Poll Res. 41 (2) : 557-568 (2022)

ISSN 0257–8050
DOI No.: http://doi.org/10.53550/PR.2022.v41i02.024

SOLID WASTES GENERATION AT VARIOUS ZONES OF UNIVERSITIES CAMPUS: CHARACTERISATION AND ITS MANAGEMENT APPROACHES

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(Received 19 October, 2021; Accepted 28 November, 2021)

ABSTRACT

Effective management strategy is required for handling the large quantities of waste produced by various societies/ organizations and waste characterization is essential to prepare this management policy. In this study, solid wastes collected from the combined campus of Chaudhary Charan Singh Haryana Agriculture University (CCSHAU) and LalaLajpat Rai University of Veterinary and Animal Science (LUVAS), Hisar was characterized through population estimation, field investigations and applying ASTM D5231-92 standard method. In the combined campus, the average quantity of solid waste generation was found to be 1047.1±214.4 kg/day. The whole campus was divided into five structural units and waste composition was determined, mixture unit waste comprised the highest fraction of food 62.13% and polythene 10.8%. The statistical estimation obtained a strong positive correlation of mixture unit waste with residential and markets waste contents, which was 0.995 and 0.997 at $p<0.01$. The analysis of solid samples showed that the biodegradable part of solid waste may be a better source for composting while some content of non-biodegradable waste can be sold into the market for recycle or reuse purpose. On the basis of solid waste characterization, a set of recommendations were suggested to strengthen the waste management processes for institutions.

KEY WORDS : Solid waste, University campus waste, Waste management

INTRODUCTION

Solid Waste is an abandoned material that has no economic value or any functional use as per producer and consumer perspective and various factors stimulate the characteristics of solid waste (Liu and Wu, 2011; Zaman and Lehmann, 2011). According to different scientists, waste is a perception based subject it may be unappreciated by one person but may be a valuable resource to another person (Moore, 2012; Starovoytova and Namango, 2018). In addition to domestic solid waste generation, Universities are also identified to contribute considerably to solid waste generation. University is a place where regularly a number of people come for work or to learning and use various types of facilities of the University like canteens, cafeterias, printing or photocopy, health centre, sports, cleaning services, etc. All these activities of people generate huge amounts of solid wastes and show various types of effects on the environment (Adeniran *et al.,* 2017; Alshuwaikhat and Abubakar, 2008). In India, the number of colleges or Universities is increasing and as per the University Grants Commission of India report, 2019, the total number of universities in India is 911. Education Institutions provide quality education to persons who develop and manage society structure (Armijo de Vega *et al.,* 2008). But, due to an increase in the number of educational institutions, a large quantity of waste is being produced. This requires the identification of waste generating sources, characterization, and suitable management plans. Okeniyiand Anwan (Okeniyi and Anwan, 2012) carried out a study at the University of Covenant, Nigeria, and determined the waste generation rate of 60.5 g/user/day. The biggest fraction of waste was leftover food, followed by polyethylene bags and plastic bottles. In a study at Staff Quarters of Pondicherry Engineering College, India. The average household solid waste generation rate was observed at 1.7 ± 0.7 kg/household/day (Rajamanikam and Poyyamoli, 2014). Painter *et al.,* (2016) determined 555 g per student of food waste produced at the dining hall of Rhodes University, South Africa. Kassaye (2018) studied at the Haramaya University (HU), Ethiopia and observed the waste generation of about 3,509,077.15 kg/year (9483.99 m^3). Dahlawi (Dahlawi and El Sharkawy, 2021) determined the 1350 kg/day of MSW generated at Imam Abdulrahman Bin Faisal University (IAU), Dammam –Saudi Arabia. This large growth of waste generation and poor waste management may create a critical problem for both human health and the environment (Abunama *et al.,* 2021; Serge Kubanza and Simatele, 2020). Therefore effective waste management policies are must require to reduce the generations of solid waste. Solid Waste Management (SWM) is a challenging task that contains environmental, socioeconomic, political, and institutional aspects (Debrah *et al.,* 2021). The implementation of solid waste management techniques are depending on the generation and waste characteristics that change with the source (Bowan *et al.,* 2020; Coker *et al.,* 2016).

In the developed nations, great progress has been done on waste management strategy at the Institutional/university level (Gallardo *et al.,* 2016). Few year ago, the Indian Government has started a major cleanliness drive titled Swachhaa Bharat Mission (SBM) for refining the waste management practices at the national levels. However, due to less availability of solid waste characterization data of Universities in India, created demand for research work related to this field.For the effective management of solid waste, this research will certainly helpful for the institutions. In this research work solid waste generation, composition estimation and characterization of the combined campus of Chaudhary Charan Singh Haryana Agriculture University (CCSHAU) and Lala Lajpat Rai University of Veterinary and Animal Science (LUVAS) has been conducted for six months. Variation in the waste composition of structural units was assessed by applying Pearson correlation analysis to find the waste recovery potential at the institution level. Waste management practices have been suggested to create a safe and healthy environment on the University campus.

