

Generation Characteristics of Solid Waste and Plastic Waste: A Case Study in Long An Highschool

Nguyen Thi Tinh Au¹, Dang Viet Hung², Hoang Thi Tuyet Nhung^{1,*}

¹Ho Chi Minh City University of Technology and Education, Vietnam

²University of Technology, Vietnam National University-Ho Chi Minh City, Vietnam

*Corresponding author. Email: nhunghtt@hcmute.edu.vn

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ABSTRACT

Long An High School in Tan An, Long An, Vietnam, undertook a study to examine the generation and physical composition of solid and plastic waste. The study sampled 899 individuals, including officers, students, and teachers. Solid waste was classified into five primary categories and established three subcategories for plastic waste. The results showed that the average daily waste generation rate at Long An High School is 0.13 kg per student, including out-boarders who generate 0.028 kg per student, and boarding and part-boarding students who generate 0.18 kg/person/day. This rate is marginally lower than the waste generation rates observed in households. The analysis of plastic waste at the school indicated that it comprised 31% (35.65 kg/day) of the overall refuse generated. Boarding and part-boarding pupils generate a daily plastic waste generation rate of 0.055 kg, while out-boarders generate 0.01 kg per person. Long An Specialized High School receives recyclable plastic (46.5%), nylon bags (35.3%), and non-biodegradable polystyrene (foam delivery packaging) (18.2%) as its primary waste materials. Due to their lack of classification, these wastes are challenging to recycle. In terms of refuse generation per capita, male students produce 0.17 kg per male per day, while female students generate 0.15 kg per female per day, on average. Male students have an average discharge of 0.051 kg/male/day, which is 0.039 kg/female/day higher than female students' average discharges. In the case of plastic No. 6 (foam delivery boxes), male pupils emit three times more than female students.

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1. Introduction

Currently, the majority of countries around the globe are experiencing a waste crisis, including Vietnam. In 2021, the world produced 353 million tons of plastic waste, but only 9% was recycled, 19% was destroyed, and nearly 50% was buried in qualified landfills. In addition, 22% of plastic waste was treated at improper landfills, burned at open-air landfills, or leaked into the environment, and the remainder was released into the natural environment [1], [2]. The majority of the 1.8 million tons of plastic waste produced annually in Vietnam is plastic bags. According to a report published by the Ministry of Industry and Trade of Vietnam in February 2022, each Vietnamese household uses approximately one kilogram of plastic bags per month, of which more than 80 percent are discarded after a single use. Vietnam's per capita plastic consumption has increased by 41.3 kg in the past 28 years, from 3.8 kg. In particular, the daily accumulation of single-use plastic that cannot be recycled and must be interred reaches 80 tons in Hanoi and Ho Chi Minh City, the two largest cities in Vietnam [3], [4]. There are preparations underway to eliminate single-use plastic from convenience stores, supermarkets, and urban markets by 2021, and the entire nation by 2025. Single-use plastic waste has direct effects on life quality, human health, and other forms of life [5]. The non-biodegradable nature of plastic waste poses the greatest threat. Even when buried in the mud, they persist for hundreds of years, altering the physical properties of the soil, causing soil erosion, rendering the soil incapable of retaining water and nutrients, and preventing oxygen from passing through the soil, thereby inhibiting the growth of plants,

species, etc.[6]. Plastic products are inextricably linked to the fossil fuel industry; therefore, the extraction and transport of fossil fuels release carbon into the atmosphere, exacerbating global warming. Numerous nations have realized that protecting the environment means safeguarding their own lives. In addition to bans on single-use plastics by government policy tool, combating plastic pollution requires a sense of community involvement and personal accountability.

Numerous waste management strategies were required to address the management of solid waste and plastic waste [7], [8]. However, policymakers in Vietnam frequently fail to allocate sufficient attention to the educational sector. Educational institutions are densely populated areas where the quantity of solid refuse is frequently underestimated or not reported, and collection infrastructure is virtually non-existent. Establishing a waste management system in educational settings not only guarantees students access to clean and hygienic surroundings but also cultivates a deeper understanding of sustainable practices, shaping their attitudes towards future pursuits such as housing and employment [9]. Data regarding the generation of solid refuse and plastic waste in the schools of Tan An, Long An are currently unavailable. We lack precise data regarding the origins and qualities of the produced refuse. However, the stakeholders bear responsibilities for school waste management, which has led to the absence of adequate guidelines for solid refuse management in schools. The audit's objective was to establish fundamental data regarding the rates of solid waste and plastic waste production, as well as their composition and quantity, at a sample of schools in the Long An region. Additionally, the study aimed to evaluate the current campus waste management practices and provide suitable suggestions. As a result, feasible and suitable alternatives that identify specific and locally relevant prospects for waste reduction, reuse, and recycling can emerge, constituting a significant stride towards environmentally sustainable and health-conscious educational institutions.

