Evaluation of Existing Solid Waste Management System in Una Town, India

Disha Thakur, Rajiv Ganguly, Ashok Kumar Gupta and Veeresh Ghali

Abstract Municipal solid waste management is an important function of the urban local body (ULB) of any city or town in India. The present study reports the existing prevalent MSW management system being carried out in Una, Himachal Pradesh. The total waste generation in Himachal Pradesh is about 350 tonnes per day (TPD) of which the total waste generation in Una town is about 6 TPD with per capita generation of 0.42 kg/day of which 5.5 TPD is disposed in an open dumpsite in Lalsinghi about 5 km from town with a collection efficiency of about 90%. The study uses the "*wasteaware*" benchmark indicators for evaluating the existing municipal solid waste (MSW) management practices. The "*wasteaware*" benchmark parameters incorporate both quantitative and qualitative methods for determining the competency of the existing systems. Further, a matrix method has been utilised to complement the "wasteaware" benchmark indicators in evaluating the existing techniques. From the results, it was observed that the collection efficiency in the study area is good categorised as M/H, while transportation, disposal and recycling facilities are lacking (low). The overall score for the Una town is 38% after evaluation from matrix method. Thus, the study showed that there is an immediate need in the improvement of the existing MSW management practices and certain suggestions have been provided in this context.

Keywords Municipal solid waste · Una · Himachal Pradesh · Open dumping · "*Wasteaware*" benchmarks · Matrix method

D. Thakur · R. Ganguly (✉) · A. K. Gupta · V. Ghali
Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, District Solan 173234, Himachal Pradesh, India
e-mail: rajiv.ganguly@juit.ac.in; rajiv.phd@gmail.com

D. Thakur
e-mail: thakurdisha66@gmail.com

A. K. Gupta
e-mail: akgjuit@gmail.com

V. Ghali
e-mail: veeresh_ghali@yahoo.com

S. K. Ghosh (ed.), *Sustainable Waste Management: Policies and Case Studies*,
https://doi.org/10.1007/978-981-13-7071-7_33

1 Introduction

Waste is defined as unwanted material (trash or garbage) of everyday item which is required to be disposed of after use Environmental Protection Agency (2009). The waste generation rate across the globe is estimated to be about 1.2 billion per year and estimated to increase up to 2.2 billion tonnes per year by 2025 (Urban Development Resources, World Bank Group). The MSW generation across the world accounts for 13.3% of the total solid wastes generated (Pappu et al. 2007). The rate of generation of MSW varies for different countries with developed countries producing more per capita waste generation than developing countries and is influenced by economic development, public habits, local climate and rate of urbanisation (Anand 2005; Pipatti et al. 2006). Effective management of municipal solid waste generated in a developing country like India poses severe problems due to multifarious issues including rapid urbanisation and increased population leading to increased consumption and thereby increased waste generation (Katiyar et al. 2013). It has been reported that the average waste generation rate in India is 0.376 kg/day and is increasing at rate of 1–3% per year. Problems in the effective management of solid wastes in developing countries are further exacerbated due to malfunctioning of the traditional waste management system which is ineffective in the present context. It is estimated that 70% Indian urban population generate about 130,000 tonnes/day of MSW with per capita generation rate of 0.5 kg/day with an expected annual increase of about 1.3% per year (Kumar and Gaikwad 2004). Recent study carried out in this context revealed that average national total generation of MSW is nearly 105,000 MT/day (Beigl and Lebersorger 2009; Kumar et al. 2009) with the waste generation in urban areas (0.2–0.6 kg/capita/day) twice than in the rural areas. Further, the per capita generation of waste is increasing enormously with improved lifestyle and social status of urban dwellers (Sharholy et al. 2008; NEERI 2010). With an urban growth rate of about 3–3.5% per annum, the annual increase in waste quantities has been estimated at 5% per annum (Dube et al. 2010). The population of urban areas has increased significantly as compared to that of the total population of India from 1960 to 2011, and the trend of population growth is shown in Fig. 1 (TERI 2015). Reported characterisation of MSW in Indian cities indicates about 40–60% of waste content is organic, 30–60% inert material, 3–6% paper and miscellaneous and others 1% (Sharholy et al. 2007; Sharholy et al. 2008; Rawat et al. 2013; Rana et al. 2017).