METHODOLOGY

The study on solid waste at the combined campus of CCSHAU and LUVAS was divided into four stages. These stages are (i) Identification of solid waste generation area, (ii) Assessment of solid waste generation, (iii) Assessment of waste composition and characteristics and (iv) Data analysis.

Identification of solid waste generation area

Chaudhary Charan Singh Haryana Agriculture University (CCSHAU) is a government-owned higher education learning institution located in Hisar, Haryana. The University has six constituent colleges: College of Agriculture, College of Agricultural Engineering and Technology, College of Basic Sciences, College of Humanities and I.C. College of Home Science and Centre of Food Science & Technology. In addition to these under-graduate courses, the University offers postgraduate programs comprising of Masters in 34 disciplines (including MBA) and Doctor of Philosophy in 30 discipline. Before, 2010 LalaLajpat Rai University of Veterinary and Animal Science (LUVAS) was also a part of CCSHAU. Now, this University is currently operating from a temporary campus located at CCSHAU. The University currently offers diploma, undergraduate, and postgraduate and doctorate degree, in Veterinary and Animal science. The Universities campus is rock standing on an area under farms 6483 acres and under buildings and roads 736 acres. In 2018-19 academic year, the CCSHAU has 1828 students' enrolled, teaching and non-teaching staff 2182 and LUVAS has 967 students' enrolled and teaching and non-teaching staff 550. The both Universities combined campus have several infrastructural facilities including 16 hostels (7 for Boys, 7 for Girls, one for PG married students, one Sai (sports) hostel), 6,8,9,10,11,12,14,32 type residential house, Fletcher Bhawan, Gandhi Bhawan, Indira Gandhi Auditorium, Giri Centre Sports Ground, Nehru Library, Campus School, Farm House, Health centre, Veterinary Hospital, HARSAC (Haryana Space Applications Centre), Community center, Bank and others building. The various waste generation sources of the University campus are shown in Figure 1.

Sanitary department of CCSHAU is responsible for the solid waste management of whole campus (CCSHAU and LUVAS). Because waste of both Universities are collectively managed, therefore this study was done for both Universities collectively. Biomedical waste of Health Centre and Veterinary Hospital are controlled by Synergy Waste Management Pvt. Ltd., hired by both Universities. The buffalo's farm wastes and green waste (grass, leaves, etc.) of Universities campus are used for making of organic manures and it is being used as fertilizer in campus by horticulture department. Whereas some parts of medical waste of veterinary department are disposed of with solid waste and for that University has no clear cut policy. For assessment of contemporary situation of CCSHAU and LUVAS campus waste management, visual assessment, field investigations and several interviews were carried out with the sanitary department persons and written information were gathered from various branches for population estimation. Before starting work of waste generation estimation, all collection points were identified. This study was conducted from May, 2018 to October, 2018 and study time duration covered examination, holiday and teaching period and in addition seasonal variations were also covered.

Assessment of solid waste generation

At thecombined campus of CCSHAU and LUVAS a total of sixty five solid waste generation points were identified and categorised in different activity units as mention in Table 1. The overall sample size of 44 was calculated using the formula (Gebreeyessus *et al.*, 2019).

$n = N/(1 + N \times x^2)$ Here n = sample size; N = total number of generation point

x = level of precision (0.1)

The solid waste generation was calculated with the help of the sanitary staff andweighing through spring balance (WMC-461265, ELEF INDIA). The per capita solid waste generation (PCG) was determined:

PCG (Kg/ day/ person) = [Total waste generation/ day]/Total population (Oumarou *et al.*, 2012).

