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Quantification and characterization of rural household waste in Konkan region

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Abstract
Management of solid waste and it's discarding now has become a global challenge. Although, today we can perceive the rapid urbanization taking place around us, about 45% of world's population and 64.61% of India's population resides in rural areas. Nonetheless, survey on characterization, quantification and management of rural communities' household solid waste is rare in both advanced as well as emerging countries. Thus, discovering some facts about the quantity and quality of household solid waste of rural communities in Konkan region was the chief objective of the present study. The results showed that the average daily per capita of household waste generation was 0.0314 kg/cap-day. About 54.89% of the total engendered waste in the studied villages was organic and food waste, while paper, cardboard, plastics, metals/glass, textiles and ash/dirt constituted 9.28, 8.04, 16.4, 1.34, 8.62, 1.41% respectively. Bulk density of the waste was determined as 166.67 kg/m^3. Furthermore, the average moisture content, carbon content, nitrogen content, phosphor content, ash content and C/N ratio (kitchen waste and organic part) of the waste was found to be 60.65%, 51.43%, 2.16% and 0.33% and 33.43% and 23.8:1 respectively. According to the results of the study and the study in the available related literature, it could be inferred that solid waste generation in rural communities is less than that in urban areas and the density of the waste generated in rural areas vary not only with the urban areas but also with different communities residing in diverse topographical, financial, social and public surroundings etc.

Keywords: Rural communities, waste generation, characterization, quantification

Introduction

Solid waste management and its disposal is a challenge faced by everyone round the globe, but it is most prominently faced in economically developing countries. There are number of factors that append to the exacerbation of this particular situation such as population explosion, life style change, rising living standards and increasing waste generation rates which has consequently leads to an increase in the land requirement for waste disposition and dumping [1, 2, 3]. Inappropriate management of waste which includes the collection and disposal of the household waste can result in glitches that jeopardize human health, affect economic, environmental balance and living organisms which will result in a sagginess in the development of the country as a whole [4]. According to the report promulgated by the World Bank 45% of the world's total population and 64.61% of the total population of India lives in rural areas. There has been a plethora of research work done on the management and disposal of municipal solid waste by number of researchers in different cities of developed and developing countries but the studies regarding the characterization, quantification and management of household solid waste of rural communities has not yet received the attention it deserves. Some limited studies have been carried out on rural household solid waste by Taghipour *et al.* (2016) [15] in northwestern Iran, Zhiyong Han *et al.* (2015) [17] in the rural areas of Tibetan plateau, Shah *et al.* (2012) [22] in villages near Tekanpur and Mohammadi *et al.* (2012) [10] in north of Iran.

Hence, very less amount of data is available universally regarding the characterization and quantification of the village household waste it's composition and generation rates. Since, without accurate detailed information rural sanitation authorities would not be able to properly design and operate the solid waste management systems in these communities. On one hand, the success of waste management not only relies on the proper and comprehensive understanding of domestic waste characteristics but also on the accuracy and reliability of the data used [18]. On the other hand, only, few studies have been carried out on the characterization and quantification of rural household waste in the rural communities of the Konkan region of Maharashtra state.

The aims of this study were to carefully analyze the generation rates, characteristics and the composition of rural household waste in rural areas of Konkan region.

Studied Area

The study was carried out in 7 villages named Wakoli, Pangari, Tetavli, Gaontale, Rukhi, Asond and Sadve located in Dapoli tehsil of Ratnagiri district situated in the Konkan division of the state of Maharashtra, India. The altitude of the selected region is 243.84 m above sea level. According, to the national census of 2011 the population of the 7 selected villages was 2001, 1284, 2008, 681, 833, 1493 and 515 respectively. The average population growth rate of the villages was found out to be 1.24%. The area covered by every individual village was reported as 4.316, 8.11, 7.618, 3.99, 5.54, 7.45 and 5.98 km^2 respectively. The average distance from the selected villages and the nearest town Dapoli is about 17 km. Maximum and minimum average annual temperature of the selected villages is around 32 °C and 23 °C whereas the maximum and minimum humidity of the region is 91.23% in the month of July and 57.71% in the month of January. The average annual precipitation of the selected region is estimated about 2700 mm.

