QUANTIFICATION AND CHARACTERIZATION OF MUNICIPAL SOLID WASTE MANAGEMENT –A STUDY OF LAND FILL DESIGN FOR PATTUKKOTTAI

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ABSTRACT

Quantification and characterization of municipal solid waste (MSW) is important for adequate decision-making in the management strategy of urban MSW of a city. The objective of this study was to characterize the MSW at a landfill in Pattukkottai, India, and suggest appropriate MSW management methods. The investigations showed that the biological treatment of MSW will be feasible as it contains high organic matter and moisture content. This would help to divert 70% of the total waste if solid waste treatment facilities were provided at the source, which would lead to enormous cost savings of waste collection, transport, and disposal. Energy generation through incineration of MSW was not feasible. The changing pattern of characterization of MSW in relation to socio-economic changes has been discussed. Though the study was focused on Pattukkottai, investigations will help solid waste management planners, materials recovery facility designers, and estimation of landfill design in developing metropolitan cities. The total amount of solid waste generated from different zones of Pattukkottai accounts for about 30000 kg/d. Food waste was the major component in the waste generated from the residential areas, which accounted respectively for 70% 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/ton of solid waste in the waste collected from the residential areas. On the other hand, the component with the lowest occurrence was sulfur, with a weighted average of 1.05 kg per tone of collected waste. Based on the quantitative analysis of the solid waste generated in Pattukkottai city, a landfill was designed for the disposal of a 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 were also incorporated in the proposed landfill design.

Keywords: MunicipalSolid Waste; Characteristics; ultimate analysis; disposal; landfill

INTRODCTION

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 . In order to implement proper waste management, various aspects have to be considered such as Source reduction, Onsite storage, Collection & transfer, Processing, and Disposal.

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).

Per capita waste generation in Indian cities ranges between 0.6 kg/d amounting to about 1.15 metric tones (MT) of waste per day and 45 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 places of Pattukkottai are given in table.

TABLE I. MSW GENERATION RATE IN DIFFERENT PLACES OF PATTUKKOTTAI MUNICIPALITY PKT 2021

SL. NO.	LOCATION OF COMPOSITE CENTRE	MSW generated (TPD)	SL. NO.	LOCATION OF COMPOSITE CENTRE	MSW generated (TPD)
1	Thattankulam	2	8	EB road	0.5
2	Subbaiya pillai street (ward no 13)	2	9	AV kula street	0.5
3	Crematorium (ward no 28)	2	10	Mattusanthai road	0.5
4	Composite yard	2	11	Alagiri market	0.5
5	Lakshathoppu (ward no 31)	2	12	Viswanath nagar	0.5
6	Verimi compost	1	13	N.R Garden	0.5
7	Nariyam palayam	2	14	RV nagar	0.5

The quantity of MSW depends upon economic activity and resource consumption. On the other hand, the waste composition depends on external factors such as geographical location, climatic conditions, the 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 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 the 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 Pattukkottai was selected as the study area and the work was performed with the following objectives:

The city of Pattukkotai, located at 104.43320 N latitude and 79.32000 E longitude, is situated in the southern region of the Thanjavur district at an altitude of 17.70 meters above mean sea level, Pattukkottai is a taluk headquarter and is well connected by district roads with the nearby urban centers and has a railway link with Karaikudi, Thiruthuraipoondi, Thiruvarur, Mayiladuthurai and to Chennai. The general topography of the town is flat. The soil of the region is classified as clay and sandy clay with lesser alluvium content. With the implementation of the Cauvery Mettur Project (C.M.P) soil on either side of the CMP canal is fertile. Two rivers, Maharaja Samundram river on the west and Nasuvini river on the east, flow parallel to the town on either side and serve to drain excess water from the town, especially during monsoons. The main water body in the town is the CMP Canal passing through the western part of the town. Besides, a number of small water bodies are distributed across the town. Pattukkottai is located 47 km south of Thanjavur - the district headquarters. The town is well connected by district roads with the nearby urban centers and has railway links with Karaikudi, Thiruthuraipoondi, Thiruvarur, Mayiladuthurai, and Chennai. Located at 17.7 km above mean sea level, the town is situated within 15 kilometers from the coastal strip of Palk Straits of the Bay of Bengal. The proximity to the sea gives the town an almost even climate round the year, with little variations in seasonal temperatures. The town receives rainfall from northwest monsoons, which last from October to December. The average annual rainfall is 100 mm.