2. Materials and Methods

2.1. Study location.

Long An Specialized High School was established on December 28, 2009, in accordance with Decision No. 2774/QĐ - People's Committee of Long An Province, on a total area of 38,457.31 m² located at 112 Nguyen Minh Duong Street, Ward 4, Tan An, Long An Province.

There are 148 rooms (6 floors) in the dormitory area, of which 140 are student rooms and 8 are administrative offices for faculty and staff. Canteen with a maximum capacity of 300 individuals.

In the school year 2022-2023, the total number of teachers, staff, and students is 899, comprised of 76 teachers and officials and staffs, 14 employees, and 809 students. 581 students out of 809 are residing in boarding and part-boarding dorms (355 girls and 226 boys). There are 350 boarding students and 231 part-boarding students.

2.2. Current status of Long An Specialized High School's waste generation and management

The total amount of solid waste generated by the school, including three areas: The majority of the waste from the dormitory, canteen, and school (classroom and school yard waste) consists of organic waste, such as leaves and leftovers, and inorganic waste, such as paper, paper boxes, aluminum cans, plastic bottles, nylon bags, foam takeaway boxes, etc. Unsorted garbage. Students use a large number of disposable containers, non-biodegradable foam takeaway boxes to eat in the classroom, etc., so the amount of plastic waste is typically quite high (qualitative).

Garbage from dorms

Each dormitory room has its own trash can; trash is not separated. Some students have engaged in waste recycling for the purpose of selling them. Students collect all garbage in their room at the end of the day or when the bins are full and transport it to the dormitory's dump site. The amount of waste plastic that is disposable is quite high (qualitative). The school's cleaning staff will separate recyclables and non-recyclables prior to the garbage truck's daily collection at 1:30 p.m.

Canteen garbage

Contractors sort canteen waste to separate food scraps for use as fish food (farm raised outside the school). Recyclables and nonrecyclables are separated from dormitory and school waste and placed in the trash for collection.



Figure 1. The canteen area categorizes leftovers for use as fish food (students sort themselves from the tray)

Figure 2. Remaining garbage (in addition to the leftovers put in the sorting bin, the remaining garbage is disposed of in the large trash bin)

Classroom waste

The waste from classrooms is collected in 15L trash cans located in the hallway outside each classroom. The students transport them (as assigned daily) to the large trash cans in the schoolyard at the end of the school day or when the bin is full. The cleaning staff sweeps and collects leaves in a separate bin, but parks them all together in the garbage collection vehicle of the public service provider.

2.3. Solid waste audit methods

Garbage is collected from the garbage dump site (located in the dormitory) and waste bins in the canteen and on the schoolyard.

Dormitory solid waste: randomly sample 30 dorm rooms (15 male rooms and 15 female rooms) and collect their trash in a separate container for classification. On each sample, the following information is recorded: male/female room, number of rooms, number of people, and sampling date. Weigh and classify the amount of waste generated by 30 randomly selected rooms. Determine the total volume of garbage in the dormitory by weighing the entire amount of waste, including a representative sample.

