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Analysis and Characterization of Municipal Solid Wastes Generated in Ifugao State University Potia Campus: A Basis For Planning of Waste Management

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ABSTRACT

The end of the COVID-19 pandemic resulted in the total return of students and employees in Ifugao State University Potia Campus, a higher education institution located in Potia, Alfonso Lista, Ifugao, Philippines. However, the return of the pre-pandemic operations on campus caused problems in managing the generated municipal solid wastes. Hence, an analysis and characterization of the generated municipal solid wastes was conducted to determine important data that can be used for future waste management planning. The generated municipal solid wastes were gathered from the various waste generators within the campus for five consecutive days. The total generated municipal solid waste on the campus was about 140.10 kg.day^{-1}, most of which was contributed by the canteens (20.86%). The generated municipal solid wastes were dominated by biodegradable waste (48.65%) and recyclable waste (37.26%). In addition, most of the generated municipal solid wastes were related to people's food and beverage consumption behavior. The total volume of the MSW generated daily was about 5.647 m^3. It is recommended that the campus create and enforce its waste management plan to specifically address the aforementioned characteristics of the generated municipal solid wastes.

INTRODUCTION

The COVID-19 pandemic has brought about several changes to the municipal solid waste (MSW) generation. Because of the restrictions brought about by the pandemic, most people were forced into confinement within the safety of their homes. As such, the bulk of MSW generation in communities has shifted from institutional, industrial, and commercial to residential, as evident in several studies (Ngohayon & Tulagan 2022, Roy et al. 2021, Sinha et al. 2020). Post-pandemic, people are free to go anywhere after the restrictions were lifted, given the lowered risk of contracting COVID-19. As such, the MSW generation is expected to change again. Hence, it is important to develop or improve existing waste management plans to address the changes in the MSW generation.

The Ifugao State University (IFSU) Potia Campus, a higher education institution in the municipality of Potia, Alfonso Lista, Ifugao, Philippines, had similarly experienced the aforementioned effects of the COVID-19 pandemic. Because of the pandemic, all the students were sent home, while only a few employees were allowed to work under a rotational schedule. Since the pandemic has ended, the campus population has grown to about 3900 people. Of this number, about 4.6% constitutes the employees, while the rest are the students (IFSU Potia Campus Human Resource and Development Office & Registrar's Office, personal communication, January 18, 2023). With this increase in population, it is also expected that there will be changes in the MSW generation within the campus.

Currently, the campus is experiencing the following problems regarding MSW management: (1) No engineered and centralized MSW storage facility exists. While there is a designated temporary storage location for the generated MSW before its collection and disposal, the capacity is insufficient, and other environmental factors were not considered. This is evident by the many tattered trash bags and littered trash around the storage location, ravaged by scavenging animals or the heavy rain. (2) Lack of proper waste segregation among the campus constituents. This is primarily due to insufficient trash cans designated for each type of waste. Hence, people would unthinkingly dump waste in the nearest available trash can. This can also be attributed to the lack of environmental awareness among the people. Therefore, even if there are some designated trash cans for each type of waste, waste segregation is still not adequately practiced, as evidenced by the prevalence of mixed waste. (3) The lack of treatment facilities. The

campus has no compost pits to dispose of its biodegradable wastes. Hence, biodegradable wastes were thrown into the ravines. In addition, there are no recycling facilities nor any market for recycled products within the community. Thus, the recyclable wastes are also being disposed of in the community's sanitary landfill. (4) Lack of institutional policies to address the generated MSW. While national laws and local ordinances exist, they do not specifically cater to the type of MSW generated on campus. Hence, this also contributes to the prevalence of the aforementioned problems in MSW management.

Clearly, there is a need for the campus to plan an MSW management that can effectively address these aforementioned problems. To do that, it is important to determine the current MSW generation data of the campus. Hence, this study was conducted to determine important MSW generation data, including the MSW generation rate, the amount of generated MSW, the composition of generated MSW, and the volume of generated MSW. The campus can use the results obtained from the study to develop policies for managing its generated MSW. In addition, future researchers can use the study results as a basis for developing interventions, such as projects and campaigns to reduce MSW generation or even utilize the generated MSW.

