

Research Article

## Solid waste management in rural areas nearby river Ganga at Haridwar in Uttarakhand, India

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### Abstract

The solid waste found in rural areas can be used as a soil conditioner providing essential nutrients to crops and enhancing agricultural productivity. It is an eco-friendly and economic preference for Municipal Solid Waste Management (MSW). This study investigates the solid waste management scenario in rural areas along the river Ganga and proposes a sustainable waste management solution. Waste quantification and composition were determined in the five villages (rural areas) viz. Sajampur, Shyampur, Kangri, Bhogpur and Dummanpuri of district Haridwar in Uttarakhand and their waste management and disposal systems were evaluated. Findings revealed that the average daily waste generation was 0.665 kg/day and per capita generation of household waste was around 0.16 kg/person/day. Major fraction of household waste was bio-degradable (74.14%) and remaining fraction comprised of paper (6.62%), polythene (2.82%), textile (2.52%), plastic (1.15%), glass (0.61%), metal (0.60%), rubber (0.35%), and inert (5.01%). The average bulk density of household waste was 460 kg/m<sup>3</sup>, whereas cattle waste bulk density was 834 kg/m<sup>3</sup>. Other waste characteristics included moisture content (60%), organic carbon (40%), nitrogen (1.7%), phosphorus (0.9%) and ash (31%). The calorific value of household waste (biodegradable) was 937.6 kcal/kg (dry basis). Since most of the waste was biodegradable, hence co-composting with cattle waste is recommended. The dry waste can be separated and stored for further processing and transported to nearby waste to energy-producing plants. The main hurdle to the program of waste recycling was the unsegregated collection of waste in rural areas. Hence, separation at the source comprised biodegradable waste, dried waste (paper, plastic, and metal) and other components are essential for the future solid waste management program.

**Keywords:** Composting, Rural areas, Solid waste characterization, Solid waste management, Source-separation

### INTRODUCTION

Presently, the amount of solid waste produced annually in the Indian towns has been found to be greater than before, i.e., from 6 million tons (1947) to 48 million tons (1997) besides the growth rate of 4.25% annually was observed. As reported by CPCB, 2004 that it is also estimated to enhance the quantity of waste to 300 million tons by 2047 (CPCB, 2004). In India, about 90% of MSW are nonstop disposed on the surface of the land in an inadequate way (Das *et al.*, 1998). According to World Data Bank report (2015), nearly 3.3 billion (46%) of the world's population and 0.83308 billion (68.8%) of the Indian population is residing in the rural region. In the Indian villages, the houses are found in the central location, surrounded by the differ-

ent types of land, i.e., agricultural land, pasture, and forest lands. In general, the family member in the Indian villages is 5-6 adult members and 4-5 numbers of cattle within each house. The residues of crop and domestic refuse (human excreta and kitchen waste) are the dominant wastes generated, most of which are piled on the land in an open yard, and compost is made away from the houses. The mixed smell of the decomposing human excreta and the smoke obtained from the incomplete burning of biomass fuels are the signs of better waste management in our villages. Several types of research have been published on urban solid waste characterization, its management, and treatment in various cities of both developed and developing countries. Simultaneously, significantly

less information is available regarding the composition and management of rural domestic solid waste examples of the few studies have been reported on rural household solid waste such as El-Messery *et al.* (2009) in Egyptian rural communities, González *et al.* (2010) in Mexico, Dorenfeld *et al.* (2012) in cities of Namibian, Shah *et al.* (2012) in villages near Tekanpur in India, Mohammadi *et al.* (2012) in Iran Ogwueleka (2013) in rural area of Nigeria, Agamuthu *et al.* (2019) and Agamuthu *et al.* (2020). However, developing countries of Asia and Africa fail to receive attention in domestic solid waste management issue in the rural areas as compared to the urban areas. The appropriate management for the crop residues and the excreta obtained from the habitats of animals and humans in the rural areas is the need of the hour. Globally, less information is available about the solid waste generation and composition in the rural areas, especially in the northern region and along with the rural riverside community. Hence, in the absence of such information, the authorities of rural sanitation are incapacitated for designing and operating solid waste management in the cities.

