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Solid Waste Management on a Campus in a Developing Country: A Study of the Indian Institute of Technology Roorkee

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Abstract: The rates of waste generation in India have been increasing with increasing population and urbanization. Since higher education campuses are like mini autonomous cities, they can act as a model for solid waste management (SWM) and enhance sustainable development. SWM is the controlled generation, storage, collection, transport, processing, and disposal of solid waste considering public health, conservation, economics, and environmental conditions. A SWM program on campus will benefit the campus through reduced resource consumption and waste diversion. Developing countries like India are lacking behind in SWM from the developed countries which are using advanced technologies along with efficient management. This paper will analyze the issues related to SWM at IITR (Indian Institute of Technology Roorkee) campus and provide feasible solutions to be implemented at IITR campus for becoming zero waste campus. The SWM at the IITR campus is disorganized and incompetent. Lack of awareness and improper collection, imprecise segregation, exposed transportation, inefficient processing and disorganized disposal of solid waste are the major reasons for it. IITR has the potential to manage its waste properly through various techniques discussed in this paper. These would reduce the amount of waste diverted to landfills and the problems arising on campus due to solid waste, thus leading to a zero waste campus. Other campuses like IITR with similar context and issues can learn from this case study and work towards a zero-waste campus. This paper identifies a need to implement a robust SWM at the IITR campus in India.

Keywords: solid waste management; zero waste campus; recycling; waste classification; technologies; campus

1. Introduction

Solid waste management (SWM) is one of the basic services arranged and administered by the municipal authorities in the country to enhance the cleanliness of the urban centers [1]. The main objectives of SWM are the maintenance of clean and hygienic conditions and reduction in the quantity of solid waste (SW), which is disposed of in the sanitary landfill facility (SLF) of the area after recovery of material and energy from it [2]. However, mostly the service is inefficient and weak due to lack of scientific methods and new approaches, low population coverage, and marginalization of the poor [3]. Poor management of waste leads to littering and thus unsanitary living conditions [4]. The growing problem of SWM due to population growth is not dealt with effectively as the municipal laws governing the urban local bodies do not have efficient and competent provisions to handle this growth [5]. Rapid urbanization is augmenting this problem, thus making it critical.

The average rates (0.5–0.99 kg per person per day) of waste generation are higher in India as compared to those (0.1–0.49 kg per person per day) in low-income countries worldwide and much lower than the developed economies (greater than 1.5 kg per day) of the world [6,7]. Figure 1 shows the comparison of global waste generation per capita per day in kg. However, there is a constant increase in the waste generation especially in the larger cities due to lifestyle changes, use of packaging materials, etc. Growth of urban population of 2.7 percent to 3.5 percent per annum will result in an increase of over five percent in a solid waste generation [1,8]. As per the estimation of the Energy and Resource Institute (TERI), the waste generation exceeds 260 million tons per year by 2047, which is more than five times the current level in India. Cities with a population over 100,000 are the major contributors (72.5 percent) of total waste generated in the country as compared to the 3955 urban centers which produce about 17.5 percent [1]. Figure 2 represents the waste generated in different cities of India with a comparison of the change in the rates of waste generation over time. The per capita per day waste generation in urban cities have changed from an average of 0.5 kg to 1.5 kg [9,10].

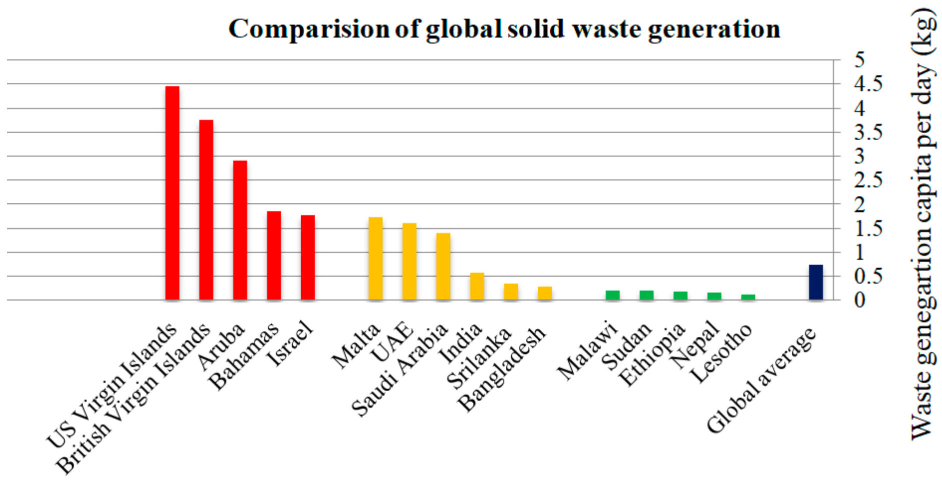

Figure 1. Comparison of global waste generation per capita per day in kg (source: http://datatopics.worldbank.org/what-a-waste/).

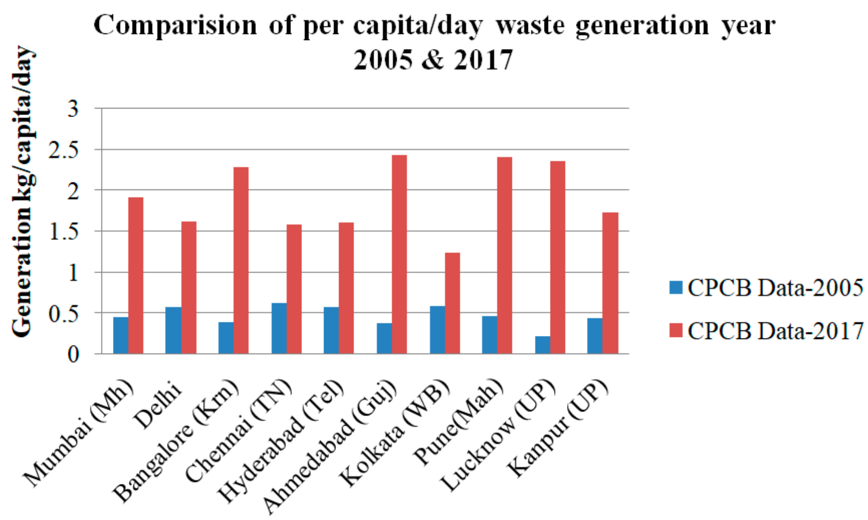

Figure 2. Per capita solid waste (SW) generation rates of various Indian cities (Source: CPCB-2004, CPCB, 2017).

Higher education institute (HEI) campuses replicate a city's characteristics on a small level, producing similar environmental impacts. Therefore, they can be considered as small cities [11]. Thus these campuses can demonstrate and influence the local neighborhoods to adopt and successfully implement sustainable practices [12]. The ever-growing global concern about environmental sustainability in HEI campuses has accelerated the concept of sustainable campuses. SWM is one of the basic parameters of environmental sustainability [13]. A dedicated SWM program on the campus will sensitize and build the consciousness of the campus occupants toward waste management; increase the productivity and performance of students and employees by providing clean and healthy workplace; influence the local community by creating a difference in the level of cleanliness between the campus and the local environment [14].

The campus occupants, through practice, and the neighborhood communities, through influence, thus become the direct beneficiaries of the concept. The community can be sensitized about the benefits of SWM through awareness programs, motivational interactions, web portal and sharing information on the issues along with the community participation [15].

The current study evaluates the solid waste profile at Indian Institute of Technology Roorkee (IITR) campus, and characterize the waste generated along with its source by means of qualitative and quantitative analysis. It also identifies SWM systems adopted in the campus. Based on the literature and technologies available for SW processing, it suggests a corrective course of action for SWM at the IITR campus to make it a 'zero-waste' campus.

2. Theoretical Background

SWM basically includes storage and collection of SW; transfer and transport of SW and last is SW disposal and treatment which includes recycling of organic waste, thermal treatment techniques, recovery of recyclable products and landfilling [16].

The management of the solid waste is done on the bases of priority listing, where the arrangement of the process is in order of rank. The conventional waste management methods are focused on the collection, transportation and disposal to the landfill site [17]. Hierarchy of the waste management needs to be strictly followed to focus on the long term environmental, economically sound results [18]. The preferred order of preference of SWM includes generation and separation; Collection, transfer and transport; recycling; treatment and final disposal [19].

