Solid Waste Management: A case study of ultimate analysis and landfill design for NIT Calicut

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Abstract — **The total amount of solid waste generated from different zones of NIT Calicut accounts to about 2500 kg/d. Paper (18.8%) and cardboard (11.7%) were the major components of waste generated in the institutional zone of the campus. Waste collected from hostel zone mainly comprised of food waste (23.5 %) and paper (16%). Food waste was the major component in the waste generated from canteen and residential area, which accounted respectively for 85.7% and 36% of the total waste. Ultimate analysis indicated that the main chemical constituent in the sample collected from all the zones was carbon. The carbon content varied from 152.90 kg/tonne of solid waste in the waste collected from canteen to 285.59 kg/tonne in the waste collected from academic area. On the other hand, the component with lowest occurrence was sulphur, with a weighted average of 1.05 kg per tonne of collected waste. Based on the quantitative analysis of the solid waste generated in the campus, a landfill was designed for the disposal of non-biodegradable portion of solid waste, with a design period of 5 years and operating in 5 phases. The plan area requirement for the solid waste dumping was 20 m X 11 m, with a maximum height of 10 m. A proper liner, leachate collection system and a landfill cover was also incorporated in the proposed landfill design.**

Keywords— Solid waste; characteristics; ultimate analysis; disposal; landfill.

I. INTRODUCTION

Solid Waste Management is one of the essential obligatory functions of the institutional and urban local bodies in India. This service is falling too short of the desired level of efficiency and satisfaction resulting in problems of health, sanitation and environmental degradation. Most institutional areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by authorities, garbage and its management has become a tenacious problem. Barring a few progressive municipal corporations and institutions in the country, most local bodies and institutes suffer due to non-availability of adequate expertise and experience, thereby the solid waste is not properly handled resulting into creation of environmental pollution and health hazards. It is reiterated that the local bodies lack technical, managerial, administrative, financial and adequate institutional arrangements. As such, it is very necessary to provide proper guidance to such Urban Local Bodies and institutes so as to make them efficient in managing the solid waste generated in their respective cities and towns.

Waste minimization is a methodology used to achieve waste reduction, primarily through reduction at source, and also including recycling and re-use of materials. The benefits of waste minimization are both environmental and financial and wide in their coverage [1]. In order to implement proper waste management, various aspects have to be considered such as: Source reduction, Onsite storage, Collection & transfer, Processing, and Disposal [2].

Solid waste contains recyclables (paper, plastic, glass, metals, etc.), toxic substances (paints, pesticides, used batteries, medicines), compostable organic matter (fruit and vegetable peels, food waste) and soiled waste (blood stained cotton, sanitary napkins, disposable syringes) [3-5].

Per capita waste generation in Indian cities ranges between 0.2 to 0.6 kg/d amounting to about 1.15 metric tonnes (MT) of waste per day and 42 million MT per year. As the city expands, the average solid waste generation rate also increases. The municipal solid waste (MSW) generation rates in different states of India are given in table 1.

TABLE I. MSW GENERATION RATE IN DIFFERENT STATES OF INDIA (CPCB, 2012) [6]

S. N.	State	MSW generated (TPD)	S. N.	State	MSW generated (TPD)
1	Andhra Pradesh	11500	15	Madhya Pradesh	4500
2	Assam	1146	16	Maharashtra	19,204
3	Bihar	1670	17	Manipur	113
4	Chandigarh	380	18	Meghalaya	285
5	Chhattisgarh	1167	19	Mizoram	4742
6	Delhi	7384	20	Nagaland	188
7	Goa	193	21	Orissa	2239
8	Gujarat	7379	22	Punjab	2794

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9	Haryana	537	23	Rajasthan	5037
10	Himachal Pradesh	304	24	Sikkim	40
11	Jammu & Kashmir	1792	25	Tamil Nadu	360
12	Jharkhand	1710	26	Uttar Pradesh	11,585
13	Karnataka	6500	27	Uttrakhand	752
14	Kerala	8338	28	West Bengal	12,557

The quantity of MSW depends upon the economic activity and the resource consumption. On the other hand, the waste composition depends on external factors such as geographical location, climatic conditions, standard of living etc.

