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Sustainable Solid Waste Management Strategies for Higher Education Institutions: Diponegoro University, Indonesia Case Study

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Abstract: Effective solid waste management strategies are recognized as efforts to achieve campus sustainability. The university campus is currently considered the center of various activities involving students, lecturers, staff, and other parties contributing to the consumption pattern of energy, water, and other resources. This study aims to estimate the quantity and compositions of waste generated on the Universitas Diponegoro (UNDIP) campus, identify the causes of waste generation, evaluate the relationships between variables through statistical analysis, and recommend possible strategies to reduce solid waste generation. The results show that the simultaneous contribution of the student-gender ratio, student awareness level, administrative staff background, and green space amounted to 67.7% of the waste generation at UNDIP. Therefore, these four factors need to be a concern for campus authorities in their efforts to handle campus waste. Student awareness in particular was determined to be the only factor that significantly affects solid waste generation. UNDIP may implement proper environmental education through sustainability courses in each faculty to reduce solid waste in higher education institutions since it has the most significant impact. Outcomes of this study could be used as a reference to develop sustainable campus strategies, recycling plans, and comprehensive waste management in higher education.

Keywords: campus sustainability; solid waste management; factors affecting; statistical analysis

1. Introduction

Universities generate significant municipal solid waste [1]. Various activities involving students, lecturers, administrative staff, and other parties contribute to the consumption patterns of energy, water, and other resources that influence the environment either directly or indirectly. The effects can be in the forms of increased air pollution, water pollution, and generated waste, particularly solid waste. As an educational institution, universities have moral and ethical obligations to work fairly with the environment and lead in environmental waste management. In many studies, solid waste management (SWM) has been a major component in achieving institutional sustainability [2–7]. The adaption of SWM sustainability within the university campus has enormous potential to reduce the amount of municipal solid waste, establishing a model for the community [8]. The integration of a sustainable/green campus through solid waste management sustainability plans has been achieved by several universities, including the University of Kansas, Harvard University, Cornell University, University of Connecticut, and Virginia Tech University [9].

SWM is an integral part of environmental management. In particular, SWM systems are the main focus for environmental sustainability on a university campus, based on the principles of reusing and recycling materials, composting, and source reduction without harming human or environmental health [10,11]. Effective SWM first includes a complete understanding of the amount of generated solid waste [12]. Additionally, SWM needs to consider the composition of the solid waste, specific target area, material types of waste, and recycling potential [13]. Prior studies [3,14–17] have shown that 55–90% of campus waste can be recycled.

Most available data and studies on SWM have mainly focused on municipalities. One not widely known study on the development of a country's campus waste management practice used a campus as a mini-pilot project for SWM practice [6,18]. Larger campuses require extra effort to manage their waste, owing to the complexity of their operations that generate significant waste [9]. At the municipal level, factors that influence sustainable SWM consist of four aspects: social acceptance, environmental benefits, economic adequacy, and technical integration [19]. In addition, the identification of major factors is vital to improving waste management on campus.

According to Erasu, et al. [20], female students at universities tend to have more consumptive habits than males. Females tend to use tissue products, papers, plastic, and other feminine materials often, generating more waste. According to Vicente-Molina, et al. [21], gender is studied since it is considered to potentially affect environmental behavior and knowledge. Environmental knowledge and awareness, which includes involving people in the program and making them environmentally responsible, are core factors for the effective implementation of sustainable SWM in higher education institutions [6,9]. The level of education has been considered a strong influence in this subject because highly educated individuals are expected to have more environmental awareness, which may result in a positive attitude towards solid waste reduction [21,22].

In addition, garden waste has become substantial, as green space generates significant waste, mostly in the form of fallen leaves and road-sweeping waste. Therefore, to fulfill the gap from previous studies [3,9,11,14–17,23,24] the factors that might influence solid waste in higher education institutions, such as the gender ratio of students, student awareness level, administrative staff background, and green areas are discussed in this paper.

Universitas Diponegoro (UNDIP) is a leading green campus in Indonesia [25]. The UNDIP Tembalang campus areas spread over 173 Hectare (Ha), consisting of an area of buildings of roughly 56 Ha and a green area of 91.2 Ha. UNDIP had 45,554 students and 4443 lecturers and administrative staff members for the 2019 academic year. The density of the UNDIP academic community in the internal campus area was 303 persons/Ha. UNDIP is representative of a typical university in developing countries but is the only university in Indonesia that has an integrated solid waste processing facility (ISWPF).

This comprehensive study aims to estimate the quantity and composition of waste generated on the UNDIP campus within one academic year, identify the factors that affect waste generation, identify relationships between variables through statistical analysis, and discuss possible strategies to improve waste management at UNDIP. This research does not discuss hazardous waste from the laboratory. Outcomes of this study can be used to develop sustainable campus strategies, recycling plans, and comprehensive waste management.

This paper is organized as follows. Section 2 describes the required material and methods such as study area, sampling of generated solid waste and composition, interviews and field visits, factors applied in this study, questionnaire surveys, and analysis of variance (ANOVA) test. Section 3 presents the results of the current solid waste situation on campus, factors affecting solid waste generation, and the relationship between factors and waste generation. Section 4 contains a discussion and recommendations to improve sustainable solid waste management at UNDIP. Section 5 presents the results of this study.

