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A Brief Assessment of Municipal Solid Waste and its impact on leachate quality at MSW sites in Vijayawada city, India

Shaheda Niloufer[1], Dr.A.V.V.S.Swamy[2]
1 Asst Professor, Lakireddy Bali Reddy College of Engineering, Mylavaram, Krishna D.t., (A.P.), India
2 Asst Professor, Department of Environmental Sciences, Acharya Nagarjuna University, Guntur, Krishna

Abstract:

With the advance of civilization and fast industrial development the cities of developing countries are facing the problem of waste which is becoming more complex in urban areas. The composition and characteristics of solid waste vary from the place to place and is influenced by various factors like population, urbanization, life style of people, climate, industrial development and management of recyclables. The present paper is an attempt to study the physical and chemical characteristics of Municipal Solid Waste (MSW) and leachate generated from MSW in Vijayawada city which is necessary to design an integrated MSW management system. The results revealed that, the average organic percentage of waste in MSW was 55%, combustibles were 37% and recyclables were 11%. However the physico-chemical parameters of the solid waste collected from disposal sites were found in moderate range and the waste was very much suitable for composting practices. The leachate produced was highly contaminated that reflected the MSW characteristics in the city.

Key words: Municipal Solid Waste (MSW), Organic waste, recyclables etc.

Introduction:

The Municipal Wastes generated from residential, commercial, institutional segments get mixed up with traces of other wastes from hospital, industrial and municipal services including construction & demolition wastes. This mix up is declining with stricter enforcement of legislation. The rate of waste generation is an index of socio-economic development and economic prosperity of the region. Increasing industrialization and raising incomes lead to greater use of resources and waste composition is influenced by factors such as extent of urbanization, standard of living and climate. Thus, waste quantities as well as composition are inextricably linked to the vibrancy of economic activity and resource consumption pattern of the society which generates the waste (Mr. D.B.S.S.R. Sastry).To design and develop integrated waste management systems, it is necessary to have information of the physical and chemical characteristics of municipal solid waste (MSW), which is practically nil in cities like Vijayawada. (Lorena De Medina-Salas *et al.,* 2013). The composition and the quantity of MSW generated form the basis on which the management system needs to be planned, designed and operated (Sharholy *et al.,* 2008). In India MSW differs greatly with regard to the composition and hazardous nature, when compared to MSW in the western countries (Gupta *et al.,* 1998; Shannigrahi *et al.,* 1997; Jalan and Srivastava, 1995). The municipal waste generation in metro cities varies between 0.2- 0.6 kg/capita/day (Zurbrugg, 2002 and Agarwal *et al.,* 2005), and urban MSW generation is estimated to be approximately 0.49 kg per capita per day. This is estimated to be two or three times more than the waste generated by rural residents (Devi *et al*., 2001). The figures, however, vary from city to city. For example, while the per capita waste generated in Delhi is 0.5 kg per day, MSW generated per capita per day is 0.35 kg in Hyderabad and 0.64 kg in Bangalore (Huysman, 1994). According to studies carried out by (NEERI) the per capita waste generated in a typical Indian metropolitan city increases by 1.3% per year while the estimated urban population growth is around 3.5% per annum (Shekdar *et al.,* 1993). These studies point out that there is a large difference between urban and rural level of waste generation, which reflect the economic extremities existing with the Indian society.

Profile of Vijayawada City

Vijayawada, the city with 10, 48,240 (2011 census) of population is the second largest city of divided Andhra Pradesh. The proposal of capital being shifted to the city will raise the population inflow to unexpected levels that may increase the burden on the MSW management enormously. Data and related information were collected for the last six months through field survey, public consultation, literature, and other appropriate means. The existing system of Municipal Solid Waste Management in the City as practiced by the Vijayawada Municipal Corporation is as below:

The city is divided into 34 sanitary divisions for primary collection there is partial house to house hold collection. This is also being done by NGO in a few areas. At the storage place at community location, the system of community bin is followed. There is no segregation of waste neither at the community bin level nor at dumping ground or processing unit. There is no facility for an engineered landfill. Presently, the VMC has adopted netting of the dumper bins during transportation to avoid spilling over etc.