Proper disposal of MSW is a necessity to minimize environmental health impacts and degradation of land resources. In developing countries like India, MSW is commonly disposed of by transporting and discharging in open dumps, which are environmentally unsafe. Systematic disposal methods are composting, landfilling and incineration. Studies indicate open dumping to be the management method for 90% of MSW in India [7]. However, the so-called landfill practiced in the country is mostly covering refuse in the dumpsite by soil neither with proper technical input nor with treatment of the emerging emissions to water, air and soil. Therefore, an extensive study has been performed to design an engineered landfill, commencing from the solid waste generation and characterization at the source. The national Institute of Technology Calicut (NIT Calicut) was selected as the study area and the work was performed with the following objectives:

1) To characterize the waste generated and source of waste generation in NITC Campus.
2) To perform the ultimate analysis of the solid waste generated at different zones of the campus.
4) To design an appropriate landfill for the solid waste generated in the campus.

II. STUDY AREA

NITC is spread over 300 acres area consisting of academic section (institutional area), 12 Boys hostels and 4 Girls hostels (hostel zone), and residential areas for the faculty (residential zone) as shown in fig. 1. The management of solid waste produced in the campus is critical due to the difference in waste composition from various zones, improper collection and segregation of waste at the source and unavailability of suitable facilities to treat and dispose of the larger amount of solid waste generated daily. Improper disposal of waste leads to spreading of diseases and unhygienic conditions besides spoiling the aesthetics.

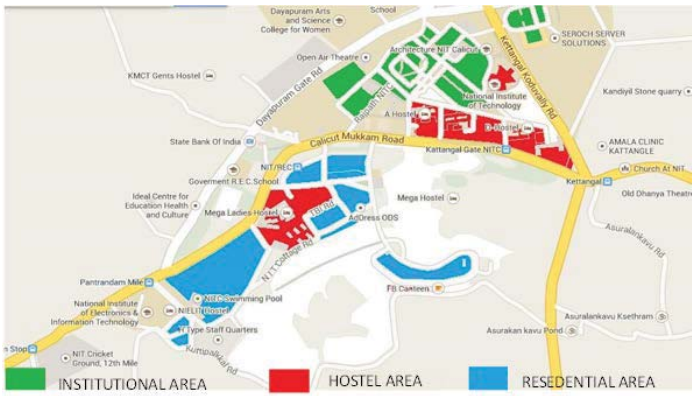

Fig.1. NITC map showing various zones of solid waste generation

III. LAYOUT OF SURVEY STRATEGY

The layout of the study is given below:

1. Identify and demarcate the survey area (by maps available on internet)
2. Collect information about
   a. Different sections of campus (from institute Administration)
   b. Their location and size (by visiting)
3. Divide the campus in to different zone in order to identify the waste quantity and characteristics at the source. The campus was divided into three zones as follows:
   a. Institutional zone, which comprises academic and departmental area
   b. Hostel zone, which includes boys hostels and girls hostels in the campus.
   c. Messes and canteen zone
   d. Residential area, which constitutes faculty and staff apartments.
5. Ultimate analysis of the solid waste generated from various zones based on their relative composition.
6. Design of landfill based on the quantity of waste generated.

IV. OBSERVATIONS

Engineering unit of the institute is responsible for the management of solid waste generated in the NITC Campus. The campus is divided into four zones Academic section, residential area, Girl's hostels and Boys hostels by the Engineering unit.

The components of waste generated from these four zones include Food waste, Plastics, Paper, Tin, Metal, Glass, Dust, Leather, and Garden Trimming etc. On the other hand the qualtities of these componenets vary from zone to zone.

Waste generation rates was work out to be 0.50 kg per capita per day. Thus, approximately 400 kg/d of waste is generated from the academic/institutional zone. Similarly the waste generated from hostels, canteens and residential areas are 800 kg/d, 350 kg/d and 750 kg /d respectively. Moreover, additional 200 kg/d waste also estimated as road side deposited solid waste. Thus, the total solid waste generation in the campus amounts to 2500 kg/d.

V. CHARACTERISTICS OF SOLID WASTE IN NITC

The composition of solid waste varies from zone to zone due to difference in activities at each zone. The quantity and composition of wastes from various zones is given in table II and the percentage of individual components in the waste is pictorially represented in fig. 2-5. Paper (18.8 %) and cardboard (11.7 %) are the major component of waste from the institutional zone. On the other hand, the waste from hostel zone mainly comprised of food waste (23.5%) and paper (16%). However, food waste was the major component of waste generated from canteens as well as residential area, which was 85.7% and 36 % respectively. The non-biodegradable components in the solid waste collected from different zones include plastic, glass, Leather, tin, wood and metal. Therefore, the total amount of non-biodegradable waste generated in the campus is around 765 kg/d.