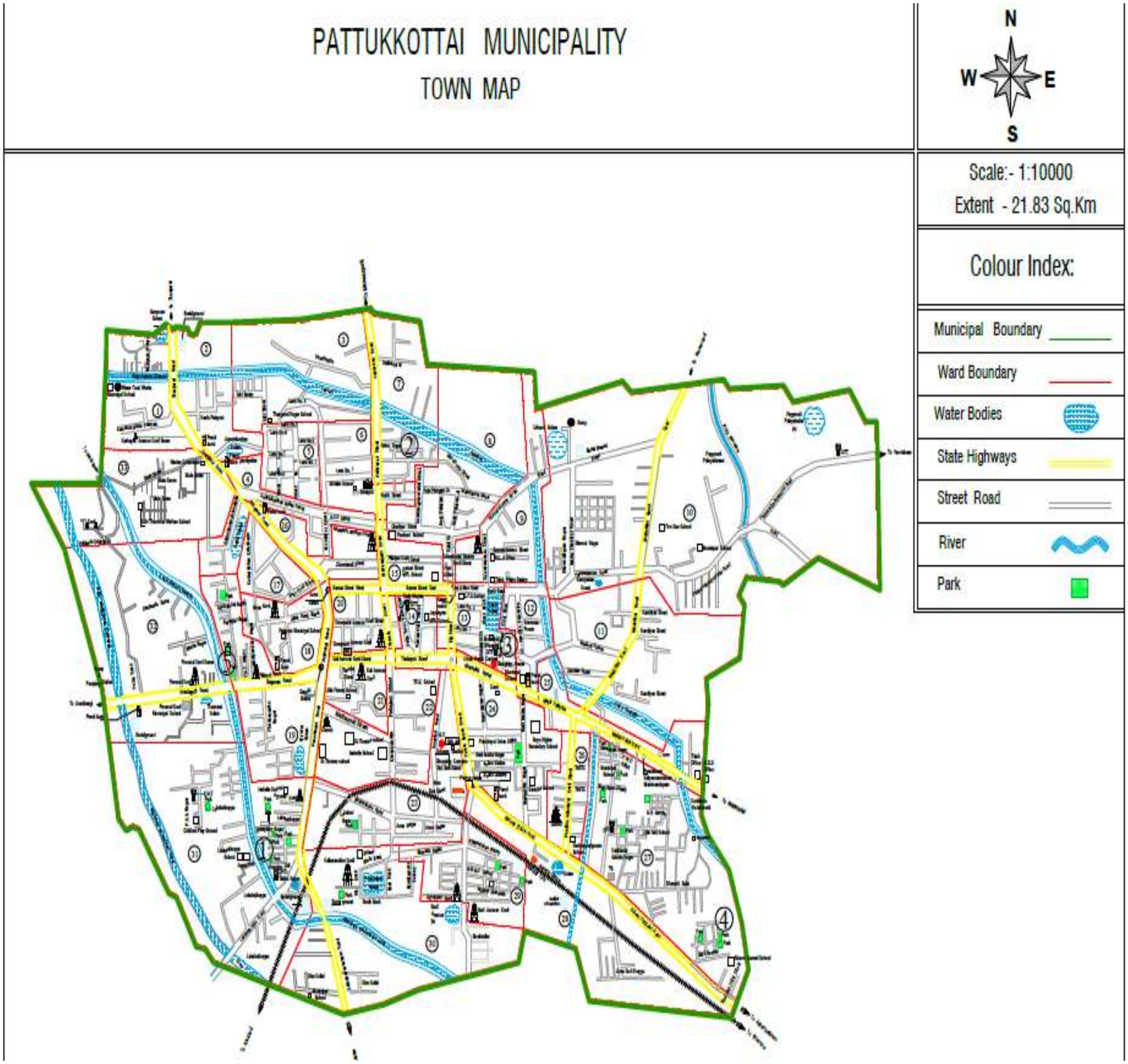
HISTORIC SIGNIFICANCE

Pattukkottai is renowned for its ancient sculptures and temples. The major attraction in Pattukkottai is the Old fort built by Raja Serfoji Maharaja. This Fort, is a well-known picnic spot, located in the village Sarabondrarajanpattinam, is an example of the Architecture of Marathas. It was built in 1814 to commemorate the victory of the British over Nepolean Bonapart in the war of Waterloo. Pattukkottai is the birthplace of eminent and profound personalities like former President Mr. R. Venkataraman, famous poet Pattukkottai Kalyanasundaram. Other places of tourist interest in and around the town include the shrine of Sheik Alauddin Sahib, Goddess Nadiamman Temple, the shrine of Venkidu Subbaiah Swamigal, Arulmigu Thurgai Amman Temple, and Gandhi Park. The nearest airport is Tiruchirapalli. Pattukkottai Railway Station is on the Karaikkudi-Tiruturaipundi line. Pattukkottai municipality was upgraded as a selection grade in 1984.

PATTUKOTTAI MUNICIPALITY

Pattukkottai Municipality has been constituted as third-grade Municipality from 1.4.1965, upgraded into Second grade from 1.4.1975, First grade from 7.4.1984, and selection grade from 22.5.98. This Municipality consists of revenue villages of Nadiyambal Puram, Kailasanatha Puram, Maharaja Samudram, Rengojiyappa Thottam, and Pappaveli Palayamkottai Revenue villages. Part-M has 33 wards each being represented in the municipal council.

PATTUKKOTTAI TOWN MAP SHOWING VARIOUS WARDS IN PATTUKKOTTAI