Reducing the waste at the prime source is the first step of waste hierarchy and coping mechanism. It is done through developing awareness by the authorities amongst the individuals. Source segregation of waste must be strictly followed through various capacity building and coping mechanism for getting recyclable material for recycling and treatment processes. An important coping mechanism is technical and financial strategy formulation, understanding the process of waste management, interlinking of stakeholders, influencing native social–cultural aspects and food habits. This helps to develop sustainable waste management system [15].

The waste flow case studies are conducted on the basis of the steps of solid waste management detailed out in Figure 3. The amount of waste present at each step is calculated along with the techniques used. The study needs to be sequential to know the advantages and disadvantages of techniques and processes used at every step of SWM [20,21].

2.1. Sound Practices in Waste Management: (Based on the Management Theories of Waste)

The sound practices of the waste management refer to policies and technologies which set the balance effectively between the environment, society and economy. Administrative interventions and community involvements contribute to sustainable SWM system [22]. Reduction of waste at source by the individual generator through the use of products which are reusable is the first option [23]. Composting is a highly efficient and beneficial technique of SWM for organic waste especially for countries like India where the generation of organic waste is higher than the developing countries. Some studies show that 80 to 90% of waste going to landfill sites can be prevented [19]. The process of recycling of inorganic waste is an economical method of utilizing the separated waste to make new products. The participation mechanism in the waste management process is extremely important as key points addresses the public participation, privatization, community participation, partnerships, capacity building and skill development. Figure 3 shows how the coping mechanism is interlinked to sound waste management practices.

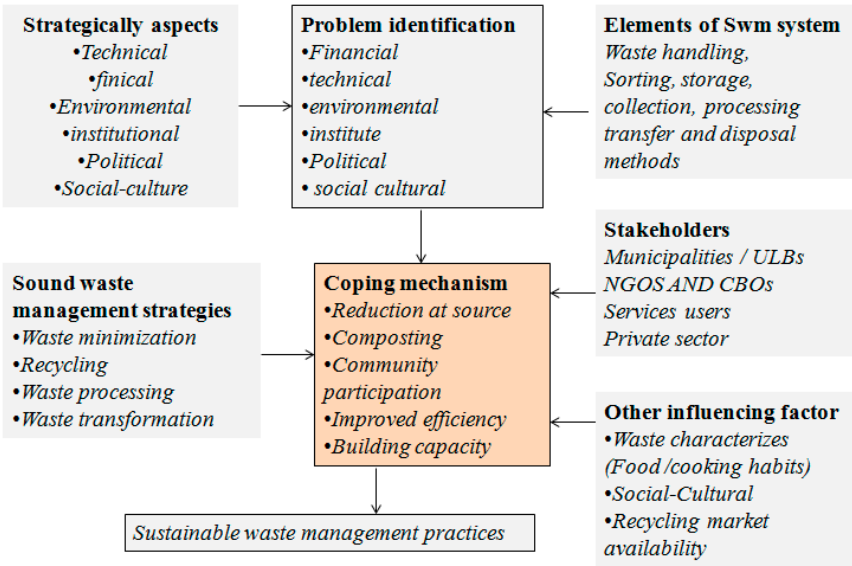

Figure 3. Conceptual framework for solid waste management (SWM) sound practices coping mechanism [1].

2.2. *Comparison of International Studies on SWM*

Segregation: sound practices are inadequate in developing countries as compared to the developed countries [24]. Kamikatsu is the first Japanese municipality which became a zero waste city of a strongly implemented SWM policy, where the residents sort 45 types of waste at the source in 13 categories. The region is able to recycle almost 81% of the total waste. As a management technique, Germany is using an advanced management technique (enhanced resolution, mobile sorting) [25]. The frequency of waste collection is an important part of the waste management system. As compared to developing countries, developed countries are far ahead with the strict rule on the collection frequency with the advanced mechanism. The segregation of waste into different typologies makes their system more efficient as a major fraction of segregated waste is recyclable or suitable for incineration [26]. Developing countries are struggling to achieve a timely collection with 100% door to door collection because of poor resources and old equipment [27]. Inefficient storage capacity is another issue faced by the municipalities [28]. There are mainly two kinds of innovative mechanism tested and utilized with positive results—composting (aerobic, anaerobic and vermicomposting) and waste to energy: (biomethanation, incineration, and pelletization, gasification, pyrolysis, etc.) in the developed [16]. Sweden has achieved the zero waste concept as their annual landfill waste is reduced to almost zero through an incineration process for generating electricity [29]. The Netherlands is following thermal waste incineration since 1919 [30]. They have introduced a landfill tax to increase the recycling rate and reduce the landfill [31]. India needs to formalize the SWM to get the best results with the treatment facilities like developed countries [32]. Collection and segregation frequency need to be mechanized [16], the waste to electricity generation is feasible along with composting and methane gas formulation as it is more effective due to major argo waste generation annually [33]. India and China have become the biggest markets for recycling of waste in recent time due to industrial and infrastructure growth with a major portion of the plastic metal and paper being processed to recycling [34].

2.3. *Key Issues of SWM in India*

Lack of implementation of comprehensive short and long term plans by the municipal authorities to handle SWM in conformity with the Municipal Solid Waste Rules (2000), India (www.cpcb.nic.in) is one of the major issues of SWM in India [35,36]. Also, the majority of the municipal authorities do not have proper waste processing and disposal facilities. Waste management is generally considered as a service to increase personal revenues. With the current increase in population, the cities and towns will not get wastelands in the future for dumping waste. Therefore, there will be a need to go for 100 percent recycling and reuse of waste, thus aim for zero waste for landfill.

2.4. Steps of SWM in India (CPCB 2000)

Figure 4 demonstrates the step of SWM as listed and advised by the Central Pollution Control Board (CPCB) in 2000 [35].

