JEB
Website : www.jeb.co.in
E-mail : editor@jeb.co.in

Journal of Environmental Biology

ISSN: 0254-8704 (Print)
ISSN: 2394-0379 (Online)
CODEN: JEBIDP

SWOT analysis of waste management practices in Chandigarh, India and prospects for sustainable cities

Suman Mor[1,2], Kamalpreet Kaur[1] and Ravindra Khaiwal[3]*

[1]Department of Environment Studies, Panjab University, Chandigarh-160 025, India
[2]Centre for Public Health, Panjab University, Chandigarh-160 025, India
[3]School of Public Health, Post Graduate Institute of Medical Education and Research, Chandigarh-160 012, India
*Corresponding Author E-mail: **khaiwal@yahoo.com**

Abstract

Unscientific disposal of solid waste is common in developing countries, which leads to various environment and human health issues. Considering this, the present study critically investigated the current practices of municipal solid waste (MSW) management in Chandigarh using strengths, weaknesses, opportunities and threats (SWOT) approach for better policy options. Chandigarh city generates approximately 350 TPD of MSW; which comprises mainly of compostable organics (50-55%), inorganics (15-20%) and inert (19-23%) fraction. The unprocessed MSW has calorific value of 1547 kcal kg^{-1} with average moisture content of 50%. The moisture content of the MSW varied significantly in different socio-economic groups including amount of waste generated and its chemical composition (e.g. C, H, N and S). SWOT analysis of MSW management practices highlighted that a single technology (such as refuse drive fuel, RDF) is not effective for complete management of various solid wastes, and hence city specific combination of technologies (e.g. Bio-methanation plant, composting / vermi-composting and recycling unit) should be adopted for sustainable waste management and to reduce its adverse impact. Further, findings of SWOT approach could help in developing a strategic action plans for sustainable cities involving community, private sector and municipal authorities.

Publication Info

Paper received:
10 June 2015

Revised received:
30 October 2015

Accepted:
21 December 2015

Key words

Communities, Hazardous waste, Sustainable cities, SWOT, Swachh Bharat Mission

Introduction

Waste management technologies and policies have not kept pace with the increase in waste production (MacRae, 2012, Kaur *et al*., 2015). The types and quantity of waste materials, rapid population growth, and limited financial resources also make sustainable waste management, complicated in large cities. Hence, solid waste is generally disposed in low-lying areas without taking precaution or operation control in most of the developing countries. This unscientific disposal of industrial, bio-medical and municipal solid waste (MSW) significantly affects not only the local/regional environment but also public health and health of other living beings in the vicinity (Mor *et al.* 2006 a,b; Achudume and Olawale, 2007).

However, negative impacts of waste can be minimized up to some extent by identifying strengths and deficiencies in the current management practices and taking appropriate action to improve them. Various analysis techniques are being used in strategic planning of waste management. Similarly, SWOT analysis gives understanding of strengths, weaknesses, opportunities and threats involved in any activity. This approach helps in specifying the objectives of any activity by assessing the internal and external factors that are favorable or not. United States Environmental Protection Agency (USEPA) recognize that SWOT model is the most relevant model for understanding waste management practices in any area. Greene and Tonjes (2014) suggested that number of indicators might be used for evaluating the quality of waste management systems and its impact on environment. Srivastava *et al.* (2005) used the SWOT analysis in MSW sector and reported that performing SWOT analysis of MSW programme helps in identifying the positive, negative, internal as well as external factors that affect management practices. However, recent review of Allesch and Brunner (2014) showed that there were only limited studies that focus the application of SWOT analysis in waste management, while it could be an effective tool to identify gaps in the existing SWM management practices and to improve them.

Considering this, current study characterized the physical and chemical properties of MSW in Chandigarh Further this study also aimed identifying key factors that are responsible for ineffective waste management and explore the prospects for best practices to reduce the ill-effects on human health and environment using the SWOT approach.

Materials and Methods

City profile : Chandigarh is located in northern side of India and spread over an area of 114 km^2. Originally designed for population of 0.5 million, the city has population of 1.05 million as per 2011 census with growth of 17.10% in this decade. Presently, the city is divided into 56 sectors; among them some sectors can be identified on the basis of income group sectors [City Development Plan Report of 'Chandigarh' (CDPR), 2010]. Hence, in Chandigarh sectors are also demarcated into classes *i.e.* High Income Group (HIG), Low Income Group (LIG) and Medium Income Group (MIG). Each sector covers an area of approximately 102 ha (CDPR, 2010).