Therefore, the micro-level characterization of solid waste generated in rural regions is necessary for designing waste management programs to prevent the harmful effects of untreated solid waste on public and environmental health and reduce economic losses. Also, there is an urgent need to manage solid waste in an eco-friendly and economically preferable mode in India's rural area. Overall, the present investigation will provide the MSW management scenario in the rural areas across the river Ganga and proposes a possible sustainable waste management solution.

## MATERIALS AND METHODS

**Study area:** Haridwar city has over 1,890,422 (Census, 2011) and about 81% population live in villages (rural areas). The studied villages come under the peripheral distance 25 km from Haridwar city. During the study, out of the five villages, two villages- (V1) Bhogpur, (V2) Dummanpuri are on the west side bank while three villages – Shyampur (V3), Sajanpur (V4) and Kangri (V5) are on the eastern side bank of the river Ganga of district Haridwar in Uttarakhand were selected as shown in Fig. 1. A survey was carried out from September to November 2018 from the selected households in most of the areas in villages. Several visits were conducted to collect necessary information, population, assess working conditions, and evaluate the current state of waste management in all the selected villages under the aegis of Namami Gange scheme initiated by Govt. of India for the effective abatement of pollution, conservation and rejuvenation of National River Ganga. Table 1 shows the population of selected five villages of Haridwar city with a combined population of nearly 20,826 during the study.

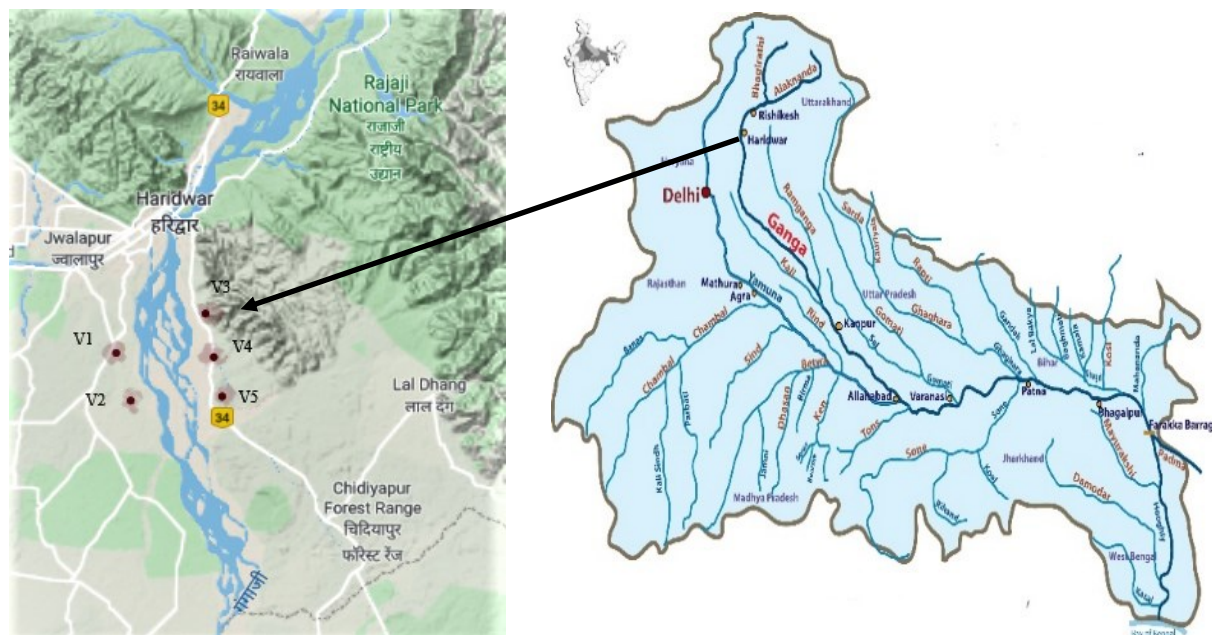
**Sample collection:** A questionnaire was prepared by