MATERIALS AND METHODS

- **Identify and demarcate the survey area (by maps available oninternet)**
- **Primary data collection**
- **Identify the waste quantity and characteristics at the source.**
- **Collection of representative solid waste samples**
- **Ultimate analysis of the solid waste generated from various zones based on their relativecomposition.**
- **Selection of disposal option**
- **Design of landfill based on the quantity of wastegenerated.**

OBSERVATIONS

- The components of waste generated from these three zones include Food waste, Plastics, Paper, cloth, Metal, Glass, stone,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 30000 kg/d of waste is generated from the pattukkottai municipality.

CHARACTERISTICS OF SOLID WASTE INPATTUKKOTTAI

TABLE II. COMPOSITION OF SOLID WASTE GENERATED IN DIFFERENT ZONES OF PATTUKKOTTAI

Sl no	**Waste composition category**	**Waste components**
1.	Food	Food, vegetable, yard trimmings, wood, leaves, grass
2.	Paper	Packaging paper, cardboard, wrapper, newsprint, magazines, officepaper
3.	cloth	Rubber, clothes, synthetic, cables,leather
4.	metal	Ferrous,non-ferrous,tin cans, metalfoils
5.	Stone	Stone, construction material, brickbats, sand, aggregate, ceramics,crockery
6.	Glass	Clear, brown, green,other
7.	Plastic	Plastic bags, packaging material, plastic bottles

Sl no	Waste composition category	Waste components %
1.	Food	69.3
2.	Paper	6.9
3.	cloth	7.8
4.	metal	0.7
5.	Stone	7
6.	Glass	1.2
7.	Plastic	7.1