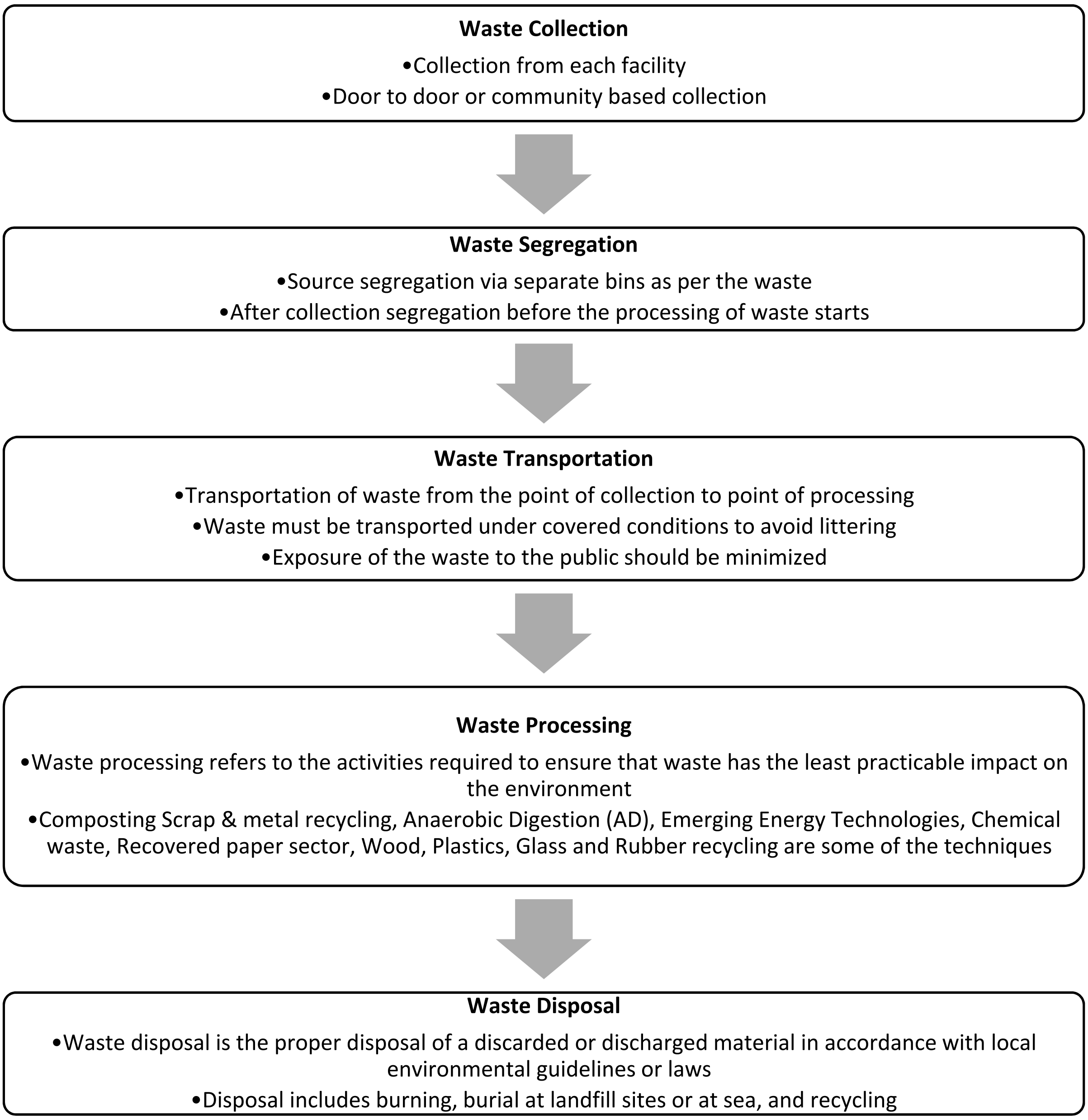

Figure 4. Steps of solid waste management [35].

2.5. Factors Governing the Choice of Technology

Economic viability and sustainability along with environmental implications are the major factors governing the choice of technology for implementation in SWM [37]. There are several other key factors such as:

i. The origin and quality of the SW.

ii. Presence of hazardous or toxic waste.
iii. Availability of outlets for energy recovered.
iv. The market for the compost produced.
v. Cost of waste processing such as land price, capital and labor costs.
vi. Capability and experience of the technology used.

2.6. Classification of SW

SW can be classified into various types depending on their sources. Table 1 details the general classification of SW.

Table 1. General classification of solid waste (SW) [38].

Type of SW	Description	Sources
Food waste (Garbage)	Waste obtained as a result of preparation, cooking and serving of food. Market refuse, handling waste along with waste produced due to handling, storage and sale of food are included.	Household, restaurants, street food corners, etc.
Rubbish	It includes two types: (i) combustible (primarily organic)—paper, cardboard, cartons, wood, boxes, clothes, leather, bedding, grass, leaves, plastic, etc., and (ii) non-combustible (primarily inorganic)—metals, stones, bricks, glass, etc.	Households, institutions and commercial facilities such as hotels, stores, markets, etc.
Ashes and residues	Waste obtained as fire residue from the cooking of food and heating of buildings, cinders, clinkers, etc.	Household and small scale plants, etc.
Bulky waste	Auto parts, other large appliances, tires, stoves furniture, trees	Shops, households' etc
Street waste	It includes dirt, leaves and animal droppings collected as a result of street sweepings.	Streets, sidewalks, vacant lots, etc.
Dead animals	It includes the dead bodies of dead animals such as cats, dogs, poultry, horses, cows, etc.	Streets
Construction and demolition waste	The SW resulting from the construction industry such as lumber, rubble wires, etc.	Construction and demolition sites
Industrial waste and sludge	It includes SW from industrial processes and manufacturing operations	Factories, treatment plants
Hazardous waste	Hazardous waste includes pathological waste explosives, radioactive materials, etc.	hospitals, laboratories, institutions, chemical factories, etc.
Horticulture waste	It comprises of the waste resulting from the horticultural activities such as tree trimmings, leaves, waste from gardens and orchards, etc.	Parks, gardens,

2.7. Technologies for Processing, Treatment, and Disposal of SW

There are various technologies available and used for management of SW. The availability of SW in mixed form in India poses a challenge to its treatment process and makes it hazardous. The main reason for this scenario is the lack of awareness among the people at various levels. Hence source separation of waste is important to get the best possible result and implement any strategies successfully.

Hence, source separation of waste is important to get the best possible result and implement any strategies successfully. The broad waste types and their relevant techniques with benefits and issues have been given in Table 2.

Table 2. Technologies available for processing, treatment and disposal of SW [1,39,40].

Types of Waste	The Technology Available for Processing	Benefits	Issues
Paper	Paper recycling	• End-use appliances for paper recycling generates writing a quality paper. • Runs successfully as a social model. • Efficiency is improving at a higher rate.	• High capital investment is required. • Business development related activities are needed to make it sustainable.
	Waste to Energy	• Converts the SW into usable energy. • No external fuel requirement and easy process • The total efficiencies of cogeneration incinerators are typically higher than 80%.	• High capital investment is required. • Proper utilization of energy thus produced has to be ensured.
Organic and Garden	Composting	• It is practically free • destructs pathogens and kills weed seeds • reduces mass and volume and odor. • reduces handling and transportation. • acts as a soil conditioner and improves nutrient qualities. • decreases pollution from chemical fertilizers. • Efficiency is high.	• Time-consuming • Odor and smell • Large land requirement • May attract pests and rodents
	Vermicomposting	• Recycles Waste • low costs • It is practically free • destructs pathogens and kills weed seeds • reduces mass and volume and odor. • reduces handling and transportation. • acts as a soil conditioner and improves nutrient qualities. • decreases pollution from chemical fertilizers. • Efficiency is high.	• Long harvesting time • High Maintenance • Pest and pathogen problems
	Anaerobic digestion and methanation	• Generates gaseous fuel • Flexible scale. • External power not required. • Reduction in greenhouse gas emission. • Free from rodent and fly problems • No bad odor. • The modular construction of plants and closed treatment leads to the lesser land requirement. • No social resistance. • Efficiency is high.	• Capital intensive technique • Not good for SW with less biodegradable matter
	Pyrolysis/Gasification, Plasma Pyrolysis Vitrification (PPV)/Plasm arc process	• Energy recovery • Proper destruction of waste • Produces liquid or gaseous fuel to replace fossil fuels • Controlled atmospheric pollution at the plant level. • Efficiency is high.	• Significant solid waste sorting operations • Highly skilled personnel required • High capital investment

Table 2. *Cont.*

Types of Waste	The Technology Available for Processing	Benefits	Issues
Inorganic	Sanitary landfills and landfill gas recovery	• Less capital required. • Potential for recovery of landfill gas as a source of energy. • Highly skilled personals are not required • Efficiency is low.	• Land requirement is high
	Waste to energy (WTE)	• Landfill waste can be reused • Less capital required • Landfill sites can be mined and material can be used as fuel • Efficiency is low.	• WTE require high capital investment • They are complex
	Production of refused derived fuel (RDF)	• Coal substitute at low price • Easy storage and transportation of RDF pellets. • Efficiency is high.	• Significant solid waste sorting operations • Highly skilled personnel required • High initial capital investment
Plastic	Incineration	• Coverts the solid waste into usable energy. • No external fuel requirement. • Easy Incineration Process. • Efficiency is high.	• Wastage of energy which could be saved while recycling
	Plastic recycling	• Energy and natural resources are conserved • Plastic recycling conserves landfill space • Creates green jobs • Efficiency is high.	• Not always cost effective • Recycled products may not last for long • Recycling sites are often unsafe
Construction and demolition waste	Reuse	• Substitute for new products. • Donation or selling of products makes it beneficial. • Efficiency is moderate.	• Materials which cannot be reused aggregate and are disposed of at the lowest costs
Chemical/ Hazardous	Recycling	• Recycled into new products • Efficiency is low.	• Skilled personal required • As per the Guidelines prescribed by Govt. of India for hazardous waste disposal system
	Portland cement	• Commonly used. • Cement based stabilization and solidification. • Efficiency is low.	• Skilled personnel required • Initially requires high capital investment
	Incineration, destruction, and waste to energy	• Reduced air pollutants in the process. • Usable energy obtained. • Efficiency is high.	• Involves high capital investment • More complex
	Hazardous waste landfill (sequestering, isolation, etc.)	• Minimum contact with hazardous waste. • Efficiency is low.	• High capital investment • Space • Contact with hazardous chemicals.