Methodology

7 villages in the tehsil of Dapoli were selected for the purpose of this study (Table 1). Population of all the villages was estimated about 8815 according to the 2011 population census. Site visits were undertaken in order to collect all the basic information, calculate the working conditions and evaluate the present condition of waste management. Before commencement of the survey, all the people involved in the project attended a training course in order to better understand the purpose of the study, importance of perils associated with working by waste materials, and thorough procedures for sorting and weighing these materials. The research team was provided with all the essential protective apparatus such as gloves, masks and aprons. To balance out the daily and seasonal variations in waste generations, the survey was planned in such a way that it will cover all the seasons of the year including major festivals celebrated in the selected area. The waste was collected from the selected households for a period of 8 days of each season (winter, summer and rainy) in 2022. So, we were able to collect the data for generation of waste on normal days as well as on the days on which the area had any festival or holiday. Total of the waste generated by the selected houses of the 7 villages were amassed to a central disposal site. In order to determine the quantity and rate of waste generation, all the generated and collected waste was weighed on a daily basis for total of 7 villages during the scrutiny period. The per capita rate of generated waste was made through dividing the total daily generated waste of 7 villages by the total population of all the villages. At the same time, the physical composition of the generated waste was found out by manually segregating the various components of the waste by collecting samples of 50 kgs for 32 times per year from the waste which was collected during the survey. The various components of the composite mixture of rural household waste were found to be organic and food waste, paper, cardboard, plastics, metals/glass, textiles and ash/dirt (this also included some kind of waste materials which are hard to be selected such as unselective construction debris, etc.). All these categories were weighed distinctly and the results were documented properly. A distinct container with the volume of 100 L was used to determine the density of loosely packaged rural household waste materials and the density of the waste that was measured was noted down in kg/m^3. Every time the survey was conducted 1 kg waste from the total waste collected of 7 villages was collected in polythene bags and brought back for measuring its moisture content in a Hot Air Oven. After finding out the moisture content every time waste was amassed in every season the waste was dried, mixed, crushed and stored for calculating the C, N, P and ash percentages by standard methods.

Table 1: Population of the selected 7 villages

Sr. No	Name of the village	Population (2011) [23]
1.	Wakoli	2001
2.	Pangari	1284
3.	Tetavli	2008
4.	Gaontale	681
5.	Rukhi	833
6.	Asond	1493
7.	Sadve	515
8.	Total Population	8815

Results and Discussion

In order to plan a highly efficient waste management and disposal system the accurate knowledge of waste generation rates is one of the many fundamental prerequisites. It plays a pivotal role in improving the existing waste management systems [15]. Details of the amount of waste generated in the 7 studied villages are shown in Table 2. As specified, for instance on the first day of the survey of all of the 7 villages in the summer season the combined generation of waste of all the 7 villages was 0.226 ton, while the average generation rate for summer, rainy and winter seasons was 0.223, 0.310 and 0.298 ton/day respectively. The waste generation rate during rainy season was high perhaps due to concurrency of Ganpati festival celebrated on a large scale in and around areas adjoining our survey site. These results signifies clearly that the average per capita of household waste generation rates in the 7 studied villages was about 0.0314 kg/cap-day. When compared to the waste generation rates of some metropolitan cities of the country, such as of Mumbai 0.63 kg/cap-day [16] it was 20 times lower. The high waste generation rates of the metropolitan areas were typically due to higher income, more consumption rate and higher standards of living [15]. As discovered in Table 3. Average per capita of household waste generation rates in Indian municipalities named as Mylavaram and Rajam was reported as 0.27 and 0.214 kg/cap-day [12]. The average per capita of household waste generation rates in the metropolitan cities of Kolkata, Delhi and Mumbai was reported as 1.10 kg/cap-day [19], 0.5 kg/cap-day [20] and 0.63 kg/cap-day [16]. The average waste generation of India as a whole was reported as 0.3-0.6 kg/cap-day [21]. Also, the rural household waste generation rates of Iran country were reported as 0.259 kg/cap-day [15]. Likewise, the amount of rural household waste generation rate in other parts of the world has been determined between 0.22 and 1.047 kg/cap-day [7, 8, 22]. In addition to this the waste generation rates of household solid waste in different cities of the world such as Chittagong, Bangkok and Tehran were reported as 0.250 kg/cap-day [4], 1.5 kg/cap-day [6] and 0.840 [8] kg/cap-day respectively. Considering, these varied waste generation rates of different villages and cities at a universal scale, it can be determined that the amount of waste generated per capita per day is different for different rural communities. Even inside a country this difference in waste generation rates between two rural communities is discernible. It can also be concluded that the waste generation rates of rural areas of Konkan is very less than that of the metropolitan cities. This depends upon a number of aspects such as socio- economic factors, climate, geographical conditions, cultural practices, purchasing power of people, food habits etc. [15].