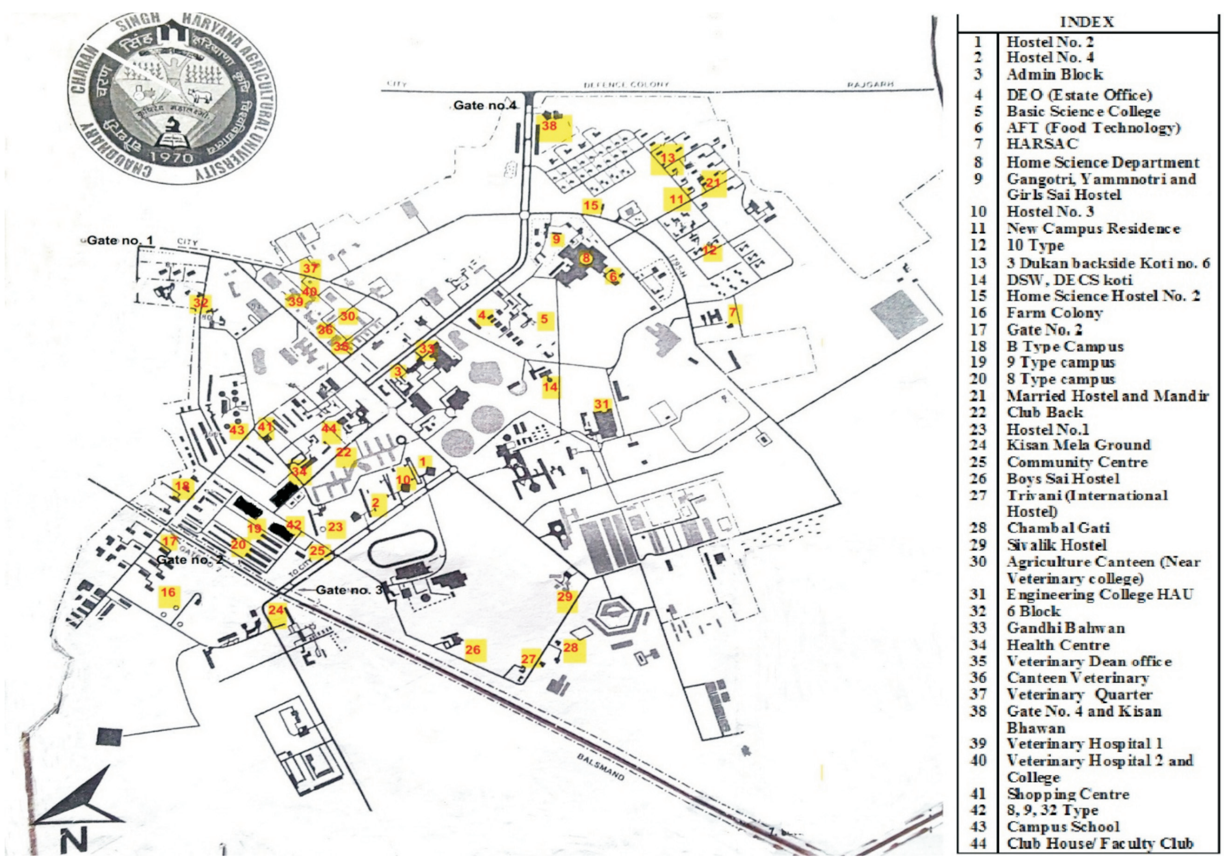

Fig. 1. Various solid waste collection locations at CCSHAU and LUVAS

Assessment of waste composition and characteristics

To determine the composition of solid waste generated from various infrastructural units, one week trial sampling was conducted (Table 1). The various types of solid wastes were classified into major categories as shows in Table 2. The number of samples required was determined by using the ASTM D5231-92 equation for continuous data (Kotrlik and Higgins, 2001).

$$n = (T.S/E.X)$$

Here Student's t-test (T) stands at 90% confidence level with 10% precision level (E). During trial sampling food waste was found the governing component and used for calculating the standard deviation (S) and mean X, i.e. S 0.03 and X 0.95. A total of 30 sampling locations were identified and every month randomly sixsamples were collected from different generation points of each unit. All collected samples of each unit were properly mixed and the reduction process was applied (Nadeem *et al.,* 2016). The compositions of waste samples were determined with the help of digital balance (SF-400a, Virgo Digital balance).

Characterization of waste

100-150g of each sample was used for analysis the physical and chemical properties.The moisture content of samples were determined in an oven at

Table 1. Different units of University campus with sampling points

Unit	Name of Unit	Sampling Points
1.	Research and Academic	Basic Science College, AFT (Food Technology), Home Science Department, Engineering College HAU. Veterinary Hospital 2 and college.
2.	Administrative centre	Admin Block, DEO (Estate Office), HARSAC, Gate No. 2, Gandhi Bahwan, Health Centre, Veterinary Dean office, Campus School, Club House/ Faculty Club, Gate No. 4 and KisanBhawan, Veterinary Hospital 2.
3.	Residential	Hostel No. 1,2,3,4, Gangotri, Yammnotri and Girls Sai Hostel, New Campus Residence, 10Type, 3-Dukan backside Koti no. 6, DSW, DECS koti, Home Science Hostel No. 2, Farm Colony, 9,8,B-Type Campus, Married Hostel and Mandir, Club back, KisanMela Ground, Community Centre place, Boys Sai Hostel, Trivani (International Hostel), Chambal Gati, Sivalik Hostel, 6 Block, Veterinary Quarter, 10/11 and Community Centre, 8, 9, 32 Type,
4.	Markets	Shopping Centre, Agriculture Canteen (Near Veterinary college), Canteen Veterinary,
5.	*Mixture	Tractor-Trailer