Collection

Residential

Presently two bin system for collection of municipal solid is being adopted in Vijayawada. The waste generated at individual premises is collected by door to door collection. Sanitary workers also dump the waste collected from sweepings at such places. Municipal Solid Waste lying in open areas/ dumper bins is collected regularly.

The waste generation in the individual households is separately collected in two bins for organic (Green bin) and other wastes (Red bin). These wastes are collected from door to door through the sanitary workers by tri cycles and autos which are shifted to separate bins provided in the vehicles. Then these wastes are dumped in the nearest dumper bin having provision for organic and other wastes. Ultimately this waste is being sent to respective disposal facilities.

Table 1: Vijayawada Population details

Population	10,48,240 (2011 Census)
Area	61.88 Sq.Km((2011)
No of House holds	2,,09,648
Density(Person/sq.km)	16,940
Wards	- 45 wards - 3 circles - Circle -1:12 wards - Circle -2:17 wards - Circle -3:16 wards

Source storage and separation of MSW is done in an informal and uncontrolled way; hardly 30–40% of city dwellers practiced it. Where the door-to-door collection system is

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unavailable, residents dispose the waste in the nearest community bins, secondary disposal sites (SDS), open land, road sides, or drains. With regard to the VMC, wastes are collected and transferred to ultimate disposal sites (UDSs). All the ultimate MSW disposal sites of Vijayawada are uncontrolled crude open dumping sites where even minimum environmental protections are not provided. Recycling, reduction, and reuse are not getting support from formal authority, even the composting, a great potential sector of waste treatment and minimization considering the nature of MSW, fails to reach the desired target due to improper planning. As a result, city authorities are facing very complicated situations for the management of the vast quantities of MSW. Due to financial constraints, lack of motivation, absence of effective legislation to protect the environment, and lack f commitment of authority, the MSW has been becoming a threat for city dwellers, planners, and other concerned stakeholders.

Total Quantity of Waste Generated

Based on the Surveys and estimations the total Quantity of waste generated is as follows:

Table 2

S.No	Details	Quantity of Waste Tons/days
1	Waste collected by vehicles	449
2	Unaccounted Waste	75
3	Waste collected by rag pickers	25
	Total Waste Generated	**549**

Assessment of Per Capita Waste Generation

Total quantity of waste generated, the present population and the waste generated per capita.

Table 3

S.No	Description	Number
1	Quantity of Waste Generated, MT/day	550
2	Population 2011	10,48,240
	Per Capita Generation Rate, gm/capita/day	**549**

Methodology

Characterization of Municipal Solid Waste

The MSW sample collection sites were so selected that all the type of area such as residential, commercial, industrial, markets (vegetable market, meat market, slaughter house, grain market etc.) and slums etc. were covered. The sampling program comprised collecting waste from four trucks each day for three consecutive days. After collecting, the waste was thoroughly mixed to homogenize it. Using coning and quartering method on this lot, about 75 kg of composite sample was drawn. After weighing, the sample was segregated into major categories of Organic matter, Paper and Cardboard, Plastics, Metals, Glass and ceramics, Rags/cloth/cotton, Sand & silt, Rubber and synthetics, Leather, Garden, Stone, debris and boulders, Biomedical waste, Coconut shells

Chemical Characterization of Waste

- The waste collected was thoroughly mixed and about 5 kg was taken for analysis in the laboratory
- Samples thus collected were double bagged in plastic bags, sealed and sent to the laboratory for chemical analysis
- Collected samples were labeled and taken to the laboratory.

Standard methods for leachate analysis

Sampling: Leachate generated from the two major dump sites of Vijayawada were used for the analysis. The first sample station was the Pathapadu dump site and the second sample station was selected at the Ajith Singhnagar dump site in Vijayawada city. The two leachate samples were collected monthly for a period of two years i.e. from June 2012 to June 2014. The leachate was analysed by APHA standard methods for physical, chemical and biological parameters.