The municipal solid waste in India is governed by municipal solid waste (Management and Handling) rules 2000 (MoEF) further revised in 2016. It has been reported that about 90% of total solid waste generated in India is dumped in open landfill (Hazra and Goel 2009). Further, composting accounts only for 5% in cities and about 6% in towns and rural areas with the rest being dumped in open grounds (CPCB 2012). Many Indian cities are facing problems in composting of the waste because of poor segregation practices. The absence of proper segregation and reduced collection efficiency of waste leads to the potential waste to energy (WTE) value being unutilised (Rana et al. 2014). Another significant issue experienced by developing countries due to such poor management of MSW generated is severe environmen-

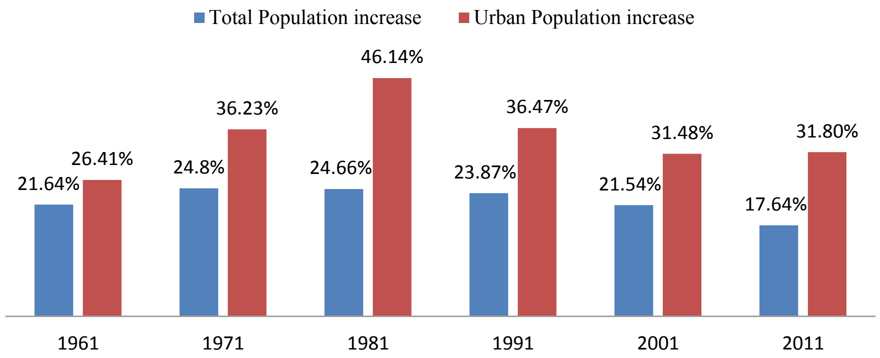

Fig. 1 Trend of urbanisation in India (TERI 2015)

tal concern arising out of the generation of such voluminous waste quantity and the adverse health effect on the humans (Al-Khatib et al. 2010). Thus, the proper management of MSW needs an effective concern in developing countries (Shekdar 2009).

Himachal Pradesh is least urbanised state in India, and hence the waste generation is comparatively much less to the total waste generated in India. The generation of municipal solid waste (MSW) in Himachal Pradesh was estimated to be 305 TPD in 2015 (CPCB 2016), and per capita waste generation is about 0.413 kg/day and is expected to rise almost 1.33% by 2041 (TERI 2015). The waste generation is expected to increase at growth rate of about 1–1.33% annually (Pappu et al. 2007). The population is expected to rise at a high rate, and thus the waste generation in the state will also increase (Ministry of Urban Development, & Government of Himachal Pradesh 2015). The estimated waste generation rate for urban population from 2011 to 2041, in Himachal Pradesh, is given by TERI (Table 1).

The present study emphasises on efficiency of functioning of existing municipal solid waste management system for Una town in Una district of Himachal Pradesh. In this context, "*wasteaware*" method has been utilised to evaluate the efficiency of the existing system and further matrix method is used for quantification and comparison

Table 1 Population growth and impact on urban waste generation in Himachal Pradesh (TERI 2015)

Year	Per capita waste generated (kg/day)	Urban population (×1000)	Waste generated (T/day)
2011	0.413	736.34	304.3
2021	0.472	883.32	416.6
2031	0.538	1023.43	550.9
2041	0.614	1155.23	709.6

with other locations. Based on the results, some remedial measures are proposed for the improvement of existing solid waste management system in the study area.

2 Study Location

Una is a district of Himachal Pradesh covering an area of 1549 km^2 located at latitude 31° 48′ and longitude 76° 28′ located at an altitude of 369 m above mean sea level (Census 2011). The state has population of about 521,173, and population of Una town is about 18,722 with a growth rate of 8.62% (Census 2011).

Due to rapid urbanisation, majority of the population of the Una district resides in urban area of Una town. The solid waste generated is dumped in an open landfill covering an area of about 0.20 ha at Lalsinghi which is located about 5 km from Una town. The waste is collected from the town which has been subdivided in 11 wards. The existing dump site has been in operation since 2010–11. The dumping of solid waste in open areas causes health hazards to the people living nearby. The soil and groundwater in the area are also liable for contamination as leachate percolated into the ground. The location of Una town has been shown in Fig. 2a and the actual dumpsite in Fig. 2b.

3 Existing Municipal Solid Waste Management in Una

Lack of proper data regarding SWM generated in a city/town by municipal corporations is one of the major problems experienced by different municipal corrections. The waste generation of the solid waste has increased rapidly at a high rate and thus is a major drawback in MSW management. The major drawbacks in solid waste management in an Indian context are poor management for segregation, collection, transportation, treatment and disposal of waste.

