16]. According to World Bank [17], Vietnam should promote the reduction of single-use but low-value plastics and encourage the use of reusable or recyclable alternatives. This study is to evaluate the potential of recyclable plastics in domestic waste sources in Can Tho city and propose wise solutions to utilize recyclable plastic for different purposes that both extend the product life cycle while limiting waste generation and minimizing adverse environmental impacts.

2. METHODOLOGY

2.1. Research Object

Plastics are the most widely used products in several applications such as packaging films, wrapping materials, shopping and garbage bags, fluid containers, toys, and industrial products, etc. [18]. In general, plastic products used in daily life can be classified into thermoplastics and thermoset plastics [19]. In addition, plastics are also divided into recyclable and non-recyclable forms. Recyclable plastics are plastic waste that can be introduced into a manufacturing process to make new materials and convert them into new products [20]. Meanwhile, non-recyclables plastics can no longer be used as raw materials in the manufacturing process [20] due to this kind of product are often contaminated or no current recycling system exists [21]. The symbols and uses of recyclable and non-recyclable plastics are given in Table 1.

Table 1. Types of plastic [22]

Symbol	Name	Uses	Purpose of recycle	Recyclable
1 PETE	Polyethylene Terephthalate	Soda bottles; Water bottles; Salad dressing bottles; Medicine jars; Peanut butter jars; Jelly jars; Combs; Bean bags; Rope; Tote bags; Carpet; Fiber filled material in warm clothing	Textiles, carpets, pillow stuffing, life jackets, storage containers, clothing, boat sails, auto parts, sleeping bags, shoes, luggage, winter coats	Yes
2 HDPE	High-Density Polyethylene	Milk jugs; Juice containers; Grocery bags; Trash bags; Motor oil containers; Shampoo and conditioner bottles; Soap bottles; Detergent containers; Bleach containers; Toys	Plastic crates, lumber, fencing	Yes
3 PVC	Polyvinyl Chloride	Some tote bags; Plumbing pipes; Grocery bags; Tile; Cling films; Shoes; Gutters; Window frames; Ducts; Sewage pipes	Flooring, mobile home skirting	Yes, with conditions
4 LDPE	Low-Density Polyethylene	Cling wrap; Sandwich bags; Squeezable bottles for condiments such as honey and mustard; Grocery bags; Frozen food bags; Flexible container lids	Garbage cans, lumber	Yes, with conditions
5 PP	Polypropylene	Plastic diapers; Tupperware; Kitchenware; Margarine tubs; Yogurt containers; Prescription bottles; Stadium cups; Bottle caps; Take-out containers; Disposable cups and plates	Ice scrapers, rakes, battery cables	No
6 PS	Polystyrene or Styrofoam	Disposable coffee cups; Plastic food boxes; Plastic cutlery; Packing foam; Packing peanuts	Insulation, license plate frames, rulers	No
7 OTHER	Miscellaneous plastics (acrylic, polycarbonate polyctide, acrylonitrile butadiene, styrene, fiber-glass, nylon)	Plastic CDs and DVDs; Baby bottles; Large water bottles with multiple-gallon capacity; Medical storage containers; Eyeglasses; Exterior lighting fixtures	Plastic lumber (which is often used in outdoor decks, molding, and park benches)	Not usually - call your recycler to verify

2.2. Research Methods

Classification of waste components to determine the percentage of plastic, the characteristics of plastic items and the proportion of plastic types in the solid waste flow. There are 4 waste sources were chosen in the two districts in Can Tho city to collect the waste. From there, evaluate the potential of recyclable and non-recyclable plastic in Can Tho city as shown in Figure 1.