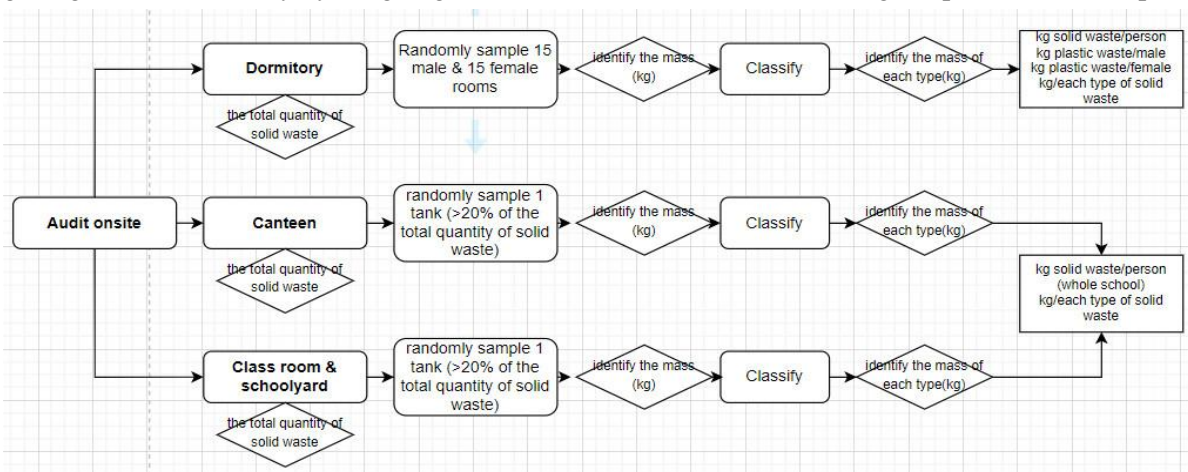


Figure 3. Solid waste audit chart

For solid waste in the canteen and in classroom: Weigh the entire daily amount of waste in both areas, then randomly select one trash bin from each area (ensuring that the quantity is greater than 20%) for auditing. Weigh the volume of garbage in each container, then pour the garbage from each container onto a tarp, and then sort it.

Four types of waste exist: organic waste, hazardous waste, recyclable waste, and residual waste. In the plastic waste group, separate plastic classification and a comprehensive audit of plastics, with a focus on single-use plastic waste, are required (styrofoam takeaway boxes, plastic bottles, plastic cups, straws, etc.)

2.4. Online survey

Part 1: Information regarding survey participants: grade, gender, residence

Part 2: The extent and location of food use

Situation regarding waste single-use plastics

Sorting garbage and using single-use plastic as a habit

Awareness of disposable plastic

3. Results and Discussion

3.1. Weight and composition of generated solid waste.

3.1.1. Solid waste audit of the entire school

According to audited data statistics, the entire school generates an average of 115.1 kg of waste per day, with a total of 899 people, including 76 teachers and staff; and 14 employees; 809 students. 581 (71.8%) of the 809 students were boarding/part -boarding students, while 228 (28.2%) were outboard students. The average per capita school rate is calculated to be 0.13 kg/person/day. However, this is an average that includes both boarding/part -boarding student and outboarding students, i.e. the number of students staying all day and the number of people students staying at home without lunch are average calculated together, so this number is inadequate. To more precisely distinguish the separate means for boarding/part -boarding and outboarding, we have detailed analysis in *Figure 9*.

Table 1. Solid waste audit results for the entire school (including dormitory, canteen and classroom)

No.	Solid waste types	Weight, kg/day	kg/person/day	% (w/w)
1	Total solid waste	115.1	0.13	100
2	Organic solid waste	27.3	0.030	23.7
3	Hazardous solid waste	0.5	0.001	0.4
4	Recyclable solid waste	41.3	0.046	35.9
5	Residual solid waste	46.0	0.051	40

The auditing process sorts waste into four types: organic waste, hazardous waste, recyclable waste, and residual waste [10]. Organic waste represented 23.7% (27.3 kg/day), recyclable waste represented 35.9% (41.3 kg/day), and non-recyclable waste represented 40% (46 kg/day), hazardous waste accounts for nearly 0.4% (0.5kg/day) (Table 1). In the audit procedure, organic waste includes a portion of leftovers with water and high humidity, resulting in a hefty weight. Although leaves from the school and dormitory premises are organic waste, they are not included in the organic waste statistics because of separate collection. The leaves for the entire school were audited at a daily rate of 1.83 kilograms. Paper, aluminum cans, PET (drinking water bottles), HPDE, and PP are included in the classification of recyclable waste. Nylon plastic is also classified separately but is included in the group of recyclable plastics. PS plastic group (primarily foam takeaway boxes) is categorized as residual plastic (non-recyclable).

Each area (dorm, classroom, and canteen) generates a different amount of waste. In the dormitory area, the highest amount of waste generated is 89.44kg/day, including organic waste 24.29kg/day (27%), recyclable waste 30.02kg/day (33.4%), and hazardous waste 0.48 kg/day (0.5%), with the residual waste amounting to 35.14kg/day (39.1%) (Figure 4). The results of the online survey, completed by 465 students (42.1% are boarders and 31.5% are part-boarders), are consistent with the measured results. These are the two groups of students who frequently stay in the dormitory and frequently bring food to

eat at the dormitory (45% of respondents). The dormitory generates the greatest amount of waste compared to the other two areas.

