Municipal Solid Waste Management in India with Special Reference to Bhimavaram Town in West Godavari District, Andhra Pradesh, India

K.M.Ganesh, A. Subrahmanyam Raju, R.Subba Rao

Abstract: ***Once the waste is collected from the different sectors of the community, the next problem to be addressed is regarding the safe, economical and efficient disposal options. Suitable decisions have to be made in this regard so as to avoid open and illegal dumping of wastes which are dangerous and threatening to the environment. The community has to weigh the different disposal options depending on several different criteria such as short-term start-up cost, long-term operational and maintenance cost, minimising the controversy over siting facilities, liability to the members of the community and minimizing environmental nuisance such as littering, odour, dust, noise, vermin and long-term benefits. One of the most noticeable environmental problem is accumulation of solid waste. Waste compostion, attributes and quantities of solid waste is necessary for which supplies the primary data on which the waste management structure is planned, designed and operate controlled, managed and designed disposal sites of municipal solid waste are the landfills, which spreading in layers, compacted to the smallest practical volume and covered by materials (soil) applied to prevent animal and vector attacks. A properly designed municipal solid waste landfill includes provision for leachate management (leachate is waste liquid that gathers pollutants as it trickles through municipal solid waste disposal landfill) and the possible collection of landfill gas and its potential use as an energy source. Leachate is created as rainfall lands on an uncapped landfill and percolates through the wastes. Rate of growth of per capita generation of solid waste is adopted as 2% for every year.***

Index Terms: ***Municipal solid waste management, India scenario, SWM practices***

I. INTRODUCTION

Municipal solid scrap making resume to grow both in per capita and overall terms in cities which increase in size faster and become overcrowded with higher people densities due to the resulting change in the way of life of the human beings. West Godavari is one among the most urbanized district in Andhra Pradesh. The district headquarters located at Eluru. The total area of West Godavari District is 7,742 Sq.Km. A few challenges among them include lack of adequate urban services, issues in local governance and high incidence of urban poverty. Bhimavaram is about 25.64 Sq. kilometers located in West Godavari District, the state of Andhra Pradesh, in the south-eastern part of India. Bhimavaram has been pre-eminently an agricultural district. It has an elevation of 7 m (23ft) above Mean Sea Level. Its geographical location is 16°50'0" N. latitude and 80° 64' 0" E longitudes, with the mean elevation of 7 meters (23feet), the location map of the study area. depicts in Fig.1[1].

As per Census 2011, Bhimavaram has 39 municipal wards with population size of 1, 42,317 Thus, total population of Bhimavaram town was 1,42,317 spread over an area of 25.64sq.km. The Draft Master Plan, is designed for 25 years i.e., up to 2042. Bhimavaram has 55 slums with a population of 32971 (Bhimavaram Municipality survey). Slums households of Bhimavaram town have 7851.Constituting 23% of total population of municipality as per 2011 census.

II. MATERIALS AND METHODS

A. Planning and design criteria

The following phases are considered for the Design of Proposed Solid Waste Management in Bhimavaram.

Generation

- Storage
- First collection
- Peripheral collection and Transportation
- Processing/ Treatment
- Final Disposal

Fig. 2 shows the schematic diagram for solid waste management

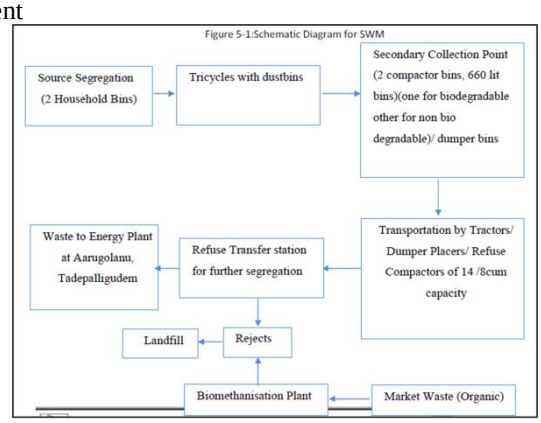

Fig. 2 Schematic diagram for SWM

Revised Manuscript Received on June 01, 2019.