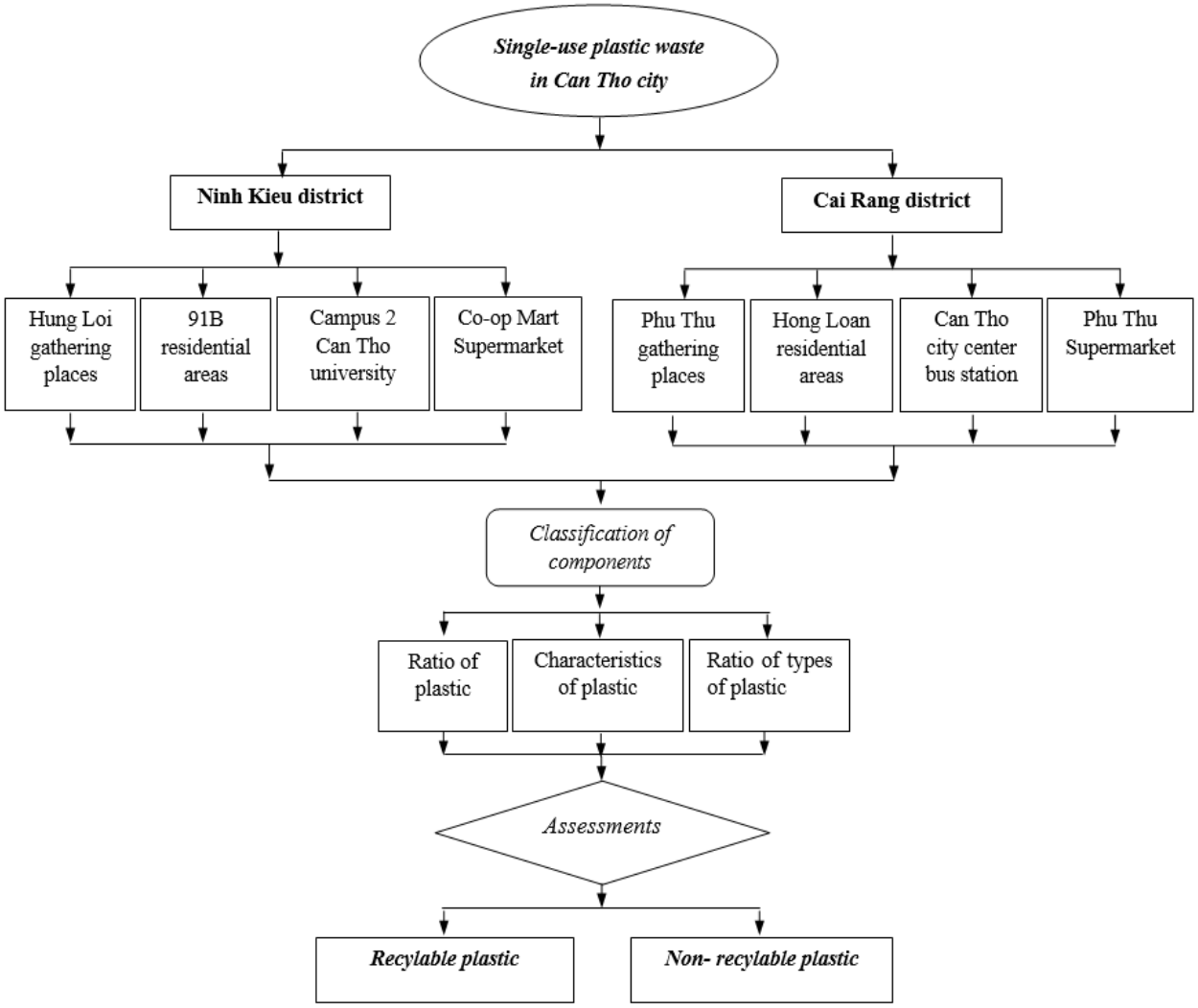

Figure 1. Schematic of research process.

2.2.1. Study Areas

Located at middle of the Vietnamese Mekong delta, Can Tho city have an area of 1,401.00 km2, and an average population density of 848 people per square kilometers. Among the districts, Ninh Kieu is the capital district where highest population density of 8,407 people has per square kilometers and Cai Rang is a sub-urban district with population density of 1,345 people per square kilometers [23]. Waste from daily activities is an environmental problem of Can Tho city as about 650 tons of daily-life waste (85 - 90 %) being collected [24]. In this study, domestic waste was collected in Ninh Kieu district at Hung Loi waste gathering place (1), 91B Residential area (2), Can Tho University (3), Coopmart Supermarket (4), in Cai Rang district at Phu Thu waste gathering place (5), Hong Loan Residential area (6), Phu Thu outdoor market (7), and Can Tho city center bus station (8) (Figure 2).