Physico-chemical characterization of MSW: MSW was characterized using established methods as detailed by Gomez *et al.* (2009). Samples were collected from vehicles unloading waste from different economic groups in the Refuse Derived Fuel (RDF) processing plant. Vehicles carrying waste from zones covering LIG, MIG, HIG areas were identified and representative samples were collected using quartile method (Tchobanoglous and Kreith, 2002) to understand variation in waste composition with respect to different socio-economic groups. Physical composition of MSW was determined on wet weight basis (without any prior drying of waste samples for removal of moisture) by segregating into various components. Representative samples (n=3) form three different groups were shifted to laboratory for proximate and ultimate analysis. The moisture content was determined by heating samples in an oven at 105°C until constant weight was obtained. Gross Calorific Value (GCV) of sample was analyzed with the help of Bomb Calorimeter. Sample preparation was done as per American Society for Testing and Materials (ASTM, 02947). Before chemical analysis, samples were oven dried at 75°C and grinded into smaller particles, pulverized and sieved through 2mm and 1mm sieves. Volatile matter and ash content were determined by furnace ignition method. Elements like C, H, N and S were measured using Organic Elemental Analyzer (Flash 2000). Oxygen and fixed carbon was calculated as per ASTM standard method. The results obtained were statistically analyzed.

SWOT/SWOC (Strengths, Weaknesses, Opportunities, and Threats/Challenges) analysis : SWOT or SWOC approach used to analyze the opportunities and threats associated with key solid waste management practices in Chandigarh City. SWOT is one of the useful techniques for identifying various factors which refer to strengths, weaknesses, opportunities and threats of a programme or any other related activity. For conducting SWOT analysis information on waste management practices in Chandigarh was collected through laboratory investigations, interview schedules and observation made during field visits. Application of SWOT could help in developing concrete strategic action plans to improve MSW management practices.

Results and Discussion

Per capita waste generation in Chandigarh is around 0.4 kg per day and overall city generates approximately 350 tons per day (TPD) of MSW (Ravindra *et al.,* 2015). Nearby areas of Chandigarh like Amritsar and Ludhiana generates 438 and 735 TPD of municipal solid waste respectively (CPCB, 2015), which is comparatively higher than Chandigarh. As mentioned, Chandigarh is divided in to 56 sectors and the waste generated by each sector varied from 2.5 -4 TPD. The major components of MSW included degradable organics (~52%), inerts (~21%), plastic, paper, cloths (~18%), glass (~1.4%) and others.

Characterization of MSW: The results of physical characterization of MSW are shown in Table 1. Compostable organic fraction formed the major fraction (52%) of MSW followed by inert (21%). In comparison to current study compostable organic fraction accounted for 65% of total MSW in Amritsar and 49.9% in Ludhiana having 61% and 65% of total moisture content respectively (CPCB, 2005). Other studies also showed that developing nations generate organic waste as major fraction (Mor *et al.,* 2006; MacRae, 2012; Khajuria *et al.,* 2010).

Among the three income groups, comparatively higher fraction of degradable materials was observed in LIG. Sharholy *et al.* (2008) also reported increase in organic fraction in MSW with decrease in socio-economic status of the area. The inorganic fractions were in the range of 15-20% on average basis and were reported to be higher in HIG, indicating more use of packaging and disposable products. Atasoylu *et al.* (2007) also reported that in Turkey amount of

Table 1: Physical composition of MSW in three income groups (on wet weight basis in %) of Chandigarh city

Components	HIG*	MIG*	LIG*	Average ± SD
Plastic/ Polythene	8.4	5.5	6.5	6.8 ±1.5
Clothes	4.4	4.4	5.3	4.7 ±0.5
Paper	7.3	5	5.3	5.9 ±1.3
Compostable organic	50.4	52	54.3	52.2 ±2.0
Glass	1.7	1.4	1.1	1.4 ±0.3
Inerts	20.7	19.5	22.5	20.9 ±1.5
Rubber/leather	1.9	0.5	1.5	1.3 ±0.7
Miscellaneous	5.2	11.7	3.5	6.8 ±4.3

*HIG- High Income Group; MIG-Medium Income Group; LIG- Low Income Group; SD: Standard deviation

Table 2 : Variation in chemical composition of MSW originating from different socio-economic areas (on wet weight basis)

Components	*HIG %	*MIG %	*LIG (%)	Average ± SD
Nitrogen	0.6	1.2	2.2	1.3 ±0.8
Carbon	36	33.7	23	30.9 ±6.9
Hydrogen	4.8	5.4	3.3	4.5 ±1.1
Sulphur	0	0	0	0.0
Chlorine	0	0	0	0.0
Oxygen	10.5	5.9	13.5	10.0 ±3.8
Moisture	43.2	51	56.5	50.2 ±6.7
Volatile	29	23.4	19.1	23.8 ±5.0
Ash	26.1	24.7	23	24.6 ±1.6
Fixed carbon	1.3	1.3	0.99	1.2 ±0.2
GCV	2208 kcal kg^{-1}	1429 kcal kg^{-1}	1004 kcal kg^{-1}	1547 ±611kcal kg^{-1}

*HIG- High Income Group; MIG-Medium Income Group; ' LIG- Low Income Group; SD: Standard deviation; GCV: Gross Calorific Valve

recyclable garbage increased as socio-economic condition improved.