For classroom waste, the average daily discharge is 17.6 kg, with recyclable waste such as milk cartons, paper, plastic water bottles (9.01 kg/day), organic waste, etc. accounting for a small amount (1.13 kg/day) (Figure 4). The majority of boarding/part-boarding students eat in the dormitory, out-boarders eat at home, and the canteen has a place to discharge leftover food. Therefore, almost no leftover food is in the classroom; instead, it is mainly recyclable waste and disposable plastic.

The average amount of waste generated in the canteen area is only 8.0 kg per day, with non-recyclable waste accounting for 3.81 kg/day. Leftover food from the canteen is separated and used to make fish food, so organic waste is negligible, at 1.92 kg/day. The daily number of recyclables is 2.27 kilograms, the majority of which consists of plastic bottles, plastic cups, and plastic straws (Figure 4).

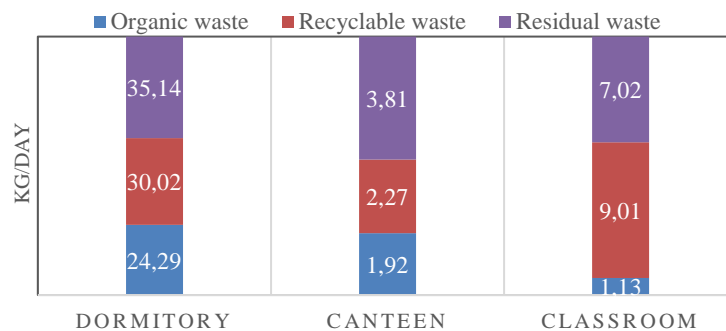


Figure 4. Waste classification of Long An Specialized High School according to three areas

According to audit results, the average total amount of plastic waste in the entire school is 35.65 kg/day (representing 31%), of which plastic waste generated from dormitory accounts for 75% (26.77 kg/day) (Figure 5). These results are relevant to 71.8% of students who reside in boarding or part-boarding. Some students bring food to class, which accounts for 19% of the classroom’s plastic waste (6.59 kg/day). Comparatively, only 6% (2.29 kg/day) of the plastic waste in the canteen is due to students buy food to eat at the dormitory and in class (23.2% of respondents eat in class) (Figure 6).

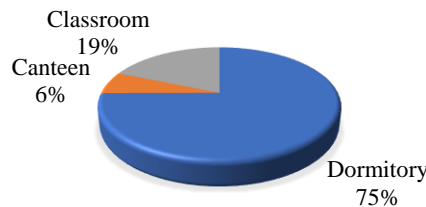


Figure 5. Plastic waste percentage in Long An Specialized High School according to three areas.

In a survey of 465 students regarding plastic waste disposal (including plastic bottles, nylon bags, foam takeaway boxes, plastic cups, and plastic straws), 54.1% dispose of 1-2 items per day, 42.4% dispose of 2-5 items per day, 2% dispose of 5-10 items per day, and 1.5% dispose of more than 10 items per day.

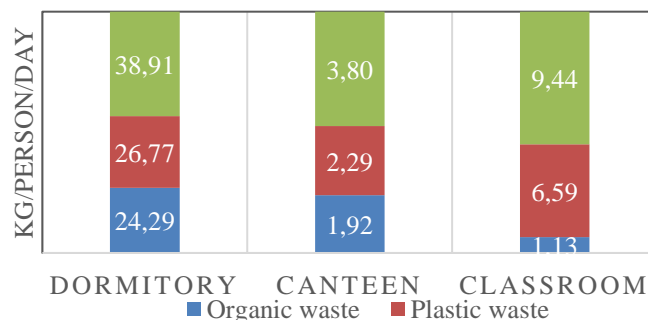


Figure 6. Plastic waste classification of Long An Specialized High School according to three areas

Plastic waste constitutes a relatively high proportion of waste in school areas, so it is also classified during the auditing process. According to the audit chart, recycled plastics (such as PET, HDPE, and PP) comprised a significant portion of the school’s areas. Among the types of plastic waste classified by label (Figure 7), recycled plastic (No. 1 PET, No. 2 HDPE, and No. 5 PP) has the greatest quantity, with an average emission of 16.6 kg/day (46.5%), followed by No. 4 LDPE plastic (primarily nylon) with an average emission of 12.6 kg/day (35.3%), and the least is No. 6 PS (foam takeaway boxes) with 6.50kg/day (18.2%).