the research group of Environmental Engineering Section, Indian Institute of Technology Roorkee (IITR), and a survey was conducted door to door. The data was obtained regarding the quantity of MSW, disposal on a daily basis, container availability, frequency of collection and level of satisfaction, etc. Similarly, the per capita generation rate of MSW (kg/capita/day) was estimated from the sampled population of the villages during the survey. Finally, based on the data collection and analysis, the best suitable alternatives were found out for the waste management other than the land-filling process. A survey was conducted covering the solid waste produced every day. The standard procedure of sample collection and MSW analysis was adopted as defined in Peavy *et al.* (1985). In each of the selected five households, containers for waste collection corresponding to the number given to that household were placed at a specific location, under the observation of the house leader to manage the separation of their garbage into these containers. Containers and waste bags were labelled corresponding to the fraction of waste, i.e., organic fraction, plastic waste, paper, and metal waste. The regular collection was done two times a week during the investigation period (September to November 2018).

The waste generation rate was determined by combining the generated and collected waste. Waste was weighed every day and the physical composition of the solid waste was investigated. The solid waste collected was mixed thoroughly, and random sampling was performed. Waste was separated manually into food waste, cardboard and paper, plastics, metals, rubber, textiles, glass, woods, and other wastes such as inert wastes, construction debris, dirt, ash, etc. This group of wastes was weighed, and the outcomes were noted. A box made up of wood of 0.028 m<sup>3</sup> was used to estimate the volume and the density of the waste onsite. The values were calculated in kg/m<sup>3</sup>. Samples were collected in the polyethylene bags and transported for further physical and chemical examination to the Environmental Engineering Laboratory of Institute Roorkee IITR, India. These samples were analyzed for moisture content (according to wet weight). Thereafter, moisture content (APHA, 2012) was analyzed, and dried samples were ground and sieved through a 0.2 mm sieve.

**Composite sampling:** 1 to 2 kg amount of mixed waste sample depended on the generation from each home in each community was collected and transported to the processing site and for further investigation. Afterwards, six samples from each site were assorted properly. Finally, sub-samples of about 20 g were preserved into airtight bag and sent to the laboratory for further examination.

**Physico-chemical characteristics:** Physico-chemical parameters such as moisture content, bulk density, carbon, nitrogen, phosphorus, and potassium were analyzed. Moisture content was evaluated by the weight loss of the sample (105 °C for 24 h) as per the



**Fig. 1.** Locations of villages in study site (V1) Bhogpur, (V2) Dummanpuri, (V3) Shyampur, (V4) Sajanpur and (V5) Kangri of District Haridwar (Source: Google map).

standard method APHA (2012). Carbon and nitrogen (%) were detected on a dry matter basis by using Vario ELIII CHNSO elemental analyzer, phosphorus (acid digest) using the stannous chloride method, potassium detected using a flame photometer (Rajpal *et al.*, 2014).

## RESULTS AND DISCUSSION

**Generation of waste:** Waste generation rate measurement is the prerequisite to plan and design the program of any waste management. It is an important parameter to improve the practices of solid waste management (Dangi *et al.* 2011; Fahiminia *et al.* 2014). The quantity of the waste produced in studied five villages (Kangri, Shyampur, Sajanpur, Bhogpur and Dummanpuri) is detailed in Table 2 and Fig. 2. These five villages collectively generated 3.97 tons/day and about 140.81 tons/day of household and cattle waste, respectively. Average individual household waste generation in studied villages, V-1, V-2, V-3, V-4 and V-5 was 651.4, 495.6, 445.9, 1741.5 and 639.3 kg/day. The generation of waste was highest in the V-4, attributing to the largest population among the others. Results indicated that the average per capita of household waste generation rates in the five studied villages, namely V-1, V-2, V-3, V-4 and V-5 was about 0.22, 0.20, 0.19, 0.18, 0.19 kg/capita.day, respectively (Table 2). It was observed that the rate of waste generation in these rural areas was estimated to be lower as compared to the urban areas of average 0.5 kg/capita.day (CPCB, 2015).