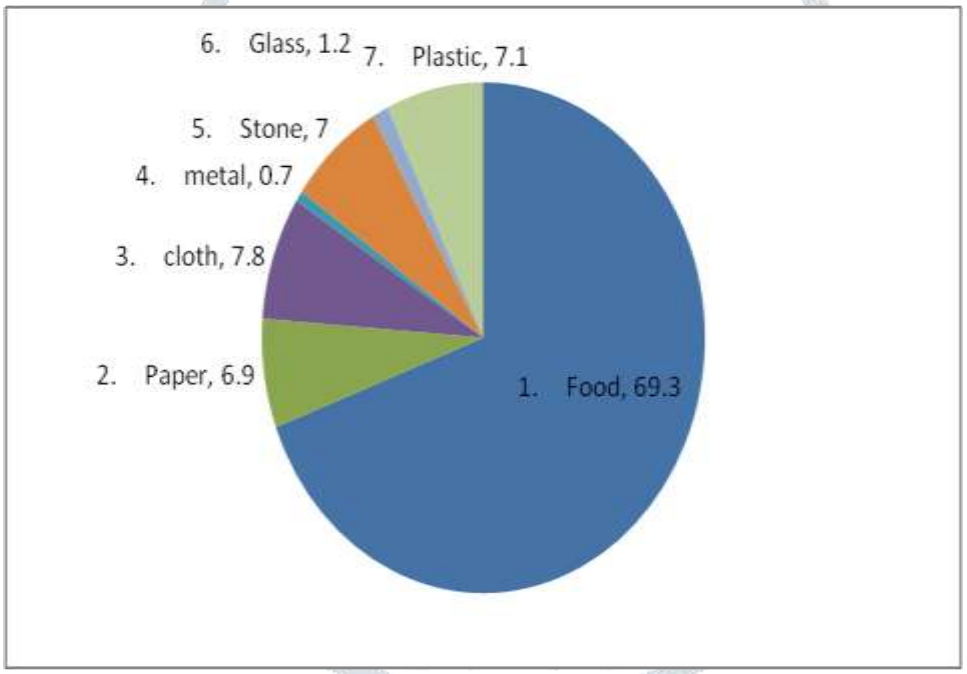


Fig.2: Waste composition category

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 pattukkottai 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, 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.

ULTIMATE ANALYSIS PER UNIT WEIGHT (DRY BASIS) OF SOLID WASTE COMPONENTS

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

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.

LANDFILL FOR WASTE DISPOSAL

The typical composition of the combined solid waste indicates the probability of incineration as the waste disposal method. This may cause operational difficulty and high cost of operation due to excess auxiliary fuel requirement during the start-up of an incinerator. Moreover, the long span of the rainy season also reduces the invulnerability 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 patukkottai. Therefore, our study routed to the design of a landfill facility for the disposal of non-biodegradable solid waste generated in the pattukkottai.

The landfill is a unit operation for the 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 infiltratingwater and supports surface vegetation, (v) A surface waterdrainage system which collects and removes all surface runoff from the landfill site, (vi) An environmental monitoring system which periodically collects and analyses air, surfacewater, 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.

LEACHATETREATMENT

- 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 (denitrification), chemical processes (such as oxidation, neutralization) and physical processes (such as air stripping, activated adsorption, ultra filtration etc.). Thetreated leachate may be discharged to surface waterbodies.
- Leachate can also be treated by recirculating it through the landfill.(9). This has two beneficial effects: (i) the process of landfill stabilization 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 entirewaste

LANDFILLGAS

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 anenvironment 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 liters/kg/year (9). Landfill gas has a calorific value of around 4500 Kcal/m^3. It can be used asa 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.

PRELIMINARY DESIGN OF LANDFILL FORPATTUKKOTTAI

Preliminary design of landfill for Pattukkottai was done based on 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 I. At present, 765 kg/d of non-biodegradable waste is generated in the pattukkottai, 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 flat ground with a water table 10 feet below the ground surface. The design life of the 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 m3 (appendix I). The landfill was designed in a rectangular shape with a length: width ratio of 2:1 and maximum possible height of 10 m. Therefore, the plan area requirement of the dumping site of the landfill was worked out to be 20 m X 11 m. The side slope of the 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.