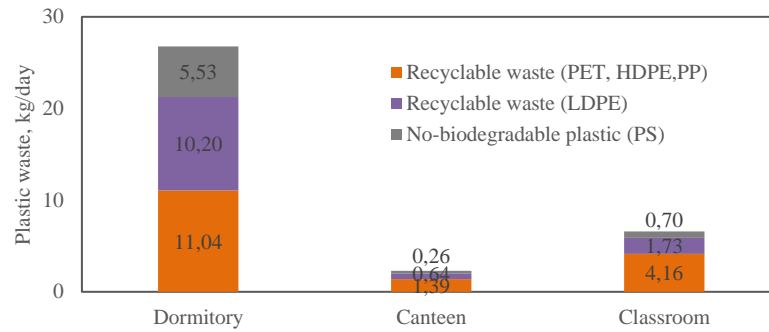


Figure 7. Plastic waste classification of Long An Specialized High School according to types of plastic

In the dormitory area, recycled plastic accounts for 41.2% of the total dormitory plastic (11.04 kg/day), nylon bags for 38.1% (10.2 kg/day), and foam takeaway boxes for 20.6% (5.53 kg/day). In the classroom area, recycled plastic (primarily PET bottles) represented 60.6% (4.21 kg/day), nylon represented 28.0% (1.75 kg/day), and foam takeaway boxes represented at least 11.4% (0.14 kg/day). The canteen has a low volume of foam takeaway boxes (0.26 kg/day) because most students use aluminum trays when eating in the canteen. Most students who use single-use plastic buy food to eat at the dorms, so the number of foam takeaway boxes in the dorms is extremely high.

Table 2. Waste audits by student residence

	Average waste generation kg/person/day	Average plastic waste generation kg/person/day	Recyclable plastic waste (PET, HDPE, PP) kg/person/day	Recyclable plastic waste (LDPE) kg/person/day	Non-biodegradable plastic waste (PS) kg/person/day
boarding/ part-boarding	0.18	0.055	0.025	0.020	0.010
Out-boarding	0.028	0.01	0.006	0.003	0.001

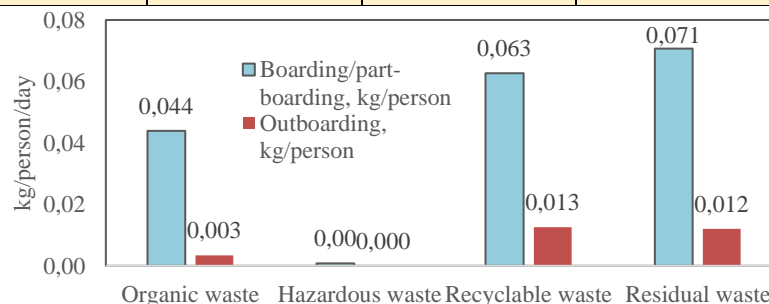


Figure 8. Solid waste rate of students according to students’ residence (kg/person/day)

As the proportion of boarding or part-boarding students is significantly greater than that of out-boarding students (71.8% versus 28.2%), the amount of waste in the dormitory area is significantly greater. The analysis in Table 2 and Figure 8 makes this abundantly clear. According to students’ residence types, the boarding/part-boarding group generates 0.18 kg/ person/day, while the outboarding group generates 0.12 kg/person/day on average. More than 65 percent of students regularly or occasionally buys food from outside the school or from the canteen to the dorm, so the amount of

waste produced by the group of boarding/part-boarding increases. The outboarding group buy food from outside school or the canteen infrequently or not at all, preferring to eat at home. As a result, the average amount of waste produced per person per day is only 0.02 kilograms.

The average amount of plastic waste generated per capita in an entire school is 0.032 kg/person/day. However, the boarding/part-boarding group spends more time at school than the outboarding group, their rate is greater. The boarding/part-boarding group generated waste plastic at a rate of 0.055kg/person/day, while the outboarding group generated waste plastic at a rate of 0.010kg/person/day (Figure 9). The average incidence of the boarding/part-boarding group is also significantly higher because the boarding/part-boarding uses disposable containers for daily meals, whereas the outboarding group does not eat breakfast, lunch, or dinner at the school.