**Waste composition:** Determination of solid waste composition is crucial for waste management to reduce, recycle, process and finally, disposal of solid

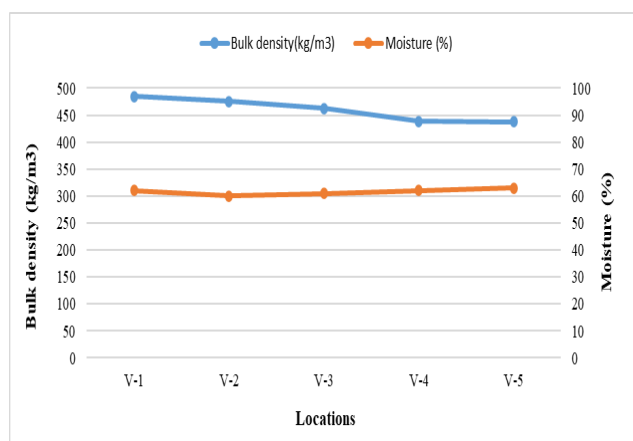
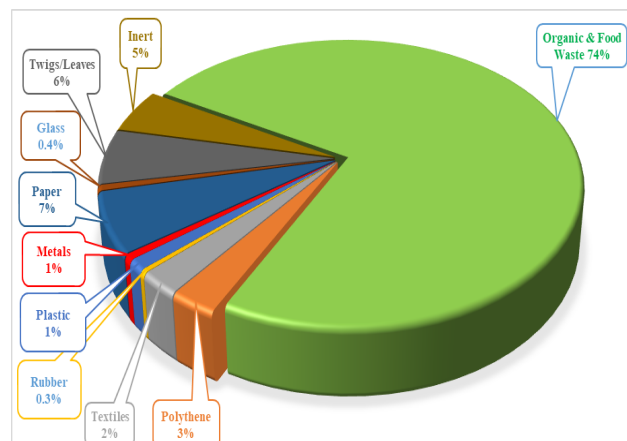
waste (Tchobanoglous *et al.* 2002; Al-Khatib *et al.* 2010; Adeniran *et al.* 2017). The density and average composition of the solid waste generated by the five villages selected for the study are presented in Fig. 3a and b. Waste composition analysis showed no significant difference among the studied communities. The density and moisture content of household waste ranged between 437.5 – 484.1 kg/m<sup>3</sup> and 60 – 63 %, respectively, in the studied villages (Fig. 2). Fig. 3 and Table 3 showed that about 70 % to 80 % of the total waste generated included organic and food waste in the studied sites. In contrast, various kinds of wastes such as paper waste, metals, plastics textiles, rubber, glass and woods comprised about 20 to 30 % of the total generated waste. Observations reported that the generated waste included 10 % recycling waste. Systematic separation of waste is essential for a successful integrated waste management system. The waste would be sorted at the source to reduce the large quantity of waste required to be disposed of. The techniques of sorting and reusing programs at the source are essential to reduce waste generation. From the results, it was observed that the high percentage of food waste and the organic content was the major component of the solid waste in the studied villages (Table 3) (Fahiminia *et al.* 2014; Ugwu *et al.* 2020). Hence, it is recommended that the techniques like pile composting and vermicomposting (Bhatia *et al.* 2011 and Rajpal *et al.* 2014) can be opted to reduce the disposal of waste generated in the rural areas. There was a noticeable difference between the study results and the observations reported earlier in other rural and urban areas, and significant variation was observed in the quantity and composition of solid