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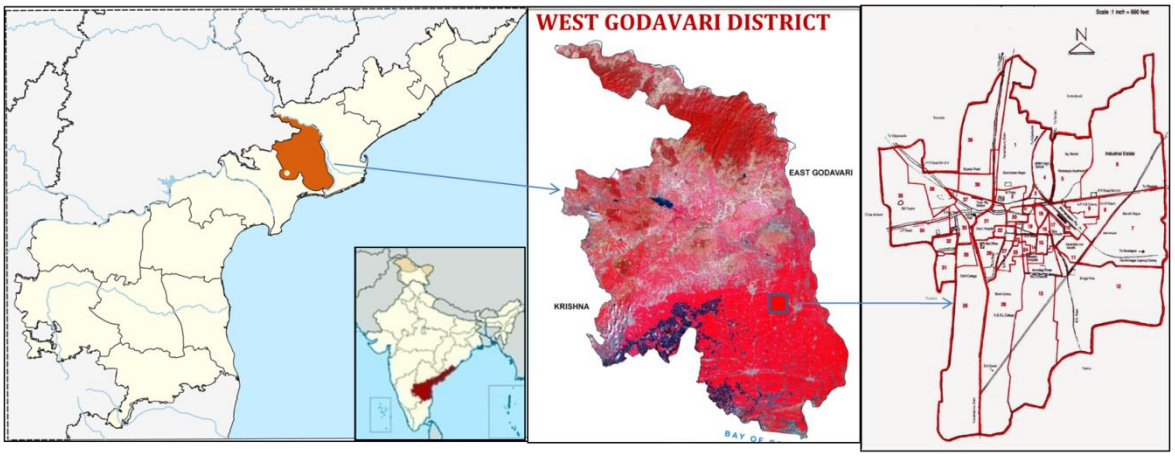

Fig. 1 Location map of the study area

Various studies, as mentioned below, are been made to assess the upturn in the per capita waste generation per annum depend on which the raise in per capita waste generation for Bhimavaram is adopted. The physical characteristics and Garbage generation will shown in Tables 1,2 and 3

Table 1 Norms for Garbage Generation	
Garbage Generated From	Average Waste
Population range upto 1 lakh	0.27 Kg per person per day
Population range 1 to 5 lakh	0.31 Kg per person per day
Population range 5 to 10 lakh	0.45 Kg per person per day
Population range 10 to 20 lakh	0.67Kg per person per day

Table 2 Physical Characteristics of Municipal Solid Wastes in Indian Cities

Population range (in millions)	Number of cities surveyed	Waste composition (in percent)					
		Paper	Rubber leather and synthetics	Glass	Metals	Total compostable matter	Inert
0.1 to 0.5	12	2.91	0.78	0.56	0.33	44.57	43.59
0.5 to 1.0	15	2.95	0.73	0.35	0.32	40.04	43.59
1.0 to 2.0	9	4.71	0.71	0.46	0.49	38.95	44.73
2.0 to 5.0	3	3.18	0.48	0.48	0.59	56.67	49.07
>5.0	4	6.43	0.28	0.94	0.8	30.84	53.9

Table 3 Physical Characteristics of Municipal Solid Wastes in Indian Cities

Population range (in millions)	Number of cities surveyed	Moisture (%) of wastes	Organic matter (%) of wastes	Nitrogen vs total Nitrogen	Phosphorous as P2O3 (%) of wastes	Potassium as K^2O(%) of wastes	C/N Ratio	Calorific value in kcal/kg
0.1 to 0.5	12	25.81	37.09	0.71	0.63	0.83	30.94	43.59
0.5 to 1.0	15	19.52	25.14	0.66	0.56	0.69	21.13	43.59
1.0 to 2.0	9	26.98	26.89	0.64	0.82	0.72	23.68	44.73
2.0 to 5.0	3	21.03	25.6	0.56	0.69	0.78	22.45	49.07
>5.0	4	38.72	39.07	0.56	0.52	0.52	30.11	53.9

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B. Storage and collection

With a dream to keep the high quality of public health, the villages and towns in the state of Andhra Pradesh, the assumed outcomes shall be total separation at source as per Municipal solid waste rules, door to-door gathering. It is for that reason the storage and primary collection system will be designed adequately. Waste is continuously produced because of human activities. As this waste cannot be continuously removed, it has to be stored and transported quickly at specific frequencies. The removal of waste from individual houses often termed as 'collection of waste' can be carried out by using various methods such as house to house and community bin system.