Table 2: The average amount of waste generated in the 7 studied villages

Sr. no	Season	Days of weighing during each season (tn/day)								
		1	2	3	4	5	6	7	8	Average
1	summer	0.227	0.203	0.263	0.240	0.259	0.214	0.195	0.188	0.224
2	rainy	0.265	0.240	0.257	0.225	0.405	0.413	0.368	0.313	0.311
3	winter	0.278	0.259	0.240	0.351	0.336	0.390	0.313	0.218	0.298
4	total households	2141.000								
5	total population	8815.000								
6	Final avg per day tn/day	0.278								
7	Total in year generated (tn/day)	101.297								
8	Average waste generation rate (kg/cap-day)	0.031								
9	Average waste generated in g/cap-day	31.484								

Waste Composition and Density

The composition of solid waste is an essential subject in waste management. It affects the density of the waste, the proposed methodology of disposal and is necessary for examining reuse, reduction and recycle of waste [5]. As well as the accurate determination of density is a critical criterion for the exact estimation of storage for the exact estimation of storage, collection, transportation and land filling capacity of any waste management program. Results of determining the composition and the density of the generated solid waste in various seasons of year in the 7 studied villages are presented in Table 4. As discovered in this table, there was no noteworthy variance in the waste composition of the studied villages in 3 different seasons. Nevertheless, maximum density was obtained in rainy season (198.23 kg/m^3), possibly due to high precipitation in the study area during this period.

Annual Average waste composition of the 7 selected villages is demonstrated with the help of a pie chart in Fig 1. Moreover, these values are also compared with the average household waste generation values of various places across the globe reported during studies carried out by different researchers in Table 5. According to Fig. 1, about 54.89±16.08% of total waste generated in the 7 villages was organic and food waste, whereas paper, cardboard, plastics, metal/ glass, textiles as well as ash/dirt constituted around 9.28±1.64, 8.04±1.00, 16.4±4.12, 1.34, 8.62 and 1.41% respectively. Results indicated that about 35.07% of the generated waste was directly recyclable waste (including paper, cardboard, plastics, metal/glass etc.). So, recycling and separation programmer if planned and followed properly in this particular area would prove to be prolific. Due to high percentages (54.89%) of food and organic waste in the household waste of the studied area, use of vermicomposting as a mode to produce compost can be suggested as a plausible and natural substitute for chemical fertilizer. However, there were discernible differences between the results of this study from the results obtained from researches undertaken at other rural and urban areas. For illustration, as shown in Table. 5, organic and food waste in the current study was 54.89±16.08% whereas it was 69% and 52.8% (Suraj and Sutar, 2015) [14] in rural areas of Solapur and Rewa province of India. Similarly, plastic fraction of the generated waste in the current study was 16.4±4.12% while, the percentages of plastics found in Solapur and Rewa Province were 10% and 7.5% [14] which indicates that the use of plastics in the area selected for study was substantially higher than the other areas. Again, major differences were spotted in the amount of paper waste generation. The generation of waste paper in the area under study was 9.28±1.64 whereas, the waste paper fraction in the village area of Solapur and Rewa province investigated by other researchers was 15% and 6.4% respectively [14]. Also, the average density of the generated waste in the studied area was 166.67±24.25 kg/m^3 while, the density of waste generated in the households of different cities were determined to be between 330 to 560 kg/m^3 [11]. One of the major reasons for density differences between the household waste of rural areas and that of cities is because of the high percentage of plastics found in the household wastes of cities which consequently increases the density of city waste.

According, to the results and survey of the related literature, it could be concluded that the composition and density of the generated wastes vary not only between rural and urban areas, but also between different rural communities of adjoining villages of the same country which is ostensibly due to variation in geographical, economic, cultural and social conditions [15].