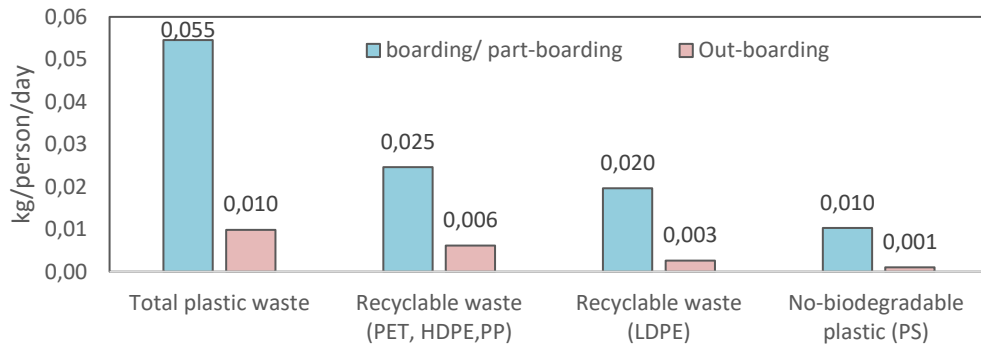


Figure 9. Plastic waste rate of students according to students' residence (kg/person/day)

3.1.2. Assessment of dormitory area waste by gender

Due to the features of the dormitory, 71.8% of boarding/part-boarding students do not cook, relying on fully prepared food from the canteen or elsewhere outside of the school. As a result, this section of the school generates the most waste. Therefore, it is necessary to evaluate and compare the differences in discharge rates between boarders/part-boarders and out-boarders, as well as between males and females.

581 boarders/part-boarders are comprised of 226 male students (representing 38.9%) and 355 female students (representing 61.1%). On average, male students produce more waste than female students, 0.17kg/male/day versus 0.15kg/female/day, respectively. According to the survey results, male students consume soft drinks frequently (such as Coca Cola, Sting, Oolong Tea...). Therefore, the male dormitory contains more plastic bottles and foam takeaway boxes, while the female dormitory contains more milk cartons. Figure 10 demonstrates that the amount of organic waste discharged by male and female students is comparable. However, for recycling and residual waste, the average discharge for male students is 0.056kg/male/day and 0.068kg/male/day, while it is 0.045kg/female/day and 0.051kg/female/day for female students, respectively.

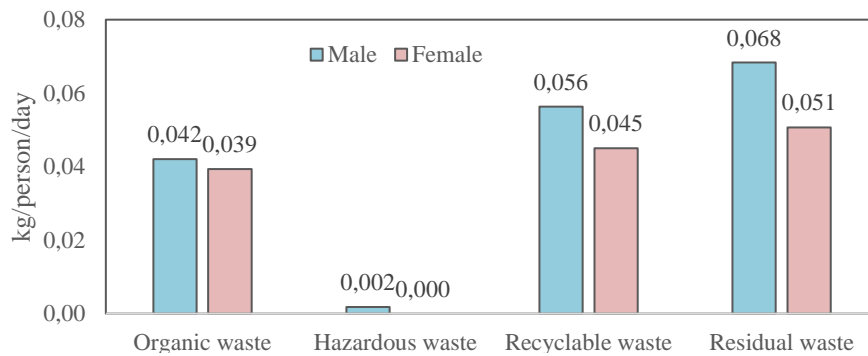


Figure 10. Solid waste rate of students according to students' gender (kg/person/day)

Male and female students have different average rates of plastic domestic waste per capita. The average discharge of male students is 0.051kg/male student/day, which is 0.039kg/female student/day greater than the average discharge of female students. Specifically for plastic No. 6 (styrofoam takeaway

box), male student rates are three times higher than those of female students (Figure 11). According to the results of the survey, the majority of male students bring food to the dormitory to eat in order to facilitate rest and enjoyment. The majority of the food is stored in Styrofoam takeaway containers.