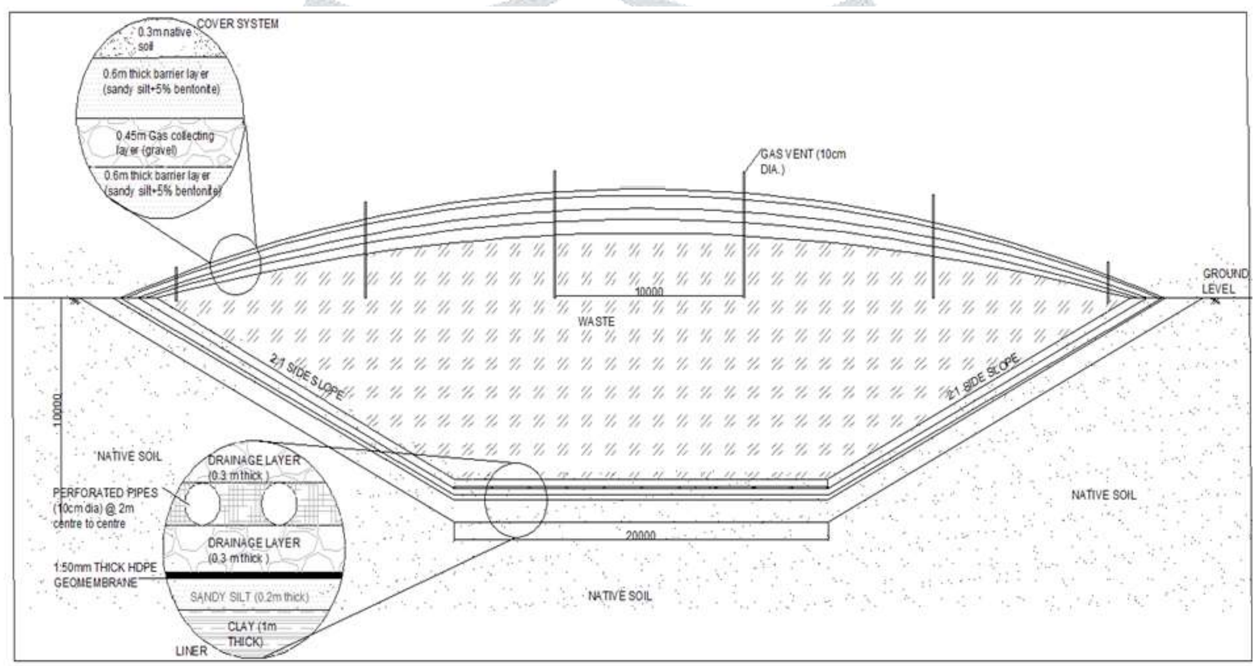


Fig.3: Cross sectional view of the designed landfill

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^2area was allocated for the leachate treatmentfacility.

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 10m.

A detailed layout of the designed landfill is shown in fig. 4. 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.

CONCLUSIONS

(a) The first step in waste management is to gain an understanding of the waste types being generated in order to design appropriate collection and disposal strategies.

(b) Characterisation of MSW of the landfill site of pattukkottai showsthatitcontainsahighpercentageoforganicmatter (69·3%) and organic content in MSW to the tuneof
32·83%, and average moisture content 48·08%, which
confirms the viability of biological treatment.

(c) Effective management of solid waste at the landfill site of pattukkottai will reduce the environmental effects oflandfill.

(*d*) The investigations of the present study will be useful for pattukkottai as well as for developing metropolitan cities when making decisions regarding the integrated solid waste management strategy and for selection of treatment and disposal options.