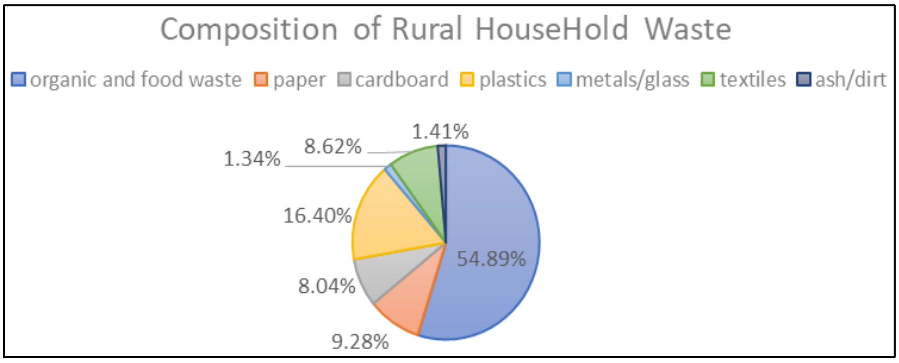

Fig 1: Average composition of all components found in household rural waste in Konkan region

Table 3: The comparison of solid waste generation rates of the studied villages with the other reported researches of various villages and urban cities

Sr. No.	Generation in kg/cap-day			
	Rural communities	**Generation rate**	**Urban communities**	**Generation rate**
1.	Study area	0.0314	Mumbai	0.63
2.	Mylavaram India	0.275	Delhi	0.5
3.	San Quintin Mexico	0.631	Kolkata	1.1
4.	Tekanpur India	0.287	Bangkok	1.5
5.	Avg of north rural Iran	0.452	Chittagong	0.25

Moisture and chemical characteristics of organic food wastes

The chemical characteristics of each component namely the moisture content, carbon, nitrogen and phosphor are vital for evaluating the composting potential of waste. The outcome of analysis of these conditions on basis of dry weight in the 7 investigated villages is presented in the Table no. 6. As given in the Table 6, the average amount of moisture, carbon, nitrogen, phosphor and ash content was 60.65, 51.43, 2.16, 0.33 and 33.43% whereas the C/N ratio of the organic ad food waste of the selected rural villages was 23.81. The amount of moisture content in organic and food waste was reported as 57.05% in previous studies in rural areas of northern Iran [15] and it was informed as 45.50% in studies undertaken in Tibetan plateau [17]. The average amount of carbon, nitrogen, phosphor and C/N ratio of organic food waste was reported as 29.4, 1.21, 0.45 and 23 [13].

It can be clinched from the above-mentioned results that the carbon content of household waste of the 7 studied villages is substantially higher than that of the carbon content of the household waste reported by [13], it is perhaps due to the amount of organic matter content present in the kitchen waste collected from the site of survey, is higher than that of the other studied villages. But, the other values of the chemical characteristics of the organic and food waste collected from of the 7 studied villages were in accordance to the values of C, N, P and C/N ratio reported by survey carried out by [13]. The C/N ratio of the organic and food wastes surveyed from the 7 selected villages was found to be 23:1 which is substantially lower than the ideal C/N ratio of 30:1, so in order to make the organic and food waste from the surveyed sites suitable to be used as organic fertilizers, it should be modified by adding compounds with high nitrogen content like sludge of wastewater treatment plants.

Table 4: Average waste composition in different seasons in the 7 studied villages

Sr. No.	Component	Season			Avg (%)
		Summer (%)	**Rainy (%)**	**Winter (%)**	
1.	Organic and food waste	50.64±13.65	58.39±20.25	55.65±14.35	54.89
2.	Paper	10.96±2.05	11.24±2.89	5.65	9.28
3.	Cardboard	8.45±1.52	6.91±1.50	8.78	8.05
4.	Plastics	13.58±2.00	14.32±4.51	21.3±5.85	16.40
5.	Metals/glass	1.85±0.50	0.25	1.92	1.34
6.	Textiles	11.68±2.02	7.63	6.55±2.50	8.62
7.	Ash/dirt	2.84±0.65	1.26	0.15	1.42

Table 5: Comparison of physical composition of analyzed solid wastes in this study with other reported researched data (rural and urban communities)

