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Physico-chemical Characteristics of Solid Waste Generated in Shimla City

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ABSTRACT

Due to its unique heritage, salubrious surroundings and engrossing backdrop, Shimla has captivated the people from all walks of life. However, the ecological and cultural legacy of Shimla is under impending threats of unplanned development. The physical and chemical characterization of solid waste generated in Shimla city was carried out using standardized methods for three consecutive years from i.e. 2011-2013 in three different seasons, i.e. summers, monsoons and winters. Season and zone-wise variation in the physico-chemical characteristics of solid waste was noticed in the city. The study revealed that the environmental cognizance was relatively less among the inhabitants of Shimla. The results recommend the provision of a dedicated Solid Waste Management Cell to streamline the design, construction, processing & care processes.

INTRODUCTION

Population growth, together with setting up of industrial manufacturing units, urbanization and modernization are increasing the generation of solid wastes. Modernization, technological development and increasing global population have raised the demand for food and other essential commodities, which in turn has raised the production of solid waste (Hamer and Zwiefelhofer 1986 and Dernbach and Henning 1987).

Waste, in general terms can be defined as useless byproduct (Mish 1984), however, some define waste as, liquid, solid, gaseous or radioactive matter which is released or produced or dumped in the environment in such a manner that changes the environment. Cointreau 1982 defined solid waste as organic and inorganic waste stuff generated by households, commercial, institutional and industrial activities, which have lost their worth in the eyes of the proprietor.

Solid waste varies in nature and depends on the nature of area from where it has been gathered. Population explosion and development of fresh stuff keep on changing the quantities and characteristics of solid waste every day. New products, new living values and prospects, change in earnings and life style practiced by well-off societies have augmented global waste quantity (Blight and Mbande 1996). Solid waste is characterized on the basis of their origin, type, production rate and constituents. According to Moeller 2005 solid wastes are corrosive, ignitable, reactive and toxic. The measurable physical characteristics in the waste are density, size, distribution of components, and moisture content. Other features which may be used in taking

decision about solid waste management are color, voids, shape of components, optical property, magnetic properties, and electric properties. While, the measurable chemical properties for solid waste are water content of waste, volatile matter, ash, fixed carbon, fusing point of ash, calorific value, percent of carbon, hydrogen, oxygen, sulphur and ash (Chandrappa and Diganta 2012).

The amount and constitution of waste vary from nation to nation making it problematic to accept for waste management system. The amount of waste produced in an urban settlement is a function of human development index which in turn is determined by life expectancy, gross domestic product and education indices (Hoornweg and Thomas 1999).

In order to examine and regulate the existing waste management systems, solid wastes must be categorized on the basis of its origin, production rates, variety of trash produced, and its components. This can help to taking monetary and monitoring resolutions. Keeping in view the growing problem of Solid Waste Management, a study was carried out in Shimla. Shimla, the capital of Himachal Pradesh, acts as a pivot of tourism and is among the top ten preferred commercial locations in India. The administrative accountabilities of Shimla and the surrounding planning areas reside with the Shimla Municipal Corporation.

MATERIALS AND METHODS

Study area

Shimla is located in Himalaya's North-western Himalayas. The length of the city is nearly 9.2 km from west to east. The setting of Shimla comprises of rough peaks, steep slopes and deep valleys. The city is located at 31' 6" 12° North Latitude and 77' 10" 20° East Longitude. Shimla is located at an altitude of 2205 meters above mean sea level.

According to 2011 Census, the population of Shimla has increased from 1.44 lakhs to 1.69 lakhs. Total area under jurisdiction of Shimla Municipal Corporation (SMC) has also increased from 19.55 km^2 to 35.54 km^2 after the incorporation of new areas. At present, Solid Waste Management Plan for Shimla Municipal Corporation is divided into twenty-five wards. There are many problems associated with solid waste particularly in the hilly towns like Shimla. Solid Waste Management is an essential function of Shimla Municipal Corporation. The Health Department of SMC is developing a sound municipal waste management system through proper collection, transportation, treatment and dumping of solid waste in a strategic and phased manner. SMC has adopted various models wherein either Municipal Corporation or a private operator is responsible for different components of Solid Waste Management. SMC through Himachal Pradesh Municipal Corporation Act, 1994 legislated Door to Door Garbage Collection Bye-laws in 2006. The implementation of these regulations is confirmed by Shimla Environment, Heritage Conservation and Beautification (SEHB) Society's door to door garbage collection initiative. The overall monitoring and supervision is carried out by Shimla Municipal Corporation and Himachal Pradesh State Environment and Pollution Control Board (HPSPCB).