2. Materials and Methods

2.1. Study Area

This study was conducted at UNDIP, the largest public university in Semarang, Central Java Province, Indonesia and was limited to the UNDIP Tembalang campus area, located about 15 km south of the Semarang city center. The UNDIP location includes a tropical climate with relatively high rainfall and an average temperature of 27 °C. Established in 1957, UNDIP has 11 faculties and two schools, with 58 undergraduate study programs, 32 vocational school study programs, 38 master study programs, 19 specialist medical education programs, four professional programs, and 15 doctoral study programs. UNDIP is also equipped with various facilities, including a student dormitory, hall, stadium, several commercial areas, a national hospital, and an ISWPF. UNDIP mainly performs activities in academia, research, and community services. In 2019, 49,997 people were on campus daily, 45,554 of whom were students. As shown in Figure 1, the zoning divisions in UNDIP are based on its activity grouping, namely academics and support, where the faculties are included in academic zones.

Figure 1. Study area: UNDIP campus.

2.2. Current Solid Waste Situation on Campus

2.2.1. Solid Waste Generation and Composition

In this study, the sampling was conducted to determine the daily solid waste generation and composition in each faculty. Sampling and analysis were performed per ASTM D5321-92 and SNI-19-3964-1994 concerning the "Method for Taking and Measuring the Sample Generation and Composition of Municipal Solid Waste". Each waste sampling was conducted four times daily for eight days on the following dates:

1. 18–25 February 2019
2. 10–17 June 2019
3. 19–26 August 2019

4. 9–16 December 2019

The sampling period includes the beginning of the semester and the end of the semester. The first semester period is from February to June, and the second semester is from August to December. The collection and measurement of waste samples implemented in the academic zone contains 11 faculties and two schools (vocational and post-graduate). The support zone includes various facilities on campus, such as training centers, rectorate buildings, and the student dormitory.

To determine the amount of solid waste generated, waste was collected and placed into large bags by the cleaning staff. All waste bags were labeled with the date and the activity area. The waste bags were temporarily stored outside the building for further weight calculation using scales (having accuracies of ± 1 kg). Furthermore, several waste bags were selected using a stratified random design and limited to a 500 L container filled with samples. Waste was sorted and separated into seven categories: leaves, food waste, paper, cardboard, plastics and polythene, metal, and other waste. After the sampling was complete, all the solid waste was brought to the ISWPF using a three-wheeled vehicle. Every shipment of solid waste that entered the ISWPF was recorded, and the amount of waste generated was estimated to determine the daily waste generation.

2.2.2. Solid Waste Management

Current SWM strategies in the campus were evaluated for further tactical planning. To assess the current waste management situation on campus, interviews and field visits were carried out with cleaning staff and administrators in the academic zone, supporting zone, and ISWPF in April and May 2019.

2.3. Factors Affecting Solid Waste Generation

The factors applied in this study were selected from those affecting municipal solid waste and included the gender ratio of students, students' awareness level, administrative staff background, and green area. The focus on students for the gender ratio and awareness level was because the gender ratio of the lecturers and administrative staff was balanced and the number of students dominated the campus population. Otherwise, the administrative staff was chosen for the educational background factor because students and lecturers have relatively the same background.

Secondary data and questionnaire surveys were used in this study. Student gender ratio and awareness level data were obtained from the UNDIP Student Affairs Unit and presented per faculty. Green area data were obtained from the UNDIP master plan 2020–2029. Furthermore, any data related to administrative staff at UNDIP were obtained from the UNDIP staffing department and questionnaire survey. A face-to-face questionnaire survey was conducted among 87 respondents on the campus in May 2019.

2.4. Statistical Analysis

Statistical analysis was carried out to determine whether the independent variables, i.e., gender ratio, green area, student awareness level, and the number of administrative staff members, had influenced the dependent variable, i.e., the waste generation at UNDIP. Prior to the statistical analysis, four assumption tests were used to verify that the resulting estimation from the obtained regression equation would be accurate, unbiased, and consistent. First, the normality test determined whether the variable test dataset was normally distributed; second, the multicollinearity test determined whether the regression model had a correlation between the independent variables; third, a heteroscedasticity test determined whether the regression model in this study had heteroscedasticity or homoscedasticity; fourth, an autocorrelation test assessed whether an autocorrelation problem existed in the regression equation.

The correlation/influence among the independent variables on waste generation was tested using an analysis of variance (ANOVA) test, revealing an F (variation within the samples) value of more than four. Furthermore, the partial effect on each independent

variable was determined using a *t*-test, resulting in a significance value below 0.05. All statistical analyses in this study were performed with statistical software.