**Table 1.** Population data of human and cattle population of selected five villages of district Haridwar.

S. No	Name of Village	Area (km <sup>2</sup> )	Co-ordinates	Human Population (2018)	Cattle Population (2018)
1	V-1 ( Bhogpur)	3.58	29°46'56"N 78°10'0"E	2961	647
2	V-2 ( Dummanpuri)	3.4	29°39'40"N 78°5'17"E	2478	2289
3	V-3 ( Shyampur)	4.91	29°52'00"N 78°10'57"E	2347	474
4	V-4 ( Sajanpur)	33.62	29°51'27.4"N 78°12'7"E	9675	3874
5	V-5 ( Kangri)	8.25	29°53'48"N 78°10'25"E	3365	539

**Table 2:** Cattle and household waste generation in the selected villages during the study period (September to November 2018).

S. No	Name of Village	Cattle Waste gen/day (kg)	Household Waste gen/day (kg)	Per capita Waste generation (kg)
1	V-1	11646	539	0.192
2	V-2	41202	422	0.18
3	V-3	8532	416	0.189
4	V-4	69732	1403	0.151
5	V-5	9702	546	0.170

**Fig. 2.** Bulk density and moisture content of the household waste in villages of district Haridwar.**Fig. 3.** Average waste composition in the selected villages of district Haridwar.

waste produced in the urban and rural communities (Sharholly *et al.* 2007). A striking feature is that the composition and density of the generated solid waste vary within the rural areas due to the dissimilarities in topographical, cultural, financial and societal conditions.

**Ultimate analysis and calorific value of household waste (dry basis):** Due to the lesser availability of data related to the characteristics and calorific value of the waste generated in the rural area. Hence, it is difficult to make complete strategies to manage solid waste. So, the ultimate analysis of the solid waste included the testing of carbon, nitrogen, C/N ratio, potassium, and phosphorus to assess the potential of waste to be composted. The results of these constituent analysis was based upon the dry weight (after measuring the moisture content) of the samples. The

amount of carbon (13.1 – 14.6%), nitrogen (1.4 -1.7%), phosphorus (0.7 – 1.0%), potassium (0.4 -0.6%), and ash (10.1 – 13%) was measured in the five villages' household organic waste, respectively as shown in Table 4 and Fig. 4. The amount of calorific value of dry organic waste ranged between 900 – 1009 Kcal/kg in selected five villages (Fig. 5). Hence, dry waste can be separated and stored for further processing or may be transferred to nearby waste to energy plants.

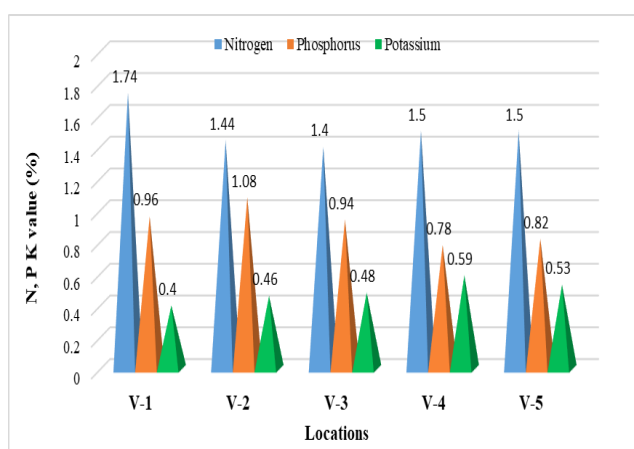
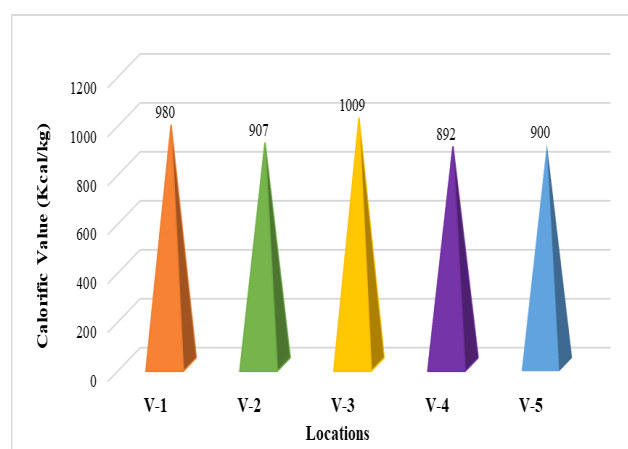
**Challenges and future perspective for solid waste management:** Segregation of the waste at the source for analyzing the organic and recyclable portions bids the significant advantage socially, environmentally and economically. Systematic separation of the solid waste program was not practical in the studied villages. Sorting of the metals by the residents was also noted. The