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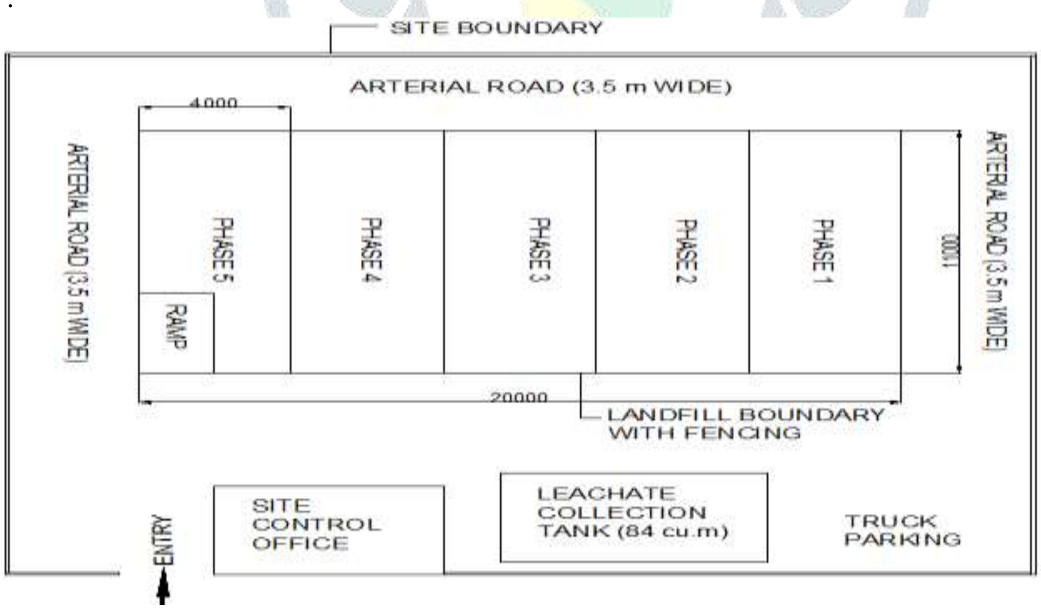

Fig.4: Proposed layout of the designed landfill.

RESULT AND DISCUSSION

A. Basicdata

Location: PATTUKKOTTAI,INDIA
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 andarea

(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 5Years

$= W(1 + x)^n$
$= 279225(1+0.01)^5$
$= 293469$ kg

(d) Total Waste Generation in 5 Years, T

$= 0.5 (W+W(1+x)^n)\, n$
$= 0.5(279225+293469)* 5$
= 1431735kg
= 1431.735T

(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 CoverSystems,

$V_c = 0.25\ V_w$
$= 0.25*1684.412$
$= 421.103\ m^3$

(h) First Estimate of Landfill Volume, C_i

$= V_w + V_c$
$= 1684.412+421.103$
$= 2105.515\ m^3$

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

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

C. Landfill section andplan

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 infrastructuralfacilities.

D. Landfill Phases

(a) Active life of landfill = 5years
(b) Duration of one phase = oneyear

(c) Number of phases = 5. (Each phase extends from base to final cover.)
(d) Volume of one phase = landfillcapacity/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 eachcell)
= (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 beused.

(ii) Surface water drain: Adjacent to arterial road alongperiphery.

(iii)

E. Liner and Leachate CollectionSystem

(a). Liner system: As per CPHEEO (9) the liner system will compromise of the following layers below thewaste:

(i). 0.30m thick drainage layer compromising of Badarpur sand 55 course sand orgravels.

(ii). 0.2m thick protective layer of sandy silt. (iii). 1.50mm thick HDPE geomembrane (iv). 1.0m thick claylayer

(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)

F. Cover SystemDesign

(a). Cover System: As per CPHEEO (9) the cover system were designed in three layers above thewaste,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.

G. Passive Gas Vents: Passive gas vent of 1m height (above the ground level) will be provided at a Spacing of 10m.. *Landfill Infrastructure andLayout*

(a). Site fencing all around thelandfill

(b). Site control office: 3m*5m (portablecabin)

(c). Access road: 3.5 m wide all along theperiphery

(b). Equipment Workshop & Garage: 30m*20m
(tentative) (e). Vehicle cleaning: within theWorkshop

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