MATERIALS AND METHODS

The study followed a descriptive research design to determine the MSW generation data of the IFSU Potia Campus. The waste analysis and characterization (WACS) approach used in the study was based on the study of Ngohayon & Tulagan (2022).

The data gathering was conducted in IFSU Potia Campus (shown in Fig. 1). The buildings and areas inside the campus were grouped according to the waste generator classification of EcoGov (2011): (1) Institutional waste generators where people often do office work, meetings, classes, laboratory activities, and to some extent, eating and cleaning. (2) Commercial waste generators, particularly food establishments, where people often do cooking, eating, and cleaning. (3) Recreational waste generators where people often do sports activities and maintenance. The campus leases several agricultural lots. However, these were not included as one of the waste generators as the generated agricultural wastes from these areas are the responsibility of the lessee and not the institution. The summary of the inventory of the waste generators within the institution is listed in Table 1.

Before the data gathering, the generated MSW from the previous days was collected to ensure that each waste generator had empty trash cans. In addition, the various focal persons for each waste generator were briefed for their assistance during the waste collection.

Data were gathered for five consecutive working days from February 20 to February 24, 2023. The institution was working under normal operations during the data gathering such that there were no celebrations, general cleaning, examination, or natural disasters during the aforementioned dates. Empty trash cans with readable labels for each type of waste were distributed in each designated waste generator.

Table 1: The inventory of the waste generators within the IFSU Potia Campus.

Waste Generators	Waste Generator Category*	No. of Buildings/ Area	Daily No. of People**
Administration Building (Admin)	Institutional	1	180[A]
Library	Institutional	1	800[B]
Research, Development, Extension, and Training Office (RDET)	Institutional	1	10[A]
College of Education (COE)	Institutional	1	738[A]
College of Criminal Justice Education (CCJE)	Institutional	1	1303[A]
College of Health Sciences (CHS)	Institutional	1	239[A]
College of Business Management (CBM)	Institutional	1	230[A]
College of Engineering and Technology (CET)	Institutional	1	188[A]
College of Agriculture and Sustainable Development (CASD)	Institutional	1	634[A]
College of Advanced Education (CAE)	Institutional	1	200[B]
Canteen	Commercial	6	2000[B]
Sports Ground	Recreational	1	500[B]

* Based on the waste generator category of EcoGov (2011)

** [A] based on the data provided by IFSU Potia Campus' Registrar's Office and Human Resource and Development Office, [B] based on personal communication with the management/focal person

Fig. 1: The map of the IFSU Potia Campus.

Table 2: Description of the types of waste used in the characterization of the generated MSW.

Category*	Description*	Sample Waste Recovered from the Study
Biodegradable	Waste that can be easily decomposed and can be turned into compost once it is exposed to various agents of decomposition.	food waste, soiled office paper waste, used paper food containers
Recyclables	Wastes which are in relatively good condition enough to be recovered and converted into new products.	plastic cups, plastic bottles, plastic cutleries, office papers, cans, textiles
Residual	Wastes that cannot be recycled anymore due to several factors such as market demand, technological limitations, costs, and quality of recycled products, among others. These are immediately transported to the sanitary landfills for disposal.	plastic straws, sando bags, polystyrene food containers, laminated food packaging (composites), ashes, soot, and dirt
Special	Household hazardous waste.	Used face masks

*Source: National Solid Waste Management Commission 2018

The trash cans were strategically placed so students and employees could easily see them. Trash bags were put inside the deployed trash cans at around 8:00 AM and collected and replaced with new trash bags at exactly 8:00 AM the following day. The MSW collected from each waste generator was brought to the Science Research Laboratory on campus for analysis and characterization.

A calibrated weighing scale was used to measure the total mass of the collected MSW from each waste generator. The generation rate for each waste generator was then calculated using the formula (Kawai & Tasaki 2016):

$$\text{Generation Rate} = \frac{\text{Total Mass of MSW}}{\text{No. of Waste Generator per Sample}}$$

properly segregated according to MSW classification in Table 2. Furthermore, the biodegradable wastes were further segregated into soiled office paper, used paper food containers, and food waste. In addition, the recyclable wastes were further segregated into plastic cups, plastic bottles, plastic cutleries, papers, cans, and textiles.