TABLE II. COMPOSITION OF SOLID WASTE GENERATED IN DIFFERENT ZONES OF NIT CALICUT

Components in Waste	Quantity (kg/d)			
	Academic area	Hostels	Canteens	Residential area
Food waste	0	188	300	270
Plastic	43	90	12	50
Paper	66	128	20	47
Glass	44	105	6	58
Cardboard	61	73	-	24
Leather	9	20	-	14
Dust	22	35	9	17
Garden trimming	56	65	-	155
Tin	29	42	1.5	21
Wood	46	30	-	38
Metal	24	24	1.5	56
TOTAL	400	800	350	750

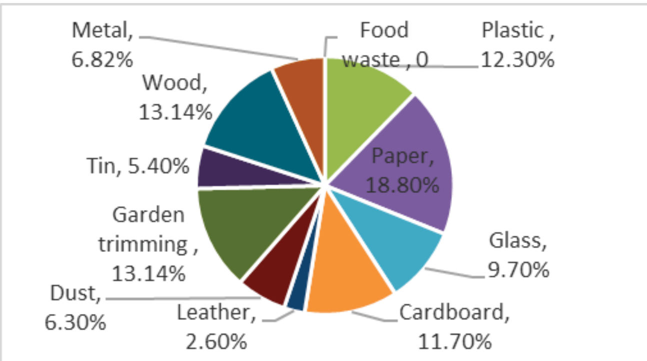

Fig.2: Composition of waste collected from institutional zone

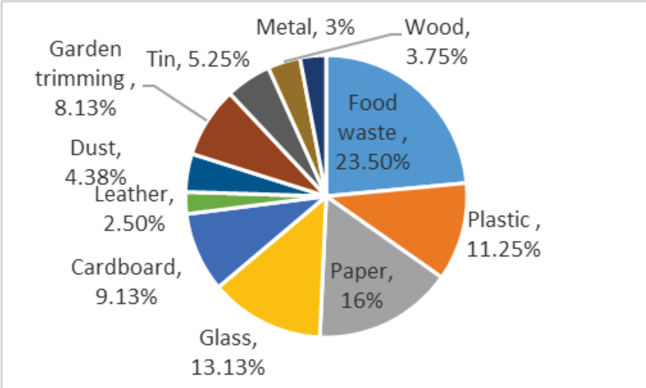

Fig.3: Composition of waste collected from Hostel zone

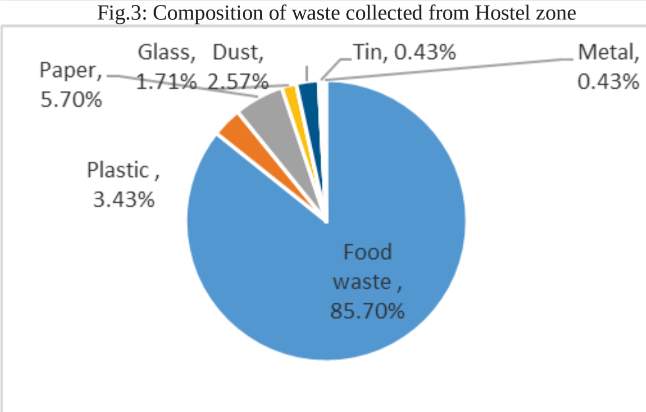

Fig.4: Composition of waste collected from Canteen

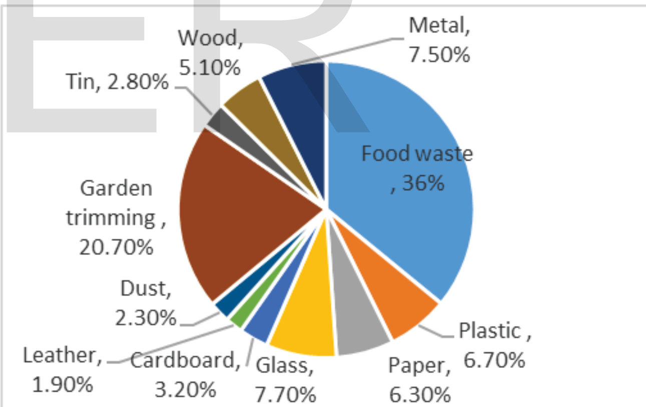

Fig.5: Composition of waste collected from Residential Area

VI. ULTIMATE ANALYSIS OF THE GENERATED SOLID WASTE

The ultimate analysis of a waste component typically involves the determination of the percent C (carbon), H (hydrogen), O (oxygen), N (nitrogen), S (sulphur), and ash. The ultimate analysis of the waste generated at different zones of the campus was performed based on the relative composition of various components at the source or waste generation points. The average moisture content (MC) of the food waste, plastic, paper, glass, cardboard, leather, dust,

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garden trimming, tin, wood and other metal are assumed as 75%, 2%, 7%, 2%, 7%, 10%, 0%, 60%, 4%, 30% and 4% respectively [8]. The percentage of C, H, O, N and S are also typical for each component in the waste as shown in table III.