*Mixed waste sample of the University campus

Table 2. Classification of institutional solid waste

Category	Description
Card board	Old corrugated cardboard, packing cardboard boxes, cereal and tissue boxes, etc.
E-waste	Electrical wire, Electronics packaging, discarded computer parts, printer cartridge, mobiles accessories
Food waste	Vegetables, raw fruits, excess cooked food, leftover fast-food, etc
Glass	Window glass, glass beverage containers, glassware from laboratories
Hazardous waste	Batteries, toxic chemicals, paint cans, etc.
Inert	Soil, stone, tiles, ceramics
Leather	Shoes, bags, belts made from leather
Laboratory waste	Chemical applied cotton, tissue paper, gloves, other plastic tubes
Metal	Iron, stainless steel, aluminum foil, copper wire,
Other	Dirty, hair, bee hives, tobacco piece and miscellaneous materials etc
Paper	Printer paper, newspaper, text books, magazines, catalogues,
Plastic	Plastic beverage containers, plastic bags and packaging, pens, plastic tray, plastic utensils, cartons, mugs, etc.
Polythene	Polyethylene packaging bags, poly wrappers, nylon ropes
Sanitary	Cotton wools, pads, diapers, tissue paper
Textile	Cloth wares, curtain, cloth ropes.

103 ± 1 °C until the change in total weight was less than 0.2% (ASTM, 2013). The moisture content (wet basis) of the waste samples was calculated using the equation below:

$$MC\ (\%Wb) = \{(Wi - Wf) / Wi\} \times 100$$

Here MC= moisture content, W_i= initial weight, W_f= final weight, W_b = net weigh.

The volatile content (VC) of the samples werecalculated by heating at 550 °C for half hours in a muffle furnace under a controlled condition by measuring its weight loss (ASTM, 2004c). The bulk density of solid waste samples was determinedby dividing the weight of a waste sample (kg) tothe volume of plastic bin i.e. 30L. The accuracy of weighing balance checked timely and measurements were done in duplicates for each waste sample. A bomb calorimeter (6100 Compensated Jacket Calorimeter, Parr) was used to determine the calorific value of solid waste samples. The calculation was accomplished by the calorimeter method (Shi *et al.,* 2016). The gross calorific (heating) value (higher heating value on a dry basis, HHV_{db}) was determined through the standard measurement. The value of higher heating on a wet basis (HHV_{wb}) was determined using the $HHV_{db}$and the moisture content of that particular sample wasappliedin the following equation (Hla and Roberts, 2015).

$$HHV_{wb} = HHV_{wb}(1 - MC \times 0.01)$$

The concentration of TC (Total Carbon) within samples was measured through Shimadzu TOC-V analyzer (Shimadzu Japan) with zero air carrier gas.

Data analysis

The data accomplishedof the waste composition practices were recorded as a data set, the percentage in weight of each fraction related to the total weight was evaluated. To identify thecorrelation between proportionsof different unit's solid waste, a statistical Pearson correlation was performed on the results of solid waste composition for these units. The analyses were calculated using SPSS16 version software.

RESULTS AND DISCUSSION

Assessment of solid waste generation

The assessment of solid waste generation rate is an essential for the valuable usage of solid waste through recycling and valorization and to minimize the probable negative impacts of solid waste (Lohri *et al.,* 2014). The daily waste generation was varied from 770.3 kg/per working day in May 2018 to 1196.8 kg/per working day in Oct 2018. The average per capita solid waste generation was 0.116 kg/day whereas monthly daily solid waste generation 1047.1±214.4 kg/day was found during study duration (Figure 2). The maximum volume of waste generation was observed in August (1250.03 kg/day) and minimum in June (768.44 kg/day). This might be due to in month of August, all hostels of the University campus are fully occupied and there is high moisture content availability in waste due to monsoon rain at that time. In June, due to the vacation, the generation rate was comparatively low. It was found to be the waste generation in campus influenced by variation in the academic schedule of the University. In University campus, the major solid waste generation points were the home science girl's hostel, community centre market and new campus residential areas.

The comparable results of solid waste generation rate of different universities indicated that CCSHAU and LUVAScombined campus has one of the medium waste generation rate (Table 3). Among reviewed results the largest level of solid waste generation rate (400.00 g/person/working day)was at METU campus, Turkey, because it is a large campus having more facilities which generates large amount of wastes (Bahçelioglu *et al.,* 2020). The lower waste generation rate of 42.00g/person/working was observed at The Massey University, Newzealand day. In the campus of this University, the solid waste management programme was implemented, that's why generation rate was low (Mason *et al.,* 2004). Additionally, the variation of waste generation among different Universities could be due toaspects like level of income, socio-economic distribution, utilization habit andpeople waste disposal habits etc. (Ugwu *et al.,* 2020).