The masses of each of the segregated wastes were measured using a calibrated weighing scale. The composition of each type of waste was calculated using the formula (Miguel et al. 2016):

$$\%\ \text{type of waste} = \frac{\text{Mass of Type of Waste}}{\text{Total Mass of MSW}} \times 100$$

After measuring the masses, the volumes of each segregated waste were measured using a calibrated container. After obtaining the data from the five-day sampling, the average daily generation rate, waste composition, and volume of generated MSW were computed.

RESULTS AND DISCUSSION

MSW Generation Rate and MSW Generated Daily

The summary of the calculated MSW generation rate and the MSW generated daily from the various waste generators in the IFSU Potia Campus is shown in Table 3. Overall, the campus generated approximately 140.10 kg of MSW daily. This is a significant increase from the reported MSW generation rate (7.40 kg.day^{-1}) among the institutions, including the IFSU Potia Campus, in Potia, Alfonso Lista, Ifugao, Philippines back in 2020 (Ngohayon & Tulagan 2022). This increase in MSW generation can be attributed to the total return of the students and the employees on campus after the COVID-19 pandemic ended.

Among the institutional waste generators, COE had the highest MSW generation (16.63 kg.day^{-1}). This can be attributed to the relatively high daily number of people (738) within its premises compared to most institutional waste generators. This is supported by several studies (Khajuria et al. 2010, Liu et al. 2019), which have shown that population directly affects MSW generation, such that the more consumers are present, the more MSW is generated. This trend may also be why CASD, which had a relatively high daily number of people (634), had a relatively high MSW generation (13.96 kg.day^{-1}). In contrast, RDET, which had the least daily number of people (10), had a relatively low MSW generation (2.84 kg.day^{-1}). However, this was not the case for CCJE, which had the highest daily number of people (1303) among the institutional waste generators, as it generated relatively lower MSW (8.37 kg.day^{-1}) than COE and CASD. This can be attributed to the overcrowding situation in CCJE. Since the CCJE building is relatively small, this forced the people, especially the students, to go elsewhere (mainly in the nearby canteen areas) while waiting for the start of their classes.

While CHS, CBM, CET, and CAE had relatively low daily numbers of people, they generated relatively high amounts of MSW. This is because their buildings are the central locations of the laboratories on campus, where various

Table 3: The MSW generation rate and the MSW generated daily in IFSU Potia Campus.

Waste Generators*	MSW Generation Rate (kg/day/building)	No. of Buildings/ Areas	MSW Generated**	
			kg/day	(%)
Admin[A]	8.17	1	8.17	5.83
Library[A]	2.35	1	2.35	1.67
RDET[A]	2.84	1	2.84	2.03
COE[A]	16.63	1	16.63	11.87
CCJE[A]	8.37	1	8.37	5.99
CHS[A]	12.32	1	12.32	8.79
CBM[A]	8.65	1	8.65	6.18
CET[A]	10.55	1	10.55	7.53
CASD[A]	13.96	1	13.96	9.96
CAE[A]	6.60	1	6.60	4.71
Canteen[B]	4.87	6	29.22	20.86
Sports Ground[C]	20.43	1	20.43	14.58
Total			140.10	100

* A - institutional, B - commercial, C - recreational

** MSW Generated Daily = MSW Generation Rate × No. of Buildings/Areas

laboratory activities are being done in addition to the usual classroom activities. Hence, these additional activities may have contributed to the MSW generated. Similarly, the Admin Building also had a relatively low daily number of people (180) yet produced relatively high amounts of MSW (8.17 kg.day^{-1}). This can be attributed to the fact that it is the central building of the campus, where most office work is being done, and is the most visited building among the employees and sometimes the students within a day. While the library had a relatively high daily number of people (800), it did not generate that much MSW (2.35 kg.day^{-1}). This is because, unlike the rest of the waste generators, fewer activities were allowed, and more restrictions were imposed on its premises. For example, only the staff were allowed to dine inside, while the students could not bring food or drinks.