Table 2. *Cont.*

Types of Waste	The Technology Available for Processing	Benefits	Issues
Medical	Off-site	• Disinfection, collection, and transportation to a common area where it is disposed of by incineration. • Efficiency is high	• Safe transportation required and high cost • As per the Guidelines prescribed by Govt. of India for medical waste disposal system
E-waste	Recycling	• Conserves natural resources • Protects the environment • Create Jobs • Saves landfill space. • Efficiency is high	• Electronic products contain hazardous materials which include poisonous chemicals
Metal	Metal recycling	• Energy and natural resources are conserved • Metal recycling conserves landfill space • Create green jobs • Efficiency is high	• High capital investment • Large space required
Glass	Glass recycling	• Energy and natural resources are conserved • Metal recycling conserves landfill space • Create green jobs • Efficiency is high	• High capital investment • Large space required

3. Data Collection and Selection of Case Study

As per the guidelines provided by the Indian Ministry of Urban Development (MoUD) in the form policies of SWM rule 2016, all gated society and campuses have been advised to develop the treatment and segregation of waste within their premise [40]. The author needed to have an immersive experience in the IIT to write this manuscript. The stay of the authors in IITR for a long period of time led to the selection of IITR as a case study to write this manuscript.

3.1. Case Study—IITR Campus

IITR is an autonomous institution funded by the central government of India. It is one of the premier institutes of India. The campus is situated in Roorkee, a town in the hilly state of Uttarakhand. The campus is spread over an area of 365 acres and is divided among the academic departments and centers, hostels for students, residences of faculty and staff and other facilities provided for the campus occupants. The current population of the campus is around 12,000 (2018–2019).

Existing solid waste management practice in the campus includes segregation of waste (only in the staff and faculty residences) at source into organic and non-organic through color coded dustbins (blue and green). The waste thus generated within the campus is collected from community bins kept/constructed at various locations and transported from community bins to disposal site located outside the campus. Finally, the waste is dumped into the municipal dumping site. The contract is given to the local contractor to carry the waste from the community bins inside the campus and dump them to the municipal dumping site outside the campus. At the building level, waste is collected daily and dumped into the community bins. From these community bins, waste is collected twice a week. Waste collectors called local-vendor (kabariwalas) also collect waste like glass bottles, newspapers, metal scrap, etc. from residences of staff and hostels. The Student organization NSS (National Service Scheme) collect old clothes from staff residents and hostels and distribute them to needy local people. Figure 5 details out the steps of SWM at the IITR campus.

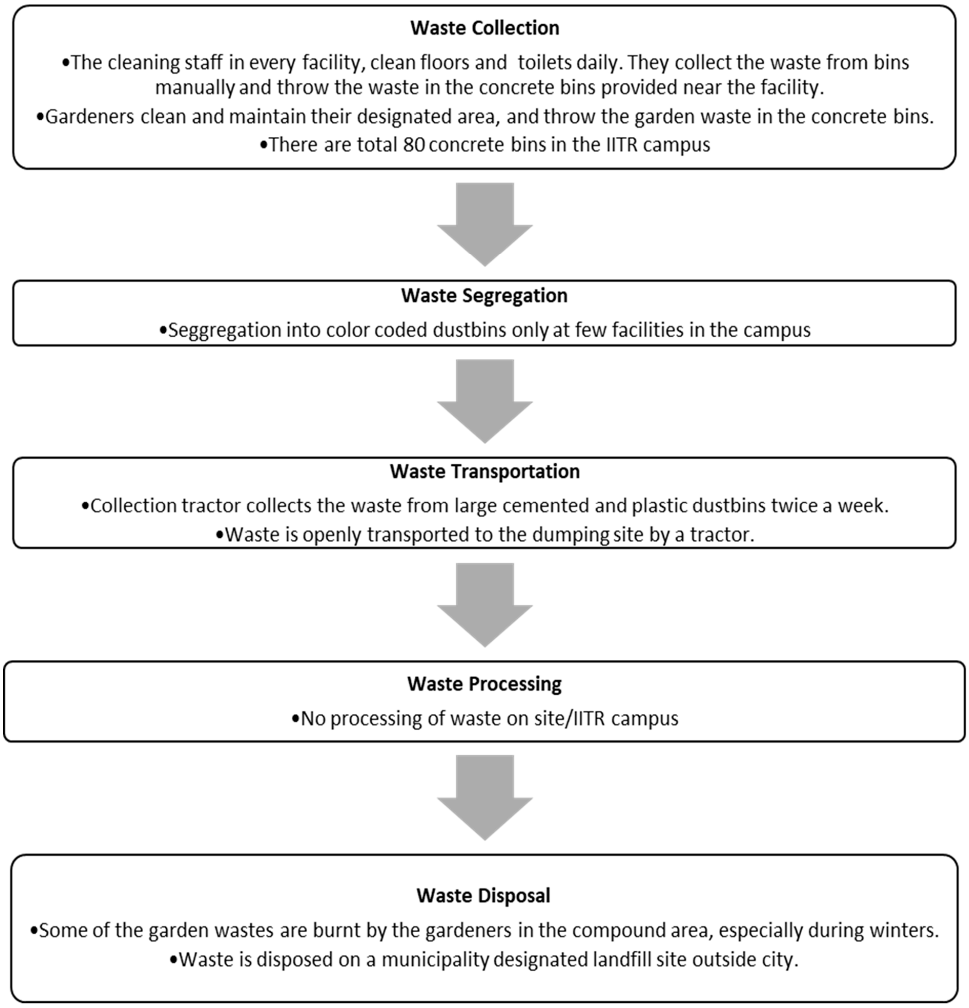

Figure 5. Steps of SWM at the Indian Institute of Technology Roorkee (IITR) campus.

3.2. Data Collection and Analysis Method

The case study was analyzed during the immersive experience of the authors on the campus during the research. For this study, primary surveys were conducted by the authors at the IITR campus over a period of two months starting from November 2018 to December 2018. During the field study, the data was collected by the authors through (a) personal observations (b) interviews with professors, students and employees, and (c) in the form of recorded documents from the campus authorities. The survey inquired about the various details of SWM at the campus. For the purpose of the study, the IITR campus was divided into nine zones and a survey of each zone was conducted to identify (i) the types of waste, (ii) quantities of waste, (iii) management practices and (iv) issues and challenges. Samples were collected from various bins qualitative (visual) and quantitative data was collected. Discussions with the mess in charge, cleaning staff and management staff were held and issues were identified. Table 3 shows a typical example of the data collection. All the data collected in the primary survey was filtered, analyzed and documented. The data was analyzed based on literature study and using Microsoft Excel as a tool. Further, all information pertaining to each step of SWM on the campus was gathered and the quantity of waste was obtained. Data was compiled and tabulated as per the type of waste generated on campus and the quantity of each type of waste. Then the data collected from these sources was diligently analyzed and tallied against each other to identify the issues of SWM in IITR campus along with the issues cited by the interviewees. An optimum solution for each issue was provided based on the Section 2, Theoretical Background. Figure 5 details out the steps of SWM at the IITR campus based on the survey.

Table 3. Data collection.

	Documents	Interviews/Sample Questions			Direct Observations and Data Recording
		Faculty/Authority (Responsible for SWM)	Students/Dependents of Faculty and Staff	Staff (Responsible for SWM)	
Number	-	59 (Faculty appointed for SWM from all the departments and hostels/residences)	105	59 (Staff appointed for SWM (e.g., sweepers, cleaning staff, etc.) from all the departments and hostels.	-
General	Documents about the existing SWM practices at the institute. Documents on SWM collected from the administrative offices of the institute.	• What kind of waste is generated in the department/hostels/residences? • How frequently the waste is collected? • What are the measures ensured to reduce waste? • Is there any waste processing facility available in the department/hostel/residence? • What are the steps of SWM? • What are the issues faced by the users/officials for SWM in the campus?			• Data were collected through direct observation (visual type of waste) and surveys (sorting and weighing) about SWM at the IITR. • (Some facilities, e.g., hostels and residences already had segregation data) • Each large cement dustbin in the institute was visited by the authors in person. • Data collection for various parameters (type, quantity, transportation and processing) was performed.