Source segregation and storage is not the primary responsibility of the Bhimavaram Municipality (BMC). However, if achieved, there will be a significant improvement in the waste quality and subsequently enhancement in the waste dispensation.

Community Participation indicates various actions that could be taken by BMC to increase the public participation for the management of Municipal Solid Waste (MSW). The following sections deal with issues that need to be considered for source segregation and various options available to Bhimavaram Municipality to implement the system.

Scrap separation at origin can be attained by storing dry and wet fraction of MSW in two various bins/ bags and dispose them individually. Table 4 showing the segregation categories.

Table 4 MSW Source Segregation – categories	
Bio-degradable (wet waste)	Recyclable & Non-bio-degradable (dry waste)
Food & Green waste : Cooked/uncooked food, vegetable, fruit, meat, borne, fish waste, leaves, grass	Paper, Plastics, glass, metal, ceramic, rubber, leather, rags, used cloths, wood, stone, sand, ash, thermocol, straw & packing materials

However, it is not easy to implement source segregation practices immediately. A prolonged campaign by BMC will be required with adequate budgetary provisions under Information Education and Communication Programs which will be, taken up with the help of Non Governmental Organizations and Ministry of Environment and Forests Recommends a 3 Bin system of storage of waste, however, such a system of segregation in the initial stages of waste management is difficult for the community to practice.

It is hence proposed to establish a system based on '2

Bin system of Solid Waste Storage at source. For Food/Green waste and Recyclables/Non-biodegradable waste, every household was motivated to keep separate Bins/containers [2].

The household bin for food & green waste could be of 30 liters Capacity made of plastic / reinforced plastic or metal. In absence, practice of any processing mechanisms and organized recovery existing disposal system of most municipal towns is miserable. Which causes to the unutilization of garbage unnecessary occupation of dumpsites leading to health hazards and inconvenience to citizens.

C. Cell Method

In this method the collected waste is deposited in a pre-constructed bonded area.This method encourages the progressive filling and restoration, it is a preferred method for industries.
Operating a cellular method of filling permits wastes to be deposited in a organized manner since the entire cell serve to both conceal the tipping and rap much of the litter, which may be generated.
Sanitary landfill helps in reclamation of land for valuable use and prevents burning of garbage also. While using sanitary landfill approach MSW rules will also be considered. This facility is provided with proper design and specifications. a cover liner would be provided whenever the planned waste levels are reached The landfill will be developed with a perspective of 20-25 years.

III. RESULTS AND DISCUSSION

A. Solid waste management system

Each household in the town is initially (first year) provided by two 10 lit capacity household bins to encourage the source segregation. Sanitary worker collects the household waste and empties in the proposed 60 lits bins allotted for biodegradable and non-biodegradable waste separately in tricycle. Around 200 households are covered by a sanitary worker for door to collection. Each tricycle is provided with 6 bins to transport to the secondary collection point.

At every secondary collection point two dumper bins/compactor bins of each 660 lit capacity, one for biodegradable and the other is for non-biodegradable, waste are proposed. The waste from primary collection is emptied in these bins. Existing tractors/dumper placer vehicles/ compactors are proposed to lift the secondary collection bins to transport to the proposed transfer station. Separate compactors are proposed for transportation of both wet waste and dry waste. The waste generates from vegetable markets, fruit markets which have high moisture content and high organic content will be processed under Biomethanisation. A Biomethanisation plant of 4 TPD (Tons Per Day) capacity is proposed within the transfer station.
In view of transporting segregated waste to Waste to Energy Plant (WTE) plant at Tadepalligudem and to reduce the fuel cost a transfer station is proposed. Magnetic separators and trommels are proposed in transfer station to retain metals and to separate the silt, street sweepings or dust from the waste. These inerts are proposed to be land filled in sanitary landfill designed for 25 years. 15 tons containers are proposed to transport the compressed waste by static compactor.