3.1 MSW Generation

For our study location of Una town, it was observed that with increase in population, generation rate of waste has also increased. Municipal Council of Una town is responsible for the effective management of solid waste in the town. The quantity of waste generated depends on food habits, seasonal variation and living standard of people in that region. Thus with increase in urbanisation and changing lifestyle of the people, the generation of MSW has increased at a large extent. The total waste generation in Una town is about 6 MT/day of which about 5.50 MT/day is collected and disposed off in an open dump. The generation of waste is also increased with increase in per capita waste generation which is 0.42 kg/day for the study region.

Detailed physico-chemical characterisation of the MSW generated at the study area is absent. Some rudimentary analysis carried out for physical characterisation showed that high proportion of organic content was present in the MSW generated and has been summarised in Table 2. As observed from Table 2, the waste generated in the town mainly consists of organic matter as it is primarily an agricultural area and the prevalence of open dumping of rotten fruits, vegetables and other disposable organics on the site.

Visual inspection of the waste revealed that paper and polythene are relatively in higher fraction because of the presence of the number of educational institutions, government/private sector offices and some small-scale industries. Additional component leading to generation of plastic waste is due to sale of goods/items in plastic bags. Though use of plastics in Himachal Pradesh is banned, the study location lies in the border regions with the neighbouring state of Punjab which does not follow the same legislation leading to an increased plastic component in the MSW generated in the region. The management of plastic waste in the area is under jurisdiction of

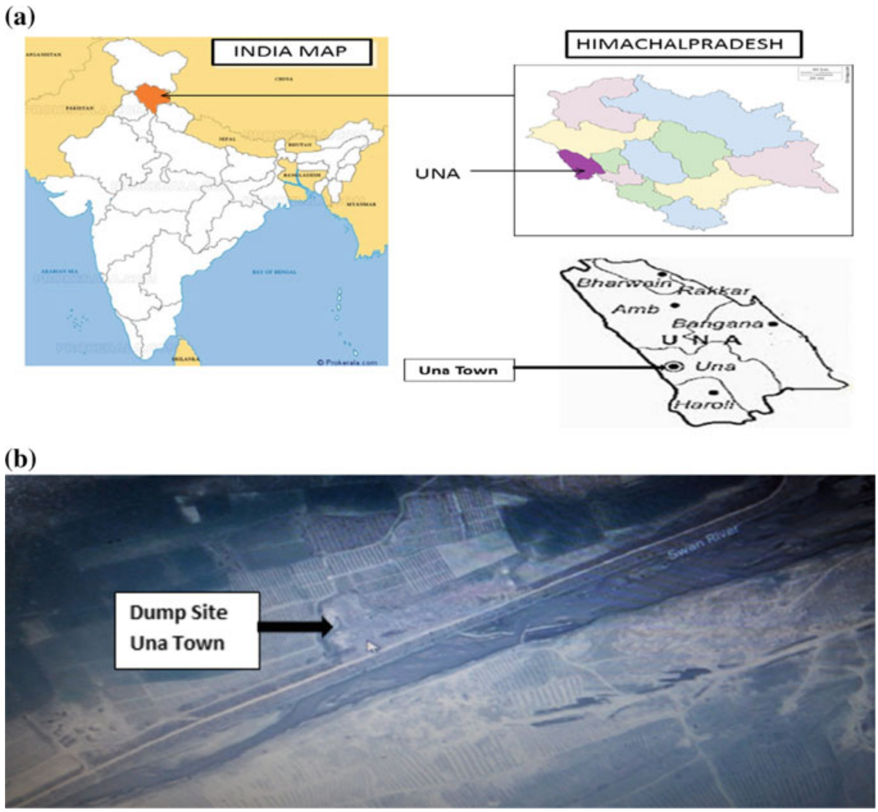

Fig. 2 **a** Location of the study region. **b** Location of dump site in the study area. *Source* Google Earth

Table 2 Composition of MSW in the study region

S. no.	Composition of waste	Percentage fraction
1	Organic	56.1
2	Paper	12.2
3	Plastic	10.3
4	Glass	1.0
5	Metal	1.2
6	Inert	10.6

agency Navnirman Media. Thus, detailed physico-chemical analysis characterisation of the waste is necessary for the effective MSW management system in the study area.

A detailed physico-chemical analysis of the MSW generated at the study location is required to determine the optimal treatment processes for the efficient working of MSW management system in the area.

3.2 MSW Collection

Proper collection of the waste is most important component in implementing an effective solid waste management system (Biswas et al. 2010). For an effective management system of the solid waste generated, the collection capacity of the collection bins should be equal to or greater than generation rate of MSW. However, collection capacity in India is always less than generation of the waste in that region leading to improper management (ENVIS 2013; Ministry of Urban Development 2016).