The six canteens under the commercial waste generator category had the highest MSW generation (29.22 kg.day^{-1}) since they had the highest daily numbers of people (2000) within the campus. This is reasonable as employees and students often visit these canteens for breakfast, lunch, and snacks. This is consistent with the results of the study of Nguyen et al. (2021) and Pandey et al. (2016), which also showed that university canteens and cafeterias generated more waste than the institutional areas in their respective university study sites.

The sports ground, under the recreational center category, had the second highest MSW generation (20.43 kg.day^{-1}). These can be attributed to several factors: (1) Typically, sporting events gather spectators in the area, which increases the MSW generation (Atchariyasopon 2017). (2) Unlike the other identified waste generators on the campus, the sports grounds span the largest area (as shown in Fig. 1). Hence, there are more areas to cover for maintenance. Because of this, there is relatively more MSW generated from the cleaning activities. (3) The sports ground also doubles as an area for drying harvested grains (mainly corn). Hence, these additional activities can also contribute to the generated MSW in the area. (4) The sports ground also has a dormitory that exclusively houses the Reserve Officers' Training Corps (ROTC) students tasked with maintaining and guarding the sports ground. Typically, these residential areas inside the universities generate many MSW round-the-clock (Arazo 2015), further contributing to the MSW generation in the sports ground.

Composition of Generated MSW

The summary of the MSW composition from the waste generators is shown in Table 4. Overall, the IFSU Potia Campus produced mostly biodegradable wastes (48.65%),

Table 4: The composition of the generated MSW in the IFSU Potia Campus.

Waste Generator*	Biodegradable (%)			Recyclable (%)						Residual (%)	Special (%)
	Soiled Office Papers	Used Paper Food Containers	Food Waste	Plastic Cups	Plastic Bottles	Plastic Cutleries	Office Papers	Cans	Textiles		
Admin[A]	20.39	3.73	23.17	2.51	17.81	1.90	18.97	0.00	0.00	10.41	1.10
Library[A]	14.96	10.68	5.13	1.35	44.23	2.69	12.82	0.00	0.00	8.12	0.02
RDET[A]	18.63	8.78	42.91	2.97	4.88	5.12	6.87	0.00	0.00	9.80	0.05
COE[A]	10.59	17.69	14.75	6.21	32.78	2.67	1.98	1.68	1.92	8.21	1.53
CCJE[A]	5.36	8.34	16.97	4.41	49.91	1.07	3.93	0.00	0.00	7.50	2.50
CHS[A]	12.57	6.13	20.58	6.81	19.26	3.51	9.43	1.77	3.22	15.60	1.11
CBM[A]	22.09	11.92	17.77	3.59	28.25	1.74	6.95	4.05	0.00	3.01	0.64
CET[A]	11.40	13.38	10.96	3.72	37.92	1.86	3.72	0.00	0.00	15.34	1.72
CASD[A]	1.57	4.55	23.12	7.03	42.01	0.28	5.04	3.31	0.34	12.32	0.43
CAE[A]	19.71	13.04	7.96	6.52	30.03	5.34	0.61	0.00	0.00	10.92	5.87
Canteen[B]	20.15	4.28	28.27	10.10	14.31	5.01	1.33	0.36	0.00	15.96	0.23
Sports Ground[C]	3.09	3.70	61.92	1.32	9.79	0.25	8.76	0.73	0.00	9.06	1.38
Total	15.24	6.46	26.95	7.43	21.30	3.46	3.88	0.86	0.33	13.25	0.84
Grand Total	48.65			37.26						13.25	0.84

* A - institutional, B - commercial, C - recreational

closely followed by recyclable wastes (37.26%), then residual wastes (13.25%), and special wastes (0.84%). In the study of Ngohayon & Tulagan (2022), it was found that the generated MSW from the institutions (including IFSU Potia Campus) within Potia, Alfonso Lista, Ifugao, Philippines in 2020 was also primarily dominated by biodegradable wastes. On the other hand, their study had relatively more residual than recyclable wastes. The higher residual wastes back then may be attributed to the changes in the consumption behavior of the people brought about by the COVID-19 pandemic, such as (1) the avoidance of people reusing or recycling potentially contaminated materials and immediately discarding them as residuals and (2) the rise of online shopping which increased the residual packaging wastes. Hence, after the COVID-19 pandemic had ended, the new changes in consumption behavior might have influenced these changes in the MSW composition.