The result of chemical analysis is shown in Table 2. Moisture content is an important parameter in understanding the nature of the waste like high moisture content indicates presence of higher fractions of vegetables and other putrescible materials. Moisture content was high in LIG (56%), while lowest was reported in HIG (43%). The presence of high moisture content in low-income areas was mainly due to higher organic fraction, while the presence of more inorganic led to lesser moisture content in high income group areas. The calorific value of MSW was found significantly high in HIG area *i.e.* 2208 kcal kg^{-1} as compared to LIG (1004 kcal kg^{-1}) and can be attributed to the presence of more combustible fraction as LIG have higher fraction of organic material and moisture content. HIG area of Chandigarh showed high calorific value which could be attributed to more use of disposables and packaging material. Annepu *et al.* (2012) reported average calorific value of 1745 kcal kg^{-1} of MSW for India, whereas Chandigarh city had average calorific value of 1547 kcal kg^{-1} of MSW.

Several studies also reported that moisture content in Indian cities varied from 17-65%, whereas C/N ratio from 17-52% (Sharholy *et al.* 2008, Kumar *et al.,* 2009). Analysis of elemental composition of MSW revealed that main element was C (30.9%) followed by O (10%), H (4.5%) and N (1.3%) with C/N ratio of 24%. Higher percentage of C was also reported by Pattnaik and Reddy (2010) in MSW samples collected from Pondicherry and in Kolkata by NEERI (2005) *i.e.* 22.35% of C and 0.8% of N.

SWOT analysis of MSW Management Practices: Municipal Corporation of Chandigarh (MCC) is the main agency responsible for the MSW management of the city including storage, collection of waste and transportation to disposal site and processing plant. Chandigarh has a 45-acre open dumping site in Sector 38 (Dadu Majra) and it is more than 30 years old. The existing solid waste management system of Chandigarh is shown in Fig. 1. Using SWOT analysis, the study aimed to identify gaps in the existing MSW management practices and ways to improve them.

Strengths: Door-to-door collection of waste is practiced and residents pay fixed monthly charges thereby, imposing less financial burden on MCC for door-to-door collection. Apart from MCC, various organizations like Resident Welfare Association (RWA), Chandigarh Animal Welfare and Economic Development Society (CAWEDS) are also involved in the management of MSW. The MSW characterization showed that ~16% of the MSW is combustible in nature. City has the provision of processing and converting it into fuel termed as Refuse Derived Fuel (RDF). This public-private venture partially reduced the pressure on the landfill. Location of separate waste collection stations i.e. Sehaj Safai Kendra's (SSKs) play important role in reducing the diversion of combustible waste fraction through informal picking or burning.

Weaknesses: Lack of source segregation affects the composition of MSW as indicated by the results of proximate analysis showing high moisture and ash content, low calorific value. Physical composition of MSW showed that more than 50% of the waste fraction was organic in nature and were dumped unscientifically at Dadu Majra disposal site. No special arrangement or treatment option were available for season specific leaf waste (urban forestry). Lack of large scale facility for treatment of MSW biodegradable waste e.g. composting unit. Lack of special management plan during monsoons to prevent addition of moisture in waste at SSKs. Absence of active sanitary landfills and formal recycling unit. The miscellaneous fraction of MSW (6.8%) was not given any attention which mainly included E-waste, hazardous waste and biomedical wastes that is still ended up in landfills as a part of municipal waste.