The Municipal Council of Una employs about 58 *safai karamchari* (waste collector) for collecting the waste from the town, and additional 50 *safai karamchari* are employed by private company in town. The manpower involved in the collection of waste is much less for the running of the effective management system. The waste collection efficiency of the study area is about 80–90% (personal communication with Una Municipal Corporation, Table 3) with poor waste management facilities. The primary waste collection process involves placement of bins nearby the residential and commercial areas. All types of waste (organic and inorganic) are collected in a single bin which is a poor practice leading to unhygienic condition (Guria and Tiwari 2010; Das and Bhattacharyya 2014).

Door-to-door collection system of MSW is also carried at those wards which are feasible. The waste collectors usually collect waste in handcarts and tricycle from residential areas, and the waste from the street is collected along with primary collected waste. The collection of the waste is indiscriminate due to shortage of proper collection bins. The waste from town is collected in bins placed near the residential areas, public places like park and shops, but the waste thrown in the bins

Table 3 Details of municipal solid waste collection

S. no.	Type	Capacity	Quantity
1	Manual sweeping	–	90%
2	Mechanical sweeping	–	Nil
3	Masonry bins	–	10 nos.
4	Covered metal/plastic container	Up to 1.1 m^3	40 nos.
		2–5 m^3	15 nos.

is incompatible which causes littering of waste. It was observed that the generation of MSW is much more than the capacity of the bins provided in the areas, causing the overflow of the wastes. Details pertaining to the collection of the waste have been summarised in Table 3.

It was further observed that the collected waste in the study location was in mixed form, without any segregation. Non-segregated waste is a mixture of biodegradable and non-biodegradable waste with a high proportion of moisture content, thereby significantly reducing the calorific value of the waste, making it non-recyclable. Further, Una is one of the hottest regions of Himachal Pradesh, and hence during summer time, waste at the dumpsite often burns due to the negligence of people, leading to emission of harmful gases to the atmosphere.

3.3 MSW Transportation and Disposal

Transportation of waste from the collection points to the dumpsite is managed by the Municipal Council of Una. The waste after collection from the residential areas, streets, shops, etc., is transported to the dumpsite by trucks and tractor. The capacity of the truck is about 4 tonnes (8.3 m^3). The efficiency of the transportation of the collected waste to the dumpsite is about 92% (Authority from MC Una).

The major problem associated with transportation of waste to dumpsite is because of inadequate number of the collection vehicle and insufficient capacity of the vehicles. The collection capacity per capita for the study area was determined to be 0.0011 m^3/day, which shows that the number of vehicles for waste transportation is less than the waste generated and additional transportation vehicles are needed. Transportation vehicles utilised along with their carrying capacity have been summarised in Table 4. Further, proper travel route management implementation is required to be adopted for economic and better collection of waste in area. After continuous dumping of waste in the site problems, many problems have arisen as the dumped MSW is not layered with cover soil or any insecticide solution leading to unhygienic condition for the people living in the surrounding areas particularly due to breeding of infectious vectors and possible contamination of groundwater and river flowing in nearby.

Table 4 Details of solid waste transportation vehicle

S. no.	Type of vehicle	Quantity	Capacity (in tonnes)
1	Tractor	1	3
2	Dumper placer	2	2.5 (single-bin system)
3	Compactor	–	–
4	Tipping truck	4	4
5	Three-wheeler	–	–
6	Backhoe loader	–	–
7	Twin lifter	–	–

4 Methodology

4.1 Analytical Framework

4.1.1 "Wasteaware ISWM Benchmark Indicator" for Waste Management

The performance of existing solid waste management system for the study location is analysed using integrated sustainable waste management (ISWM) to allow benchmarking of performance and monitoring the developments over time. The purpose of benchmarking is to enhance and appraise the awareness of stakeholders of local SWM system. Further, it gives an overview of performance of system even in the absence of detailed data. *Wasteaware* benchmark uses existing data for the ISWM system and provides platform for evaluation of both qualitative and quantitative indicators (Wilson et al. 2013, 2015). The indicators allow for rapid benchmarking of the performance of solid waste management system, comparison of cities and monitoring progress of city for sustainable solid waste management system. Benchmark indicators are presented and compared with three physical components and three governance strategies for management of the generated MSW. The quantitative components include public health collection, environmental controlled disposal and resource management—reuse, reduce and recycling, while the qualitative indicators include governance parameters; user and provider inclusivity; financial sustainability; and the national policy framework and local. The qualitative system is fivefold to match the score system. The score system performance of indicators is categorised as low (L), low to medium (L/M), medium (M), medium to high (M/H), high (H). For rapid visual assessment, "traffic light" coding system has been used to rate the performance of each quantitative indicator. The conventions used for assessment of low correspond to overall score of 0–20% and are coded as red, medium/low 21–40%, red amber, medium 41–60%, amber, medium/high 61–40%, green amber and high 81–100%, green. Table 5 shows the benchmark indicator results of Una town, Himachal Pradesh.