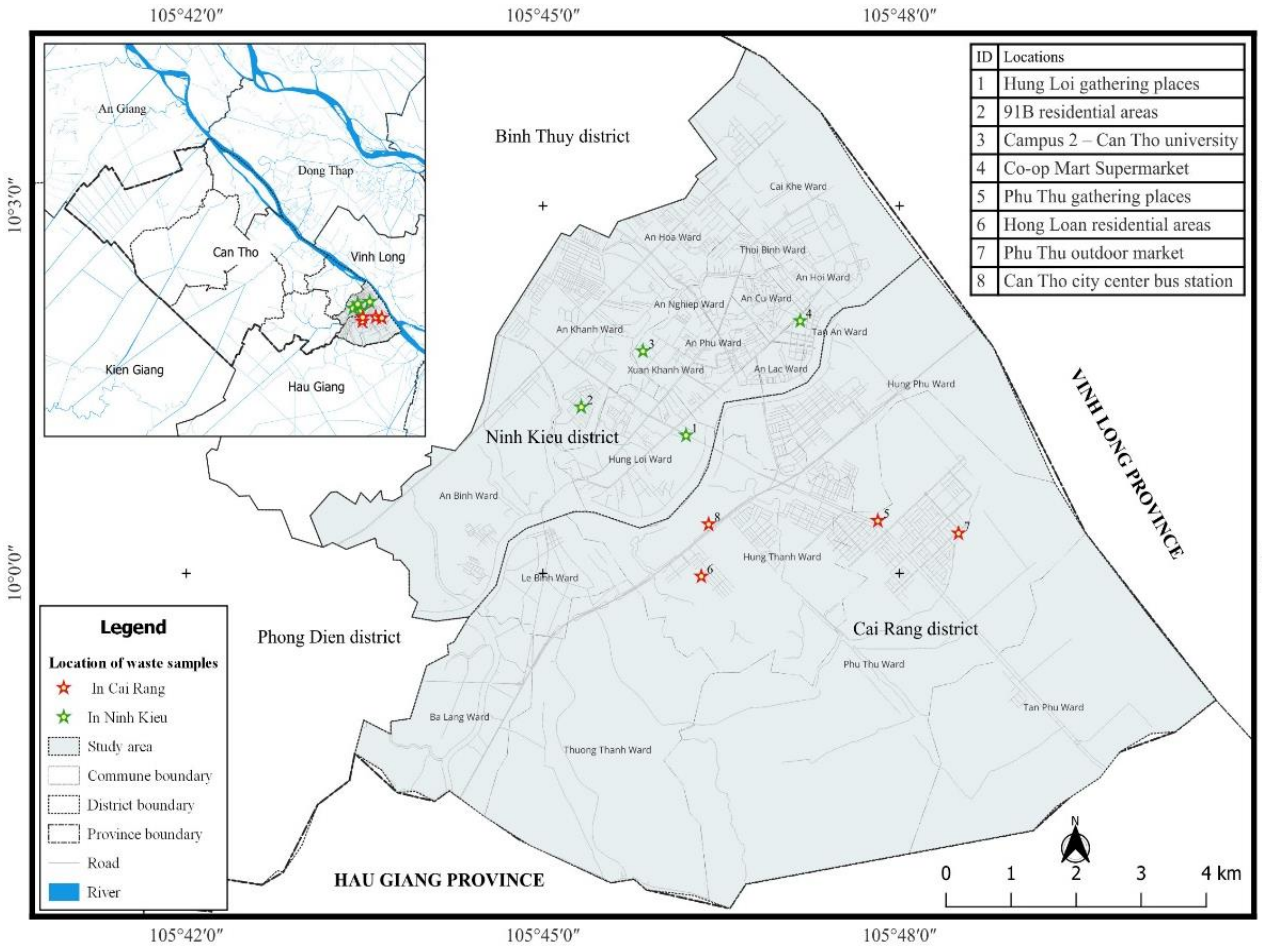

Figure 2. Sampling locations.

2.2.2. Sample Collection

At each sampling location, the volume of garbage in the day at public trash cans (within the sampling area) were collected randomly according to the method of determining the composition of untreated municipal solid waste by manual classification [25]. The collected waste volume in each sampling location is ranged from 91 kg to 136 kg representative. Trash samples from each sampling location is collected in a separate bag, labeled, and transported to the Laboratory of Solid Waste, College of Environment and Natural Resources - Can Tho University, then classified them. Trash samples were collected in 2 phases: phase 1 from April 13 - 16th 2021 (middle of the month) and phase 2 from April 27 - 30th 2021 (end of the month).

2.2.3. Sample Analysis

First, the waste was classified to record its components. Waste components are classified according to TCVN 9461:2012 - Standard test method for determination of the composition of unprocessed municipal solid waste by 9 categories including papers, plastics, and rubbers, organic, woods, textiles and leathers, metals, glasses, inorganic, and hazardous [25].

The plastic items were separated and dried at 85 °C (oven Memmert UN110-Germany, ± 0.5 °C) to constant the weight. Then, the plastic was categorized according to its consumables [22, 26]. The gathered plastic was weighed by the analytical balance (OHAUS PAJ2102-USA, ± 0.01 g).

2.2.4. Data Analysis

The collected data were inputted and summarized by MS Excel. Then, ANOVA analysis was performed to find out the differences in plastic composition between sampling locations and the differences of plastic types from each other by Duncan's test at the 5 % significance level of IBM SPSS Statistics 20 software.

3. RESULT AND DISCUSSION

3.1. Total Sample Weight

Figure 3 shows the weight of solid waste collected at 4 sites in each district of Can Tho city over the two sampling periods in April 2021. Overall, the weight of solid waste collected at each site reached the representative weight according to evaluation standards. The average weight of solid waste collected is 92.93 ± 3.20 kg in Ninh Kieu district, and 100.94 ± 7.05 kg in Cai Rang district. The collected solid waste weights are suitable to the requirement quantity of 100 kg that stated from the TCVN 9461:2012 Solid waste - Composition of untreated municipal solid waste.