4. Results and Discussions

All the data collected in the primary survey was filtered analyzed and documented. The data was analyzed based on literature study and using Microsoft Excel as a tool. The quantity and various types of waste were obtained on the basis of the survey (Tables 4–6).

Table 4. Classification of solid waste as per different building.

S. No.	Source	Type of Waste
1	Mess	Food, tin, plastics, paper, dust, glass
2	Residential	Food, plastics, paper, tin, rubber, metal, glass, dust, textile, e-waste, medical, sanitary, garden trimming, cardboard
3	Academics	Plastics, paper, dust, cardboard, garden trimming
4	Hostel	Plastics, paper, tin, glass, dust, leather, cardboard, e-waste, medical, sanitary
5	Roadside	Plastics, paper, glass, wood

Table 5. Total amount of waste generation (kg/day).

S. No.	Source Area	Amount of Waste
1	Mess	521 kg
2	Residential	1711 kg
3	Academics	1209 kg
4	Hostel	1570 kg
5	Recreation and facilities	488 kg
	Total	5500 kg

Table 6. Types and quantity of solid waste.

Area	Quantity in kg/day										
	Paper	**Garden**	**Organic**	**Inorganic**	**Plastic**	**Construction**	**Chemicals**	**Medical**	**E-waste**	**Metal**	**Glass**
Overall IITR Campus	1580	569	1676	595	613	36	53	47	45	175	111
Bhawans	638	146	317	238	159	3	0	10	10	22	27
Bhawan Mess	10	25	456	15	17	0	0	0	0	0	0
Academics and Admin	519	140	189	67	58	19	47	0	11	127	33
Residential	292	160	553	225	337	11	6	30	24	26	47
Recreational and facilities	121	99	162	51	43	4	0	7	0	0	3

4.1. Issues Identified

As evident from Table 6, organic and garden waste together constitute the most solid waste generated on campus, paper waste being the second largest solid waste generated on campus that has the scope of recycling. The issues identified at each step of SWM in the campus are listed in Table 7.

Table 7. Issues identified at each step of solid waste management (SWM) at Indian Institute of Technology Roorkee (IITR) campus.

S. No.	Issues	Steps
1	Lack of dustbins in certain areas and facilities	Collection
2	Lack of segregation of waste in the academic buildings leading to a higher quantity of waste being sent out to be dumped.	
3	Burning of the garden waste (leaves and weeds) in certain areas occasionally.	
4	The construction/demolition debris is not being disposed of regularly, but rather stored in heaps at various locations on the campus.	
5	Inefficient design of large bins.	
6	No holistic waste segregation despite of the fact that the major waste generated is paper and organic waste.	Segregation
7	Chemical bottles and discarded glass bottles are dumped directly into the community bins.	
8	Many discarded bottles of hazardous chemicals is being kept near the compound wall for a long period of time.	
9	Biotech department disposes of their experimental waste directly into the community bins.	
10	Open transportation of solid waste from campus bin to dumping site	Transportation
11	The waste is accessible to stray animals like cows and dogs, which dislodge the fallen garbage from the trolley.	
12	Food waste is putrescible and hence, attracts pests like rats and flies if transported uncovered or dropped on the way.	
13	No waste management system allocated for electrical waste such as tube lights, wires, switchboards, insulators, etc.	Processing and disposal
14	No paper, plastic, metal and glass waste processing on campus.	
15	Proper processing and disposal of organic waste are required.	
16	Recycling the solution to the major problems of SWM.	

4.2. Potential Solutions

The SWM in IITR campus is inadequate and needs development. The SW needs to be segregated and disposed of off with scientific methods to reduce environmental impact. Various processing systems need to be adopted for a different type of waste. Medical waste is already being treated/incinerated as per the prescribed medical waste guidelines. Plastic, metal and glass waste has the scope of recycling. Organic waste being the largest contributor of the SW generated at IITR has the scope of decomposing within the campus itself. Table 8 enlists the potential solutions for SWM at the IITR campus. Table 9 lists the advanced recycling strategic formation for the I.I.T. Roorkee Campus.

Table 8. Potential solutions for SWM at IITR campus.

Issue	Solution
1	Increase the number of dustbins targeting the areas with no or less no. of dustbins.
2, 6, 7, 8, 9	Waste segregation at the micro level is a necessity; separate bins for recyclable and non-recyclable wastes have to be set up throughout the campus.
3, 15	Decomposing of inorganic waste via decomposing machines. Implementation of Biodegradable waste management in the premises of the campus itself.
4	Awareness has to be created in the people through various programs and policies, emphasis to be laid on –reduce, reuse and recycle'.
5	Anthropometric design of the concrete bins with lids on them to be set up to facilitate users and keep away stray animals.
10, 11, 12	Covered waste transportation has to be done to reduce air pollution and littering.
13, 14, 16	Paper: install paper recycling machines available on the market on campus
	Plastic: send to recycling units near IITR campus
	Glass: send to recycling units near IITR campus
	Metal: send to recycling units near IITR campus
	E-waste: send to recycling units near IITR campus
Money	Develop a mechanism for ring-fence revenue realized from the management of waste and resources to reinvest in waste and recycling initiatives.
Zero waste	Attempt to zero waste on the campus, targeting each type sequentially

Table 9. Advance recycling strategic formation for the IITR Campus.

Process	Smart Strategies/Technique	Current Situation	Reference
Generation: (0.46 kg/capita)	Smart bins integrated system	None	[41–44]
	Color coding system	Yes	
	Alarming system	Not available	
	Remote sensing and GIS connectivity	Not available	
	GPS connectivity with bin	Not available	
Source segregation (primary): Partial	Smart chute	Not available	[45]
Awareness/attitude	Smartphone app	Not available	[41,42]
	Notification Smart pickup	None	
	Weekly awareness meeting	Often	
	Reward and penalty	None	

Table 9. *Cont.*

Process	Smart Strategies/Technique	Current Situation	Reference
Collection (100%)	Mechanical system, GIS/GPS Connecting	Manual collection (Door to Door): daily bases	[41]
Segregation (secondary)	Smart Manual (vending machine)	Segregation by local vendor: yes On-site campus segregation: None	[42]
	Smart mechanical (non-contact segregation machine)	Not available	
Storage	Filled Alarming system	Dallas (Cemented): manual Community bin: manual	[41,42]
	Remote sensing/GIS/GPS connectivity	Not available	
Transportation: (motorized and manual)	Green fuel (CNG),	Tractors + trolley, Tata ace vehicle: petrol and diesel fueled	[42]
	Solar electric battery vehicle	Not available	
	Vacuumed based underground waste collection system	Not available	
Treatment/Recycling			
Food and Organic Waste	Anaerobic bio-digester	None	[46,47]
Organic (food waste) 1675.87 kg/day: Kitchen, Mess/canteen, juice kiosk waste	Biogas/methane	Not done	
	Composting (aerobic)	Not done	
	Animal feed	Partially	
Dry organic waste: (569.38 kg/day) Seasonal leaves Garden trimming	Compost/Manure	Partially done	
	Briquetting/fuel pallets	None	
	Biogas/methane	Not done	
Paper: (1579.97 kg/day) Cardboard, Newspaper, Plain paper, packaging Other paper	Paper recycling/handmade paper	Not done	[46,48–50]
	Paper craft/up cycle/reuse	Not done	
	Briquetting/fuel pallets	Not available	
	Paper Crete (bricks)/partition wall/furniture making	Not available	
	Incineration/WtE (decentralized)	Not available	
Plastic: (613.39 kg/day) Pet bottles HDFEPPE Other plastic	Plastic Recycling	Not done	[50–53]
	Plastic to brick	Not available	
	Plastic to pavement/roof tiles	Not available	
	Plastic to furniture/barricades making	Not available	
	Incineration/WtE (decentralized)	Not available	