**Table 3.** Percentage of household waste composition in each village of district Haridwar.

Component	Unit	V-1	V-2	V-3	V-4	V-5
Organic & Food Waste	%	79.42	78.18	70.71	72.62	69.78
Polythene	%	3.14	2.25	5.45	1.53	1.74
Textiles	%	1.48	1.29	6.65	1.6	1.56
Rubber	%	0.38	0.36	0.34	0.32	0.35
Plastic	%	1.27	1.2	1.14	1.09	1.03
Metals	%	0.66	0.58	0.81	0.51	0.45
Paper	%	4.57	5.83	8.44	6.14	8.42
Glass	%	0.68	0.75	0.66	0.58	0.37
Twigs/Leaves	%	4.39	4.33	2.86	10.64	8.57
Inert	%	4.05	5.28	2.95	5.04	7.73

**Table 4.** Ultimate analysis of household organic waste in each village of district Haridwar.

Component	V-1	V-2	V-3	V-4	V-5
Carbon (%)	13.1	14.3	14.1	14.6	14.0
Hydrogen (%)	8.3	7.7	8.0	8.4	8.3
Oxygen (%)	65.8	65.0	63.4	64.0	66
Nitrogen (%)	1.7	1.4	1.4	1.5	1.5
Sulphur (%)	0.08	0.07	0.08	0.08	0.09
Ash (%)	11	11.5	13	11.4	10.1

**Fig. 4.** N, P, K value of household (dry waste basis) generated in the villages of district Haridwar.**Fig. 5.** Calorific value of household (dry waste basis) generated in each village of district Haridwar.

villagers were not much aware of the detrimental effects of poor solid waste disposal practices on the environment and health. It was observed that in the studied rural communities, a major portion of the solid waste generated was dumped openly. Open dumping is unaesthetic and unhygienic, which could be a major aspect of public health. To financially and technically manage the waste, the officials of local government like municipality helped the village council or village panchayat. However, the support was not enough for the execution of an integrated solid waste management plan. Therefore, the solid waste generated do-

mestically in the villages needs to be classified into organic and inorganic waste for sustainable waste management. The total generated waste could be divided into food waste and can be supplied for livestock as fodder and biodegradable organic waste for farming. Since most of the waste is biodegradable, hence co-composting with cattle waste is recommended. The waste (food waste) can be used for livestock as feed supplied to a livestock farm. The leftovers would be composting separately or in a common composting facility. The recyclable waste could be separated and sold for recycling. The dry waste can be separated

and stored for further processing and directed to nearby waste to energy plants. The rest of the inorganic waste should be disposed of at the nearby dumping

and landfill sites. Hence, a simple model can be applied for solid waste management for the rural communities for its proper utilization (Fig. 6).