TABLE III. ULTIMATE ANALYSIS PER UNIT WEIGHT (DRY BASIS) OF SOLID WASTE COMPONENTS [8]

Waste	C (%)[a]	H (%)[a]	O (%)[a]	N (%)[a]	S (%)[a]	Inert (%)[a]
Food waste	48	6.4	37.6	2.6	0.4	5
Plastic	60	7.2	22.8	-	-	10
Paper	43.5	6	44	0.3	0.2	6
Glass	-	-	-	-	-	99
Cardboard	44	5.9	44.6	0.3	0.2	5
Leather	60	8	11.6	10	0.4	10
Garden trimming	47.8	6	38	3.4	0.3	4.5
Tin	-	-	-	-	-	99
Wood	49.5	6	42.7	0.2	0.1	1.5
Metal	-	-	-	-	-	99

[a.] % by weight (dry basis)

Based on the assumed moisture content (MC) and weight of individual component of solid waste generated in different zones per day, the dry weight of each component were calculated using eq. 1 (data not shown). Thereafter, the chemical compositions of the solid waste (kg of C, H, O, N, S or inert per tonne of solid waste) collected from different zones were calculated based on the ultimate analysis data in table III. The main chemical constituent in the sample collected from all the zones was carbon. The carbon content varied from 152.90 kg/tonne of solid waste in the waste collected from canteen to 285.59 kg/tonne in the waste collected from academic area (table IV).

$$dry\ weight\ of\ the\ component\,(kg) = \frac{wet\ weight\ of\ the\ component\,(kg)\ X\ (1-\%MC)}{100} \quad (1)$$

TABLE IV. ULTIMATE COMPOSITION OF SOLID WASTE GENERATED FROM DIFFERENT ZONES

Source	Composition (kg/tonne of waste)					
	C	H	O	N	S	Inert
Academic area	285.59	45.39	271.14	8.47	1.37	316.03
Hostels	249.95	32.27	177.59	5.85	1.00	266.74
Canteens	152.90	20.09	112.13	5.86	1.01	59.53
Residential area	193.96	136.61	136.61	7.28	0.93	209.97
Weighted average	223.12	66.72	170.54	6.77	1.05	225.26

Weighted average indicates that chemical composition combined solid waste collected from different zones constitutes 222.12 kg of carbon per tonne of collected waste. The component with lowest occurrence was sulphur, with a weighted average of 1.05 kg per tonne of collected waste. The

VII. LANDFILL FOR WASTE DISPOSAL

The typical composition of the combined solid waste indicates the probability of incineration as the waste disposal method. However, being an educational institution, the campus closes for vacation for around two months in a year, which results in intermittent supply of waste to the incinerator. This may cause operational difficulty and high cost of operation due to excess auxiliary fuel requirement during the start-up of incinerator. Moreover, the longer span of rainy season also reduces the incinerability of the generated solid waste.

On the other hand composting or anaerobic decomposition can be practiced for the biodegradable fraction of solid waste. Currently there are initiatives to design anaerobic digesters and bio-farming for the management of biodegradable solid waste generated in the campus. Therefore, our study routed to the design of a landfill facility for the disposal of non-biodegradable solid waste generated in the campus.

Landfill is a unit operation for final disposal of MSW on land, designed and constructed with the objective of minimum impact to the environment. The essential components of landfill include (i) A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil, (ii) A leachate collection and control facility which collects and extracts leachate from within and from the base of the landfill and then treats the leachate, (iii) A gas collection and control facility (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery, (iv) A final cover system at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation, (v) A surface water drainage system which collects and removes all surface runoff from the landfill site, (vi) An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site and (viii) A closure and post-closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.

The primary objective of landfill site design is to provide effective control measures to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, as well as the resulting risks to human health arising from landfilling of waste. Therefore, the design should consider all environmental media that may be significantly impacted through the life of the landfill. The chosen design will have a major influence on the operation, restoration and aftercare of the facility. Aspects that should be considered in the design of a landfill are nature and quantities of waste, protection of soil and water, leachate management, gas emission control, reduction in environmental nuisance etc.