3. Results

3.1. Current Solid Waste Situation on Campus

3.1.1. Solid Waste Generation

In 2019, UNDIP produced an average waste generation of 4574.1 kg/day from the academic and supporting zones. The majority of the organic waste was from canteen and garden waste, while the inorganic waste was primarily paper waste from educational activities and administration. As shown in Table 1, the academic zone, including student unit activities, teaching and learning processes, and administrative correspondence, was the largest waste contributor, generating 4252.7 kg/day. The engineering department provided a considerable amount of waste generation of 790.2 kg/day with 8750 diverse students, lecturers, and administrative staff members. Meanwhile, the smallest solid waste generation was produced by the graduate schools with 14.5 kg/day of solid waste, having only 320 students, lecturers, and administrative staff members. The supporting zone, consisting of the residential area and student facilities, such as the meeting hall, rectorate building, laboratory, and stadium, had a moderate waste generation of 321.4 kg/day.

Table 1. Average solid waste generation in 2019.

Academic Zone	Population (p)	Average Annual Waste Generation			Supporting Zone	Average Annual Waste Generation	
		(m^3/day)	(kg/day)	(kg/p/day)		(m^3/day)	(kg/day)
Faculty (Fac) of Law	3435	2.5	225.7	0.07	Training Center	0.2	18.1
Fac of Economics and Business	5467	5.8	509.7	0.09	Rectorate Building	0.5	39.9
Fac of Social and Political Science	3507	3.4	297.2	0.08	Board of Trustee Unit	0.3	26.5
Fac of Cultural Science	3371	3.3	292.2	0.09	Students Dormitory	1.3	118.9
Fac of Psychology	1182	0.9	82.3	0.07	Campus Hostelry (Undip Inn)	0.1	8.0
Fac of Public Health	1927	1.8	155.7	0.08	National Hospital	0.6	48.8
Fac of Medicine	4976	4.3	381.3	0.08	Public Hall (GSG & Soedarto hall)	0.1	8.9
Fac of Animal and Agricultures	2659	2.3	207.9	0.08	Stadium and Sports Hall	0.1	11.5
Fac of Science and Mathematics	3801	3.6	317.3	0.08	Gas Station	0.3	22.2
Fac of Fisheries and Marine Sciences	3428	3.8	335.3	0.10	Central Laboratory	0.2	13.3
Fac of Engineering	8750	9.0	790.2	0.09	Central Mosque	0.1	5.3
Post-graduate School	320	0.2	14.5	0.05			
Vocational School	7174	7.3	643.5	0.09			
Total Academic Zone	49,997	47.9	4252.7	–	Total Supporting Zone	3.6	321.4
Total (m^3/day)					51.6		
Total (kg/day)					4574.1		

In addition, Figure 2 shows the occurrence of monthly waste generation fluctuation which obtained from the ISWPF 2019 report. The waste generation generated in July 2019 in the academic zone was more significant than in other months. In July, no lecture activities were happening because of national holidays and semester changes. An increase in waste generation at the end of the semester (June and December) occurred because UNDIP students are more active on campus, preparing for final semester exams.

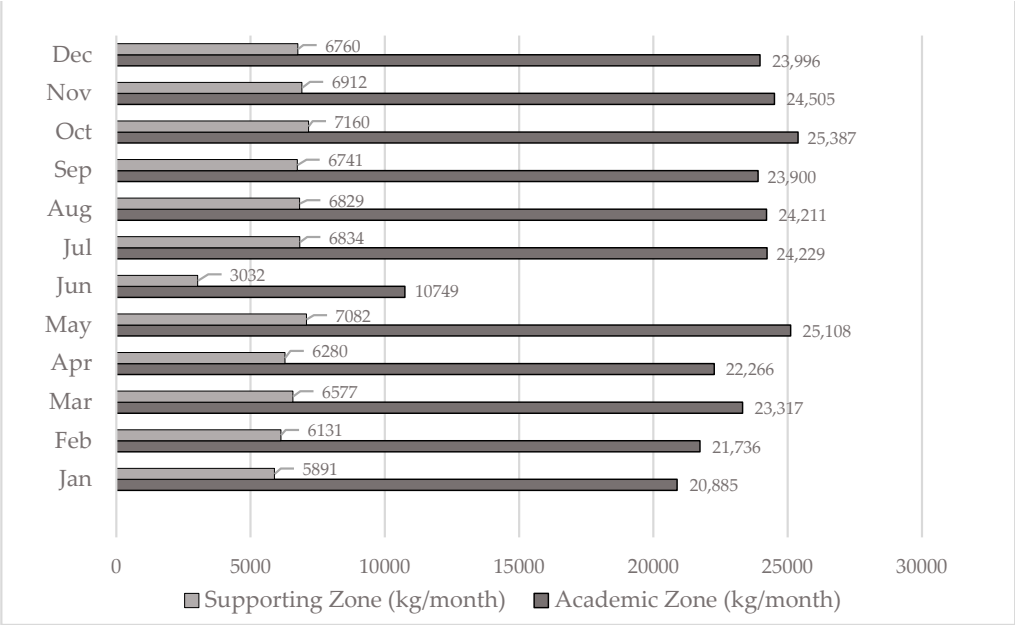

Figure 2. Monthly solid waste generation in 2019.