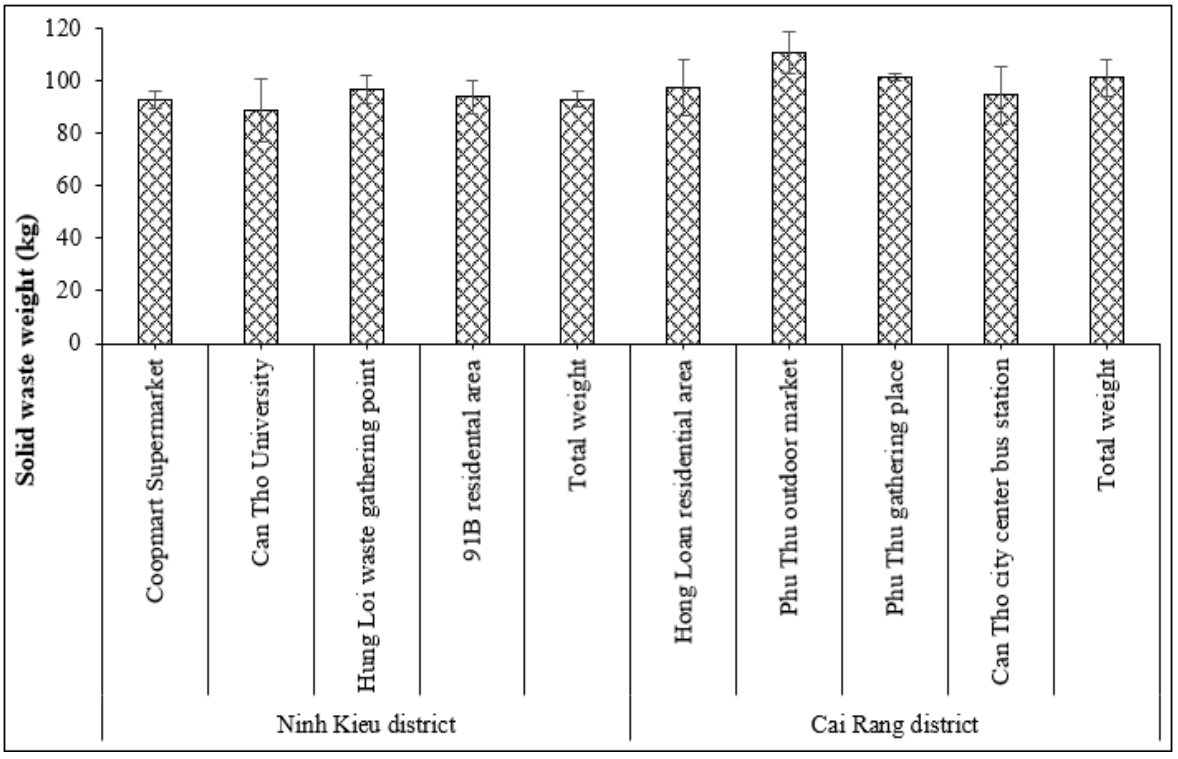

Figure 3. The weight of trash collected from sampling points.

3.2. Ratio of Plastic

Figure 4 shows the ratio of solid waste components from eight collection locations, in which the organic is recorded as the highest part at each sampling location. The organic component ranged from 60.81 to 88.76 % (76.09 ± 12.60 %) in Ninh Kieu district, and from 59.46 to 83.67 % (73.02 ± 10.08 %) in Cai Rang district. Notably, the next component is plastic that account 14.89 ± 10.35 % of the total solid waste weight in Ninh Kieu district, higher than 6.82 ± 3.78 % in Cai Rang district. The results show that in Can Tho city, the capital district of Ninh Kieu has higher emission ratios of organic and plastic compared to the suburban district of Cai Rang. Counting both districts, plastic composition accounts for 10.86 % which is consistent to previous study given that plastic waste and plastic bags account for about 10.00 % of total waste generated by humans [2]. Other studies analyzed the recyclable urban waste components and recorded the proportion of plastic waste in Can Tho city accounted for 6.13

%, similarly to Hue of 6.00 %, but lower than other places such as Hoi An (from 8.40 to 14.00 %), Ha Noi (8.00 %), Ho Chi Minh City 16.00 % [27], and Thanh Ha district in Hai Duong province (7.96 %) [28]. According to data from the Department of Natural Resources and Environment of Can Tho City, by 2022, the rate of urban solid waste collection and treatment reached 98.50 % with a volume of 238,673.5 tons/year, or an average of about 653.9 tons/day [29]. It is forecasted that by 2025, the total amount of daily life solid waste generated on average will be more than 900.0 tons [30]. Thus, from research data, with the proportion of plastic accounting for 10.86 % of the total amount of waste, currently Can Tho city discard an average 71.01 tons of plastic every day and 25,919.94 tons/year, and it will be 97.74 tons/day by 2025.