Table 5 Result and comparison for wasteaware ISWM benchmark indicator in Una, Himachal Pradesh

S. No.	Category	Indicator	Una town results	Baddi, Himachal Pradesh	Chandigarh city
Background information on city					
B1	Country income level	World Bank income category	Lower-middle	Lower-middle	Lower-middle
		GNI per capita	$1140	$1140	$1140
B2	Population	Total population of the city	18,722	29,911	1,055,450
B3	Waste generation	MSW generation (tonnes/year)	2190	6570	135,050
Key waste related data					
W1	Waste per capita	MSW per capita (kg per year)	153.3	157	128
W2	Waste composition		4 key fractions—as % of total waste generated		
W2.1	Organic	Organic (food and green wastes)	56%	52%	52%
W2.2	Paper	Paper and card	12%	16%	6%
W2.3	Plastics	Plastics	10%	13.5%	7%
Physical components					
1.1	Public health waste collection	Waste collection coverage	90% (M/H)	60% (L/M)	90% (M/H)
1C		Quality of waste collection service	89% (M)	74% (M)	90% (M/H)
2	Environmental control waste treatment and disposal	Controlled treatment and disposal	<10% (L)	17% (L)	30% (L)
2E		Degree of environmental protection in waste treatment and disposal	0% (L)	0% (L)	0% (L)
3	Resource management reduce, reuse and recycle	Recycling rate	0% (L)	0% (L)	0% (L)
3R		Quality of 3R's-reduce, reuse and recycle-provision	<10% (L)	10% (L)	17% (L)
Governance factors					
4U	Inclusivity	User inclusivity	51% (L/M)	52% (L/M)	75%(M)
4P		Provider inclusivity	59% (L/M)	61% (L/M)	78% (M)
6N	Sound institution, proactive policies	Adequacy of national SWM framework	52% (L/M)	52% (L/M)	60% (L/M)
6L		Local institutional coherence	55% (L/M)	58% (L/M)	75% (M)

4.1.2 Matrix Method Evaluation of SWM System

The matrix method is the quantification method for understanding evaluation of the existing MSW management system (Rana et al. 2015; Rana et al. 2017). Using the matrix method, weights have been assigned to parameters in benchmark. In "wasteaware" benchmark, the grading system is assigned and five-point classification is assigned to each grade in benchmark as $L = 1$, $L/M = 2$, $M = 3$, $M/H = 4$ and $H = 5$. Some parameter like background information is excluded as not used in evaluation system.

5 Results and Discussion

The wasteaware indicators were used to assess solid waste management system in the study location, and accordingly suitable scores were assigned to the qualitative and quantitative indicators based on the collected information. The benchmarking indicators of the study area were compared with Baddi and Chandigarh city. Certain differences are observed from Table 5 including the large difference in population and living standard of the people in Chandigarh city compared with our study location and Baddi city. The comparison with Baddi is being done because both the regions are hot regions and are located in the boundary areas of Himachal Pradesh. The benchmark indicator results in Table 5 showed that the collection efficiency and waste collection services are good in Una and Chandigarh categorised as *M*/*H* and Baddi as *L*/*M*, but the environmental control and resource management are almost nil for the two locations in Himachal Pradesh, slightly improved for Chandigarh for all three areas and categorised in low index (*L*). The provision for the treatment, disposal and recycling of the waste is negligible in the study area.

The results obtained in Tables 6 and 7 using the matrix methodology have been compared with both Baddi and Chandigarh cities. The overall efficiency of the waste management system obtained from the study area shows 38% which is slightly higher than Baddi (34%) and much lower than Chandigarh (46%). The results of the quantitative analysis of the wasteaware benchmark parameters were determined to be 36, 30, and 40% for Una, Baddi and Chandigarh respectively. Chandigarh being a planned city has a slightly higher efficiency value on the wasteaware benchmark parameters than the study locations as it is a planned city (Rana et al. 2017). The qualitative parameters have weightage 40% for Una and Baddi but were lower than Chandigarh (55%). Thus, the results from the matrix analysis showed that overall management for the study area and Baddi is categorised as *low* whereas for Chandigarh city it is categorised as low/medium.