Table 9. *Cont.*

Process	Smart Strategies/Technique	Current Situation	Reference
Chemical: (52.8 kg/day)	Recycle/Reuse (systematic disposal)	As per the SWM (hazardous waste) rule 2016, India	
Medical: (46.51 kg/day)	Recycle/reuse	As per the SWM (medical waste) rule 2016, India	
E-waste: (44.59 kg/day)	Precious metal extractions	Not done	
Metal: (174.52 kg/day)	Recycle/reuse	Send to local vendor	
Glass: (110.66 kg/day)	Recycle/reuse	Mixed to waste	
Construction and demolish (C&D) waste: (35.91 kg/day)	Pavement tiles/blocks makings	Not available	
Disposal: City dump sites available	Engineered landfill site	About 80–90% goes to dump sites	
	Bio-gas extraction	Not available	

4.3. Attempt at Zero Organic Waste at the IITR Campus

A lot of organic waste is generated on the campus primarily from the hostel mess, green areas, and trees. This waste, as a regular practice, is disposed of along with the other waste. Around 1675.87 kg of waste generated on the campus can be decomposed to obtain organic manure. Composting is an easy and natural bio-degradation process that takes organic wastes i.e., remains of plants and garden and kitchen waste and turns into nutrient-rich food for your plants. Composting, normally used for organic farming, occurs by allowing organic materials to sit in one place for months until microbes decompose it. Composting is one of the best methods of waste disposal as it can turn unsafe organic products into safe compost. On the other hand, it is a slow process and takes a lot of space. Due to the limitation of land, machines can be used for organic decomposing and shredding of waste.

Sellable recyclable, non-recyclable and e-waste need to be separated at the source itself or at a specific area within the campus and sent to respective recycling industries directly, and hence minimize the waste sent to the landfill sites. The campus, in future, needs to develop an on-campus decentralized treatment system, where biodegradable waste can be utilized to make biogas; plastic and styrofoam can be utilized to obtain alternative fuel, pavement tile and used in road construction. Dry leaves can also be utilized to make pallet with the briquetting technique, which is a good coal substitute for cooking food in the mess or heating purposes. Construction and demolition waste can be used to make pavement blocks. As a result of the literature review and Table 2, Table 10 has been derived for the IITR campus to show the strategies which can be used to treat different type of waste.

Suggestions

i. Sensitizing and motivational programs need to be conducted for making people more aware of the zero waste campus concept and its benefits.
ii. Organic waste Shredders will take care of food waste, green vegetables, bones, garden waste, green coconut, etc.
iii. Bio–mechanical Composter converts organic waste added to the machine into nitrogen-rich compost by reducing its volume by almost 70–80% of the original.
iv. To develop in house biogas and compost production techniques.
v. Women-based employment can be generated through waste recycling and reuse by promoting them to make artifacts from waste paper, plastic, old clothes, and metal pieces.
vi. Regular workshops and various competitions need to be organized to synthesize awareness among the people about waste.

Table 10. Strategies used to treat different type of waste.

Waste Typology	**Methods of Treatment and Recycling**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Paper and cardboard	✓	✓			✓	✓				✓					✓	✓
Food waste	✓							✓	✓	✓					✓	
Garden waste	✓							✓	✓	✓					✓	
Plastics	✓	✓			✓	✓				✓					✓	
Cloth/textile	✓	✓				✓				✓					✓	✓
Wood	✓	✓				✓				✓					✓	✓
Glass	✓	✓				✓				✓					✓	
Metals	✓	✓				✓							✓		✓	
Rubber	✓		✓	✓			✓			✓	✓	✓		✓	✓	
E-waste	✓	✓				✓				✓					✓	

Methods: 1—prevention; 2—preparation for re-use; 3—re-treading; 4—recovery, use at road surfaces; 5—close loop recycling; 6—recycling; 7—re-treading method; 8—anaerobic digestion; 9—composting: other energy recovery technologies; 10—energy recovery; 11—another recovery; 12—gasification/incineration; 13—recycling after energy recover; 14—microwave treatment; 15—final disposal; 16—low-grade fuel (briquetting).

4.4. Comparative Studies of Other Campuses

There is no significant approach been used in term of SWM in the MNIT Jaipur campus. The waste is collected through the door to door service and disposed-off behind the campus [54]. The study conducted by the students of NIT Calicut, India for their campus shows 200 kg per day of organic waste produces 50 kg of biogas equivalent to 1.29 cylinder per day (weight of one LPG cylinder 19.2 kg) [55]. Another such study in the University of Tabriz, Iran has shown 80% of waste reduction within the campus by the production of compost and recyclables sent to respective recycling agencies directly from the campus [56]. The study of the campus in Kenya shows how knowledge, practices, awareness, and attitude towards waste need to be improvised to move towards the careful management of waste. The polices on the campus, which also inspires the competitive attitude and behavior can make changes in the waste management system [57]. A study conducted by Sreedevi S. in Hyderabad shows that color coded dustbins are the most basic ways of segregation of waste [58]. General awareness and careless attitude of the students and staff members towards waste management is a challenge, which further creates a filthy situation for the campus environment. A study conducted by a student of Master of Arts in Environmental Planning and Management, Department of Geography and Environmental Studies, University of Nairobi, Kenya has found that there is an urgent need of lawful and forceful implementation of the policies within the campus [59]. The educational campuses are adapting and becoming self-motivated towards zero waste concepts. Some good strategies have been shown by the institutes like Vivekananda Education Society Mumbai, in which 70kg/day of organic waste from the total waste is processed to produce 130 kg of compost and rest left out dry waste/inorganic waste is being segregated, collected and transported to authorized recycler out site the campus [60].

5. Conclusions

Though the per capita waste generation rates in India is lower than its counterparts in the world, it needs immediate attention due to its increasing rates each year. Developed countries have many efficient SWM systems with advanced technologies both at small scale and large scale. Campuses can act as an example to the cities for implementing SWM programs and achieving zero waste campus along with educating the occupants and neighborhoods. The SWM system of IIT Roorkee campus is unsystematic and inefficient. It lacks at many levels of execution and maintenance. Negligence and lack of awareness are some of the factors responsible for the same. A carefully chalked out system of waste segregation, collection, disposal, transport, recycling, etc. is essentially required to be able to upgrade the esteemed campus to a 'zero-waste campus'. To achieve this goal, awareness must be spread regarding the reduction of waste production, reuse, sanitary habits and careful handling of waste, by inculcating the value of waste as a resource, into the minds of all. Educating the users, cleaning staff and management staff regarding the necessity of proper methods of separation of various kinds of waste at source is necessary. Apart from this ergonomic design of concrete bins and providing separate bins for recyclable, non-recyclable and biodegradable waste, new technologies for waste management on both on campus and off campus are required. The aim for 'zero-waste campus' should be achieved in steps by processing and disposing of all types of waste sequentially. As organic waste constitutes the highest quantity of the total waste generated on campus, it needs attention first. Construction of decomposing pits or decomposers available in the market could be used for decomposing organic and garden waste. This will reduce the cost of chemical fertilizers, and pollution and improve soil fertility. Another important target should be the recycling of the solid waste within the campus, thus saving energy and providing education to the students. The study will help in evolving a more contextualized SWM system for the Indian campus which in turn will help in boosting sustainable development in Higher Education Institutes. Also taking an example of this Indian campus, other campuses around the world with similar issues can learn from it and move forward along similar lines.