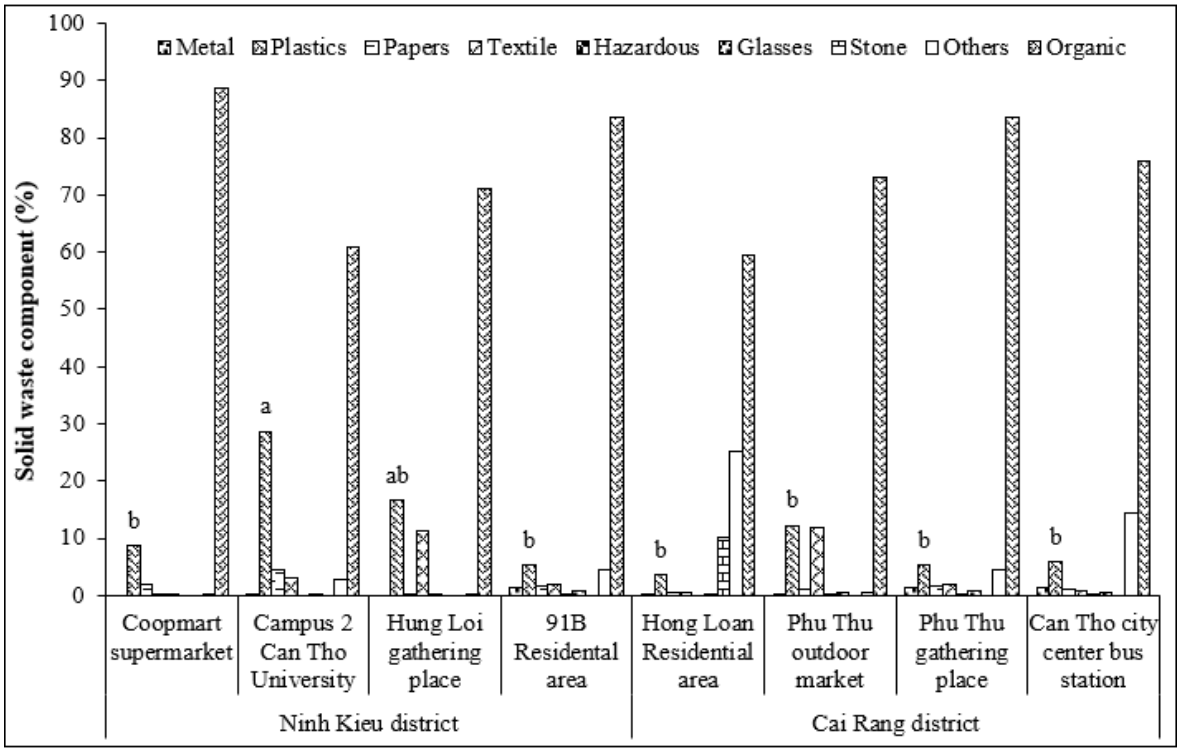

Figure 4. Ratio of waste components.

Note: Columns with at least 1 similar letter is not significantly different at the 5 % level by Duncan's test.

Plastic composition in Ninh Kieu district varied at four sampling locations, from 5.42 to 28.72 %. The waste sample collected at Can Tho University had the highest plastic component of 28.72 %, while the lowest plastic composition was recorded at the 91B Residential area (5.24 %). In the campus of Can Tho University, the garbage is obtained from students' occasional littering, in which plastic pieces are single-use items of the take-away food or drink containers. In previous survey also at Can Tho University in 2021, the volume of plastic waste only accounts for 11.40 % [31], while it accounted up to 20.00 % at the office area in Thuong Cat ward, Ha Noi city [32]. The plastic ratio in the 91B Residential area reached 5.24 %, which is 2 times smaller than the plastic ratio of 10.60 % in the residential area at Thuong Cat ward in Ha Noi city [32]. At the Hung Loi waste gathering location, the plastic composition accounting 16.69 % is the second highest among the four sampling locations in Ninh Kieu district. This ratio approximately the same as the plastic composition of 19.00 % at free residential landfills, of 18.00 % at waste gathering location, but smaller in the landfills of 23.00 % compared to the report of World Wide Fund for Nature [33]. At the Coopmart supermarket, the plastic ratios of 8.75 % is lower than the plastic composition of 22.90 % in the market and supermarkets in Ha Noi [34].