Characterization and Analysis of solid waste

In order to characterize the solid waste generated in Shimla city, detailed survey of area under Municipal Corporation was undertaken for three consecutive years, i.e. 2011-2013. Solid waste was collected from different sectors, i.e., residential sector, commercial sector and mixed sector. The total quantity of waste so collected, was thoroughly mixed and reduced by method of quartering till a sample of reasonable size was obtained, which can be easily handled in a laboratory. The sample so obtained was subjected to physical and chemical analysis. Samples collected for physical and chemical analysis were packed in plastic bags, sealed and taken to the laboratory for analysis. The following physical and chemical parameters were analyzed:

Physical Characterization: In order to determine the physical characteristic of Municipal Solid Waste, samples were collected from three zones. The samples were collected by taking ten grab samples of roughly one kilogram each from different depths of the dumps. The grab samples

were then mixed thoroughly. The mixed sample was then physically analyzed for its composition such as paper, plastic, glass, and metals and expressed as % of total sample weight.

Chemical Characterization: Municipal Solid Waste (MSW) generated varies in quality as well as in quantity depending on different parameters like- lifestyles of community, locality, climatic conditions, etc. The chemical characteristics of solid waste also show seasonal variation. Chemical characteristics of the MSW were determined, this included pH, moisture content, calorific value, nitrogen, phosphorous, potassium, total carbon, C/N ratio, temperature, organic matter, etc. Analysis of MSW was carried out as per following standard procedures:

(a) Determination of pH: pH of MSW was determined by using pH meter with a glass electrode. 10 gms of sample was placed in a flask, to this 500 ml distilled water was added and stirred for 3 to 5 minutes. Mixture was allowed to settle for 5 minutes and pH was measured by using pH meter with a glass electrode, previously calibrated and corrected for temperature.

(b) Determination of Moisture Content: Approximately 20 grams of properly mixed sample of MSW was taken in dish and the initial weight of the dish containing sample was taken. The dish containing sample was kept in oven at 105°C for 24 hours. Final weight of the sample was taken and moisture content was determined by following equation-

$$m = \frac{w_1 - w_2}{w_2} \times 100$$

where,

m = moisture content (%)

w_1 = initial wt. of sample (in gm)

w_2 = final wt. of sample (in gm)

(c) Determination of Calorific Value: Calorific value of MSW was determined by using the standard procedure using bomb calorimeter and gram size sample was adopted. The calorific value was determined by following formula:

$$HCV = \frac{(w-w)\ (t_2-t_1)}{m}$$

where:

HCV= higher Calorific value in Kcal/Kg

W= mass of water taken in calorimeter in gm

m= mass of MSW taken in calorimeter in gm

w= water equivalent of calorimeter, thermometer and stirrer in gm

t_1= initial temperature of water in calorimeter in °C

t_2= final temperature of water in calorimeter in °C

(d) Determination of Nitrogen: Determination of Nitrogen was carried by using standardized method.

(e) Determination of Phosphorous: Phosphorus was estimated in MSW by using method based on the reduction with Stannus Chloride. A blue color is produced by the reduction of phosphomolybdic acid with freshly prepared stannous chloride solution.

(f) Determination of Potassium: Solid waste containing organic matter was decomposed by treatment with mixture of sulphuric-nitric acid. Ashing was done to convert to their respective sulphates and the residue was treated further with acid mixture containing HF to make it silica free. Sample was then subjected to flame photometric analysis. Determination of Nitrogen, carbon and organic matter was carried out by using standardized method.

RESULTS

Information on the nature of wastes, its composition, physical and chemical characteristics and the quantities generated are basic requirements for devising solid waste management plans. Quantity and characteristics of solid waste generated varies with income, socio-economic conditions, social developments and cultural practices. It is observed that the quantity of waste generated has been increasing with improvement in the life style. The characteristics of solid wastes too have been very inconsistent with time. There have been tremendous changes with time, and these changes are expected to continue.