Table 4: Methods used for the Analyses of physico-chemical characteristics of Leachate

Sl. No.	Parameters	Methodology	References
1	Temperature oC	Direct, Mercury Thermometer	
2	pH	Electrometric method Digital pH meter (Hanna make of model PHEP)	APHA (1998)
3	Electrical Conductivity (µS)	Electrometric method Conductivity meter (Hanna make with model number DiST-4)	APHA (1998)
5	TDS (mg/L)	Electrometric, (Hanna make with model number DiST-4)	APHA (1998)
6	Total Alkalinity (mg/L)	Volumetric analysis, Titrimetric	Grasshoff (1999)
7	Total Hardness (mg/L) EDTA	Titrimetric method	APHA (1998)
8	Calciu hardness (CH)	Titrimetric method	APHA (1998)
9	Magnesium hardness (MH)	Titrimetric method	APHA (1998)
10	Chloride	Argentometric, Titration	APHA (1998)
11	Sodium (Na^{+})	mg/L	Flame Photometer (ELICO make)
12	Potassium (K^{+})	mg/L	Flame Photometer (ELICO make)
13	DO (mg/L)	Modified Winkler's method	APHA (1998)
14	BOD (mg/L)	Winkler modified, Titration	APHA (1998)
15	COD (mg/L)	Open Reflux Method	APHA (1998)
16	Nitrate - N (mg/L)	Brucine method	Grasshoff (1999)
17	Total Phosphorous (mg/L)	Stannous chloride method Spectrophotometric	Grasshoff (1999)
18	Heavy metals (B, Cd, Cu, Pb, Cr, Ni & Zn)	AAS (Perkin Elmer-AAnalyst 300)	APHA (1998)

Results and Discussion

Physical Characterization of Waste

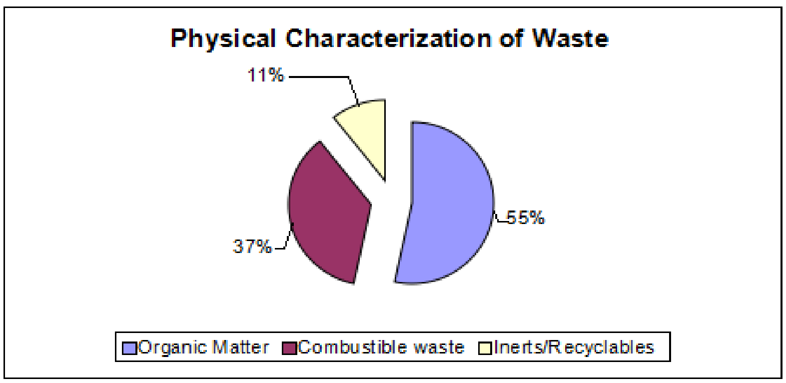
The percent composition study of solid waste collected from selected were carried out and the results were summarized in Table 5 and Fig. 1.

The physical composition of the waste is obtained as a percentage of the different constituents. The paper content generally varies between 1.0 and 6.0% and increases with the increase in population (Bhoyar *et al.*, 1996). Physical Characteristics of MSW samples collected from the trucks is shown in the table below.

Table 5

S.No	Description	Percentage
1	Organic Matter	55.00
2	Combustible waste	37.00
3	Inerts/Recyclables	11.00
	Total	**100**

Figure 1



The results revealed the following composition distribution of the MSW: Organic matter (55 %), Combustible waste (37 %) and Inerts and recyclables (11%). This revealed that the MSW has good potential for the production of compost. Biodegradability food materials and yard wastes normally dominate in MSW of developing countries while paper and hardboard dominate in developed countries (Joseph *et al.*, 2003; Vishwanathan and Trakler, 2003). From table above, we can deduce the waste has a high content of organic matter, which makes it suitable for processes like composting and anaerobic digestion. The C/N ratio is between 20-30 and this ratio is very suitable for composting (Eiland *et al*, 2001). The waste also has a high moisture content which makes it unsuitable for incineration.