In Cai Rang district, largest plastic component of 12.32 % recorded at Phu Thu outdoor market. This ratio lower than the composition of plastic waste in the market and supermarkets in Ha Noi accounted for 22.90 % [34]. Next, the plastic composition at the Can Tho city center bus station reached 5.83 %, lower than the ratio of 13.50 % at the

public area in Thuong Cat ward, Ha Noi city [32]. At the Phu Thu waste gathering location, plastic component accounted for 5.42 % that much smaller than the previous survey data at the free residential landfill accounts of 19.00 %, the waste gathering location accounts of 18.00 %, and the landfill accounts of 23.00 % [33]. The plastic composition in Hong Loan Residential area is the smallest and accounting for 3.72 %, nearly three times lower than the rate of plastic waste at residential areas in Thuong Cat ward, Ha Noi city of 10.60 % [32].

In general, the plastic composition at sampling site of Can Tho University and Hung Loi waste gathering place is the highest compared to other sampling locations and significant difference at the 5 % level by Duncan's test.

3.3. Characteristics of Plastic

The proportions of plastic at the 8 sampling locations of both Ninh Kieu and Cai Rang districts are shown in Figure 5. In general, the type of emitted plastics was varied depending on the characteristics of the emission source.

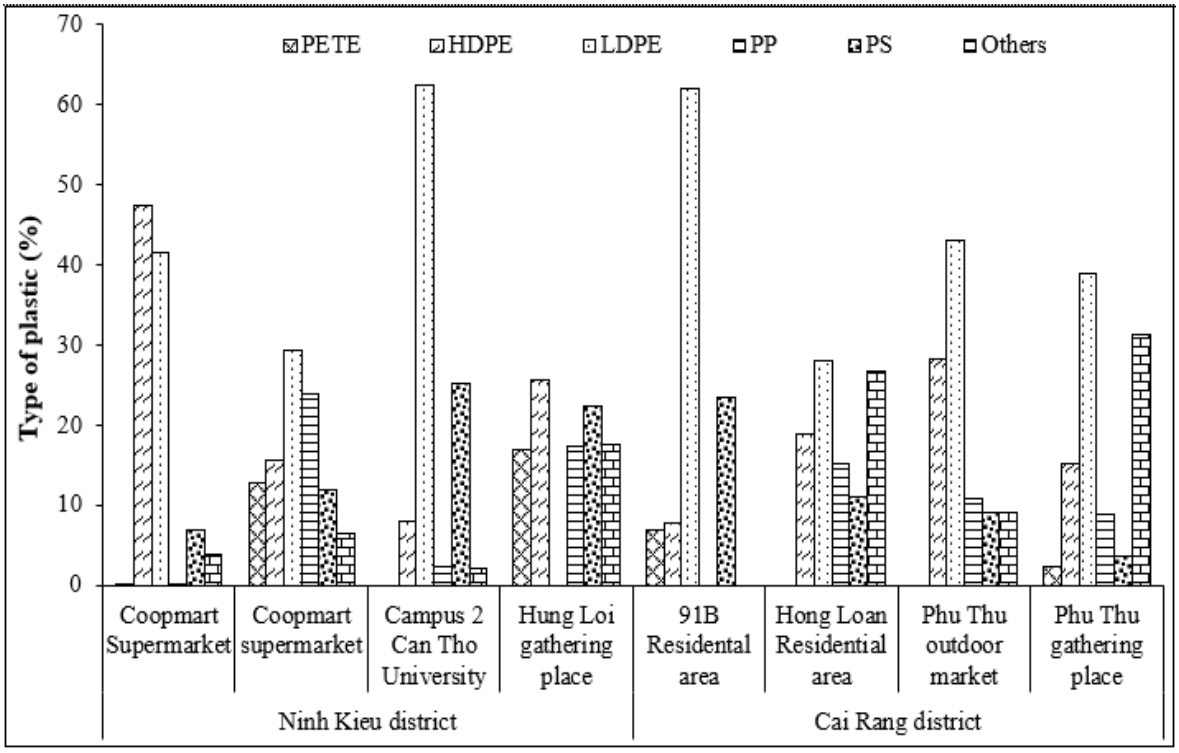

Figure 5. Types of plastic emissions.

As shown in Figure 5, in Ninh Kieu district, the sampling site at Can Tho University shows a full range of plastic components. In which, LDPE plastic is the highest ratio of 29.36 % that found in plastic bags containing of food and drink, similarly to the situation of using 29.00 % plastic products in Thu Dau Mot city [35]. Next is the PP plastic which accounts for 23.85% in plastic cups for takeaway drinks, compared to 29.00 % of plastic cups in Thu Dau Mot city [35]. Other types of PS, HDPE and PETE plastics accounted for 11.93 %, 15.60 % and 12.84 %, respectively. Single-use items are made from the mentioned plastics such as foam boxes, straws, drinking water bottles of all kinds. Among these plastics, PETE from drinking water bottles of all kinds is sold as scrap by plastic waste collectors. However, in the closed campus of Can Tho University, it is difficult for collectors to pick up the bottles, so this plastic pieces accounts for a large proportion of 12.84 % compared to the remaining sampling locations in Ninh Kieu district, except the sampling location at the 91B Residential area of 17.00 %. Comparing to Cai Rang district, all four sampling locations recorded the PETE composition very low from 1.46 to 2.23 %, even there are two sampling locations in Phu Thu outdoor market and Phu Thu waste gathering location did not find the PETE components. At Coopmart supermarket in Ninh Kieu district, the HDPE and LDPE plastic components are dominant