VIII. LEACHATE TREATMENT

The type of treatment facilities to be used depends upon the leachate characteristics. Typically, treatment may be required to reduce the concentration of degradable and non-degradable organic materials, specific hazardous constituents, ammonia and nitrate ions, sulphides, odorous compounds, and suspended solids prior to discharge. Treatment processes may be biological processes (such as activated sludge, aeration, nitrification (dentrification), chemical processes (such as oxidation, neutralisation) and physical processes (such as air stripping, activated adsorption, ultra filtration etc.). The treated leachate may be discharged to surface water bodies.

Leachate can also be treated by recirculating it through the landfill.(9). This has two beneficial effects: (i) the process of landfill stabilisation is accelerated and (ii) the constituents of the leachate are attenuated by the biological, chemical and physical changes occurring with the landfill. Recirculation of a leachate requires the design of a distribution system to ensure that the leachate passes uniformly throughout the entire waste

IX. LANDFILL GAS

Landfill gas is generated as a product of waste biodegradation. Biological degradation of the waste may occur in the presence of oxygen (aerobic bacteria), in an environment devoid of oxygen (anaerobic bacteria), or with very little oxygen (facultative anaerobic bacteria).

The rate and quantity of gas generation with time, is difficult to predict. Typical generation rates reported in literature vary from 1.0 to 8.0 litres/kg/year (9). Landfill gas has a calorific value of around 4500 Kcal/m^3. It can be used as a good source of energy, either for direct thermal applications or for power generation.

As the landfill gas produced mainly contains methane (60%), therefore it can be used locally as biogas for residential purposes such as cooking, water heating etc by creating a biogas plant.

X. PRELIMINARY DESIGN OF LANDFILL FOR NITC

Preliminary design of landfill for NIT Calicut was done based for the non-biodegradable portion of waste generated from different zones of the campus. The detailed design of the landfill and its sub-components is given in appendix II. At present, 765 kg/d of non-biodegradable waste is generated in the campus, which amounts to 279225 kg of non-biodegradable waste production per year. The average annual precipitation was taken as 3266 mm per year. A site selected for the landfill was a flat ground with water table 10 feet below the ground surface. The design life of landfill was selected as 5 years. The waste generation after 5 years was worked out as 1431.735 T, assuming an annual average increase in population as 1%. The total volume required for the landfill was obtained as 1684.412 m^3 (appendix II). The landfill was designed in rectangular shape with a length: width ration of 2:1 and maximum possible height of 10 m. Therefore, the plan area requirement of the dumping site of landfill was worked out to be 20 m X 11 m. The side slope of landfill above and below the ground level was 4:1 and 2:1 respectively (Fig. 6). The operation was designed in five phases with a design period of 1 year for each phase, which consists of cells, lifts, daily cover, intermediate cover, liner and leachate collection facility, gas control facility and final cover. The plan area of one phase was worked out to be 11m by 4m and the plan area of one cell was obtained as 1.1m X 1.1m.

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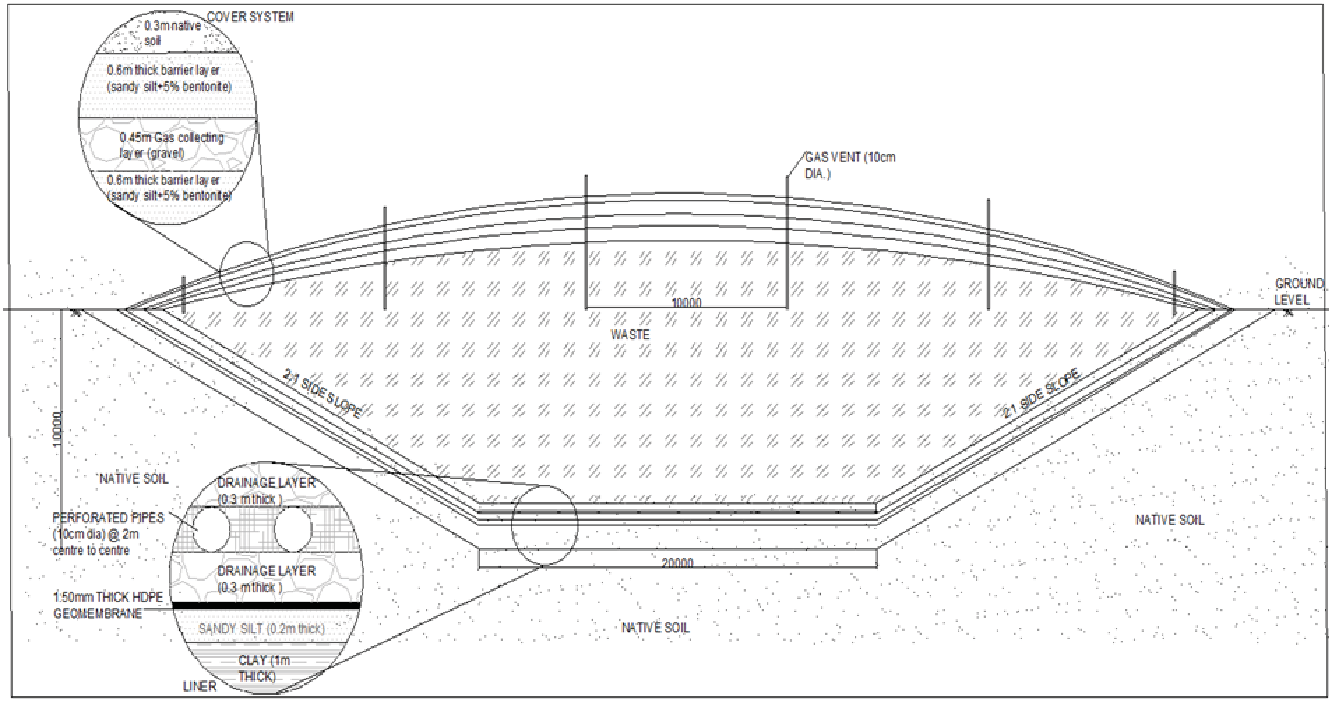