- Infrastructure required for House Hold Collection of Waste and transportation – Bins and tricycles
- Infrastructure required for collection of waste from commercial establishments, markets and other institutions – Bins.
- Vehicles for secondary transportation – Existing Tractors and dumper placers are utilised, newly Compactors are proposed.
- Transfer Station
- Transporting the waste to Waste to Energy Plant at Tadepalligudem, west Godavari district, Andhra pradesh
- Bio Methanantion plant for highly biodegradable organic matter from Markets

B. Population projection

The population projection methods namely, arithmetic progression, geometric progression and incremental increase method have been tried to project the population. Owing to the decrease in % growth of population Geometric method found not suitable. Arithmetic method is adopted to forecast the population for 25 years for the town. Table 5 shows projected population by different methods.

Table 5 Projected Population – Bhimavaram

Year	Arithmetical Increase Method (Pn)	Geometrical Increase Method(Pn)	Incremental Increase Method (Pn)
2011	142317	142317	142317
2015	149247	155185	149015
2017	152712	162049	152314
2022	161374	180567	160416
2027	170036	201200	168312
2032	178698	224192	176000
2037	187360	249810	183480
2042	196022	278356	190754
2046	202951	303524	196423

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Table 6 Projected Population – Bhimavaram			
Year	Projected population	Year	Projected population
2017	152712	2030	175233
2018	154444	2031	176965
2019	156177	2032	178698
2020	157909	2033	180430
2021	159641	2034	182163
2022	161374	2035	183895
2023	163106	2036	185627
2024	164839	2037	187360
2025	166571	2038	189092
2026	168303	2039	190825
2027	170036	2040	192557
2028	171768	2041	194289
2029	173501	2042	196022

Arithmetical Increase method is best suited for Bhimavaram which matches the previous year population data compared to other population projection method. Following table shows projected population by Arithmetical Increase method for next 25 years. Table 6 shows projected population of Bhimavaram

C. Estimation of Per capita Waste generation and Present Waste Quantity

To arrive at the present quantity of waste generated, Sample surveys for estimation of per capita generation from various sources of waste generation and an assessment of waste collected by the solid waste carrying vehicles and uncollected waste on a typical day has been carried out. Some portion of the waste is also picked by the rag pickers and is being recycled.

A detailed inventory waste generating sources and comprehensive surveys to arrive at the per capita waste generation trends for domestic sources and assessment surveys for non-domestic sources.

Project team has provided sampling polythene bags to the households and commercial establishments for collection of solid waste produce in a day in plastic bags and same was collected on next day. On site quantity assessment has been carried out by survey team through weighing machine.
Rate of growth of per capita generation of solid waste is acquired as 2% for every year. Projected waste generation from the Urban Local Bodies is shown below. Table 7 showing the Solid waste generated in Bhimavaram.

D. Physico-chemical characteristics of solid waste

Characterization of municipal solid waste is carried using out by taking representative samples from dump sites of respective towns. Sample waste collected has been sorted using Quarter & coning sampling Procedure. Physical characteristics of waste is derived at the site by in-situ manual sorting of the waste. Table 8 shows the constituents and their average weights in percentage of waste [3].

Intensively varied so gathered the total quantity of waste and then lowered by method of quartering till a sample of such size is procured which can be lifted in the laboratory. Table 10 showing the chemical attributes of the waste.