3.1.2. Solid Waste Composition

The most dominant composition of waste at UNDIP in 2019 was organic, amounting to 50% of the total in the academic zone and 56.2% in the supporting zone. Organic waste from fallen leaves, grass cutting, road sweeping, and canteen food scraps totaled 2147.6 kg/day from the academic zone and 180.7 kg/day from the supporting zone. As shown in Table 2, the largest amount of food waste was generated in the supporting zone, amounting to 24.3%. Food waste generation mostly results from supporting zones where a more intense cooking culture and higher consumption of food exist outside of academic activities. Meanwhile, the inorganic waste composition generated on campus was dominated by plastic and polythene, and paper. Paper waste resulting from educational activities and offices amounted to 808 kg/day. Plastic waste was quite common in both zones, with a similar contribution of 19%.

3.1.3. Solid Waste Management

Solid waste generated at UNDIP was collected by cleaning staff using a three-wheeled vehicle and then brought to the campus ISWPF. The volume and weight of all waste entering the ISWPF were recorded to determine the daily waste generated. In general, ISWPF acts as a final waste collection point at UNDIP. The ISWPF authorizer was tasked with collecting, managing, and processing solid waste resulting from the academic and supporting zones. The ISWPF includes several waste processing facilities. First in the process, organic waste is chopped to obtain uniform sizes, and then the composting process is carried out for 6–8 weeks. In inorganic waste processing, plastic waste is chopped, washed, and dried. The paper, cardboard, sheet plastic, and metal waste are then compacted and tied. All treated waste is stored in warehouses for sale to third parties. Figure 3 presents the potential for re-saleable waste in UNDIP, with the academic zone accounting for 46% and the support zone with 36.6%.

Table 2. Waste composition in different areas.

	Academic Zone		Supporting Zone	
Organic Waste	**%**	**kg/day**	**%**	**kg/day**
Leaves	37.0	1573.5	31.9	102.6
Food waste	13.5	574.1	24.3	78.1
Total Organic Waste	50.5	2147.6	56.2	180.7
Inorganic waste	**%**	**kg/day**	**%**	**kg/day**
Paper	19.0	808.0	9.4	30.1
Cardboard	7.0	297.7	5.2	16.7
Plastics and polythene	19.0	808.0	18.9	60.8
Metal	1.0	42.5	3.1	10.0
Other waste	3.5	148.8	7.2	23.1
Total Inorganic Waste	49.5	2105.1	43.8	140.7

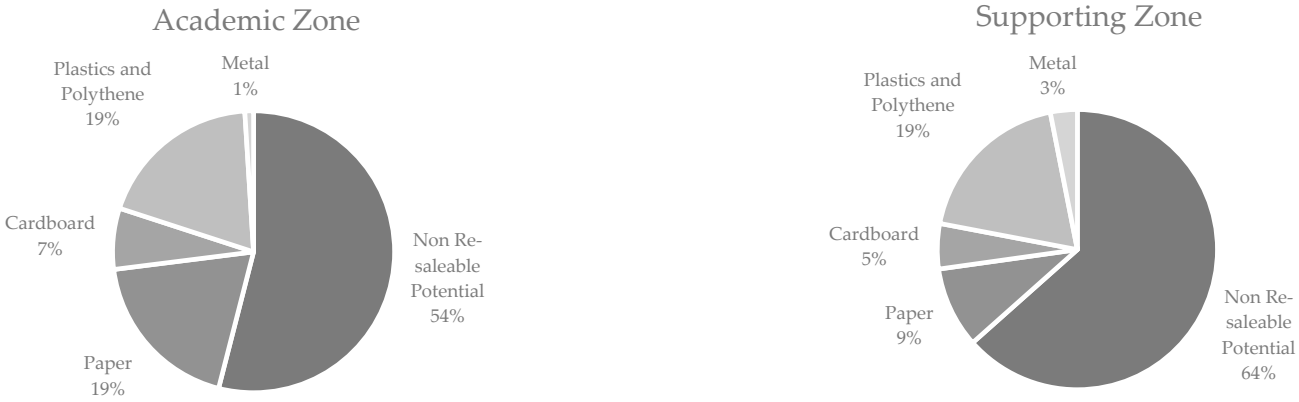

Figure 3. Each zone's resalable potential.

3.2. Factors Affecting Solid Waste Generation

3.2.1. Student Gender Ratio

UNDIP produces waste from academic and supporting activities. Student activities on campus can increase campus waste production. Table 3 presents the student gender populations, percentages of student gender, and the ratio of female to male students (F/M) for each faculty at UNDIP. Table 3 shows a total of 4566 male students at the engineering faculty, with the highest male percentage. Meanwhile, a small fraction of students were in the post-graduate school with a dominant female percentage of 51%. At the faculty of fisheries and marine science, the female population was significantly higher than the male student population. Thus, the marine and fisheries faculty was a larger waste generator at UNDIP with its high female percentage. As mentioned earlier, the faculty of fisheries generated 0.1 kg of solid waste per person per day. On the other hand, the engineering faculty had the smallest waste generation, owing to its high percentage of male students, which generated 0.09 kg of solid waste per person per day. Although the student population of the fisheries and marine department is less than 60% of the engineering department, they have an almost similar amount of solid waste.

Table 3. Student gender distribution in each faculty.