Table 1 (A): Physical Characteristics of Municipal Solid Waste of Shimla City in the year 2011

Component	Summer Season						Monsoon Season					
	Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg		Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg	
	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%
Metal	29.41	0.29	9.80	0.98	96.91	0.96	30.31	0.30	8.90	0.89	97.51	0.97
Glass/ceramic	147.05	1.47	68.62	0.68	167.40	1.67	146.05	1.46	69.51	0.69	166.50	1.66
Biodegradable waste	4264.70	42.64	1882.35	18.82	2599.11	25.99	4165.60	41.65	1772.25	17.72	2490.12	24.90
Paper/ cardboard	1588.25	15.88	3274.50	32.74	1806.16	18.06	1478.25	14.78	3164.40	31.64	1702.16	17.05
Textile	549.01	5.49	313.75	3.13	687.24	6.87	540.01	5.40	310.75	3.10	680.24	6.80
Plastic	823.54	8.23	1705.88	17.05	1444.95	14.44	818.54	8.18	1616.88	16.16	1332.95	13.32
Leather/rubber	88.23	0.88	274.54	2.74	484.58	4.84	87.20	0.87	264.41	2.64	472.29	4.72
Inert	823.54	8.23	607.82	6.07	1136.56	11.36	940.64	9.40	730.70	7.30	1416.56	14.16
Miscellaneous combustible	735.29	7.35	431.37	4.31	475.77	4.75	843.30	8.43	531.10	5.31	440.55	4.40
Miscellaneous incombustible	950.98	9.50	1431.37	14.31	1101.32	11.01	950.10	9.50	1531.10	15.31	1201.12	12.01

* Commercial Sector includes hotels, markets and tourist spots

Source: Primary Data

Table 1 (B): Physical Characteristics of Municipal Solid Waste of Shimla City in the year 2012

Component	Summer Season						Monsoon Season					
	Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg		Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg	
	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%
Metal	28.41	0.28	10.80	0.10	86.91	0.86	40.31	0.40	18.90	1.89	87.51	0.87
Glass/ceramic	140.05	1.40	58.62	0.58	177.40	1.77	136.05	1.36	59.51	0.59	176.50	1.76
Biodegradable waste	4354.70	43.54	1782.35	17.82	2499.11	24.99	4265.60	42.65	1672.25	16.72	2590.12	25.90
Paper/ cardboard	1578.25	15.78	3374.50	33.74	1906.16	19.06	1578.25	15.78	3264.40	32.64	1602.16	16.05
Textile	629.01	6.29	414.75	4.14	787.24	7.87	440.01	4.40	410.75	4.10	780.24	7.80
Plastic	733.54	7.33	1606.80	16.06	1344.95	13.44	718.54	7.18	1516.88	15.16	1232.95	12.32
Leather/rubber	76.23	0.76	374.54	3.74	584.58	5.84	187.20	1.87	254.41	2.54	572.29	5.72
Inert	833.54	8.33	508.82	5.08	1036.56	10.36	840.64	8.40	740.70	7.40	1316.56	13.16
Miscellaneous combustible	625.29	6.25	534.37	5.34	575.77	5.75	743.30	7.43	631.10	6.31	640.55	6.40
Miscellaneous incombustible	1000.90	10.00	1334.37	13.34	1001.32	10.01	1050.10	10.50	1431.10	14.31	1001.12	10.01

* Commercial Sector includes hotels, markets and tourist spots

Source: Primary Data

Table 1 (C): Physical Characteristics of Municipal Solid Waste of Shimla City in the year 2013

Component	Summer Season						Monsoon Season					
	Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg		Residential Sector Sample size: 10 kg		Commercial Sector Sample size: 10 kg		Mixed Sector Sample size: 10 kg	
	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%	Weight (gms)	%
Metal	59.41	0.59	7.80	0.78	98.91	0.98	31.31	0.31	9.90	0.99	99.51	0.99
Glass/ceramic	117.05	1.17	70.62	0.70	165.40	1.65	145.05	1.45	70.51	0.70	164.50	1.64
Biodegradable waste	4464.70	44.64	1682.35	16.82	2499.11	24.99	4265.60	42.65	1672.25	16.72	2590.12	25.90
Paper/ cardboard	1388.25	13.88	3474.50	34.74	1906.16	19.06	1378.25	13.78	3264.40	32.64	1602.16	16.05
Textile	749.01	7.49	413.75	4.13	587.24	5.87	640.01	6.40	410.75	4.10	780.24	7.80
Plastic	623.54	6.23	1605.88	16.05	1544.95	15.44	718.54	7.18	1516.88	15.16	1232.95	12.32
Leather/rubber	98.23	0.98	374.54	3.74	584.58	5.84	77.20	0.77	364.41	3.64	572.29	5.72
Inert	813.54	8.13	507.82	5.07	1036.56	10.36	950.64	9.50	630.70	6.30	1316.56	13.16
Miscellaneous combustible	835.29	8.35	531.37	5.31	575.77	5.75	943.30	9.43	630.10	6.30	540.55	5.40
Miscellaneous incombustible	850.98	8.50	1331.37	13.31	1001.32	10.01	850.10	8.50	1430.10	14.30	1101.12	11.01