compared to the remaining plastic components, respectively of 47.44 % and 41.51 % compared to other plastic components. These types of plastics are found in hard bottles, grocery bags and plastic bags. Especially, at Hung Loi waste gathering location, the LDPE plastic composition is very high (62.52 %) including common plastic bags that accounts more than half of the plastic composition and following by the second most popular PS resin composition of 25.19 %. At the 91B Residential area, the plastic composition is also diverse and most of them have resins such as PETE, HDPE, PP and PS with nearly equal proportions.

Similarly, in Cai Rang district, the LDPE component was dominant over other resins at all four sampling sites. At the Phu Thu outdoor market, the plastic components are relatively uniform among the four types of HDPE, LDPE, PP and PS. Particularly, at the sample collection location at Can Tho Bus station, the other plastic composition was very high (31.25 %), this is the mixed plastic found in the damaged and discarded car lampshade. The PETE is very rare to found in all four sampling sites, except the Hong Loan Residential area reached to 6.89 %.

3.3. Ratio of Types of Plastic

By calculate the level of emitted plastics by administrative unit (Figures 6), the LDPE has the highest emission rate compared to other plastics in both Ninh Kieu and Cai Rang districts, from 33.35 to 43.00 %, respectively. Next, the HDPE plastic ranked 2nd in terms of composition, accounting for 24.13 % in Ninh Kieu district, while in Cai Rang district the 2nd component was other plastics of 36.41 %, and the HDPE ranked 4th accounting for 17.50 %. In Cai Rang district, the PS and PP ratios are 11.76 % and 8.73 %, but in Ninh Kieu district is 16.59 % and 10.92 % respectively.

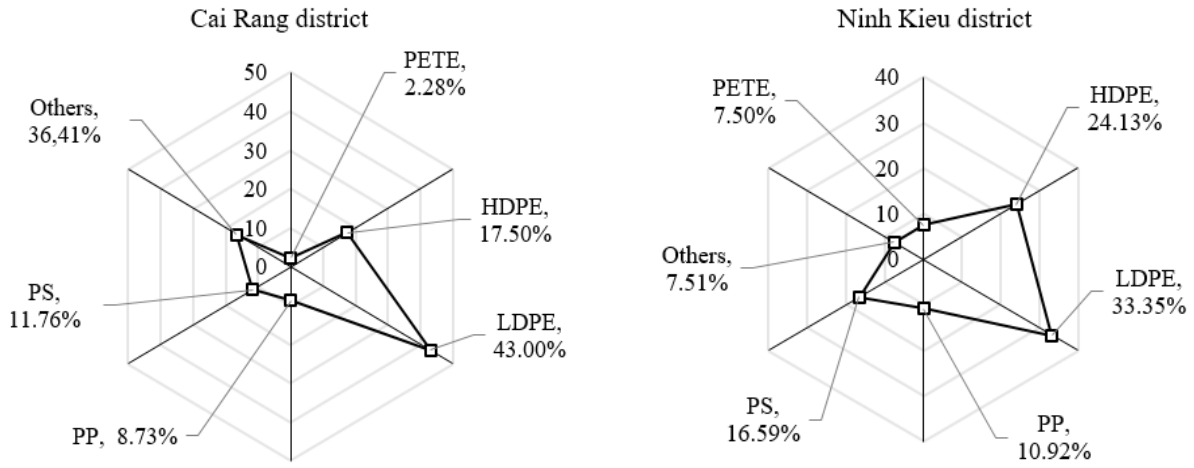

Figure 6. Ratio of plastic types.

In Vietnam, plastic bags are recycled to produce plastic stone to replace of aggregate component within pour concrete for construction works by Nguyen Dinh Duong [36]. In addition, the LDPE was added to hot asphalt concrete and studied on mechanical parameters of concrete in the laboratory [37], using plastic waste as an additive to enhance the mechanical properties of asphalt concrete [38], and evaluate the effect of waste nylon on the elastic modulus of asphalt concrete [39]. PETE waste plastic is applied in hot asphalt in Ho Chi Minh City to improve the mixture properties, improve the working quality of asphalt pavement [40]. According to a World Bank report (2019), Vietnam recycles about 33.00 % of plastics, in which, PETE packaging has the highest recycling collection rate among all plastics [41]. Another report by the Global Plastics Action Partnership in 2022 states that about 10.00 to 15.00 % of Vietnam's plastic waste is collected for recycling [42].