Fig.6: Cross sectional view of the designed landfill

A perforated HDPE pipe 10 cm diameter was provided at a spacing of 2 m to facilitate collection of leachate generated in the landfill. A leachate holding tank of 7 m length, 4 m width and 3 m depth was provided to hold a leachate produced during a period of 3 days. The leachate has to be treated before disposal to avoid contamination of soil or surface water. Tentatively, 600 m^2 area was allocated for the leachate treatment facility.

A properly designed landfill should be provided with final cover system, which could enhance surface drainage, reduce infiltration, and control the release the landfill gases. The cover system was designed with (i) a 0.45m thick gas collection layer comprising of gravels, directly above the waste, (ii) 0.6m thick barrier layer (sandy silt+5% bentonite) above the gravel layer and (iii) 0.3m thick surface layer of local top soil for the growth of vegetation. A passive gas vent of 1m height (above the ground level) was also provided at a spacing of 10 m.

A detailed layout of the designed landfill is shown in fig. 7. In addition to the basic sub-components, a potable cabin was also provided at the entry of the landfill to serve as site control office. Moreover, an access road of 3.5 m width was provided along the periphery of the landfill to facilitate dumping of the waste. Tentatively, $600m^2$ area was allocated for equipment workshop and garage, which facilitate maintenance, repair as well as cleaning of landfill operational equipments.

A separate leachate collection and treatment facility was proposed for the landfill. The collection tank volume was designed as 84 m^3. The past researches indicate that the biological process alone will result in higher treatment time and thus larger volume for the treatment facility. On the other hand, biological treatment preceded by advanced oxidation processes proved to be a better alternative for the landfill leachate treatment (10). There for it is proposed to have a photocatalytic pre- treatment system for the leachate generated in the present landfill followed by activated sludge process for complete its stabilization. However, the detailed design of the treatment system is yet to be carried out.

XI. CONCLUSIONS

The characteristics of solid waste generated in different zones of NITC campus was analyzed for their quantity and chemical characteristics. The ultimate analysis indicated a carbon content varying from 152.9 to 285.59 kg/tonne of solid waste. The weighted average indicated the lowest occurrence of sulphur in the collected solid waste (1.05 kg per tonne of waste). The prevailing climatic conditions in the area and non-continuous supply of solid waste eliminate the design of incinerator for the solid waste treatment. On the other hand, aerobic or anaerobic treatment could be adopted for the management of biodegradable portion of solid waste. However, the non-biodegradable portion of the waste has to be properly disposed of. Based on the quantity of non-biodegradable solid waste generated in the campus, a landfill with a design period of was designed to operate in five phases. The area requirement for waste dumping in the landfill was worked out as 20 m X 11 m, keeping the maximum height of landfill as 10 m. The proposed design also comprises of a proper liner, leachate collection system and a landfill cover. A systematic approach in collection and segregation of waste could be done for the efficient working of the landfill.