From table above we can deduce that in Vijayawada the overall percentage of inert material is very high. This can cause hindrance to processes like incineration and anaerobic digestion if the waste is not segregated prior to processing.

Chemical Characterization of Waste

The chemical characterization of waste is important to understand the utilization as well as the pollution potential of the waste (Dr**. *R. Ajayakumar Varma).*** The average values, range of the chemical characteristics of MSW samples are as follows

Table 6

S.No	Parameters	Range (%)	Average values
1	pH	6.2-8.0	7.16
2	Moisture Content, %	27.44 – 51.92	36.93
3	Total Organic Carbon, %	10.64 – 12.03	11.93
4	Total Nitrogen	0.25 – 0.39	0.31
5	C/N Ratio	30 – 43	38.39
6	Potassium as K_2O, mg/g	0.35 – 1.14	0.63
7	Phosphate as P_2O_5	0.12 – 0.47	0.25
8	Ash Content, %	30.17 – 47.74	37.46
9	Calorific Value, Kcal/Kg	2016 – 3216	2558
10	Lead as Pb, mg/g	6.30 – 17.88	11.27
11	Cadmium as Cd, mg/g	0.06 - 0.88	0.29
12	Zinc as Zn, mg/Kg	67.0 – 195.4	109.84
13	Nickel as Ni, mg/Kg	< 0.1	0.1
14	Mercury as Hg, mg/g	< 0.1	0.1
15	Arsenic as As_2O_3	0.1 – 0.44	0.421

The pH of the waste ranged from 6.2 to 8.0 with average value of 7.16, which is tending towards neutral or alkaline pH. Water holding capacity and moisture content of waste were in good amounts that ranged between 27.44 – 51.92 with average value of 36.93 %. Total metal concentrations of Pb, Cd, Zn, Ni, Hg and Ar were also analyzed and trace levels of heavy metals were obtained in the waste samples (11.27, 0.29, 109.84, 0.1, 0.1, and 0.421 mg/kg). Metal contamination at dumpsite was in the order of Zn>Pb>Ar>Cd>Ni=Hg imparting highest contamination to dumpsites.

Physico-Chemical Characteristics of Leachate

To study the characteristics of leachate, two samples of leachate were collected during three seasons from the two major dumpsites of Vijayawada and analysed for physico-chemical parameters. The characteristics of the leachate samples collected from the dumpsite are presented in Table below and compared with the standards specified by BIS (1991) and FEPA (1991).

Table 7: Physico-Chemical analysis of Leachate at two stations

S.No	Parameters	Station I Mean±SD.value	Station II Mean±SD.value	BIS-Standard	FEPA-Standard
1	Temperature	28.72±2.14	28.86±1.87	-	35
2	pH	7.89±0.33	7.97±0.38	5.5-9.0	-
3	Total Dissolved Solids (TDS)	8589.46±1092.63	8292.46±807.19	2100	2000
4	Electrical Conductivity (EC) (µmhos/cm)	12820.1±1630.79	12376.8±1204.77	2250	125
5	Total hardness	5525±877.86	5452.08±722.81	-	200
6	Calcium hardness	419±148.47	690.04±105.66	-	-
7	Magnesium hardness	5106±867.44	4762.04±672.88	-	-
8	Total alkalinity	3393.13±3966.66	568.04±182.75	-	75
9	Fluorides	1.185±0.770	1.419±0.744	-	-
10	Silicates	17.66±1.88	16.96±1.94	-	-
11	Sodium	1048.93±230.14	950.62±170.52	-	0.5
12	Potassium	308.23±154.76	277.6±97.64	-	100
13	Chlorides	2486.71±2233.36	1696.46±468.27	600	600
14	Nitrates	44.29±10.50	54.08±14.52	-	20
15	Phosphates	1.970±0.430	1.927±0.424	-	50
16	Dissolved Oxygen(DO)	Nil	Nil	-	-
17	Biological Oxygen Demand (BOD)	643±98.02	595.32±176.74	100	30
18	Chemical Oxygen Demand (COD)	861±185.23	881.79±108.13	-	75
19	Boron	BDL	BDL	2	-
20	Cadmium	0.143±0.053	0.113±0.050	-	0.01
21	Chromium	ND	ND	-	0.20
22	Copper	1.030±0.554	1.048±0.788	-	5
23	Lead	0.137±0.049	0.174±0.063	-	0.05
24	Nickel	0.447±0.453	0.765±0.624	-	0.01
25	Zinc	0.921±0.777	1.794±0.770	-	6.00-9.00