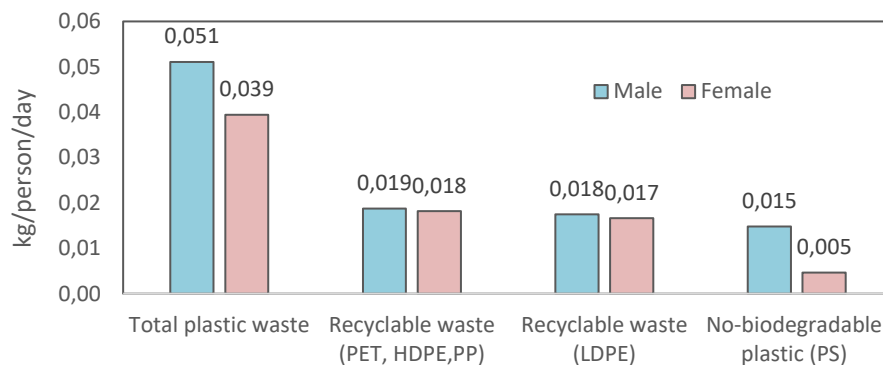


Figure 11. Plastic waste rate of students according to students' gender (kg/person/day)

3.2. Online survey of students' awareness of solid waste

Males accounted for 35.1% of the 465 students who responded to the question about their sense of waste disposal, while females accounted for 64.9%. The configuration of the survey by grade consisted of 10th graders comprising 30.4%, 11th graders comprising 39.7%, and 12th graders comprising 29.9%, with boarding students comprising 42.1%, part-boarding students comprising 34.5%, and outboarding students comprising 23.4%.

In terms of awareness, 88.7% of the 465 students surveyed stated that plastic waste (disposable plastic waste) is a serious environmental issue. However, when asked about their garbage sorting habits, 57.7% of the 456 respondents did not sort their trash, while the remaining 42.3% classified it into two or three categories. Nine respondents did not provide an opinion about this section. This demonstrates that students lack information on waste segregation and are unaware of the necessity of sorting garbage.

455 respondents out of 465 individuals polled answered using single-use plastic, 25.9% not reusing single-use plastics but instead discarding them, 57.1% occasionally reusing plastic bottles, and 16.7% frequently reusing, primarily plastic food containers; the remaining 10 individuals have no opinion. Few young people are interested in reusing packaging such as bottles, jars, and containers, resulting in an increase in plastic waste.

449 students responded to a question regarding their intention to change their habit of using single-use plastic products; 66.4% intended to change, 27.6% were unsure, and 6% did not intend to change. 16 respondents did not comment. It demonstrates that the majority of students are environmentally conscious and willing to participate whenever possible.

In addition, up to 38.6% of respondents believe that the use of single-use plastic products is neither increasing nor decreasing, as there are currently few alternatives available. Although the community's awareness is gradually being raised, there are numerous forms of propaganda encouraging the use of recycled and environmentally friendly products. However, many food establishments continue to use them because they are convenient and inexpensive. This leads to an increasing amount of plastic waste.

3.3. Strategies for effective waste reduction

Based on the audit results and survey data presented above, it is evident that students understand the harmful effects of plastic waste but do not know how to classify trash. Certain students have separated recyclables but not organic waste. Only about one-third of students believe that the amount of plastic waste will decrease in the future as a result of Generation Z's altered awareness and behavior. However, approximately two-thirds of students desire to alter their consumption habits to reduce the impact of single-use plastic products. As a result, it is possible to reduce waste, particularly plastic waste, through the following activities proposed for the Long An specialized school:

Activity 1: Organize propaganda for waste segregation.

Schools should publicize waste separation activities to each class, each student, and organize a week of waste separation in an effort to make it a daily student habit. This activity is made possible by weekly schoolyard meetings involving propaganda.

A poster instructing students on how to sort waste is posted in the bin area. Label each piece of trash with its appropriate classification.

A poster about sorting waste at the source is posted in the bin area. Put a classification label on each garbage item.

Encourage students to bring sorted organic waste to the canteen's sorting box in order to make fish food.

Activity 2: Organize activities to reduce plastic waste through propaganda.

Conducting propaganda and communication activities to increase awareness of solid waste segregation and reduce the use of single-use plastic products, such as propaganda bulletin boards, training in disseminating knowledge about plastic waste, organizing "Green Sunday" activities, urging classes to clean up on a regular basis, and placing trash in the right place even when leaving school.

Encourage students to bring reusable personal items such as reusable water bottles and food containers to reduce the use of single-use plastic items.

The canteen should replace plastic cups, food containers, nylon bags, etc. with more eco-friendly alternatives like paper cups and reusable food containers. Encourage students to eat in the canteen to reduce the use of single-use items, or implement a policy of lending stainless steel food trays to dorm rooms.

Hold a contest to raise awareness of the harmful effects of plastic waste and encourage the reduction of plastic waste.

Organized painting activities to promote the reduction of plastic waste. On the bulletin board, nice paintings are displayed to promote the activity.