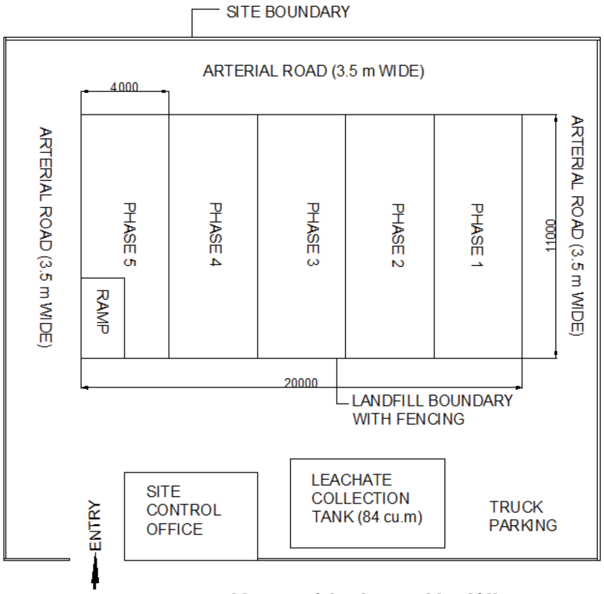

Fig.7: Proposed layout of the designed landfill.

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APPENDIX I

TABLE A-1. ULTIMATE COMPOSITION OF VARIOUS COMPONENTS OF SOLID WASTE GENERATED FROM INSTITUTIONAL ZONE AND HOSTEL ZONE

Component	Chemical composition in kg/tonne of waste (Institutional zone)						Chemical composition in kg/tonne of waste (Hostels)					
	C	H	O	N	S	Inert	C	H	O	N	S	Inert
Food waste	0.00	0.00	0.00	0.00	0.00	0.00	28.20	3.76	22.09	1.53	0.24	2.94
Plastic	63.21	7.74	24.51	0.00	0.00	10.75	66.15	7.94	25.14	0.00	0.00	11.03
Paper	66.75	9.90	72.60	0.50	0.33	9.90	64.73	8.93	65.47	0.45	0.30	8.93
Glass	0.00	0.00	0.00	0.00	0.00	108.90	0.00	0.00	0.00	0.00	0.00	127.34
Cardboard	62.40	9.00	68.02	0.46	0.31	7.63	37.34	5.01	37.85	0.25	0.17	4.24
Leather	12.15	1.80	2.61	2.25	0.09	2.25	13.50	1.80	2.61	2.25	0.09	2.25
Dust	14.47	1.65	1.10	0.28	0.11	37.40	11.51	1.31	0.88	0.22	0.09	29.75
Garden trimming	26.77	8.40	53.20	4.76	0.42	6.30	15.54	1.95	12.35	1.11	0.10	1.46
Tin	0.00	0.00	0.00	0.00	0.00	71.78	0.00	0.00	0.00	0.00	0.00	49.90
Wood	39.85	6.90	49.11	0.23	0.12	1.73	12.99	1.58	11.21	0.05	0.03	0.39
Metal	0.00	0.00	0.00	0.00	0.00	59.40	0.00	0.00	0.00	0.00	0.00	28.51
TOTAL	285.59	45.39	271.14	8.47	1.37	316.03	249.95	32.27	177.59	5.85	1.00	266.74

TABLE A-2. ULTIMATE COMPOSITION OF VARIOUS COMPONENTS OF SOLID WASTE GENERATED FROM CANTEENS AND RESIDENTIAL AREA

Component	Chemical composition in kg/tonne of waste (Canteens)						Chemical composition in kg/tonne of waste (Residential area)					
	C	H	O	N	S	Inert	C	H	O	N	S	Inert
Food waste	102.86	13.71	80.57	5.57	0.86	10.71	43.20	33.84	33.84	2.34	0.36	4.50
Plastic	20.16	2.42	7.66	0.00	0.00	3.36	39.20	14.90	14.90	0.00	0.00	6.53
Paper	23.12	3.19	23.38	0.16	0.11	3.19	25.35	25.64	25.64	0.17	0.12	3.50
Glass	0.00	0.00	0.00	0.00	0.00	16.63	0.00	0.00	0.00	0.00	0.00	75.03
Cardboard	0.00	0.00	0.00	0.00	0.00	0.00	13.09	13.27	13.27	0.09	0.06	1.49
Leather	0.00	0.00	0.00	0.00	0.00	0.00	10.08	1.95	1.95	1.68	0.07	1.68
Dust	6.76	0.77	0.51	0.13	0.05	17.49	5.96	0.45	0.45	0.11	0.05	15.41
Garden trimming	0.00	0.00	0.00	0.00	0.00	0.00	39.51	31.41	31.41	2.81	0.25	3.72
Tin	0.00	0.00	0.00	0.00	0.00	4.07	0.00	0.00	0.00	0.00	0.00	26.61
Wood	0.00	0.00	0.00	0.00	0.00	0.00	17.56	15.14	15.14	0.07	0.04	0.53
Metal	0.00	0.00	0.00	0.00	0.00	4.07	0.00	0.00	0.00	0.00	0.00	70.96
TOTAL	152.90	20.09	112.13	5.86	1.01	59.53	193.96	136.61	136.61	7.28	0.93	209.97