Student Gender Ratio					
Location	**Number of Females**	**Number of Males**	**Female Percentage**	**Male Percentage**	**Ratio (F/M)**
Faculty of Law	2113	1843	53%	47%	1.15
Fac. of Economics and Business	2609	1850	59%	41%	1.41
Fac. of Social and Political Science	2076	1136	65%	35%	1.83
Fac. of Cultural Science	2102	907	70%	30%	2.32
Fac. of Psychology	1025	270	79%	21%	3.79
Fac. of Public Health	1517	281	84%	16%	5.39
Fac. of Medicine	3411	1336	72%	28%	2.55
Fac. of Animal and Agricultures	1550	1051	60%	40%	1.48
Fac. of Science and Mathematics	2294	1243	65%	35%	1.85
Fac. of Fisheries and Marine Sciences	1624	1058	61%	39%	1.53
Fac. of Engineering	2816	4566	38%	62%	0.62
Post-Graduates School	181	174	51%	49%	1.04
Vocational School	3519	3004	54%	46%	1.17
Total	26,836	18,718			
Total Student	45,554				

3.2.2. Student Awareness Level

To influence a student's understanding of solid waste management, environmental and sustainability courses were offered, and events such as conferences, environmental service, environmental cleanup, mangrove cultivation, and community service were held in several UNDIP faculties. The number of environmental and sustainability courses in 2019 is presented in Figure 4. As shown in Figure 4, the Faculty of Engineering offered many courses related to the environment and sustainability. The environmental engineering study program at the Faculty of Engineering broadly accommodates material related to environmental management through coursework. On the other hand, the faculty with the least number of environment-related courses was the Faculty of Psychology. In 2019, the engineering faculty produced a waste generation of 0.09 kg/person/day. However, this value is not sufficiently related to the level of understanding of students about the responsibility of waste management because the engineering faculty had the second-largest waste generation.

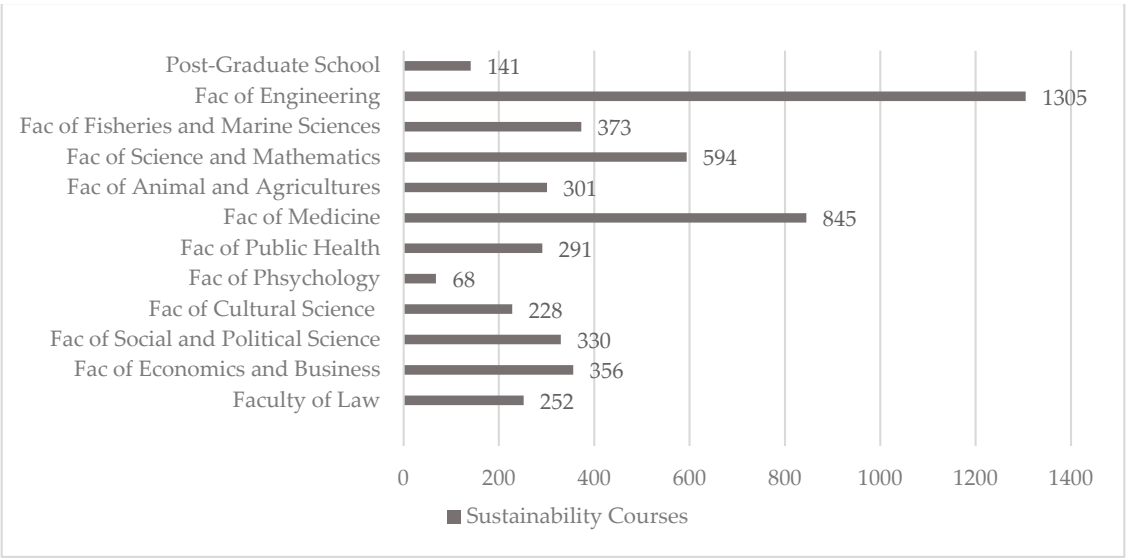

Figure 4. Number of environmental and sustainability courses in UNDIP.

3.2.3. Administrative Staff Background

The analysis of waste generation at UNDIP involved 87 respondents out of a total of 988 employees who worked as administrative staff at UNDIP. In this study, their education level and background were used as variables in analyzing the solid waste generated at UNDIP. Based on data obtained from the 2019 UNDIP staffing section, the educational background of the administrative staff at UNDIP is presented in Table 4. Regarding the highest degree of education, 38% of the administrative staff at the faculty have a high school education, 22% have high school diplomas, 38% have bachelor's degrees, and 2% have master's degrees. Employees with undergraduate educational backgrounds commonly worked on campus because the job requires a bachelor's degree at a minimum.

Table 4. Administrative staff background each faculty.