Composition of the solid waste

To make a proper planning of solid waste management, the precise data of the solid waste composition was required because more changes occurs in waste composition with time and due to various activities (Hoornweg and Bhada-Tata, 2013; Iliæ and Nikoliæ, 2016). Figure 3 shows the solid waste composition for different structural units of CCSHAU and LUVAS combined campus.

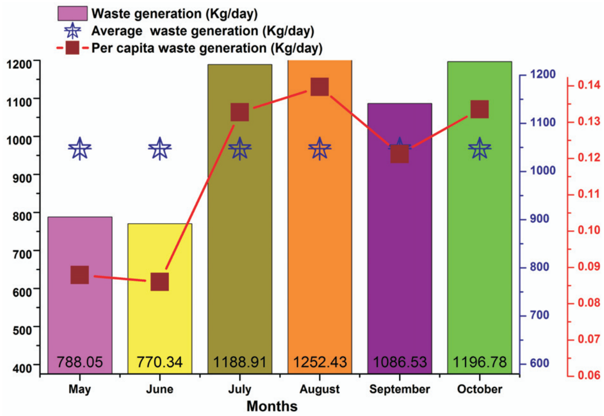

Fig. 2. Solid waste generation in different months at combined campus of CCSHAU and LUVAS

Research and academic

Research and Academic unit samples were collected from different college buildings and the proportions of solid waste generated are shown in Figure 3(a). The largest fraction of solid waste produced from this unit was paper waste (18.42%). It might be due to the examination schedule in May and September. At the University of Lagos paper waste was found to be 15% of the whole generated waste (Adeniran *et al.*, 2017). The another major wastes fraction were food waste, polythene, plastic and cardboard which were 17.35%, 15.97%, 12.07%, and 8.16%, respectively. The fraction of food waste is also high because with each college building there are facilities of canteens. In the current study, due to the laboratory work and veterinary hospital, chemical applied cotton/ medical waste was also obtained and it was 4.91%.

Administrative Centre

The generation of solid waste from all offices of the Universities combine campusinvolved under this unit and results are illustrated in Figure 3(b). The average value of paper waste was observed 27.84% that was the highest fraction at this unit. The larger quantity of paper was observed in the months of May and September. The paper waste contributes about 32% and 29.1% at the University of British Columbia, Vancouver and the University of Northern British Columbia, Canada, respectively (Felder *et al.*, 2001; Smyth *et al.*, 2010). At administrative centre the other major fractions of waste were the cardboard (18.56%), food waste (17.27%), polythene (11.08%) and plastic (9.94%). The food waste content was found to be high throughout the year at the administrative centre. It might be due to most staff person does their lunch in the offices and canteens facilities is available. Inert waste contents were found higher in months of May (5.26%) and June (5.31%). It may be because of dry weather in which more dust is generated. The generation of E-waste was also observed in the month of May, June and August with the average value of 0.51%.

Table 3. Rate of solid waste generation in various universities

Name of University	Waste generation rate of University (g/person/working day)	Sources
Massey University	42.00	(Mason *et al.*, 2004)
Universidad Autónoma de Baja California	45.60	(Armijo de Vega *et al.*, 2008)
University of Lagos (Unilag) Akokacampus	53.11	(A E Adeniran *et al.*, 2017)
Covenant University	60.50	(Okeniyi and Anwan, 2012)
Universidad Jaume I	89.50	(Gallardo *et al.*, 2016b)
CCSHAU and LUVAS campus	**116.0**	**Present study**
University of Tabriz	131.50	(Taghizadeh *et al.*, 2012)
Pondicherry Engineering College,India	324.17	(Rajamanikam and Poyyamoli, 2014b)
Universidad Iberoamericanaa	330.00	(Ruiz Morales, 2012)
METU campus, Turkey	400.00	(Bahçelioglu *et al.*, 2020)

Residential

This unit of Universities campus covered staff quarters, all hostels and other residential buildings. The results depict that the proportion of food waste generation was the highest (49.88%) amongst all other waste category (Figure 3(c)). This proportion varied in different months as low food waste generation was observed in the month of May and highest was generated in the September. Thelowest component of food waste might be because ofholiday's period in month of May. Mbuligwe

(2002) studied the waste generation from the residential hall of three universities namely UCLAS, UDSM and WRI in Tanizia and found these units encompasses high organic wastes i.e. 40.0%, 54.5% and 67.5%, respectively. At residential unit the other fractions of waste generated according to their proportion were polythene (10.3%), plastic (6.1%), sanitary (5.26%), cardboard (4.94%), paper (4.9%), glass (4.1%) and others (3.7%). The proportion of medical waste was 0.39%. The result was contemporary with the recognised 0.16% medical waste at University of Nigeria, Nsukka campus (Ugwu *et al.,* 2020).