Table 8 Physical characteristics of Bhimavaram Municipality					
S. No.	Physical characteristics	Old Gollavanithippa road	Dump site at 1 st Day	Dump site at 2nd Day	Average
1	Organic waste	47.2%	46.8%	47.4%	47.1%
2	Garden waste	7.9%	7.2%	6.9%	7.3%
3	Coconut shells	3.2%	3.6%	3.1%	3.3%
4	Ply wood, wood chips, broken furniture	5.9%	6.2%	6.3%	6.1%
5	Plastics	3.5%	3.6%	3.4%	3.5%
6	Paper	7.4%	6.9%	6.9%	7.1%
7	Textiles	2.9%	2.8%	3.1%	2.9%
8	Metals	1.1%	1.3%	1.4%	1.3%
9	Glass & ceramics	0.8%	11%	1.2%	1.0%
10	Rubber & Synthetics	0.9%	0.8%	0.8%	0.8%
11	Dust, stone, debris & boulders	19.2%	19.7%	19.5%	19.5%

The above constituents are classified as follows in the Table 9.

Table 9 Physical characteristics of Solid waste			
S.No.	Type of waste	Physical Characteristics	Average
1	Bio-degradable waste	Organic waste	47.1
		Total	47.1
2	Dry waste/combustibles	Garden waste	7.3
		Coconut shells	3.3
		Ply wood, wood chips, broken furniture	6.1
		Plastics	3.5
		Paper	7.1
		Textiles	2.9
		Total	29.9
3	Recyclables	Metals	1.3
		Glass & ceramics	1.0
		Rubber & synthetics	0.8
		Total	3.1
4	Inert and dust	Dust, stone, debris & boulders	19.5
		Total	19.5
		Grand total	99.7

Table 7 Solid waste generated in Bhimavaram

Year	Projected Population	Domestic Waste Generation (Grams PerCapita/ Day)	Total Domestic Waste(TPD)	Commercial Waste Generation (Grams PerCapita/ Day)	Commercial Establishment (TPD)	Institutional Waste Generation (Grams PerCapita/ Day)	Institutional (TPD)	Street Sweeping Silt Waste Generation (Grams PerCapita/Day)	Street Sweeping Silt Waste (TPD)	Total Waste Generated (TPD)
2015	149,247	270	40	162	24	0	0	108	16	80.59
2016	150,979	275	42	165	25	0	0	110	17	83
2017	152,712	281	43	169	26	0	0	112	17	86
2018	154,444	287	44	172	27	0	0	115	18	89
2019	156,177	292	46	175	27	0	0	117	18	91
2020	157,909	298	47	179	28	0	0	119	19	94
2021	159,641	304	49	182	29	0	0	122	19	97
2022	161,374	310	50	186	30	0	0	124	20	100
2023	163,106	316	52	190	31	0	0	127	21	103
2024	164,839	323	53	194	32	0	0	129	21	106
2025	166,571	329	55	197	33	0	0	132	22	110
2026	168,303	336	57	201	34	0	0	134	23	113
2027	170,036	342	58	205	35	0	0	137	23	116
2028	171,768	349	60	210	36	0	0	140	24	120
2029	173,501	356	62	214	37	0	0	143	25	124
2030	175,233	363	64	218	38	0	0	145	25	127
2031	176,965	371	66	222	39	0	0	148	26	131
2032	178,698	378	68	227	41	0	0	151	27	135
2033	180,430	386	70	231	42	0	0	154	28	139
2034	182,163	393	72	236	43	0	0	157	29	143
2035	183,895	401	74	241	44	0	0	160	30	148
2036	185,627	409	76	246	46	0	0	164	30	152
2037	187,360	417	78	250	47	0	0	167	31	156
2038	189,092	426	81	255	48	0	0	170	32	161
2039	190,825	434	83	261	50	0	0	174	33	166
2040	192,557	443	85	266	51	0	0	177	34	171
2041	194,289	452	88	271	53	0	0	181	35	176
2042	196,022	461	90	277	54	0	0	184	36	181
2043	197,754	470	93	282	56	0	0	188	37	186
2044	199,487	479	96	288	57	0	0	192	38	191
2045	201,219	489	98	293	59	0	0	196	39	197
2046	202,951	499	101	299	61	0	0	200	40	202
2047	204,684	509	104	305	62	0	0	204	42	208

E. Phase wise Landfill Design for the Proposed Site

The depth of landfill has been considered keeping the ground water table at the site in to consideration. The height of the landfill is fixed at 10 m above Ground Level (GL) and 2.5 m below ground level considering the volume of waste to be dumped over a period of 15 years [4].

