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Quantification and Characterization of Urban Solid Waste and Its Ecological Accounting in Manali City of Hilly Region

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ABSTRACT

The study was conducted to quantify and characterize the urban solid waste and its ecological accounting in Manali town of Himachal Pradesh during 2020–21. Manali municipality is divided into 7 wards with a population of 8,095. 15 residential households, 8 commercial establishments, and 2 government/semi-government institutes were considered in selected 7 wards. The present study concluded that the MSW generation was higher in summer than winter and out of which biodegradable waste was generated higher than non-biodegradable. The domestic sector contributes the highest waste from different wards. In winter, 132.65 kg of MSW was generated from hotels and restaurants, 85.12 kg from dhabas, 52.54 kg from shops, 21.07 from offices and 6.16 kg from schools. During summer, 164.6 kg of MSW was generated from hotels and restaurants, 58.23 kg from dhabas, 45.22 kg from shops, 16.47 kg from offices and 7.03 kg from schools from different sectors. The urban solid waste of Manali contained 241.31 kg of biodegradable waste and 28.64 kg of non-biodegradable during winter and during summer it contained 262.70 kg of biodegradable and 28.54 kg of non-biodegradable waste. Presently, the 1.47 ha land is required for the disposal of urban solid waste in Manali town. The per capita ecological footprint was found to be 0.000742 gha during winter and during summer the per capita total ecological footprint was 0.00147 gha. The production of bio-compost from biodegradable waste could be important to reduce biodegradable waste.

KEYWORDS: Biodegradable non-biodegradable, characterization, ecological footprint, solid waste, quantification

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1. INTRODUCTION

The population explosions have moved people from rural areas to cities, generating thousands of tonnes of garbage every day. As the living standard increases, the quantity of waste generated also increases (Seo et al., 2004). In small towns, the amount of solid waste is lower than in urban areas and the amount of waste per capita is between 0.2–0.5 kg day^{-1} (Siddiqui et al., 2006). Quantification and characterization of solid waste components consider important steps in MSW management procedures (Elzaki and Elhassan, 2019). MSW management is a multifaceted process comprised of different components (Erami et al., 2015). The quantity and composition of the generated waste are important for the effective planning of household waste (Moftah et al., 2016). Integrated waste management systems are the greatest challenge for sustainable development (Vega et al., 2008). The best system is the one that collects mixed wastes, organic material, and multiproduct waste door-to-door and glass from drop-off points (Gallardo et al., 2012). MSW is a reflection of the culture that generates it and negatively impacts the health of humans and the environment (Khan et al., 2022). The problem that arises with the generation of waste in tourist destinations is related to infrastructure (Munoz and Navia, 2015). Economic development and population growth have resulted in an increase in the MSW generation (Wang and Wang, 2013). The cost of MSW management after implementing MSW sorting regulation is increased (Xiao et al., 2020). Population, education and culture can influence waste generation and composition (Han et al., 2018). The overall technical arrangement, including storage and discharge, collection and transport, and disposal is still in poor condition, which leads to environmental and health risks (Seng et al., 2011) Open disposal of solid waste has various consequences and can cause odor disturbances, flies, rats, rodents, soil and sewage contamination (Ejaz et al., 2010). Composting the MSW and using it on land is the best way of solid waste disposal (Pokhrel and Viraraghavan, 2005). Waste disposal system covers about 60% of the total waste generated (Supriyadi et al., 2000). The improper and poor MSW management caused environmental problems originating from the uncontrolled release of methane and leachate (Agdag, 2009). The analysis of the organic content of MSW indicates that it is a good source of nutrients for the agriculture sector whereas inorganic material can be used for landfill (Thitame et al., 2010). Source reduction can be introduced as one of the first priorities for solid waste management (Abduli and Azimi, 2010). Chung and Poon (2002) reported that waste characteristics are essential data for waste disposable facilities planning and waste management policy formulation. Solid waste generation is positively affected by variables associated with per capita income, employment rate and construction activity (Martins and Cro, 2021). The ecological footprint of waste is a measure of the area of biological production required to adapt the waste from which it is generated. The size of the municipal population, geographic location, and household expenditure have a significant influence on unit waste generation (Pathak et al., 2020). The increase in tourists by one per cent causes the overall increase in MSW (Sbert et al., 2013). Of the waste generation, hotels have been accountable for 20 t of waste at Manali (Kuniyal et al., 2003). To better manage MSW several possible and appropriate solutions like intensifying source separation, promoting a green lifestyle and establishing specialized regulations and policies (Gu et al., 2017). Manali town is a tourist place where the population generally increased 4 times during the summer season which causes an increase in MSW. This led to the study of the generation of waste during the winter and summer seasons.