Organized a "trash for gift" booth as part of the series of events to commemorate Earth Hour: CLA Green Club set up a plastic waste exchange booth at a school location, where students exchanged recyclables for gifts.

Generally, for state and local officials

To promote student awareness, there should be a garbage sorting vehicle at the entrance to the school to collect separate types of garbage after students have sorted it.

It is necessary to implement policies that encourage people to replace disposable plastic products with eco-friendly alternatives.

Reduce the price of environmentally friendly products to make them more accessible to consumers.

Community education regarding the use and disposal of single-use plastic products.

Limit the production of single-use plastic products by businesses.

There are policies that favor businesses that produce environmentally friendly alternatives to existing products or materials.

4. Conclusions

The results of the first audit conducted from December 6th to December 10th, 2022 indicate that the average daily amount of waste generated is 115.1 kilograms, while the average amount of waste per capita is 0.13 kg/person/day (for the total number of people in the school - 899 students). The average amount of waste produced by boarders and part-boarders is significantly higher than that of out-boarders (0.18 kg/person/day versus 0.028 kg/person/day, respectively).

The audit of plastic waste revealed that this type of waste accounted for 31% (35.65 kg/day) of the school's total waste. 0.055 kg/person/day of plastic waste is generated by boarding/part-boarding students, while 0.01 kg/person/day is generated by out-boarders. The majority of the waste at Long An Specialized High School consists of recyclable plastic (46.5%), nylon bags (35.3%), and non-biodegradable polystyrene (foam takeaway box) (18.2%). These wastes are not classified, so them difficult to recycle.

There are 226 male students (representing 38.9%) and 355 female students (representing 61.1 percent) among 581 boarders/boarders. Male students generate more waste per capita than female students, 0.17kg/male/day versus 0.15kg/female/day on average, respectively. The average discharge of male students is 0.051kg/male/day, which is 0.039kg/female/day greater than the average discharge of female students. Specifically for plastic No. 6 (foam takeaway box), male students' emission rate is three times higher than that of female students.

Since there is no cooking in the dormitory, the amount of organic waste is negligible, but the volume is high due to the organic waste's highwater content, so the rate is 23.7% (27.3 kg/day). The canteen generates a substantial amount of organic waste, which is collected separately for use as fish food. In general, the school's organic waste, including leaves (1.8 kg per day), is insufficient to produce fertilizer as intended.

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Conflict of Interest

The authors declare no conflict of interest

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Nguyen Thi Tinh Au. Major: Utilization and Protection of Environmental Resources. Ph.D. in Institute for Environment and Resources, Vietnam National University Ho Chi Minh City, 2018. She became a lecturer in 2004 after working at ChoongnamVina Company for 6 years as a lab vice manager. From 2013 – currently, Vice Dean of Faculty of Chemical and Food Technology, HCMC University of Technology and Education. Fields of Research: Environmental Management, Climate Change, Natural Resources Assessment: Water, Soil...Email: tinhou@hcmute.edu.vn. ORCID: <https://orcid.org/0000-0003-2409-5705>.



Dang Viet Hung. He was born in Ho Chi Minh City, Vietnam. He got Bachelor in Chemical Engineering at Ho Chi Minh City University of Technology, Vietnam in 1994 and Master degree in Environmental Engineering at Institute for Environment and Resources – Vietnam National University of Ho Chi Minh City in 2000. His PhD degree was at Pukyong National University, Korea. He is a full-time Associate Professor at Faculty of Environment and Natural Resources, University of Technology, Vietnam National University of Ho Chi Minh City. He has studied to apply suitable technologies in wastewater treatment in Vietnam. Email: dvhung70@hcmute.edu.vn. ORCID: <https://orcid.org/0000-0001-7259-7887>



Hoang Thi Tuyet Nhung. She was born in Ho Chi Minh city, Vietnam. She got her Bachelor and Master degree in Environmental technology at Ho Chi Minh City University of Technology in 2005 and 2008, respectively. Her PhD degree was at Ho Chi Minh city Institute for Environment and Resources in 2018. She is a Full-time Lecturer in Environmental Technology at Faculty of Chemical & Food Technology, Ho Chi Minh City University of Technology and Education. She has studied to develop materials for applications in water and wastewater treatment. Email: nhunghtt@hcmute.edu.vn. ORCID: <https://orcid.org/0009-0001-1683-0100>