Market

The Universities campus has two major markets, small canteens and tea stalls at different places. Focussing the market waste, the fraction of food waste generation was found highest with the average value of 51.75% (Figure 3(d)). This high content of food waste might be due to the number of food foundries at community centre market and other canteenswhere unavoidable trimmings of food items like food scraps,fruit covers and vegetable peelings, etc. The proportion of cardboard was 12.16% which was the second largest proportion and it consist of coffee or soft drink cups and waste ofphoto state and other shops that used packed materials. The fraction of plastics was 7.27% and it was found more than glass 1.35% because the plastic packaging was consumed more habitually than glass bottles in the canteens. The other fractions of waste observed were polythene 7.83%, paper 7.78%, sanitary 4.08%, others 2.5%, inert 2.05%, metals 1.53%, and textile 1.60% at market place. Similar results were also observed bySmyth *et al.,* 2010 and Taghizadeh *et al.,* 2012.

Mixture

The mixed waste samples were taken directly from collecting vehicle that collect waste of the whole Universities campus and data is represented in Figure 3(e). Similar to residential and market unit, food wastes fraction of this unit was also found highest (62.13%). This highest proportion might be due to the large population of students (68.2%) and staff (45.3%) are residing in the campus. Zhang *et al.* (2016) studied that 60.83% fraction of food waste was generated at the LL Campus of HAU in China. Furthermore, other waste contents found to be polythene 10.8%, paper 6.3%, plastic 6.1%, cardboards 3.9%, textile 2.7%, inert 2.3%, glass 1.6%,

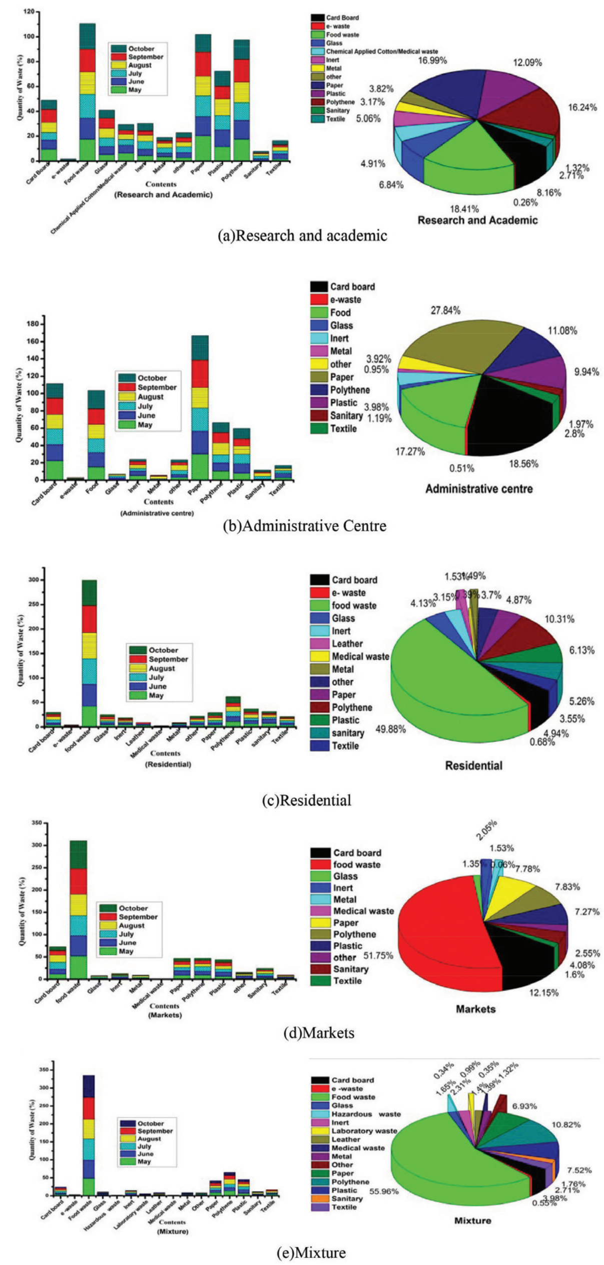

Fig. 3. Month wise and average solid waste composition of different structural units at combined campus of CCSHAU and LUVAS

leather waste 1.4%, hazardous waste 0.3% and medical waste 0.3%. The laboratory solid wastes such as gloves, chemical used cotton, etc. contributed by research laboratories and academic structural units of the Universities campus were foundto be in the months of May, June, September and October with the average value of 0.9%. Armijo de Vega *et al.* (2003) and Gallardo *et al.* (2016) had also obtained the similar results of hazardous wastes generation as 0.3% and 0.28%, respectively.

Characterization of solid waste

Table 4 presents the average values of various physico-chemical characteristics of solid waste generated in different structural units of the combined campus of CCSHAU and LUVAS. These characteristics were found to be valuable for evaluating environmental impact of solid waste and waste to energy conversion approaches.