* Commercial Sector includes hotels, markets and tourist spots
Source: Primary Data

PHYSICAL CHARACTERISTICS OF SOLID WASTE

Table 1 (A, B and C) shows the physical characteristics of solid waste generated in residential, commercial and mixed zones of Shimla city during the three consecutive years, i.e. 2011-2013. Physical characterization was carried out twice in a year, i.e. in summers and monsoon season. The main components of waste includes metals, glass/ceramic, biodegradable waste, paper/ cardboard, textile, plastic, leather /rubber, inert, miscellaneous combustible and miscellaneous incombustible. In all the three zones the proportion of biodegradable waste was observed maximum followed by paper/ cardboard. During the summers, residential areas reported highest (42.6%) generation of biodegradable waste, followed by mixed zone (25.99%) and commercial zone (18.82%). During the monsoon season, the generation of biodegradable waste was highest in residential area (41.65%), followed by mixed zone (24.90%) and commercial zone (17.72%). However, the seasonal variation was noticed in the generation of biodegradable waste. The production of biodegradable waste was higher in all the three zones during the summer season as compare to monsoon season. The trend remained almost similar in all three years.

In addition to this, the presence of plastic was higher (17.05%) in commercial zone, followed by 14.44% in the mixed zone during the summer season. Similar trend was noticed in the generation of plastics during the monsoon season; however, it was comparatively less in the monsoon season. Generation of inert showed an increase in all the three zones during the monsoon season as compare to summer season.

Presence of paper, textile and leather also showed a decrease in all the three zones in monsoons as compare to summers. Thus, the seasonal variation in characteristics of solid waste gives an idea about the arrangements that have to be made for collection, transportation and disposal of MSW generated during different seasons.

CHEMICAL CHARACTERISTICS OF SOLID WASTE

Table 2 (A, B and C) shows the chemical characteristics of solid waste generated in residential, commercial and mixed zones of Shimla city during three different seasons, i.e. summers, monsoons and winters for three consecutive years, i.e. 2011, 2012 and 2013.

The pH of MSW collected from residential area during the summer season was 6.4, while that collected from commercial zone had pH 6.8 followed by 6.3 from the mixed zone. The pH values of solid waste collected from three zones was less than 7, which indicates the acidic nature of solid waste. There was slight variation in the pH of solid waste during the monsoon and winters, which is indicative of the fact that the pH varies with change in the season.

The moisture content of MSW collected from residential area during the summer season was 58.2, while it was 52.8 from mixed zone and 40.6 from commercial zone. There was much variation in the moisture content of solid waste during the monsoons and winters. The moisture content was highest in the monsoon season followed by winter season and least in summers which is indicative of the fact that the moisture content varies with changing seasons. Nitrogen (%) content of solid waste shows a variation in each zone. For the samples collected during summers, it was highest for residential zone (0.88%), followed by 0.73% for mixed zone and 0.69% for commercial zone. Similarly, the percentage of phosphorus also varies for the three zones. It was highest (0.40%) for residential zone, followed by 0.28% for mixed zone and 0.19% for commercial zone. Seasonal difference was noticed in the percentage of phosphorus in the samples collected from different zones.