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References

1. Asnani, P.U. *India Infrastructure Report 2006: Urban Infrastructure*; Oxford University Press: New Delhi, India, 2006.
2. Ammar, A.; Khawaja, K.M.; Amer, K.A.; Nawafleh, A.S.; Al-Safadi, A. Portable Biogas Digesters for Domestic Use in Jordanian Villages. *Recycling* **2019**, *4*, 21. [CrossRef]
3. Sorme, L.; Voxberg, E.; Rosenlund, J.; Jensenand, S.; Augustsson, A. Coloured Plastic Bags for Kerbside Collection of Waste from Households—To Improve Waste Recycling. *Recycling* **2019**, *4*, 20. [CrossRef]
4. Ordóñez, I.; Rexfelt, O.; Hagy, S.; Unkrig, L. Designing Away Waste: A Comparative Analysis of Urban Reuse and Remanufacture Initiatives. *Recycling* **2019**, *4*, 15. [CrossRef]
5. Mukhtar, E.M.; WilliamsI, D.; Shaw, P.J.; Ongondo, F.O. A Tale of Two Cities: The Emergence of Urban Waste Systems in a Developed and a Developing City. *Recycling* **2016**, *1*, 254–270. [CrossRef]
6. Gupta, S.; Mohan, K.; Prasad, R.; Gupta, S.; Kansal, A. Solid waste management in India: Options and opportunities. *Resour. Conserv. Recycl.* **1998**, *24*, 137–154. [CrossRef]
7. World Bank Data. What a Waste-2 2019. Available online: http://datatopics.worldbank.org/what-a-waste/ (accessed on 14 January 2019).
8. Narayana, T. Municipal solid waste management in India: From waste disposal to the recovery of resources? *Waste Manag.* **2009**, *29*, 1163–1166. [CrossRef] [PubMed]
9. Solid Waste Generation in 46 Metro Cities. Status of Compliance by CPCB. Central Pollution Control Board: New Delhi, India, 2014. Available online: https://www.cpcb.nic.in/trend-of-solid-waste-generation-in-46-cities/?&page_id=trend-of-solid-waste-generation-in-46-cities (accessed on 20 June 2019).
10. Waste Generation and Composition. Status of Compliance by CPCB. Central Pollution Control Board: New Delhi, India, 2014. Available online: https://www.cpcb.nic.in/waste-generation-composition/?&page_id=waste-generation-composition (accessed on 20 June 2019).

11. Alshuwaikhat, H.M.; Abubakar, I. An integrated approach to achieving campus sustainability: Assessment of the current campus environmental management practices. *J. Clean. Prod.* **2008**, *16*, 1777–1785. [CrossRef]
12. Parvez, N.; Agrawal, A. Assessment of sustainable development in technical higher education institutes of India. *J. Clean. Prod.* **2019**, *214*, 975–994. [CrossRef]
13. Armijo de Vega, C.; Benítez, S.O.; Barreto, M.E.R. Solid waste characterization and recycling potential for a university campus. *Waste Manag.* **2008**, *28*, 21–26. [CrossRef] [PubMed]
14. Smyth, D.P.; Fredeen, A.L.; Booth, A.L. Reducing solid waste in higher education: The first step towards 'greening' a university campus. *Resour. Conserv. Recycl.* **2010**, *54*, 1007–1016. [CrossRef]
15. Rajamanikam, R.; Poyyamoli, G. Towards Zero-Waste Campus: Compositional Analysis of Solid Waste at the Staff Quarters to frame Inclusive Sustainable Campus. *Waste Manag. Syst.* **2014**, *3*, 11255–11264.
16. Sharholy, M.; Ahmad, K.; Mahmood, G.; Trivedi, R.C. Municipal solid waste management in Indian cities—A review. *Waste Manag.* **2008**, *28*, 459–467. [CrossRef] [PubMed]
17. Mwangi, M.; Thuo, A. Towards conceptual and theoretical foundation for identifying problems, challenges and mechanisms for municipal waste management in developing countries. *Int. J. Innov. Sci. Res.* **2014**, *2*, 230–251. Available online: https://pdfs.semanticscholar.org/b6af/4a9399998568d863c2fb6bacc486143c6d63.pdf (accessed on 20 June 2019).
18. Vashi, M.P.; Desai, K.A. A Review on Recent Advancement in Solid Waste Management Concept. *J. Environ. Eng. Stud.* **2018**, *3*, 1–8. Available online: http://matjournals.in/index.php/JoEES/article/view/2563 (accessed on 23 June 2019).
19. Guerrero, L.A.; Maas, G.; Hogland, W. Solid waste management challenges for cities in developing countries. *Waste Manag.* **2013**, *33*, 220–232. Available online: https://www.ncbi.nlm.nih.gov/pubmed/23098815 (accessed on 20 June 2019). [CrossRef] [PubMed]
20. Henry, R.K.; Yongsheng, Z.; Jun, D. Municipal solid waste management challenges in developing countries—Kenyan case study. *Waste Manag.* **2006**, *26*, 92–100. [CrossRef] [PubMed]
21. Manaf, L.A.; Samah, M.A.A.; Zukki, N.I.M. Municipal solid waste management in Malaysia: Practices and challenges. *Waste Manag.* **2009**, *29*, 2902–2906. [CrossRef] [PubMed]
22. Morrissey, A.J.; Browne, J. Waste management models and their application to sustainable waste management. *Waste Manag.* **2004**, *24*, 297–308. Available online: https://www.ncbi.nlm.nih.gov/pubmed/15016418 (accessed on 20 May 2019). [CrossRef] [PubMed]
23. Waste Prevention and Sustainability: Case Studies for Local Governments 2005. ICLEI—Local Governments for Sustainability. Available online: http://www.indiaenvironmentportal.org.in/files/file/LS2012_GLOBAL_REVIEW.pdf (accessed on 20 June 2019).
24. Marshall, R.E.; Farahbakhsh, K. Systems approaches to integrated solid waste management in developing countries. *Waste Manag.* **2013**, *33*, 988–1003. [CrossRef] [PubMed]
25. Srivastava, R. Waste Management: Developed and Developing. *Int. J. Sci. Res.* **2016**, *5*, 202–203. Available online: https://www.ijsr.net/archive/v5i3/NOV161825.pdf (accessed on 23 May 2019).
26. Mmereki, D.; Baldwin, A.; Li, B. A comparative analysis of solid waste management in developed, developing and lesser developed countries. *Environ. Technol. Rev.* **2016**, *5*, 120–141. [CrossRef]
27. Joshi, R.; Ahmed, S. Status and challenges of municipal solid waste management in India: A review. *Cog. Environ. Sci.* **2016**, *2*, 1–18. Available online: http://home.iitk.ac.in/~{}anubha/H13.pdf (accessed on 23 June 2019). [CrossRef]
28. Solomon, U.U. The state of solid waste management in Nigeria. *Waste Manag.* **2009**, *29*, 2787–2788. [CrossRef] [PubMed]
29. Sverige, A. Swedish Waste Management 2018. Available online: https://www.avfallsverige.se/fileadmin/user_upload/Publikationer/Avfallshantering_2018_EN.pdf (accessed on 15 June 2019).
30. Eionet. Factsheet for Netherlands 2012. Available online: http://scp.eionet.europa.eu/facts/factsheets_waste/2009_edition/factsheetcountry=NL (accessed on 15 June 2019).
31. European Commission. Environment: Waste 2014. Available online: http://ec.europa.eu/environment/waste/ (accessed on 15 June 2019).
32. Bhat, R.; Ahmad Dar, S.; Ahmad Dar, D.; Hamid Dar, G. Municipal Solid Waste Generation and current Scenario of its Management in India. *Int. J. Adv. Res. Sci. Tech.* **2018**, *7*, 419–431. Available online: https://www.researchgate.net/publication/324756753_Municipal_Solid_Waste_Generation_and_current_Scenario_of_its_Management_in_India (accessed on 23 June 2019).