6 Municipal Solid Waste Management Options in the Study Area

The "wasteaware" benchmark results showed that effectiveness of the existing solid waste management system of the study area is poor. However, the collection efficiency is quite good in Una despite that the environmental control, disposal and recycling of waste are not in practice in the area. From the results of matrix method, it was observed that overall efficiency of SWM in the study area was very poor (less than 40%). Improvement of the solid waste management system in the study area is of immediate need. Hence, some recommendations are suggested for the improvement of the existing solid waste management system at the study location.

6.1 Segregation at Source

During the study of the solid waste management at Una, it was observed that segregation of waste is not in practice. Source segregation is an effective way to reduce the waste quantity at the site and for proper management of the municipal solid waste generated. The solid waste (recyclable and reusable) at point of generation needs to be segregated, both of which are neither a costly nor a time-consuming process. The process involves separation of several designated materials and be collected into their own specific containers, while other separation techniques may use only two containers—one for the storage of mixed recyclables and the other for regular wastes. Further, the segregation of waste can be done as biodegradable and non-biodegradable material as biodegradables form a significant proportion of the MSW generated at the study location. Biodegradable material like food wastes is conformable to energy generation by anaerobic treatment leading to generation of methane. The segregation of non-biodegradable materials but recyclable materials like paper, plastic, metal and glass can be done by rag pickers, which provide a source for their earning, reduce the burden of dumpsite and thus increase the lifespan of landfill site. Segregation of the waste is important as without segregation it leads to less recycling. Thus, segregation provides the better management of MSW in the area for effective processing/working of management system.

6.2 Reutilisation of Plastic, Polythene and Inert Waste Material

The generation of waste in Indian cities is increasing enormously and having high content of plastic, polythene and other inert materials. Hence, it has become imperative to utilise this material in different applications like in pavements, road construction, as fill material, admixture and binder. Plastic have range of unique properties and can be used at wide ranges of temperature. They can be also be used as pavement and fill material in the embankments or admixtures and binders in cement producing plant. The potential reuse of such type of waste material will significantly reduce the burden of the landfill.

6.3 Implementing Material Recovery Facility (MRF) Centre

A Material Recovery Facility (MRF) is a centralised facility that receives, separates, processes and markets recyclable material. It can be operated with both drop off and curbside programmes. The primary advantage of MRF is that it allows materials to be directly accessed from the municipalities and processes them uniformly. A MRF plant is generally designed to handle all types of recyclables. Implementation of a

MRF in a municipality depends upon a number of factors including market demand, separate collection or segregation, number of different recyclables and quantities of materials. Market demand determines if additional processing is required. Implementation of an MRF is more practical and useful when buyers provide the material specifications. Separate collection system requires residents to separate their recyclables; intermediate separation and processing are required. In general, a MRF will be more beneficial when a large number of different recyclables are collected. Since MRF involves substantial capital and operating costs (e.g. buildings, equipment and labour), it is expected to handle a significant amount of materials to justify its operation.

6.4 Implementation of 4Rs Practices and Aiming for "Zero Waste"

Development and implementation of strategies for waste management are essential to reduce environmental and socio-economic problems. For the proper management and efficient working of the management system, implementation of 4Rs practices should be of absolute necessity. These practices are highly desirable for the effective management in developing countries (Goel 2008).

Waste minimisation can be achieved by focusing on first of 4Rs, i.e. "reduce" followed by "reuse", "recycle" and "recover". The principle of reduction involves utilisation of less quantity of raw products and should be promoted in the study area as well as in other areas of Himachal Pradesh. The study location should also promote the concept of "reuse". It involves reutilisation of the material that is recyclable. "Recycling and recovery" of the waste materials like paper, glass, cardboard, glass leads to reduction in the burden of the landfill. Such processes should be carried out by Municipal Corporation in consultation with NGOs. This is important as the sanitary workers employed by the Municipal Corporation can be properly trained by the NGO. The efficiency of processes depends upon the segregation efficiency in the source. Hence, more the practice of recovering and recycling, further will be the increase in life of dumpsite. Moreover, the concept of "zero waste" is an approach that aims to abolish waste rather than to manage waste. It is an integrated concept for aiming to eliminate waste and allowing us to challenge old ways of thinking. Zero waste describes a "whole-system approach" to redesigning resource flows to minimise harmful emission and to minimise resource use. In this context, zero waste is redesigning cycle of resource extraction, consumption and discard management, so no resources are wasted at any point. Thus, benefits of zero waste are that it helps in pollution reduction, resource conservation, waste cost reduction, increase in the lifespan of landfill, reduction in climate changes and efficient waste management system. The zero waste is an extraordinary concept and can lead society and cities to innovative breakthroughs that can save environment, lives and expenditure (American Env. Health Studies Project 2010).