The overall emission for Can Tho city shows that LDPE plastic is the highest (accounting for 38.17 %) and has a significant difference at the 5 % level by Duncan's test in all 7 types of plastic (Figure 7). In contrast, PETE plastic is the lowest (accounting for 4.89 %) with a significant difference at the 5 % level compared to HDPE and LDPE plastics, but not a significant difference at the 5 % level by Duncan's test compared to PP plastic, PS plastic, and

other plastics. Next, HDPE plastic accounted of 20.81 % significantly different from LDPE and PETE plastics but not different from PP plastic, PS plastic, and other plastics at the 5 % level by Duncan's test. Meanwhile, PP plastic, PS plastic, and other plastics have not significantly different from each other at the 5 % level by Duncan's test, accounting for 9.83 %, 14.12 %, and 12.12 %, respectively. From the results, the ratio of recyclable plastics including PETE and HDPE account for 25.70 %. Normally, the LDPE and PVC plastics are used to produce plastic bags, grocery bags [22, 26]. However, the LDPE and PVC plastics can also be recycled (accounting for 38.17 %, without PVC plastic in this study), but must require some specific conditions according to the guidance of Mertes [22]. Therefore, the total plastic ratio which can be recycled (PETE, HDPE, and LDPE) is up to 63.88 %. In contrast, completely non-recyclable plastics (PS, PP, and others) accounted for 36.12 %. According to another study on assessment of plastic waste generation and its potential recycling of household solid waste in Can Tho City in 2010, the proportion of recyclable plastic waste accounts for 11.00 %, including plastic packaging and plastic containers (95.64 %), and plastic shopping bags accounting for 45.72 % of total plastic waste [43].

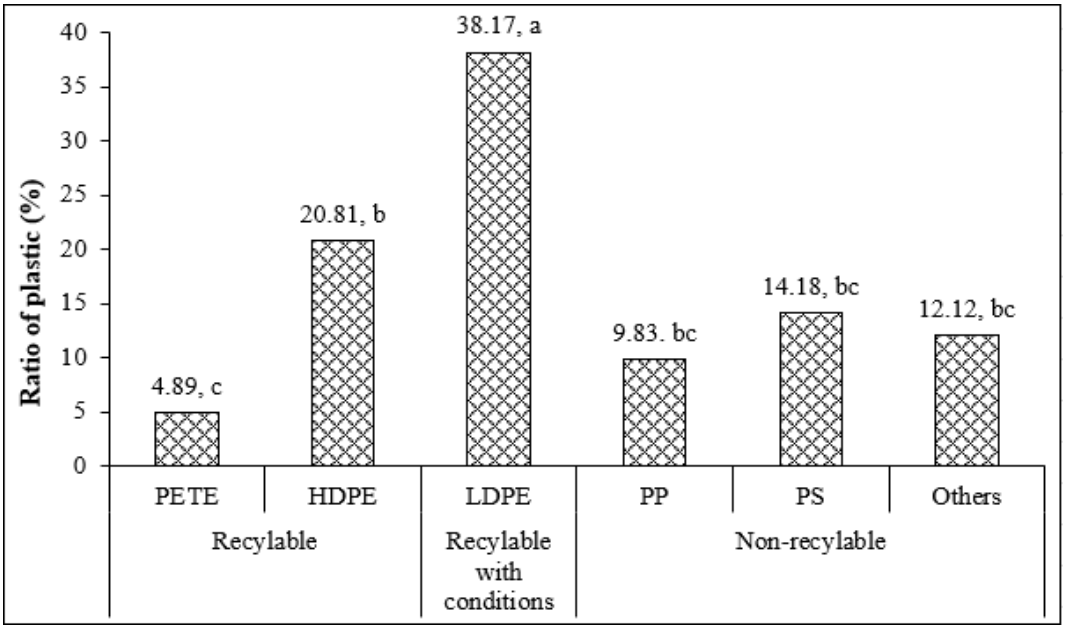

Figure 7. Ratio of recyclable plastic and non-recyclable plastic.

Note: Columns with at least 1 similar letter is not significantly different at the 5 % level by Duncan's test.

CONCLUSION

In summary, the total amount of recyclable waste plastic in Can Tho city reaches 63.88 % and is 1.5 times higher than the amount of non-recyclable plastic. It is found that LDPE plastic is highest portion with the recyclable plastic group, while PETE plastic is less commonly found due to it was collected and sold as scrap at emitted source. From the results, big quantity of recycled plastic in Can Tho city can be suitable for circular economy model because it both prolongs the product life cycle, reduces waste generation, and minimizes the impact on the environment.

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