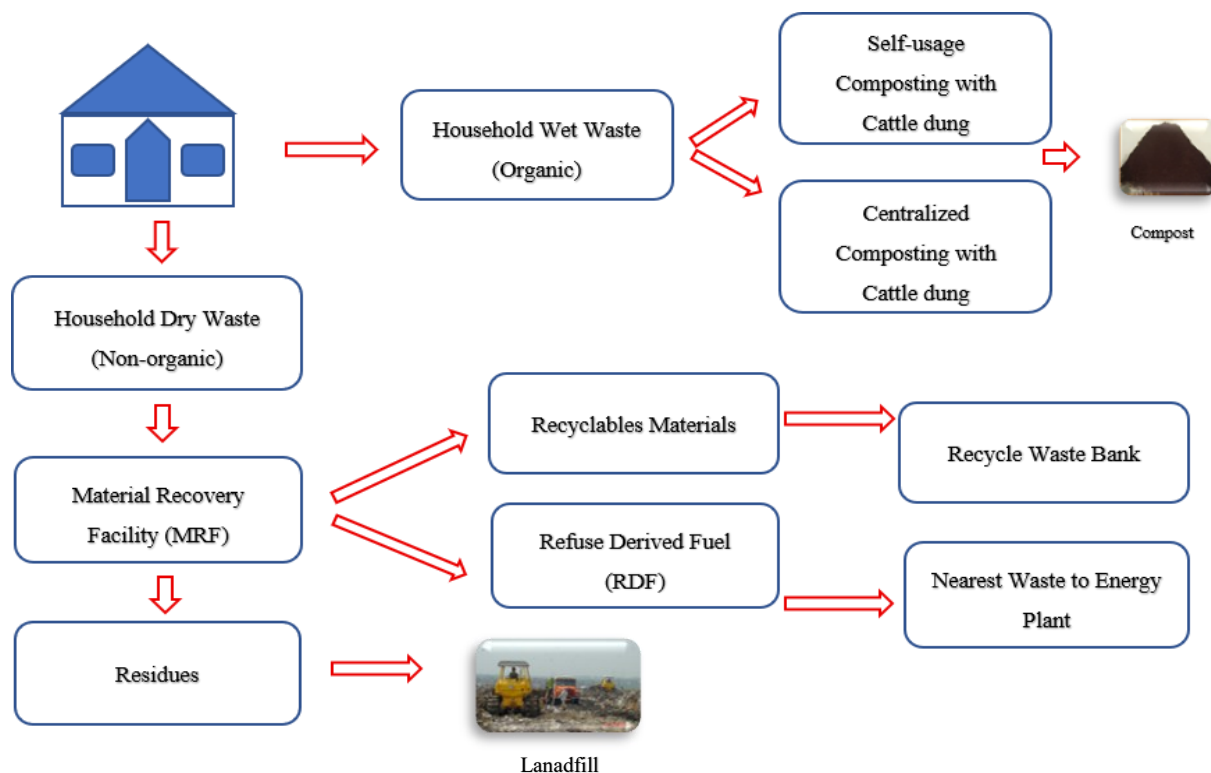


Fig. 6. A simple model for solid waste management for rural areas.

## Conclusion

Based on the observations, more than 90% of the total generated waste in the villages of District Haridwar was cattle dung, and the rest 5-10% was household waste containing 70-80% biodegradable portion. The major waste management problem in rural setup is the lack of source separation and proper disposal strategy as generally. The household waste is dumped outside the houses and across the road. Due to the lack of garbage collection facilities, the majority of rural residents are not following the recommended waste separation and disposal practices. This solid waste produces odour and anaesthetic look and ultimately pollute the river Ganga during the rainy season. Hence, it has to be appropriately managed at the household level by collecting dry and wet waste separately to reduce the public health risk. Composting organic (biodegradable) household waste with animal waste is the best option, which can be used as a fertilizer in agriculture. The dry fraction (non-biodegradable) can be transferred to waste to energy facilities in nearby areas. General public awareness is a must in the success of any public project for implementing a waste management strategy. The municipality and village panchayat should organize social and environmental awareness programs for rural waste utilization in agriculture. Another requirement is

developing better garbage collection facilities, such as garbage storage centers and garbage collection bins, should be designed. The study outcome will help to create the concept of waste management and disposal systems, mainly for rural areas situated along the rivers. Hence, it is concluded that the micro-level characterization of solid waste generated in rural areas is the best suited sustainable waste management solution.

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## Conflict of interests

The authors declare that they have no conflict of interests.

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