While determining the potassium content of solid waste collected during summers, it was found that it was highest (0.65%) in mixed zone and least (0.29%) in the commercial zone. There was slight seasonal variation in the same. Total carbon

Table 2 (A): Chemical Characteristics of Municipal Solid Waste of Shimla City in the year 2011

Parameter	Summer Season			Monsoon Season			Winter Season		
	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector
pH	6.4	6.8	6.3	6.6	6.9	6.5	6.7	6.4	6.8
Moisture (%), w/w	58.2	40.8	52.6	60.5	50.6	65.4	65.1	48.5	62.4
Nitrogen (%), w/w	0.88	0.69	0.73	0.89	0.70	0.79	0.86	0.65	0.71
Phosphorus (%), w/w	0.40	0.19	0.28	0.46	0.25	0.32	0.41	0.22	0.23
Potassium (%), w/w	0.34	0.29	0.65	0.31	0.28	0.61	0.32	0.22	0.61
Total Carbon (%), w/w	35.5	25.06	36.98	31.6	21.04	38.90	33.5	23.06	39.98
C/N Ratio	40.82	36.85	52.09	46.81	33.81	59.09	45.81	38.81	50.02
Calorific value (Kcal/ kg)	2848	2480	2950	2640	2270	2260	2545	2570	2630
Temperature, °C	13.6	10.9	12.8	12.4	10.2	11.3	7.6	4.9	3.8
Organic matter (%), w/w	14.9	30.05	47.9	15.0	31.25	49.9	13.8	29.09	45.8

* Commercial Sector includes hotels, markets and tourist spots
Source: Primary Data

Table 2 (B): Chemical Characteristics of Municipal Solid Waste of Shimla City in the year 2012

Parameter	Summer Season			Monsoon Season			Winter Season		
	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector
pH	6.7	6.9	6.5	6.6	6.8	6.6	6.8	6.5	6.9
Moisture (%), w/w	59.2	41.8	53.6	61.5	52.6	66.4	67.1	47.5	63.4
Nitrogen (%), w/w	0.89	0.67	0.74	0.88	0.72	0.76	0.87	0.66	0.72
Phosphorus (%), w/w	0.42	0.18	0.27	0.48	0.28	0.35	0.44	0.23	0.24
Potassium (%), w/w	0.35	0.28	0.64	0.33	0.29	0.64	0.34	0.25	0.64
Total Carbon (%), w/w	36.5	26.07	38.96	32.5	22.02	37.91	32.4	22.08	38.97
C/N Ratio	41.82	35.83	54.07	45.71	34.82	58.07	47.87	39.88	51.03
Calorific value (Kcal/ kg)	2844	2479	2949	2642	22769	2261	2553	2569	2631
Temperature, °C	14.2	10.5	12.6	12.2	10.5	11.6	7.8	4.8	3.7
Organic matter (%), w/w	14.8	29.05	46.9	16.0	32.24	48.9	13.5	28.05	45.7

* Commercial Sector includes hotels, markets and tourist spots
Source: Primary Data

Table 2 (C): Chemical Characteristics of Municipal Solid Waste of Shimla City in the year 2013

Parameter	Summer Season			Monsoon Season			Winter Season		
	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector	Residential Sector	Commercial Sector	Mixed Sector
pH	6.8	6.9	6.2	6.7	6.6	6.4	6.8	6.3	6.9
Moisture (%), w/w	59.1	39.8	50.6	59.5	49.6	64.4	63.1	49.5	63.4
Nitrogen (%), w/w	0.89	0.68	0.71	0.88	0.73	0.78	0.86	0.64	0.73
Phosphorus (%), w/w	0.39	0.17	0.26	0.42	0.22	0.31	0.46	0.26	0.27
Potassium (%), w/w	0.32	0.28	0.64	0.32	0.24	0.65	0.31	0.21	0.62
Total Carbon (%), w/w	34.6	23.08	35.99	32.7	22.07	37.90	32.5	24.06	39.99
C/N Ratio	41.81	35.84	51.09	47.81	36.81	55.09	46.82	37.81	52.02
Calorific value (Kcal/ kg)	2748	2380	2850	2540	2170	2160	2445	2670	2640
Temperature, °C	13.5	10.8	12.7	12.3	10.1	11.4	7.5	4.7	3.9
Organic matter (%), w/w	13.9	31.05	46.9	16.0	32.25	48.9	12.8	28.08	46.7

* Commercial Sector includes hotels, markets and tourist spots
Source: Primary Data

content of the solid waste was highest (36.98%) for the samples collected from mixed zone during the summers followed by 35.5% for residential zone and least (25.06%) for commercial zone. Minute variation was noticed in the total carbon content of samples collected during monsoons and winters. The C/N ratio was highest (52.09) for mixed zone followed by 40.82 for residential zone and 36.85 for commercial zone in the samples collected during summers. Calorific value is the amount of heat produced by the complete combustion of a material. It is measured in units of energy per amount of material. The calorific value (Kcal kg^{-1}) was highest (2950 Kcal kg^{-1}) for the samples collected during summer season from the mixed zone and least (2480 Kcal kg^{-1}) for the samples collected from the commercial zone. The calorific value of all the samples collected from all zones during summers was highest as compared to monsoons and winters. This indicates that the calorific value of solid waste decreases with increase in moisture content, which is highest during the monsoon season.