Among the various types of wastes, it can be seen that those related to food and beverage consumption dominated the overall MSW generated: (1) food wastes and (2) food packaging wastes, including used paper food containers, plastic bottles, plastic cups, plastic cutleries, and the majority of the residual wastes (plastic straws, sando bags, polystyrene food containers, and laminated food packagings).

Food waste is a common, notorious occurrence, especially in the canteens and cafeterias of schools and universities. Food waste may arise from various wasteful behaviors: (1) On the food preparation side, it can include the overproduction of cooked meals, over-purchasing, and ineffective food planning and management, among others (Filho et al. 2023). (2) On the food consumption side, it can include reasons such as the consumers not liking the food or that the servings are too big to finish, among others (Acheson 2023). However, the current study did not assess if the obtained food wastes were generated from the preparation of the food or food leftovers. Hence, future studies should look into this aspect to develop a food waste reduction or utilization project to address the generated food waste.

While there were already initiatives in reducing plastic food packaging through the use of biodegradable paper food containers, it was still not enough as most of the aforementioned food packaging wastes were made up of non-biodegradable plastic materials. To reduce the plastic bottle and plastic cup waste, the campus can enforce a policy that limits or even bans the use and selling of these receptacles. Instead, the campus should encourage the use of refillable water receptacles. To supplement this, the campus can also look into installing water dispensers and water bottle refilling stations within the campus. This is supported by several studies (The Travel Foundation 2011, United Nations Environment Programme & World Travel & Tourism Council 2021, Willis et al. 2019, University of Michigan-Dearborn 2022), which have shown positive effects upon the use of installed water dispensers and water bottle refilling stations, particularly with the decreased in the use of single-use water bottles and the increase in awareness and positive outlook among the users.

Plastic cutleries can also be reduced by banning them while promoting wooden cutleries and/or encouraging people to bring their reusable cutleries. This is evident in the study of Marazzi et al. (2020), which found that using wooden and reusable cutleries can help reduce tonnes of plastic cutlery waste. Furthermore, future studies can also look into the production of edible tableware, which recently gained traction in several countries (Natarajan et al. 2019). In particular, future studies could look into fabricating edible tableware made of locally available raw materials in the community.

Among the generated residual wastes, some notable ones related to food and beverage consumption were plastic straws, sando bags, polystyrene food containers, and laminated food packaging (composites). Several straw alternatives can be explored, such as bamboo straws, wheat straws, polylactic acid (PLA) straws, and stainless-steel straws, which offer several efficient and environmentally friendly benefits compared to plastic straws (Qiu et al. 2022). Cotton tote bags can be an excellent alternative to sando bags used in carrying items as they are reusable and washable (Iheukwumere et al. 2020). On the other hand, for sando bags used as simple food packaging, banana leaf packaging can be explored since these are cheap, biodegradable, have antioxidant and antibacterial properties (Rikasa & Mufeez 2023, Pratama & Junianto 2021), and are ubiquitous in the community. Moreover, people can bring their reusable lunch boxes to reduce further reliance on paper food containers, sando bags, and polystyrene food containers. For laminated food packaging (composites), commonly used in commercial food products such as chips, cookies, instant noodles, and nuts, among others, there is still no systematic separation and recycling process available in the country (World Wide Fund Philippines 2020). Hence, these always end up in sanitary landfills. To reduce the generation of these types of waste, the canteens on campus can look into offering a variety of food products that do not use any laminated food packaging. Instead, they can be served using the previously mentioned food packaging alternatives.

Typically, institutional units have highly recyclable office papers due to various office works such as printing, note-taking, and crafting, among others (Ngohayon & Tulagan 2022). However, this was not the case for the campus, as

Table 5: The volume of generated MSW daily in IFSU Potia Campus.