Moisture content

The moisture content of raw waste samples varied from 24.53±2.79 to 40.67±2.94 (Table 4). The variation in moisture contents might be due to waste variation, weather and seasonal conditions at the sampling time (Hui *et al.,* 2006). The maximum value of moisture was observed in mixture unit's waste which mainly consist of food waste. Due to monsoon season in the month of July and August the highest moisture content in solid waste was observed. The similar finding of high moisture content in solid waste wasstated by Gupta *et al.,* 2015 and Chavan *et al.,* 2019. While, the minimum value for moisture was found to be in administrative centre unit waste of CCSHAU and LUVAS campus that might be due to lowest fractionof food waste.

Volatile content

The values of volatile content described the quantity of organic materials present in solid waste. Institutional waste having organic contents such as newspapers and cardboard are highly volatile but less biodegradable. The calorific value of waste will be higher if the more volatile contents are present and waste can be consumed for energy production by incineration/biomethanation (Jerie, 2006). The average values of volatile content for different units were varied from 22.30±3.39 to 65.03±4.32. In the administrative unit the highest content of volatile solids was detected that might be due to more fraction of paper and cardboards in the solid waste (Table 4). Similar results were reported by Baawain *et al.,* 2017; Kuleape *et al.,* 2014.

Bulk density

Table 4 represents the bulk density of MSW of different structural units. The highest value of bulk density 480.23±12.78 kg/m^3 was observed in residential waste that might be due to more value of moisture content of residential waste. Similarly the higher bulk density were also found to be in mixture and market solid waste. The lowest bulk density 170.23±17.89 kg/m^3 was observed at research and academic units because the waste of this unit mainly consisting of paper and polythene, which were lighter in weight. Mbuligwe (Mbuligwe, 2002) identified the similar results of bulk density at three institutions namely UCLAS, UDSM and WRI of Tanzania. Similarseasonal variation in bulk density of solid waste has been observed by Li *et al.,* 2021.

Calorific value

The calorific value or high heating values (HHV) determination of solid waste is much required for any combustion procedures and it is mainly correlated with the moisture content of the solid wastes (Baawain *et al.,* 2017). The CCSHAU and LUVAS combined campus units waste have generated calorific values from 3,998±123 kJ/kg to 7,523±140 kJ/kg on a dry basis and 2,980±102 kJ/kg to 5,678±104 kJ/kg on a wet basis (Table 4). The total energy content was found highest for the administrative unit that might be due to higher fraction of plastic, cardboard and paper materials in the waste. It have beenreported in many studies that the calorific value of more than 1000-6000 kJ/kg deliberated during waste combustion as high heating value (Tian *et al.,* 2001). In view of this potential, waste-to-energy generation can be applied for the Universities campus waste. Kumar *et al.* (2009) studied the HHV_{db} of municipal solid waste (MSW) of different metro cities, state capitals, class I cities, and class II towns in India. The results were

Table 4. Moisture content, Volatile content, Calorific value, bulk density and total carbon content of solid wastes samples

Parameter	Research and academic		Administrative centre		Residential		Markets		Mixture	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Moisture (%)	25.47	3.88	24.53	2.79	34.29	2.99	38.66	2.92	40.67	2.94
Volatile content (%)	41.72	3.38	65.03	4.32	38.07	2.57	22.30	3.39	41.23	2.59
Calorific value(kj/kg) dry basis	3998	123	7523	140	5187	134	4356	121	6678	101
Calorific value(kj/kg) wet basis	2980	102	5678	104	3408	91	2584	98	4096	39
Bulk density (kg/m3)	220.46	10.53	170.23	17.89	480.23	12.78	380.45	21.21	420.56	14.57
Total carbon	18.56	1.54	15.46	1.45	34.78	2.42	30.45	1.82	27.78	1.94

concurrent with the high calorific values reported for the municipal solid waste of Jalandhar City, Nasik city of India and Maramures County (Sethi *et al.,* 2013; Ungureanu *et al.,* 2021; Yadav *et al.,* 2016).

Total carbon (TC)

Table 4 represents the TC contents of different samples and its values werevaried from 15.46±1.45% to 34.78±2.42%. The highest carbon content was observed atresidential unit waste that having large fraction of food waste. This more carboncontained wastecan be easily converted into compostable materials or production of biogas (affordable and clean energy). While the lowest value of carbon content was found to be in research and academic unit waste that might be due to the high fraction of inert materials and less availability of food waste. la Cour Jansen (la Cour Jansen *et al.,* 2004) analysed the average of 46.8 % carbon content insource-separated organic household waste. Similar studies were reported forthe municipal solid waste of Jalandhar City and waste disposal sites in Karachi, Pakistan (Sethi *et al.,* 2013; Sohoo *et al.,* 2021).