Faculty	Educational Background					Total Staff
	High School	Diploma	Bachelor	Master	Doctor	
Faculty of Law	37	11	42	2	0	92
Fac. of Economics and Business	52	24	31	0	1	108
Fac. of Engineering	57	44	59	6	0	166
Fac. of Medicine	55	51	57	1	0	164
Fac. of Animal and Agricultures	32	8	17	0	0	57
Fac. of Cultural Sciences	24	10	22	1	0	57
Fac. of Social and Political Sciences	13	11	28	1	0	53
Fac. of Public Health	20	9	20	3	0	52
Fac. of Science and Mathematics	18	11	33	2	0	64
Fac. of Fisheries and Marine Sciences	25	9	20	1	0	55
Fac. of Psychology	15	7	10	0	0	32
Vocational School	19	13	26	3	0	61
Post-Graduate School	11	3	12	1	0	27
Total	378	211	377	21	1	988
	38%	22%	38%	2%	0%	100%

A survey through questionnaires stated that 94% of respondents with a bachelor's education background were the most knowledgeable and able to implement good waste management, such as minimizing waste, sorting waste, and waste processing. Table 5 shows that more than 90% of administrative staff with bachelor's and master's educational backgrounds reported having a better awareness of waste management. UNDIP administrative staff with 80% high school level already had an awareness of waste management. However, they were still primarily limited to disposing of solid waste in the correct place without sorting it, using environment-friendly products rather than single-use plastics, and willing to pay fees for moving solid waste.

Table 5. Level of waste management awareness based on educational background.

Highest Level of Education	High School	Bachelor	Master
Aware and implemented	80%	94%	91%
Aware, but did not implement	20%	6%	9%
Not aware and did not implement	0%	0%	0%

3.2.4. Green Area

The green space in UNDIP of 24 Hectare (Ha) is an elongated area/pathway, which is more open, a place to grow plants, both naturally growing and planted. The UNDIP green space can affect total waste generation, especially organic waste from fallen leaves and road sweeping. As shown in Figure 5, the engineering faculty has a green area of 8.84 Ha, the largest among the faculties. The highest generation of organic waste follows this situation in the engineering faculty in 2019, resulting in 99.2 kg/day. On the other hand, the public health faculty has non-constructed land of 0.04 Ha, the smallest among

the built-up land areas. The organic waste generated in this faculty is relatively small at 21.74 kg/day, mainly consisting of fallen leaves.

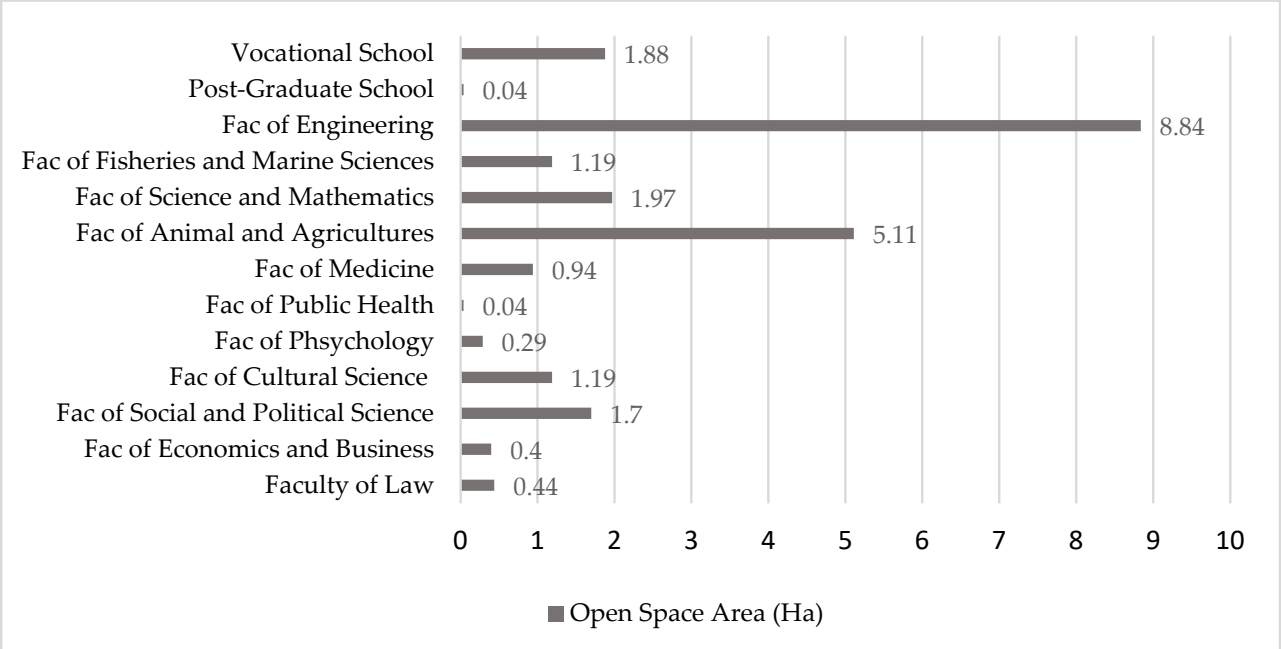

Figure 5. Green area availability each faculty.