Waste Generator*	Daily Volume (m^3/day)				Total
	Biodegradable	Recyclable	Residual	Special	
Admin[A]	0.091	0.200	0.059	0.002	0.352
Library[A]	0.062	0.068	0.032	0.001	0.163
RDET[A]	0.069	0.039	0.025	0.001	0.134
COE[A]	0.303	0.296	0.115	0.011	0.725
CCJE[A]	0.093	0.134	0.027	0.011	0.265
CHS[A]	0.136	0.212	0.204	0.004	0.556
CBM[A]	0.216	0.125	0.019	0.002	0.362
CET[A]	0.166	0.244	0.081	0.007	0.498
CASD[A]	0.076	0.275	0.109	0.001	0.461
CAE[A]	0.174	0.116	0.070	0.015	0.375
Canteen[B]	0.473	0.402	0.273	0.001	1.149
Sports Ground[C]	0.194	0.278	0.130	0.005	0.607
Total	2.053	2.389	1.144	0.061	5.647

* A - institutional, B - commercial, C - recreational

its overall recyclable office papers were only about 3.88%. This can be attributed to the prevalent mixing of the various types of waste within the campus - the supposedly recyclable office paper wastes get mixed with other waste types and are soiled by food scraps and other liquids. Hence, the soiled office paper waste (15.24%) was classified as biodegradable. Therefore, it is recommended that strict compliance to waste segregation be enforced and followed to prevent the soiling of recyclable office paper waste.

It should be noted that there are currently no recycling projects on the campus or in the community. Similarly, this is also the case for special wastes that do not have a dedicated hazardous waste disposal facility. Because of these, both the recyclables and special wastes are being treated as residual wastes, bringing the residual wastes to a total of 51.35%. Thus, about half of the campus's generated MSW were disposed of in the community's sanitary landfill.

The Volume of Generated MSW Daily

The summary of the calculated volumes of generated MSW daily per type of waste and per waste generator in the IFSU Potia Campus is shown in Table 5. The generated MSW from the canteen had the largest volume because it is also the top waste generator, as previously discussed. Although the biodegradable wastes had the highest mass contribution, as previously shown, this did not translate to having the largest volume. Instead, the recyclable wastes garnered the largest volume. This is because recyclable wastes, such as office paper wastes and plastic containers, typically have lower densities than biodegradable wastes (Bowan & Tierobaar 2014).

The total volume of the generated MSW daily on the campus is approximately 5.647 $m^3.day^{-1}$. This is significantly higher than the generated MSW from institutions (including IFSU Potia Campus) in 2020, which was only 0.11 kg.day-1 (Ngohayon & Tulagan 2022). Similarly, the increase in the volume of generated MSW daily in the present study can be attributed to the increase in the number of people within the campus as both the employees and the students have fully returned after the COVID-19 pandemic has ended.

CONCLUSIONS

About 140.10 kg of MSW is generated within the IFSU Potia Campus daily. Among the various waste generators, the canteens generated the highest MSW. It was also found that the daily number of people, the type of activities, and the area size may influence the amount of MSW generated among the various waste generators on the campus. The overall composition of the generated MSW was dominated by biodegradable waste (48.65%), closely followed by recyclable waste (37.26%), then residual waste (13.25%), and special waste (0.84%). In addition, most of the generated MSW was found to be related to food and beverage consumption, such as food waste and packaging waste. It was also found that the waste composition of the generated MSW in IFSU Potia may be influenced by people's consumption and waste segregation behavior. The volume of the MSW generated daily was about 5.647 m^3. Among the types of waste, recyclable wastes

contributed the most, closely followed by biodegradable wastes, then residual wastes. It was also found that the density of the waste may influence its volume.

While there are available national laws and local ordinances, they are not being strictly implemented, which resulted in the irresponsible usage of various single-use plastic products and the mixing of various types of waste within the campus. Hence, it is recommended that the campus create and enforce its waste management plan to specifically address the type of MSW generated within its area. It can include the development of policies that ban specific types of materials, such as single-use plastic products, and promote more eco-friendly alternatives. To supplement this, the campus can also organize a periodic awareness campaign among its constituents and develop knowledge resources such as videos and infographics that can be distributed online.

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