2. MATERIALS AND METHODS

The present research analysis of quantification and characterization of urban solid waste and its ecological accounting in Manali town of Himachal Pradesh during 2020-21. The town consists of 1,234 residential buildings, 380 commercial buildings and 141 government/semi-government buildings. Seven wards were selected for study: Dhungri, Bhajogi, school area, Model town, Manu market, Gompa area, and Police station area. A total of 175 establishments were selected, 25 from each ward out of which 15 households come from the residential area, 8 households in the commercial area and 2 from government/semi-government establishments. For quantification of urban solid waste in Manali, the waste was collected, separated and weighed to classify it as biodegradable and non-biodegradable waste. The climate of the town is cold and temperate. The average temperature in Manali remains 2.1°C and precipitation normally is about 1851 mm annually. October is the driest month with rainfall of 54 mm and maximum (255 mm) precipitation observed during February.

The town council manages the waste generated by the town. Garbage collected from various sectors was placed on a line 3 km away from the town. The town has chosen the door-to-door method for collecting garbage. After garbage collection, the loaded truck was sent to the landfill area. Garbage collectors also collect recyclable materials in the town and sell them for disassembly.

The ecological footprint was calculated using the formula of Habibi et al. (2015).

Total waste per year (kg)×landfill area ×EF (gha/kg) ....(1)

3. RESULT AND DISCUSSION

3.1. Ward-wise distribution of waste in Manali town during winter and summer

Table 1 showed that the household sector contributes up to 230.08 kg of waste from various wards, 132.65 kg from hotels and restaurants, 85.12 kg from small cooking shops, 52.54 kg from shops and 21.07 kg from offices and 6.16 kg from schools in winters. The total volume of daily household waste from wards 1–7 was 98.27 kg, 74.35 kg, 51.41 kg, 69.57 kg, 89.54 kg, 48.69 kg, and 95.79 kg. Per capita, daily waste generated from Ward 1, Ward 2, Ward 3, Ward 4, Ward 5, Ward 6, and Ward 7 was 0.012, 0.009, 0.006, 0.008, 0.011, 0.006, and 0.011 kg respectively. Statistical analysis showed that the average mean of houses was 32.86, followed by small cooking shops (12.16), shops (7.5), hotels/restaurants (18.95), offices (3.01), and schools (0.88). Comparison of the critical difference with the average of all the sectors showed that the average value was greater than the critical value and it was statistically significant.

Table 1: Ward-wise solid waste (kg day^{-1}) generation in Manali during winter

Sl. No.	MC area	Residential	Commercial			Government		Mean	Total	Per capita
			Dhabas	Shops	Hotel Restaurant	Offices	School			
1.	Ward 1	38.5	25.30	10.35	19.99	3.11	1.02	16.37	98.27	0.012
2.	Ward 2	40.25	4.47	1.01	25.32	2.10	1.20	12.39	74.35	0.009
3.	Ward 3	20.44	10.49	2.26	12.50	4.47	1.25	8.56	51.41	0.006
4.	Ward 4	30.32	1.09	2.44	30.55	4.17	1.00	11.59	69.57	0.008
5.	Ward 5	40.29	12.22	19.27	15.11	2.01	0.64	14.92	89.54	0.011
6.	Ward 6	20.05	5.23	12.66	7.25	2.66	0.84	8.11	48.69	0.006
7.	Ward 7	40.23	26.32	4.55	21.93	2.55	0.21	15.96	95.79	0.011
	Total	230.08	85.12	52.54	132.65	21.07	6.16		527.62	
	Mean	32.86	12.16	7.5	18.95	3.01	0.88			
	SEm±	0.68								
	CD (p=0.05)	1.91								

Table 2 showed that the household sector contributed 225.7 kg of MSW from different wards, 187.94 kg from hotels and restaurants, 58.23 kg from small cooking shops, 45.22 kg from shops, and 16.47 kg from offices and 7.03 kg from schools daily during summer. The per capita daily waste generated from Ward 1, Ward 2, Ward 3, Ward 4,