Design Criteria for Landfill

(i) Active of Life of each Phase: 5 Years
(ii) Topography : Flat Terrain
(iii) Water Table : 10 m below ground surface
(iv)Average Precipitation : 1072 mm/ Year
(v) Base Year : 2017
(vi) Side slope : 1:4 side slope for the above ground portion of the landfill.
(vii) Side slope : 1:2 side slope for the below ground portion of the landfill.
Since the land available at Bank of River is not sufficient for 15 years, the available land is utilized for 10 years and for the next 5 years a new land has to be found. Table 11 shows the design criteria for landfill.

F. Leachate generation

The following factors causing the sanitary landfill of leachate volume:

- The area of rainfall
- Groundwater /surface runoff
- MSW moisture
- Degree of compaction
- Evaporation
- Capacity of the soil and the MSW to retain moisture

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Table 11 Design criteria for landfill

S.No.	Description	Unit	2017-2022	2023-27	2028-32	2033-37	2038-42	Total
1	Total volume of waste leading to land fill site in starting year per day	Cum/Day	8.0	10.00	11.00	13.00	15.00	57.00
2	Proposed life of landfill	Years	5	5	5	5	5	
3	Total volume of waste leading to land fill site after 5 years per day	Cum/Day	9.00	11.0	13.00	14.00	16.00	
4	Total volume of waste in 5 years (Vw)	Cum	15513	19163	21900	24638	28288	
5	Dialy cover considered	% of Total Volume (Vw)	10%	10%	10%	10%	10%	
6	Total volume of daily cover in 5 years (on the basis of 15 cm soil cover on top and sides for lift height of 1.5 to 2 m) (Vc=0.1 xVw)	Cum	1551	1916	2190	2464	2829	10950
7	Liner and clo ser cover considered	% of Total Volume (Vw)	25.00%	25.00%	25.00%	25.00 %	25.00%	
8	Total volume required for components of liner system and of cover system (VL=0.25xVW)	Cum	3878	4791	5475	6160	7072	27376
	(on the assumption of 1.5m thick liner system (including leachate collection layer) and 1.0m thick cover system (including gas collection layer)							
	Vc=k Vw(cum) (k=0.25 for 10m high landfill, 0.125 for 20 m high landfill and 0.08 for 30 m high landfill. This is valid for landfills where width of landfill is significantly larger than the height)							
9	Volume available within 10 years due to settlement/biodegradation of waste @ 10% of Total Volume (Vs=0.1 x Vw)	Cum	1551	1916	2190	2464	2829	
10	Total landfill capacity (Vn=Vw+Vc+VI-Vs)	Cum	19391	23954	27375	30798	35360	136878
11	Proposed height of landfill (H)	Mtr	10	10	10	10	10	
12	Area required for landfill (AI=Vn/H)	Sq.m	1940	2396	2738	3080	3536	13690
13	Area required for infrastructure (at 15% of total area) (Ai)	Sq.m	291	360	411	462	531	2055
14	Total area required (At=AI+Ai)	Sq.m	2231	2756	3149	3542	4067	15745
15	Size of Landfill							
	Length	Mtr	63.0	70.0	74.0	79.0	85.0	371.0
	Width	Mtr	31.5	35.0	37.0	39.5	42.5	185.5

The rainfall is the head origin of the leachate of volume.

Not only by rainfall in the area but also by runoff of the landfill is accountable for leachate,

Either by increasing the amount of filtration or by direct precipitation the scrap deposited there through craks in the land of which increases the quantity.

The volume of leachate processed is often determined by using coefficients that correspond the formerly intimated parts since it is hard to obtain climatologic details.