Sr. No	Component	Studied Area (%)	Rural Area of Tibetan Plateau (%)	Bangkok (%)	Rural Area of Northern Iran (%)	Avg of USA (%)
1.	Organic and food waste	54.89	16.25	43	76.9	11
2.	Paper	9.28	11.29	12.1	7.4	17
3.	Cardboard	8.05	0	0	0	20
4.	Plastics	16.40	21.34	10.9	7.1	11
5.	Metals/glass	1.34	1.38	9.65	1.8	8
6.	Textiles	8.62	4.71	4.7	1.3	7
7.	Ash/dirt	1.42	0.61	16.6	5.6	14
8.	Inert waste	-	23.25	-	-	0
9.	Density (kg/m3)	166.67	65±10	-	392±21	-

Table 6: Moisture content and chemical characteristics of organic food wastes at studied villages in different villages

Sr. No.	Component	Summer (%)	Rainy (%)	Winter (%)	Average (%)
1.	Moisture	58.36±3.55	72.40±10.50	51.20±5.50	60.65
2.	Carbon	46.6	54.5	53.3	51.4
3.	Nitrogen	2.1	2.9	1.6	2.2
4.	Phosphor	0.3	0.3	0.4	0.3
5.	Ash	28.5	32.1	39.7	33.4

Current condition of solid waste management

Waste segregation at the source, especially organic and recyclable portions have great environmental and economic advantages [15]. Regrettably, an organized, methodological and efficient source separation program has not been applied for solid wastes (including food waste, plastics, paper and board, metal, and glass) at the studied villages. Generally, the people do not have enough cognizance about undesirable environmental and health risks of solid waste disposal at the studied villages. In all of the 7 studied villages, the villages' councils were responsible for waste collection and transportation. But the collection, separation and disposal of village waste was not taken seriously at the site of study. The wastes collected by vehicles (in 2 of the 7 selected villages) like small trucks and vans are directly being transported to open dumping sites. The other remaining 5 villages don't even have a waste management system. The personnel, working in waste collection and transportation service, are not expert and trained well about perils associated with handling of solid wastes. Moreover, generally they are not provided with the necessary protective apparatus such as overalls, masks, gloves, and special boots. The residents of the remaining 5 villages either dump the waste in their backyard or burn it in their traditional cook stoves by using it as a fuel while cooking food. Meantime, the safe and steadfast long-term disposal of waste by considering health, environmental, and economic aspects is an important component of an integrated solid waste management system. As mentioned, in the current condition 2 of the 7 studied villages send their wastes to a central municipal waste landfill for final disposal which does not meet the criteria of a sanitary landfill and has many design and operational complications. The site actually is being used as a dump site for waste; also, sometimes waste recycling and feeding of livestock were illegally carried out in it and only occasionally the wastes were covered with a layer of soil. So, there is concern from environmental and public heath threatens in the final disposal sites in the area. In addition, the residents and mostly women working in the kitchen of the remaining 5 villages where some of the components of waste generated in the household such as paper, plastics, cardboard etc., were burnt in the churl has itself during cooking are susceptible to grave respiratory problems and diseases caused due to inhalation of smoke produced by burning plastics.

Conclusions

Rendering to the results found out by surveying and investigating the 7 villages as well as, by properly scrutinizing the available literature, it could be concluded that the amount of solid waste production per capita varies in different rural communities, even within a country. It could also be concluded by the studies undertaken in the 7 villages that the waste generation of rural areas of Konkan region is 0.0314 kg/cap-day, is significantly lower than that of the waste generation rate of urban areas such as Mumbai which is 0.63 kg/cap-day, that is about 20 times lower. Moreover, it can also be concluded that the composition and the density of the generated waste vary not only between rural areas, but also between rural communities with various geographical, socio-economic and cultural conditions. It was also concluded that domestic waste generated in rural areas have unique features including low generation rate, good compressibility, high proportion of recyclable materials, high C/N ratio of food and organic wastes etc.

So, if there exists a classified and properly maintained household waste collection, segregation and disposal system it will prove beneficial for the villagers as well as to the environment as it will undoubtedly, reduce the risk of respiratory diseases and will probably help to keep the village clean. But unfortunately, very scarce data is available regarding the quantification and characterization of village household waste, when compared to the size of data available concerning the studies of household waste of urban and metropolitan areas. So, additional studies are suggested to be undertaken regarding the quantification, characterization of village household waste and also the solid waste management and disposal system. It is also advised, to the municipal authorities to spread awareness among the villagers about the precarious effects of mismanagement of domestic wastes, and they should, if possible, also attempt to educate more and more villagers about benefits of a proper waste management and disposal systems.

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