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APPENDIX II. PRELIMINARY DESIGN OF LANDFILL FOR NIT CALICUT

(As per The Central Public Health and Environmental Engineering Organization (CPHEEO))

A. Basic data

Location: NIT Calicut
Waste (non-biodegradable): 765 kg per day (current)
Design Life: Active Period = 5 years
Topography: Flat ground (of selected site)
Water-table: 10 feet below ground surface
Average Total Precipitation: 3266 mm per year

B. Landfill capacity, height and area

(a) Current waste generation per year, W =279225kg
(b) Estimated rate of increase of waste generation per year (rate of growth of population), x = 1%
(c) Estimated waste generation after 5 Years
$= W (1 + x)^n$
$= 279225 (1+0.01)^5$
= 293469 kg

(d) Total Waste Generation in 5 Years, T
$= 0.5 (W+W (1+x)^n) n$
= 0.5(279225+293469)* 5
= 1431735 kg
= 1431.735 T

(e) Total Waste Volume (assumed density 0.85 t/m^3),
V_w = T /0.85
= (1431.75) /0.85
$= 1684.412 m^3$

(f) Volume of Daily Cover,
$V_{dc} = 0.1 V_w$
= 0.1* 1684.412
$= 168.44 m^3$

(g) Volume of Liner and Cover Systems,
$V_c = 0.25 V_w$
= 0.25*1684.412
$= 421.103 m^3$

(h) First Estimate of Landfill Volume, C_i
$= V_w + V_c$
= 1684.412+421.103
$= 2105.515 m^3$

(i) Likely Shape of Landfill
Rectangular in plan (length: width = 2:1)

(j) Possible Maximum Landfill Height = 10 m
(k) Area Required = 2105.515/10
$= 210.55 m^3$
(l) Approximate Plan Dimensions = 20m x 11 m

C. Landfill section and plan

Landfill Section and Plan is evaluated by providing a side slope of 4:1 and 2:1 respectively, for the portion above-ground surface and the portion below the ground surface. The material excavated from the site is used as the material for daily cover, liner and final cover. Extra space was provided around the waste filling area for infrastructural facilities.

D. Landfill Phases

(a) Active life of landfill = 5 years
(b) Duration of one phase = one year
(c) Number of phases = 5. (Each phase extends from base to final cover.)
(d) Volume of one phase = landfill capacity/5
= 2105.515 / 5
$= 421.103 m^3$
(e) Plan area of phase
= (Volume of one phase)/landfill height
= 421.103 / 10
$= 42.11 m^2$
= 4*11m
(f) Number of daily cells = 365
(g) Plan area of one cell (on the basis of 1m lift of each cell)
= (Volume of one phase)/365
= (4*11*10)/365
$= 1.205 m^2$
= 1.10*1.10m
(i) Temporary holing area: Excavated portion half to be used.
(ii) Surface water drain: Adjacent to arterial road along periphery.

E. Liner and Leachate Collection System

(a). Liner system: As per CPHEEO (9) the liner system will compromise of the following layers below the waste:
(i). 0.30m thick drainage layer compromising of Badarpur sand 55 course sand or gravels.
(ii). 0.2m thick protective layer of sandy silt.
(iii). 1.50mm thick HDPE geomembrane
(iv). 1.0m thick clay layer
(b). Leachate Collection Pipe
Diameter of HDPE pipe (perforated) = 10cm
Spacing of one pipe required =2m
(c). Leachate holding tank
Size of holding 3 days leachate = 7m*4m*3m
(d). Leachate treatment facility: 40m*20m (in plan) (tentative)

F. Cover System Design

(a). Cover System: As per CPHEEO (9) the cover system were designed in three layers above the waste,i.e.,
(i). 0.45m thick gas collection layer comprising of Gravels
(ii).0.6m thick barrier layer (sandy silt+5% bentonite)
(iii). 0.3m thick surface layer of local top soil for Vegetation growth.
(b). Passive Gas Vents: Passive gas vent of 1m height (above the ground level) will be provided at a Spacing of 10 m..

G. Landfill Infrastructure and Layout

(a). Site fencing all around the landfill
(b). Site control office: 3m*5m (portable cabin)
(c). Access road: 3.5 m wide all along the periphery
(d). Equipment Workshop & Garage: 30m*20m (tentative)
(e). Vehicle cleaning: within the Workshop

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