The below method allow to make a simple, quick assessment of the flow of Leachate or percolate liquid by using the calculation

$$Q = P \times A \times K$$

Q = Mean leachate flow generated (m3/month)

P = Maximum monthly precipitation (m/month)

A = Surface area of the landfill (m2)

K= Coefficient that depends on the degree of waste compaction

- For weakly densed landfills with specific weight of 0.4 to 0.7 t/m3, the estimated production of Leachate is between 25 and 50% (K=0.25 to 0.50) of the mean annual precipitation for the landfill area.
- For strongly dense landfills with specific weight ≥ 0.7 t/m3 the assessed making of the Leachate is between 15 and 25% (K=0.15 to 0.25) of the mean yearly precipitation for the landfill area.

Table 10 Chemical characteristics of waste					
S. No.	Characteristics	Units	Old gollavanithippa road	Old waste at dump site	Fresh waste at dump site
1	Density of waste	kg/cum	420	400	390
2	Moisture content	%	48.1	47.7	47.2
3	pH(5% solutions)	--	7.98	8.01	8.02
4	EC(5% solutions)	Um/cm	1220	1260	1280
5	Total waste soluble	%	4.8	4.9	5.1
6	TOC	%	17.9	18.2	18.1
7	C/N ratio(Dry)	--	24.52	26.00	25.49
8	Calorific Value	k.cal/kg	920	950	960
9	Total Phosphorus	%	0.56	0.56	0.58
10	Total Potassium	%	0.50	0.52	0.52
11	Nitrogen as N	%	0.73	0.70	0.71
12	Arsenic	mg/kg	20	20	30
13	Cadmium	mg/kg	3	3	4
14	Chromium	mg/kg	40	40	50
15	Nickel	mg/kg	50	50	60
16	Lead	mg/kg	130	140	140
17	Zinc	mg/kg	120	130	130
18	Copper	mg/kg	110	120	120

Since leachate generation occurs mainly during rainy periods and for diverse days subsequently and stop during dry periods, it is a good idea to adopt monthly precipitation instead of yearly.

The Table 12 values have been adopted for estimating leachate generation.

Table 12 Estimation of leachate		
Leachate generation from sanitary landfill	Qty	Units
Rainfall (p)	0.15	m
No of rainy days in that particular month	8	Nos
K=0.2 (landfill)	0.2	
A=(landfill area)	8092	Sqm
Q=P*A*k	242.80	Cum/month
No of rainy days in that particular month	8	Nos
Q(m3/day	30.3	Cum/day

IV. CONCLUSION

Municipal solid waste management (MSWM) is great important for a clean and beneficial environment. The following inferences could be pinched from the studies:

Most of the MSWM practices existing in India are not satisfactory and do not follow the MSW management and grasping rules. Among the studies, Bhimavaram town had satisfactory Solid waste Management practices because of application of systematic and scientific MSWM practices, door to door collection, public awareness and involvement. In India different regions have different meteorological parameters, environmental conditions, geological, socio-economic and cultural conditions. So we could not fix a single solution to be applied throughout India.

For subsequent, studies should be focused on cardinal of climatic conditions, socio-economic-cultural pattern and geographical conditions. More studies require to be conducted and severe laws must be enforced for proper municipal solid waste management. Perception should also be created among people and authority for proper waste management practices. Land filling is considered as the low priority technique in the waste management hierarchy, it is still the preferred disposal route for municipal solid waste all over the world. In developed and developing countries, substantial increase in recycling and consequently a reduction in landfilling appeared in the last decade of the 20th century. Within the East European countries in 1995, approximately 86% of solid waste was landfilled and 2.4% was incinerated. The data for 1999 shows an improvement in reducing landfilling to 83.7% while the share of incineration of municipal solid waste increased to 6% and the share of incineration increased to nearly 160%.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Principal and Management of S.R.KR.Engineering College (Autonomous), Bhimavaram, W.G.District, Andhra Pradesh, India for his outstanding help with this paper.

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