Table 2: Ward-wise solid waste (kg day^{-1}) generation in Manali during summer

Sl. No.	MC area	Residential	Commercial			Government		Mean	Total	Per capita
		Houses	Dhabas	Shops	Hotel/Restaurant	Offices	School			
1.	Ward 1	40.28	26.04	12.35	22.59	2.01	0.80	17.34	104.07	0.128
2.	Ward 2	32.96	0.98	0.25	31.18	0.89	1.01	11.21	67.27	0.008
3.	Ward 3	34.33	2.94	5.66	24.59	1.58	2.66	11.96	71.76	0.008
4.	Ward 4	3.54	1.55	1.99	23.29	3.59	0.85	5.80	61.81	0.008
5.	Ward 5	25.82	4.89	18.11	21.26	3.55	0.35	12.33	73.98	0.009
6.	Ward 6	21.55	0.58	1.58	34.55	2.74	0.91	10.31	61.91	0.007
7.	Ward 7	40.22	21.25	5.28	30.48	2.11	0.45	16.63	99.79	0.012
	Total	225.7	58.23	45.22	187.94	16.47	7.03		540.59	
	Mean	28.38	8.31	6.46	26.84	2.35	1.00			
	SEm±	2.77								
	CD (p=0.05)	6.41								

Ward 5, Ward 6 and Ward 7 was 0.128, 0.008, 0.008, 0.008, 0.009, 0.007, and 0.012 kg respectively. The statistical analysis showed that the critical difference and standard error mean to have a significant difference in wards and sectors during summer. There was the least significant difference in means of all wards and sectors. The critical difference was 6.41 and the standard error mean was 2.77.

3.2. Seasonal characterization of MSW generated in Manali

Table 3 revealed the composition of MSW generated in different sectors during the winter and summer seasons. Under biodegradable waste, food waste accounted for 56.34%, wood waste (0.55%), cloth waste (0.73%) and paper and cardboard waste was 19.98%. Off non-biodegradable waste glass waste was 1.40%, plastic waste (19.17%) and tin waste contributed 1.83% during winter. During summer under biodegradable waste, food waste contributed 58.30%, wood waste (0.40%), cloth waste (0.50%) and paper and cardboard waste (20.05%). Under non-biodegradable waste, glass waste was 0.29%, plastic waste (18.75%) and tin waste (2.01%) during summer. Miezah, (2015) reported that the organic fraction in the waste was the highest in the waste stream and paper increased the percentage of biodegradable. The biodegradable waste generation includes paper (13.42%), food waste (20.14%), cloth (11.10%) and non-biodegradable as plastic (17.06%), glass (15.89%) and metal (16.42%). Noufal et al. (2020) also revealed the same trend of generation in household composition. The highest composition in this study consisted of organic waste (69.10%), paper (4.60%), wood waste (0.60%), plastic (10.60%) and textile 2.5%. The amount of biodegradable waste generated daily was 241.31 kg (95.58%) and the amount of non-biodegradable waste in winter was 28.64 kg (5.42%). In summer, 262.70 kg day^{-1} (94.00%) of biodegradable waste and 28.54 kg day^{-1} (6.00%) of non-biodegradable waste were generated. Ogwueleka (2013) reported that there was little difference between household size and per capita waste in the low-income groups. Kumar (2018) revealed a similar trend in seasonal biodegradable and non-biodegradable waste. In winter, 328.185 kg of biodegradable waste and 35.308 kg of non-biodegradable waste were generated, and in summer 439.165 kg of biodegradable and 38.502 kg was non-biodegradable waste was generated in the town. The total (biodegradable and non-biodegradable) waste generated during winter comes out to be 269.95 kg and during summer it was 291.24 kg. The total daily MSW generated during both seasons is almost the same as reported by Verma and Tripathi, (2016) who found waste generation in summer (18,812.17 kg) and in winter (20,514.3 kg). The paired t-test was used to compare the winter and summer seasons using OPSTAT. The output indicated that the mean for winter and summer was 11.29, the standard deviation was 21.5 and the standard error of the mean was 8.1. The significance for two-tailed was 0.021, since the p-value is less than the significance level of 0.05 then it showed that the composition of MSW was significant. This analysis showed that there were more droppings in summer than in winter.