3.3. Relationship between Factors and Waste Generation

To verify that the regression equation obtained is accurate in estimation, unbiased, and consistent, the classic assumption tests were performed. The four classic assumption test results are presented in Table 6. First, the normality test results showed that all test variable data were normally distributed with a significance greater than the confidence level of 0.05. Second, the multicollinearity test showed no correlation between the independent variables with a variance inflation factor (VIF) less than 10. Third, the heteroscedasticity test result showed that the regression model in this study did not have heteroscedasticity or homoscedasticity with a significance greater than the confidence level of 0.05. Finally, the results of the autocorrelation test showed no autocorrelation problem in the regression equation, as evidenced by the presence of a DW (Durbin–Watson) value of 1.33, which is between 0.4445 and 2.3879 and with the number of observations of 13. After confirming the feasibility of the regression equation, the ANOVA and *t*-tests were carried out.

Table 6. Classic assumption test results.

	Normality (Significance.)	Multicollinearity (VIF)	Heteroscedasticity (Significance.)	Autocorrelation (DW)
Student gender ratio	0.930	1.400	0.831	1.331
Student awareness level	0.832	2.282	0.734	
Administrative staff background	0.266	1.364	0.528	
Green area	0.291	2.143	0.409	

An ANOVA analysis is conducted to examine the effect of an independent variable on a dependent variable. The dependent variable was the waste generation at UNDIP, and the independent variables included the student gender ratio, student awareness level, administrative staff background, and green area. The ANOVA results in Table 7 show that the student gender ratio, student awareness level, administrative staff background, and green area all simultaneously have significant effects on waste generation at UNDIP,

as evidenced by the F value of 7.725, (>4). The adjusted R-squared (R2) in this test was 0.677, which means that the simultaneous contribution of the student gender ratio, student awareness level, administrative staff background, and green space was 67.7% towards waste generation at UNDIP, and other variables influenced the remaining 32.3%. Table 8 shows the results of the *t*-test used to determine the partial effect of each variable; this has the potential for further research. The results show that only student awareness level has a significant effect on waste generation at UNDIP with a significance of 0.03 (lower than the standard level of 0.05).

Table 7. ANOVA statistical calculation for all independent variables.

	Sum of Squares	*df*	Mean Square	*F*	Significance	Adjusted R-Squared
Regression	1.294	4	0.810	7.725	0.009	0.677
Residual	0.356	8	0.104			
Total	1.650	12				

Table 8. *t*-test statistical calculation.

	B	Std Error	Beta	*t*	Significance
Constant	2.195	0.371		3.003	0.017
Student gender ratio	0.316	0.292	0.210	1.079	0.312
Student awareness level	0.714	0.271	0.654	2.636	0.030
Administrative staff background	0.076	0.301	0.049	0.254	0.806
Green area	0.195	0.127	0.369	1.537	0.163

4. Discussion

As mentioned, a majority of the organic waste produced at the UNDIP campus was from canteen and garden waste, while the inorganic waste was primarily paper waste from educational activities and administration. Organic waste can release greenhouse gases into the atmosphere and attract vectors to households. This waste can therefore create environmental and health issues if not disposed of or appropriately used to produce alternative energy for universities, animal feed, or compost products [3]. Meanwhile, the inorganic waste composition generated on campus was dominated by plastic, polythene, and paper. Polyethylene plastic is commonly found in various drinking packages, such as plastic bottles for water and soft drinks [26]. High-density plastics from discarded household items such as buckets, reservoirs, plastic chairs, and appliances also contributed to waste generation. Plastics comprised the largest waste contributor at UNDIP after organic waste. Plastic has a considerable contribution to total waste mass generated despite its low weight [27].

Compared with other campuses, the average waste generation at the UNDIP campus is less than at the Center East Specialized College (METU) campus in Turkey and the University of Lagos (UNILAG) campus in Nigeria. The METU campus has a population of 35,780 with an average waste generation of 5261.6–9344.0 kg/day [9]. Meanwhile, the UNILAG campus has a population of 550,000 with an average waste generation of 32.2 tons/day [17]. In addition, one of Indonesia's waste management practices is carried out by handing over resaleable waste to third parties (recycling companies) [28]. Solid waste often encountered in recycling companies includes cardboard waste, white paper, clear polyethylene terephthalate (PET) bottles without labels, cans, and metal scrap. At this time, UNDIP needs waste management development, especially related to the optimization of a waste sorting system at the faculty scale. In this study, several faculties were provided with waste containers classified according to organic and inorganic waste composition. However, several campus zones still do not have classified containers. The availability of waste management facilities such as adequate containers can increase public awareness

of SWM. If the facility does not provide the appropriate tools, the public contribution to waste management will suffer [1,29].

The amount of solid waste varies at each location. Awan and Abbasi [2] stated that the amount of waste can be different owing to the level of income, activity background, public knowledge, consumption habits, and disposal characters. All solid waste generated at UNDIP was identified and quantified by correlating the considered factors of student gender ratio, student awareness level, administrative staff background, and green area. According to Talalaj and Walery [30] gender has an influence on the quantity of waste, in that a greater percentage of women in a community contribute to a greater amount of waste production. Knowledge and habits also influence a student's understanding of solid waste management. More students with a solid understanding of waste management can reduce the amount of waste generated [21]. Furthermore, Administrative staff with bachelor's and master's educational backgrounds were accustomed to separating waste from its source, using non-single-use plastics to avoid waste generation, processing organic waste by composting, and contributing to waste management through waste banks [31]. This is in accordance with research conducted by Qaderi, et al. [32] that staff with higher education have high awareness compared with participants with low education.