(All the values are expressed in mg/L except where specifically mentioned)

The total mean Temperature of leachate was almost similar at both the stations. The temperature of leachate at Station I was comparatively higher than the temperature of leachate at Station II. The total mean pH of leachate generated was neutral to weakly alkaline at both Stations (Table), indicating that the dumpsites were in methanogenic phase. The total mean of TDS observed at both the stations were much more than the MoEF specified standards for leachate i.e. 2100 mg/L, indicating the presence of organic and inorganic solids that can provide adsorptive sites for certain chemicals and biological agents. The TDS concentration was high at Station I (Pathapadu dumpsite) than the Station II (Ajith Singh Nagar dumpsite). As high EC is related to high TDS concentrations in leachate, a similar pattern of EC values were observed at both the Stations as observed for TDS. The EC value was high at Station I (Pathapadu dumpsite) than the Station II (Ajith Singh Nagar dumpsite). The total mean of total hardness of leachate was observed to be high at Station I (Pathapadu dumpsite) than Station II (Ajith Singh Nagar dumpsite). At both the stations the Total Hardness concentrations were much more than the FEPA specified limit of 200 mg/L for leachate. The total mean of Calcium hardness of leachate was observed to be high at Station II (Ajith Singh Nagar dumpsite) than at Station I (Pathapadu dumpsite). The total mean of Magnesium hardness of leachate was observed to be high at Station I (Pathapadu dumpsite) than at Station II (Ajith Singh Nagar dumpsite). The total mean alkalinity of leachate was much high at Station I than Station II. This might be due to the age of the dumpsite. Dissolution of metal carbonates under prevailing pH conditions might be the reason to increase the alkalinity with time (Bhambulkar, 2011). The leachate produced from the aged landfills was more alkaline than the new dumpsites. As the Pathapadu dumpsite was comparatively older than the Ajith Singh Nagar dumpsite this resulted in more alkaline leachate at Station I. The total alkalinity of leachate was much more than the FEPA specified standard of 75 mg/L for leachate at both the stations. The mean Fluoride concentration of leachate at Station II was slightly more than Station I during the study period. But the Fluoride concentration of leachate at both the stations did not exceed the standards specified by MoEF, 2000 i.e. 2 mg/L. The total mean concentration of Sodium, Potassium and Chlorides were recorded high at Station I (Pathapadu dumpsite) than Station II (Ajith Singh Nagar dumpsite) during the period of study. The high concentration of Sodium in leachate at Pathapadu dumpsite may be due to the agricultural activities happening in the vicinity of the dumpsite that might have contributed to comparatively high Sodium levels to leachate. The total mean concentration of Nitrates was recorded high at Station II (Ajith Singh Nagar dumpsite) than Station I (Pathapadu dumpsite) during the period of study. The high concentration of Nitrates in leachate at Pathapadu dumpsite may also be due to the agricultural activities happening in the vicinity of the dumpsite that might have contributed to comparatively high Nitrates levels to leachate. The total mean concentration of Phosphates was almost similar at both the Stations (i.e. Pathapadu dumpsite and Ajith Singh Nagar dumpsite) during the period of Study.