Table 3: Characterization of municipal solid waste (%) generated in Manali during winter and summer

Sl. No.	Sector	Food waste		Plastic waste		Paper cardboard		Glass		Tin		Wood waste		Cloth	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S
1.	House	42.87	43.67	15.12	15.81	16.76	19.15	0.98	0.16	1.55	1.87	0.55	0.40	0.73	0.50
2.	Dhaba	12.56	10.30	0.58	0.25	0.36	0.26	0.03	0.09	0.12	0.09	-	-	-	-
3.	Shop	0.32	0.88	2.50	0.44	0.90	0.02	-	0.04	-	-	-	-	-	-
4.	Hotel	2.13	3.45	0.75	2.02	0.54	0.47	0.39	-	0.16	0.05				
5.	Office	-	-	0.43	0.22	0.78	0.13	-	-	-	-		-	-	-
6.	School	-	-	0.09	0.01	0.64	0.02	-	-	-	-	-	-	-	-
7.	Total	56.34	58.30	19.17	18.75	19.98	20.05	1.40	0.29	1.83	2.01	0.55	0.40	0.73	0.50

Season	Mean	Standard Deviation	SEm±	Significance
Winter-Summer	11.2943	21.5802	8.1565	0.021

W: Winter; S: Summer

3.3. Ecological footprint (gha) of municipal solid waste in Manali town

Table 4 revealed the per capita ecological footprint which followed the order as ward 1 (0.000122 gha)>ward 3 (0.000081 gha) > ward 6 (0.00076 gha)>ward 7 (0.00035 gha)>ward 5 (0.000012 gha)>ward 4 (0.000011 gha) > ward 2 (0.00009 gha during winter. Similarly, in summer, the per capita ecological footprint followed the order of ward

Table 4: Ward-wise ecological footprint (g ha) of solid waste during winter and summer

Ward	Ecological footprint			
	Winter		Summer	
	Total	Per capita	Total	Per capita
Ward 1	0.00174	0.000122	0.00185	0.00015
Ward 2	0.00132	0.00009	0.00119	0.00022
Ward 3	0.0095	0.000081	0.00127	0.00013
Ward 4	0.00123	0.000011	0.00115	0.00010
Ward 5	0.00159	0.000012	0.00131	0.00036
Ward 6	0.0086	0.000076	0.00112	0.00012
Ward 7	0.0017	0.00035	0.01774	0.00039
Total	0.02568	0.000742	0.0966	0.00147
Mean	0.003668		0.001381	
SD	0.0036901		0.000303	
CV	100.5874891		21.9251	

7 (0.00039 gha)>ward 5 (0.000036 gha)>ward 2 (0.000022 gha)>ward 1 (0.000015 gha) > ward 3 (0.000013 gha) > ward 6 (0.00012 gha) > ward 4 (0.00010 gha).

The total ecological footprint (EF) of solid waste was 0.02568 gha, and per capita was 0.00074 gha in winter and in summer the ecological footprint was 0.0966 gha, and per capita, the footprint was 0.000147 gha. The total ecological footprint was higher in summer than in winter. The per capita EF was found to be 0.013 gha. Burritt (2017) Accounting the direct waste flow and activities local government mostly collects more physical information than monthly information. Singh (2019) found the per capita ecological footprint of waste on the university campus as 0.0640 gha and 0.000024 gha. The statistical mean during winter comes out to be 0.00366, the standard deviation is 0.00369, and the coefficient of variation was 100.58. During summer statistical mean was 0.001381, the standard deviation was 0.000303 and the coefficient of variation was 21.925 (Table 4). It showed that the solid waste ecological footprint varied significantly between winter and summer. At present, the area of the landfill for household waste is 1.47 ha. The generation of household MSW continues to grow, and after that, the area required for their disposal will also increase.

4. CONCLUSION

Manali produced 527.62 kg and 540.59 kg of household waste, 241.31 kg and 262.70 kg of biodegradable and 28.64 kg and 28.54 kg of non-biodegradable waste during winter and summer respectively. The total ecological footprint was 0.02568 gha and 0.0966 gha and per capita, EF was 0.000742 gha and 0.00147 gha during winter and summer respectively. Presently, the 1.47 ha land is required for the disposal of urban solid waste in Manali town.

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