As mentioned, statistical analysis results showed that the student gender ratio, student awareness level, administrative staff background, and green area are factors affecting the waste generated at UNDIP. The student awareness level has the most significant effect. These results were in accordance with Afroz, et al. [33] and Moreira, et al. [34], who stated that good education for students, especially those related to environmental awareness, will foster a habit of sorting waste at its source, reduce waste by minimizing single-use plastics, and increase awareness on the impact of improper waste management on the environment. In addition, education related to proper environmental management will decrease waste generation because students have more awareness of the effects of improper waste management [34,35].

According to Budihardjo, Ramadan, Putri, Wahyuningrum and Muhammad [25], the success of sustainable development goals (SDGs) in higher education institutions is determined by several factors, such as learning, research, campus operations, administration, and socialization. On this basis, the following are suggestions to improve sustainable SWM at UNDIP: (i) establishment of a campus waste management organization (CWMO), (ii) infrastructure improvement, (iii) online monitoring, and (iv) social media for environmental awareness (SMEA).

Campus Waste Management Organization. The CWMO, as part of the Center for SDGs at UNDIP, can develop strategies and implement a green campus, especially integrating SWM. This organization begins with an environmental engineering lecture with students from staff members of different faculty.

Environmental engineering is a major offered in the engineering faculty. The scope of this department includes efforts to control pollution and waste treatment. Therefore, this department is suitable to lead the organization. With staff from various faculties, comprehensive student awareness information can be collected on which future research can collaborate. The CWMO aims to (1) create an up-to-date integrated waste management strategy in the long and short terms, (2) prepare an extensive report that includes accomplished and planned objectives and the new target, (3) coordinate discussion groups with students, volunteers, and stakeholders, and (4) promote through social media. The educational campaigns/events and the addition of environmental sustainability courses would be major programs in this organization. According to Grodzińska-Jurczak, et al. [36], environmental campaign activities and waste management education delivered through courses are highly recommended; waste generation can be reduced by 55%, and student knowledge of waste issues can increase [36]. Campaigns/events related to environmental management, such as competitions for cleanliness and environmental management between faculties, zero-waste programs and the reduce, reuse and recycle 3Rs principle, and waste segregation by type.

Furthermore, courses related to environmental sustainability can be offered through seminars and public lectures at various faculties that lack environmental education. Education related to proper environmental management can trigger a decrease in solid waste generation because students have more awareness of the effect of improper waste management [37].

Infrastructure improvement. Adequate infrastructure should be prioritized to improve SWM [19]. The selection and development of technical plans suitable for campus conditions are vital while building infrastructure for solid waste collection and transportation based on waste types. When the waste is separated by type, processing waste in the on-site ISWPF is easier and more effective. Improvements in the ISWPF are also necessary with the increased recycling and composting activities along with rising waste generation.

Online monitoring. Online monitoring is a solution to ensure that waste is collected and transported at a specific time and location. Historically, waste collection and transport have suffered from the lack of accountability. Sometimes, waste is not collected from each waste bin in various faculty, owing to poor employee performance [38]. In addition, daily waste data should be uploaded online, including waste generated per day, waste composition, and the amount of waste being processed. This data can facilitate the analysis of improved waste management and provide the basis for updating strategies and further research.

Social media for environmental awareness. SMEA focuses on social aspects, including conversations, connectedness, openness, communities, and participation. Several environmental awareness campaigns have been successfully carried out using social media. Various of these have been conducted using social media; for example, social media has been used to foster environmental behavior, sign petitions, provide news, provide motivation, and raise awareness [39]. SMEA will be managed by the CWMO to provide relevant information to individuals. Social media users interact by generating and distributing content (media and text), which allows them to communicate and collaborate with each other. Tlebere, Scholtz and Calitz [37] argued that social media is effective in conducting environmental campaigns because it can disseminate information quickly and cost-effectively.

5. Conclusions

This study reported the amount of solid waste generated by UNDIP in 2019 and its composition per faculty. The daily waste generation at UNDIP was 16.21 m^3/day, with 52% organic as dominant compositions. The solid waste generated at UNDIP correlates with several considered factors: student gender ratio, student awareness level, administrative staff background, and green space. The simultaneous contribution of student gender ratio, student awareness level, administrative staff background, and green space was 67.7% towards waste generation at UNDIP. Those factors significantly influence the amount of waste generation. However, the student gender ratio, administrative staff background, and green area do not have a strong enough individual impact on solid waste generation. Consequently, student awareness was the only factor found to significantly affect solid waste generation. The following actions were discussed and suggested to improve sustainable SWM at UNDIP: (i) establishment of a CWMO, (ii) infrastructure improvement, (iii) online monitoring, and (iv) SMEA. Moreover, the methodology, results, and recommendations presented in this study should contribute to the literature on SWM in higher education. Importantly, the current study is limited to UNDIP, which means comparative analyses with the sustainable solid waste management of other HEIs are needed. These can be examined using the identified factors and methods in this study.

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