The DO was not detected in the collected leachate samples during the study period indicating much organic load in the leachate from both the dumpsites. The BOD was exceeding all the limits specified by BIS (i.e. 100 mg/L), FEPA (i.e. 50 mg/L), and MoEF (i.e. 30 mg/L) in the leachate samples from both the dumpsites indicating much of biodegradable organic load in leachate. BOD value varies according to age of landfills. The total mean of BOD concentrations were observed to be high at Station I than Station II during the period of study. The COD was exceeding all the limits specified by FEPA (i.e. 75 mg/L), and MoEF (i.e. 250 mg/L) in the leachate samples from both the dumpsites. This may be due to the reason that with time the solid waste material gets degraded and the waste constituents percolate down along with rainwater thus polluting groundwater nearby to MSW landfill site. For new landfills BOD values vary from 2000 to 30000 mg/L; for mature landfills the BOD values varied from 100 to200 mg/L (Tchobanoglous *et al.*, 1993). The total mean of COD concentrations were observed to be comparatively high at Station II than at Station I during the period of study.

The metal Boron was below detection levels at both the stations during the period of study. The concentrations of Chromium were not detected in the leachate collected from both the stations during the study period. The total concentrations of Cadmium were observed to be similar at both the stations during the period of study. They were exceeding the FEPA specified standard of 0.01 mg/L at both the stations but were within the MoEF specified limit of 2 mg/L for leachate. This might be due to the disposal of batteries and consumer electronic devices into the dumpsites. The total concentrations of Copper were observed to be similar at both the stations during the period of study. They were within the FEPA specified standard of 5 mg/L and MoEF specified limit of 3 mg/L for leachate at both the stations. The source of copper in leachate may be from the metal scrap and consumer electronic devices dumped into the dumpsites. The total concentrations of Lead were observed to be similar at both the stations with

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slightly high concentrations at Station II than Station I during the period of study. They were exceeding the FEPA specified standard of 0.05 mg/L and MoEF specified limit of 0.1 mg/L for leachate at both the stations. The source of Lead in leachate may be from the metal scrap, and consumer electronic devices and lead batteries dumped into the dumpsites. The total mean concentrations of Nickel were observed to be high at Station II than Station I during the period of study. They were exceeding the FEPA specified standard of 0.01 mg/L, but were within the MoEF specified limit of 3 mg/L for leachate at both the stations. The source of Nickel in leachate may be from the metal scrap and consumer electronic devices dumped into the dumpsites. The total mean concentrations of Zinc were observed to be high at Station II than Station I during the period of study. The Zinc concentrations were within the FEPA specified standard of 6.0 to 9.0 mg/L and the MoEF specified limit of 5 mg/L for leachate at both the stations. The source of Zinc in leachate may be from the metal scrap and consumer electronic devices dumped into the dumpsites.

Conclusion

On comparing the leachate parameters with MSW it was observed that pH was neutral to alkaline in MSW and also in leachate. But the potassium was observed to be much higher in leachate samples than solid waste indicating that some other sources might have contributed to high potassium than MSW. Phosphates were slightly more in leachate than MSW. Whereas heavy metals like lead and zinc were much higher than leachate which might have diluted in leachate whereas the concentrations of Cd and Ni were almost similar in MSW and leachate.

Though there is considerable data on the generation of MSW, the physical and chemical characterization of waste is also significant to deal with the handling and disposal methods of the waste. However, they play a key role for planning and implementing comprehensive MSW management programmes as stipulated in the MSW (Management & Handling) Rules, 2000. The results obtained during the present investigation revealed that;

i) The waste generates from the city comprised a maximum portion of organic waste as compared to non-degradable portion of waste.

ii) The characterization study of waste collected from waste disposal sites revealed that, parameters of waste viz. pH, moisture content, organic matter, organic carbon and NPK were found in the reasonable range.

iii) It reflects that waste generated from Vijayawada city area is suitable for application of composting practices.

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