33. Gupta, N.; Yadav, K.K.; Kumar, V. A review on current status of municipal solid waste management in India. *J. Environ. Sci.* **2015**, *37*, 206–217. Available online: https://www.researchgate.net/profile/Neha_Gupta22/publication/282149291_A_review_on_current_status_of_municipal_solid_waste_management_in_India/links/5721cd1408ae5454b23156e2.pdf (accessed on 21 May 2019). [CrossRef]
34. Al-Salem, S.M.; Lettieri, P.; Baeyens, J. Recycling and recovery routes of plastic solid waste (PSW): A review. *Waste Manag.* **2009**, *2*, 2625–2643. [CrossRef] [PubMed]
35. Akolkar, A. Status of Solid Waste Management in India Implementation Status of Municipal Solid Waste. anagement and Handling Rules 2000 Central Pollution Control Board, New Delhi. 2005. Available online: http://www.indiaenvironmentportal.org.in/files/file/MSW_Report.pdf (accessed on 21 May 2019).
36. Ghosh, S.K. Swachhaa Bharat Mission (SBM)—A Paradigm Shift in Waste Management and Cleanliness in India. *Procedia Environ. Sci.* **2016**, *35*, 15–27. [CrossRef]
37. Status of Compliance by CPCB with Municipal Solid Wastes (M&H) Rules. Central Pollution Control Board: New Delhi, India, 2000. Available online: https://www.cpcb.nic.in/displaypdf.php?id=em9iaG9wYWwvTVNXX0d3YWxpb3IucGR (accessed on 23 December 2018).
38. Bhide, A.D.; Sundaresan, B.B. Solid Waste Management in Developing Countries. Indian National Scientific Documentation Center: New Delhi, India, 1983. Available online: https://www.ircwash.org/sites/default/files/343-83SO-778.pdf (accessed on 23 June 2019).
39. UNEP. Solid Waste Management. 2005. Available online: http://www.unep.or.jp/ietc/publications/spc/solid_waste_management/Vol_I/Binder1.pdf (accessed on 20 March 2019).
40. MoEF, S.O. 1357(E) [08-04-2016]: Solid Waste Management Rules, Gaz. India, D. 2016, pp. 52–90. Available online: http://www.moef.nic.in/content/so-1357e-08-04-2016-solid-waste-management-rules-2016/ (accessed on 20 December 2018).
41. Ramson, S.; Moni, D. Wireless sensor networks based smart bin. *Comput. Electr. Eng.* **2017**, *64*, 337–353. [CrossRef]
42. Hidalgo, D.; Juaristi, J.; Marroquín, J.; Corona, F. Sustainable vacuum waste collection systems in areas of difficult access. *Tunn. Undergr. Sp. Technol.* **2018**, *81*, 221–227. Available online: http://uest.ntua.gr/athens2017/proceedings/pdfs/Athens2017_Hidalgo_Juaristi_Martin_Marroquin_Corona.pdf (accessed on 20 March 2019). [CrossRef]
43. CPHEEO. *Municipal Solid Waste Management Manual*; Swachh Bharat Mission: New Delhi, India, 2016; pp. 1–604.
44. Mundhe, N.; Jaybhaye, R.; Dorik, B. Assessment of Municipal Solid Waste Management of Pune City using Geospatial Tools. *Int. J. Comput. Appl.* **2014**, *100*, 24–32. Available online: https://research.ijcaonline.org/volume100/number10/pxc3898184.pdf (accessed on 20 March 2019). [CrossRef]
45. Waste Chute Systems (Manual). 2018. Available online: http://www.wastech.com.au%0ADesign (accessed on 22 June 2019).
46. Srivastava, N.S.L.; Narnaware, S.L.; Makwana, J.P.; Singh, S.N.; Vahora, S. Investigating the energy use of vegetable market waste by briquetting. Renew. *Energy* **2014**, *68*, 270–275. [CrossRef]
47. Kaur, A.; Roy, M.; Kundu, K. Densification of biomass by briquetting: A review. *Int. J. Recent Sci. Res.* **2017**, *8*, 20561–20568. Available online: https://www.researchgate.net/publication/320946222_DENSIFICATION_OF_BIOMASS_BY_BRIQUETTING_A_REVIEW (accessed on 20 March 2019).
48. Alam, M.; Rikta, S.Y.T.; Hasnine, M.T. Production of Eco-friendly Handmade Paper from The Waste Paper Generated in Municipalities of Dhaka City, Bangladesh. *Eurasia Waste Manag. Symp.* **2016**, *1*, 1–8. Available online: https://www.researchgate.net/publication/301806278_Production_of_Eco-friendly_Handmade_Paper_from_The_Waste_Paper_Generated_in_Municipalities_of_Dhaka_City_Bangladesh (accessed on 20 June 2019).
49. Sudarsan, J.S.; Ramesh, S.; Jothilingam, S.; Ramasamy, V.; Rajan, R.J. Papercrete brick as an alternate building material to control environmental pollution. *IOP Conf. Ser. Earth Environ. Sci.* **2017**, *80*, 1–8. Available online: https://iopscience.iop.org/article/10.1088/1755-1315/80/1/012017 (accessed on 23 June 2019). [CrossRef]
50. Lorson, H.; Kasdarli, C. Decentralised Waste Incineration Plant, R. Vandhoo in the North of the—Project Experience, Energy Use and First Operation Results. *Waste Manag.* **2015**, *5*, 179–190. Available online: http://www.vivis.de/phocadownload/Download/2015_wm/2015_WM_179-190_Lorson.pdf (accessed on 23 June 2019).

51. Manjarekar, A.S.; Gulpatil, D.; Patil, V.P.; Nikam, R.S.; Jeur, C.M. Utilization of Plastic Waste in Foundry Sand Bricks. *Int. J. Res. Appl. Sci. Eng. Technol.* **2017**, *5*, 977–982. Available online: https://www.ijraset.com/fileserve.php?FID=7143 (accessed on 23 June 2019). [CrossRef]
52. Ghuge, J.; Surale, S.; Patil, B.M.; Bhutekar, S.B. Utilisation of Waste Plastic in Manufacturing of Paver Blocks. *Int. Res. J. Eng. Technol.* **2019**, *6*, 1967–1970. Available online: https://www.irjet.net/archives/V6/i4/IRJET-V6I4427.pdf (accessed on 23 June 2019).
53. Menaria, Y.; Sankhla, R. Use of Waste Plastic in Flexible Pavements-Green Roads. *Open. J. Civ. Eng.* **2015**, *5*, 299–311. Available online: https://file.scirp.org/pdf/OJCE_2015090913503150.pdf (accessed on 23 June 2019). [CrossRef]
54. Upadhyay, V.; Jethoo, A.S.; Poonia, M.P. Solid waste collection and segregation: A case study of MNIT campus Jaipur. *Int. J. Eng. Innov. Technol.* **2012**, *1*, 144–149. Available online: http://www.ijeit.com/vol%201/Issue%203/IJEIT1412201203_31.pdf (accessed on 20 March 2019).
55. Mani, G.T.; Mathew, B.G.; Daniel, G.G.; Varghese, A.J.; Cyriac, E. Solid Waste Management at NITC Campus. Project Report for the Course Environmental Studies for Mechanical Engineers 2013. Available online: https://www.academia.edu/5899767/SOLID_WASTE_MANAGEMENT_AT_NITC_CAMPUS_PROJECT_REPORT_FOR_THE_COURSE_Environmental_Studies_for_Mechanical_Engineers_ME3003 (accessed on 20 March 2019).
56. Taghizadeh, S.; Ghassemzadeh, H.R.; Vahed, M.M.; Fellegari, R. Solid waste characterization and management within university campuses case study: University of Tabriz. *Pollution* **2012**, *43*, 6650–6654. Available online: https://www.elixirpublishers.com/articles/1350298408_43%20(2012)%206650-6654.pdf (accessed on 20 March 2019).
57. Starovoytova, D.; Namango, S. Solid Waste Management at University Campus (Part 4/10): Perceptions, Attitudes, and Practices of students and vendors. *J. Environ. Earth Sci.* **2018**, *8*, 2224–3216.
58. Sreedevi, S. Solid Waste Generation and its Management—A Case Study. *Int. Res. J. Environ. Sci.* **2015**, *4*, 90–93. Available online: http://www.isca.in/IJENS/Archive/v4/i1/15.ISCA-IRJEvS-2014-260.pdf (accessed on 20 March 2019).
59. Aseto, S.A. Waste Management in Higher Education Institutions: A Case Study of University of Nairobi, Kenya 2016. Project Report for Masters of Arts and Environmental Planning and Management. Department of Geography and Environmental Studies, University of Nairobi, 2016. Available online: http://erepository.uonbi.ac.ke/bitstream/handle/11295/99283/SUSAN%20ATIENO%20ASETO.pdf?sequence=1&isAllowed=y (accessed on 20 March 2019).
60. Article in the Better India. Available online: https://www.thebetterindia.com/50386/mumbai-college-zero-waste-campus/ (accessed on 9 June 2019).