The temperature of the MSW samples collected was determined and it was found to be highest (13.6 °C) for residential zone, followed by 12.8°C for mixed zone and 10.9 °C for commercial zone. Decrease in temperature was noticed during different spells. It was least during the winter season.

The percentage of organic matter of MSW also differs for the samples collected from three zones during summer season. It was 47.9 for the mixed zone and 30.05 for the commercial zone. Slight variation was noticed in the organic content of solid waste collected from different zones during monsoon and winters. Thus, the chemical characteristics of solid waste vary for different zones across different years, which is indicative of the fact that chemically the MSW shows disparity.

DISCUSSION

In India, Municipal Solid Waste (MSW) varies significantly with regard to the constituents and harmful nature, when compared to Municipal Solid Waste generated in western countries. Developing nations have high waste densities with high moisture content containing large organic fraction. The reasons for variation in waste quantities are (1) differences in consumption pattern; (2) differences in reuse at source of generation, and (3) changes in culture (Chandrappa and Diganta 2012). Apart from households, the type and quantity of waste also vary at airports, railway station and bus stands, etc. The quantity of solid waste also depends on special events like festival, sports events, conferences, elections and disasters. Festivals and elections increase the quantity of waste by two to ten times per day. On the other hand, disasters can increase the waste by 300–500 times per day (Blight and Mbande 1996).

Composition of solid waste is governed by many factors, such as degree of economic growth, cultural standards, topographical situation, energy sources, and climate (Shekdar 2009). As the nation urbanizes and population becomes better-off, utilization of inorganic materials, for instance plastics, paper, and aluminum increases, while the comparative organic segment drops. Usually, low and middle-income nations have a high proportion of organic matter in the urban waste stream, ranging from 40 to 85% of total. Topography affects the composition of waste by determining the type of construction stuff used, ash content, quantity of street sweepings, and farming waste. Climate can also influence waste generation in a city, country, or region (ISWA 2009). Humidity also affects waste composition by shaping moisture content (UNEP/GRID-Arendal 2004).

Physical characterization was carried out in residential, commercial and mixed zones of Shimla city. The main components of waste which were reported included metals, glass/ceramic, biodegradable waste, paper/ cardboard, textile, plastic, leather /rubber, inert, miscellaneous combustible and miscellaneous incombustible material. In all the three zones, the proportion of biodegradable waste was observed maximum followed by paper/ cardboard. Similar results were reported by Agrawal et al. (2013) in their study carried out at Raipur city, wherein the researchers

reported annual composition of MSW of the city as biodegradable 45.92 %, paper 4.38 %, plastic 4.45 %, glass 0.48 %, metals 0.11 %, textile & leather 0.90 % and inert material 43.93 %. The composition and the quantity of MSW generated forms the basis on which the management system needs to be planned, designed and operated. MSW differs greatly with regard to the composition and hazardous nature, when compared to MSW reported from the western countries. Thus, the results of present study are in accordance with the finding of the studies carried out by Gupta et al. 1998, Shannigrahi et al. 1997, Jalan and Srivastava 1995. The waste generated in India, Mexico and Great Britain is of biodegradable nature (Flintoff 1976), and is also established by PCSIR study (Khatib et al. 1990), and confirmed during the present research study. Chemical characteristics of solid waste generated in three zones of Shimla city during different seasons revealed seasonal variation in pH, moisture content, nitrogen, phosphorus, potassium, total carbon, C/N ratio, calorific value, temperature and organic matter.

The study revealed that the environmental cognizance was relatively less among the inhabitants of Shimla. Therefore, stringent rules together with environmental awareness programs can reduce the problems associated with solid waste management. Responsiveness, concern and care for significant stroke to deal with solid waste management seems to resolve the problem, although there are many hurdles, including incomplete knowledge on current status of solid waste production and management, community's attitude and readiness to pay, it is expected that results of this study will be useful in framing the future course of action.

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