Relationship in waste contents of various structural units

The Pearson correlation analysis between the different structural units wastes (paper, glass, inert, plastic, polythene, food waste, metal, textile, sanitary and other) of the combined campus of CCSHAU and LUVAS are illustrated in Table 5. A statistically substantial correlation of waste dispersal among the research and academic and other structural units was found to be negative. This showed that the large variations in wastes generation between research and academic unit and other structural units. The administrative unit have a week correlation of 0.420, 0.492 and 0.483 with residential, market and mixture units waste. A strong positive correlation of mixture unit waste was observed with residential and markets waste contents, which was 0.995 and 0.997 at $p<0.01$. These results verified that all dominated waste contents of the mixture unit have similarities with wastes of residential and markets units. Similar finding has been analyzedby Adeniran *et al.,* 2017 and Ugwu *et al.,* 2020.

Solid waste management practices and plans for its sustainability

According to Municipal Solid Waste (Management and Handling) Rules, 2016, it is essential for every association/group to handle the solid waste at the personal level if that generates more than 100 kg/day of solid waste. The solid wastes are generated from combined campus in large quantities, so, there is a huge space for upgrading the campus waste management approach. Solid waste reduction is a leading phase of an effective waste management approach (Zaman and Lehmann, 2011). The combined campus of CCSHAU and LUVAS has generated a small proportion (7.08%) non-recyclable waste similar to other studies performed by researchers (Adeniran *et al.,* 2017; Armijo de Vega *et al.,* 2008; Smyth *et al.,* 2010; Ugwu *et al.,* 2020; Zhang *et al.,* 2020). Therefore through a particular waste management plan of an organization, a load of solid waste on dumping sites can be reduced, which will decrease the emission of greenhouse gases that

Table 5. Relationship among various structural units of University campus using eight main wastes contents#

		Research and academic	Administrative	Residential	Markets	Mixture
Research and academic	Pearson Correlation	1	-0.109	-0.010	-0.014	-0.063
	Sig. (2-tailed)		0.764	0.979	0.969	0.862
Administrative	Pearson Correlation	-0.109	1	0.420	0.492	0.483
	Sig. (2-tailed)	0.764		0.227	0.149	0.157
Residential	Pearson Correlation	-0.010	0.420	1	0.994**	0.995**
	Sig. (2-tailed)	0.979	0.227		.000	.000
Markets	Pearson Correlation	-0.014	0.492	0.994**	1	0.997**
	Sig. (2-tailed)	0.969	0.149	0.000		0.000
Mixture	Pearson Correlation	-0.063	0.483	0.995**	0.997**	1
	Sig. (2-tailed)	0.862	0.157	0.000	0.000	

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed) and
Note: paper, glass, inert, plastic, polythene, food waste, metal, textile, sanitary and other composition was used for establishing relationship between different units.

cause climate change effect.

Results presented that solid wastes included some fraction of hazardous and laboratory wastes; which demanded separate management of such types of waste. The combined campus of Universities has hired Synergy Waste Management Pvt. Ltd., services for the management of biomedical waste. For the safe handling of waste, safety equipment must be provided to the waste handling staff and proper training/counselling should be planned to build their technical skills. Universities are good places for starting the waste reduction programme related to non-recycled as well as recyclable wastes. During the study period at the combined campus of CCSHAU and LUVAS, a large fraction food waste (55.96%)was observed which can be utilized for composting/biogas production. In India due to the low economic value of organic waste and very little availability of market for composting, its recycling is still refused by private authorities (Balasubramanian, 2018). But universities can start biogas production and composting units at their own level and can utilize this compost on institution campuses. About 30.65% of the waste produced at the combined campus could be recycled in existing recycling markets. Through these activities,Institutions can reduce the waste volume, as well as they, have some economic gain.

CONCLUSION

The average waste generation at the combined campus of CCSHAU and LUVAS was found to be 0.116 kg/day/capita and the major contributor's area are the home science girl's hostel, community centre, market and new residential areas. It was determined through the waste composition analysis that the waste contents vary in different structural units based on the various activities of a particular unit. The waste recycling potential of the combined campus of CCSHAU and LUVAS was observed high because of high food waste (55.96%) and recyclables materials (30.65%)such as paper, plastic, polythene, cardboard and metal. The solid waste of combined campus of CCSHAU and LUVAS have the potential for the production of clean energy because it contained more fraction of food waste. The calorific value of the mixed waste sample was observed 6678±101 kJ/kg.Thus can be easily utilized for the waste energy process. The study mainly focused on the solid waste characterization that can become helpful for the effective solid waste management approaches to the Universities campus.

Declaration on conflict of interest: There is no conflict of interest between authors and organizations.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

ACKNOWLEDGEMENT

The authors acknowledge the TEQIP-III GJUS&T, Hisar for providing financial assistance with letter number TEQIP-III/2018/1841-1142 to conduct this research.

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