6.5 Integrated Solid Waste Management

Integrated waste management (IWM) helps in achieving environmental objectives using economically sustainable systems tailored to the specific needs of a community or region. IWM includes use of combination of treatment methodology and technique for effectively managing the MSW stream and is based on fact that waste stream is made up of different components that can be managed and disposed off separately. IWM provides facility of recycling of reusable sources as paper, plastic, metal, glass recovery of sources of energy as refuse-derived fuel (RDF) from high calorific value fraction of waste, compost or biogas from organic (biodegradable) waste. It stimulates innovative development of technology in area like waste to energy and encourages green jobs that ensure safe working condition. IWM encourages the participation of multi-stakeholder in decision-making process with involvement of non-governmental organisation (NGO), community-based organisation (CBO), rag pickers, private sectors, residential and commercial communities with government.

6.6 Installation of Biomethanation Plant and RDF Units

The reported literature has shown that Southeast Asian countries including India have high proportions of organics in the generated MSW. With proper segregation techniques, the organic waste can be used to generate the biogas. The biodegradable organics can be used as the source of energy because the decomposition causes generation of methane. Thus, biomethanation plant can be installed in the study area to utilise the waste. However, generation of biogas will be severely affected during winter seasons due to very low temperatures affecting microbial activity and hence proper heat insulation of the digester would need to be employed. Further, the inorganic component of the waste can be utilised to generate RDF (refuse-derived fuel) and such units can be installed in the study area depending upon the composition and overall generation of the waste.

6.7 Engineered Landfill

For the proper disposal of the generated MSW, well-engineered landfill should be constructed in the study area. The collection of leachate through designed leachate collection system and proper liner system should be constructed to reduce the migration of leachate into ground, thereby preventing contamination of soil and groundwater in the immediate vicinity. Further, ventilation system should be provided to prevent accumulation of landfill gases. This system should be incorporated in the town for better management of solid waste system.

7 Conclusion

Based on the present study, it was observed that the waste generation in the study area is about 5–7 tonnes per day with per capita daily waste generation of 0.42 kg. The collection efficiency of the waste collection is about 80–90% which is quite better than the other cities of the state. However, the collection efficiency of the area is good but despite that storage and transportation facility of the waste are not good because of insufficient number of collection bins and transportation vehicles. Waste is dumped in an open land which causes environmental and health problems. Provision for segregation, reuse and recycling of waste in the town is absent. Based on the benchmark analysis and matrix method, the efficiency of the waste management system in the area was also evaluated which showed poor collection and management system in the study area. The treatment and 4Rs facility in the area are having poor performance in the study area. Thus based on the study of the present municipal solid waste management in area, options for better management were suggested.

References

Al-Khatib, I. A., Monou, M., Abdul, S. F. Z. A., Hafez, Q. S., & Despo, K. (2010). Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district—Palestine.

Anand, S. (2005). Solid waste generation and management in Delhi: A sustainable approach. In J. Singh (Ed.), *Environment and development* (pp. 621–639). New Delhi: I.K. International Publisher.

Beigl, P., & Lebersorger, S. (2009). Forecasting municipal solid waste generation for urban and rural regions. In *XII International Waste Management and Landfill Symposium Sardinia*, Italy.

Biswas, A. K., Kumar, S., Babu, S. S., Bhattacharyya, J. K., & Chakrabarti, T. (2010). Studies on environmental quality in and around municipal solid waste dumpsite. *Resources, Conservation and Recycling, 55* (2) (Kolkata, Nagpur).

Census Report of India. (2011). Provisional population of India. *Director of CensusOperations*, New Delhi, India.

CPCB. (2012). Status of municipal solid waste management.

CPCB. (2016). Solid waste management rules 2016. Available online at: http://cpcb.nic.in/displaypdf.php?id=aHdtZC9TV01fMjAxNi5wZGY=

Das, S., & Bhattacharyya, B. K. (2014). Estimation of municipal solid waste generation and future trends in greater metropolitan regions of Kolkata, India. *Industrial Engineering and Management Innovation, 1*(1), 31–38.

Dube, R., Vaishali, N., & Ramana, G. (2010). Sustainable MSWM in Indian cities—Challenges and opportunities by GTZ (pp. 1–8). [online]: http://www.iswa.org/uploads/tx_iswaknowledgebase/Dube.pdf.

ENVIS. (2013). Manual on municipal solid waste management. Available online at: http://www.envis.org/technology/solid-waste-management

Goel, S. (2008). Municipal solid waste management (MSWM) in India—A critical review. *Journal of Environmental Science & Engineering, 50*(4), 319–328.

Guria, N., & Tiwari, V. K. (2010). Municipal solid waste management in Bilaspur City (C.G.) India. *National Geographer, XLV*(1). ISSN-0470-0929 (Allahabad, UP).

Hazra, T., & Goel, S. (2009). Solid waste management in Kolkata, India: Practises and challenges. *Waste Management, 29,* 470–478.

Katiyar, R. B., Suresh, S., & Sharma, A. K. (2013). Characterization of municipal solid waste generated by city of Bhopal, India, ICGSEE-2013. *International Conference on Global Scenario in Environment and Energy, 5*(2), 623–628.

Kumar, S., Bhattacharyya, J. K., Vaidya, A. N., Chakrabarti, T., Devotta, S., & Akolkar, A. B. (2009). Assessment of the status of MSWM in metro cities, state capitals, class I cities, and class II towns in India: An insight. *Waste Management, 29,* 883–895.

Kumar, S., & Gaikwad, S. A. (2004). Municipal solid waste management in Indian urban centres: An approach for betterment. In K. R. Gupta (Ed.), *Urban development debates in the new millennium* (pp. 100–111). New Delhi: Atlantic Publishers & Distributors.

Ministry of Urban Development. (2016). Municipal solid waste management manual. Part III: The compendium. Available online at http://moud.gov.in/pdf/5853d62984e79584e4bd75a49057efad458c5b0Book301.pdf. Accessed on May 02, 2017 at 1.30 PM.

Ministry of Urban Development, & Government of Himachal Pradesh. (2015). Waste free Himachal Pradesh—A feasibility study.

NEERI. (2010). *Assessment of status of municipal solid waste management in metro cities, state capitals, Class I Cities and Class II Towns*. Annual Report.

Pappu, A., Saxena, M., & Asolekar, S. (2007). Solid waste generation in India and their recycling potential in building materials. *Building and Environment, 42,* 2311–2320.

Pipatti, R., Sharma, C., & Yamada, M. (2006). Generation, composition and management data guidelines for national greenhouse gas inventories.

Rana, P. R., Yadav, D., Ayub, S., & Siddiqui, A. A. (2014). Status and challenges in solid waste management: A case study of Aligarh City. *Journal of Civil Engineering and Environmental Technology (JCEET), 1*(4), 19–24.

Rana, R., Ganguly, R., & Gupta, A. K. (2015). An assessment of solid waste management in Chandigarh City, India. *Electronic Journal of Geotechnical Engineering, 20*(6), 1547–1572.

Rana, R., Ganguly, R., & Gupta, A. K. (2017). Parametric analysis of solid waste management in satellite towns of Mohali and Panchkula-India. Article accepted for publication in *Journal of Solid Waste Technology and Management*, November Edition.

Rawat, M., Ramanathan, A. L., & Kuriakose, T. (2013). Characterization of municipal solid waste compost from selected from selected Indian cities—A case study for its sustainable utilization. *Environmental Protection, 4*(2), 163–171.

Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R. C. (2008). Municipal solid waste management in Indian cities—A review. *Waste Management, 28*(2), 459–467.

Sharholy, M., Ahmad, K., Vaishya, R., & Gupta, R. (2007). Municipal solid waste characteristics and management in Allahabad, India. *Waste Management, 27*(4), 490–496.

Shekdar, A. (2009). Sustainable solid waste management: An integrated approach for Asian countries. *Waste Management, 29,* 1438–1448.

TERI. (2015). Urban waste management in Himachal Pradesh. Available online at http://www.teriin.org/projects/green/pdf/HP-Waste-management.pdf. Accessed on May 02, 2017 at 3.28 PM.

Wilson, D. C., Rodic, L., Cowing, M. J., Velis, C. A., Whiteman, A. D., Scheinberg, A., et al. (2013). Benchmark indicators for integrated & sustainable waste management (ISWM). In *Proceedings of ISWA World Congress, International Solid Waste Association*, Vienna, Austria, October.

Wilson, D. C., Rodic, L., Cowing, M. J., Velis, C. A., Whiteman, A. D., Scheinberg, A., et al. (2015). Wasteaware benchmark indicators for integrated sustainable waste management in cities. *Waste Management, 35,* 329–342.