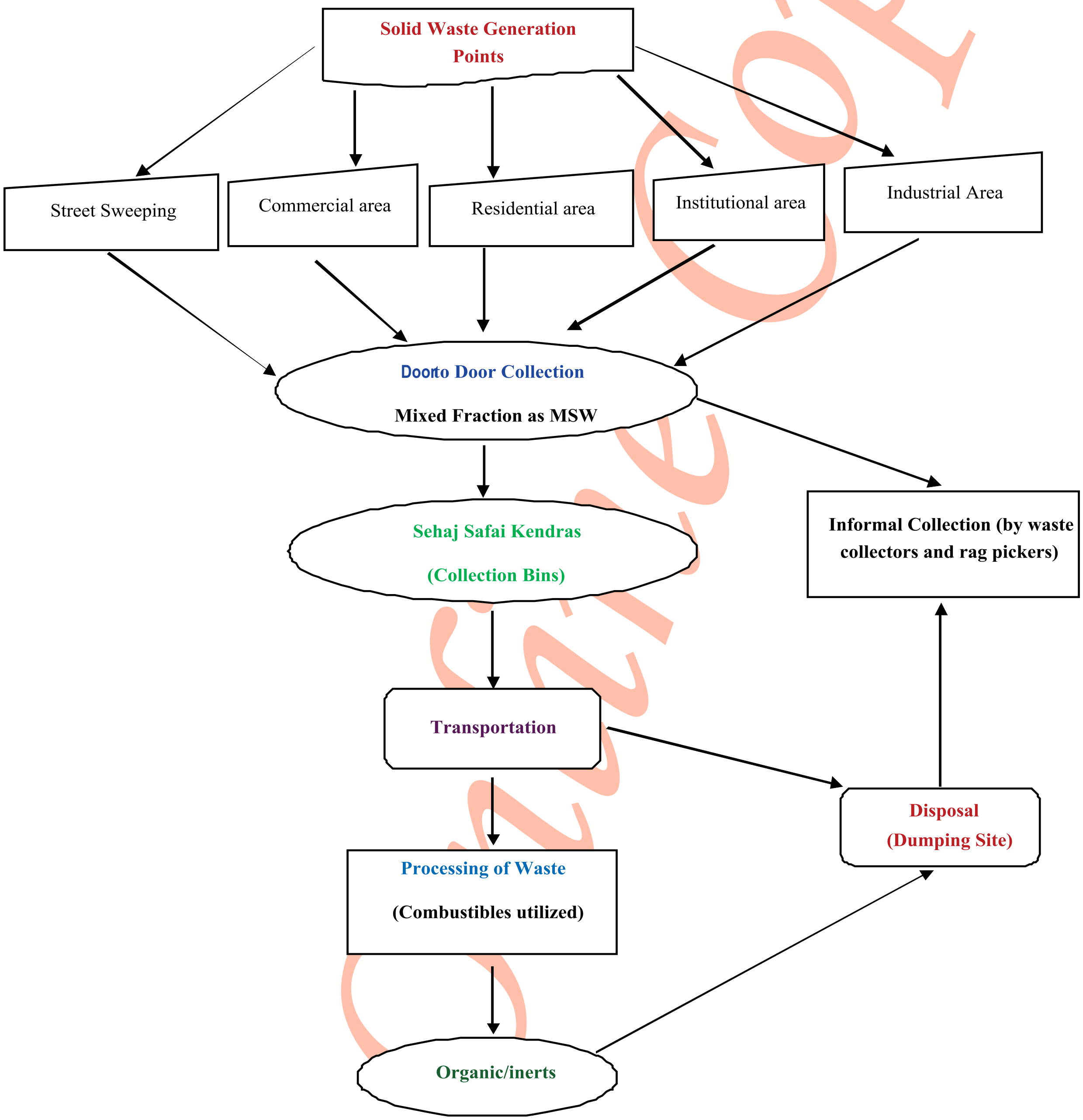

Fig. 1 : Existing MSW management practices in Chandigarh

Table 3 : Opportunities and challenges associated with the key MSW stakeholders in Chandigarh

	Internal factors		External factors	
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Public sector	Existence of waste management system Door-to-door collection of waste is practiced Location of defined waste collection stations or Sehaj Safai Kendra's (SSK) Effective Transportation. Public-private sectors working in good coordination Combustible fraction (16%) of MSW is collected and transported for processing as refuse drive fuel	Lack of source segregation of waste >50% of the waste fraction is organic and dumped unscientifically Absence of active sanitary landfills and recycling units. Miscellaneous fraction of MSW (6.8%) including *E*-waste, hazardous waste and biomedical wastes ended at landfills	Involvement of private sector in waste segregation practices Bio-methanation / composting plant for organic waste Training and facilities for Composting Exploration and expansion of Green consciousness in residents	Dealing with the environmental issues of already existing un-scientific dumpsite Waste handlers are prone to number of health risks· Limited landfill capacity
Community sector	Requisite fee paid by resident for waste collection	Conflict of interest for the location of SSKs Lack of participation in waste segregation	Active participation in waste segregation and composting	Lesser awareness campaigns
Private sector	Processing combustible fraction in RDF 'Refuse Derived Fuel'	Cost–effectiveness of waste processing	Suitable market for recycle products and RDF	Mixed fraction of waste affects overall quality of fuel

Opportunities: Chandigarh can act as role model for 100% compliance of MSW (Handling and Management) Rules, 2000 of India. Based on MSW characterization, study infered that composting and bio-methanation plant for organic waste (e.g. hotel waste) should be established. In-house composting facilities could be set up at the collection points and the capacity could be identified based on different economic group sectors. If sanitary landfill starts working, landfill leachate could be utilized as fertilizer and for irrigating the neighboring agricultural field (Mor *et al.,* 2013, Chen *et al.,* 2014). Source segregation of MSW could help in managing and treating the miscellaneous fraction of MSW in cost-effective way. Establishment of recycling facility could be worked out, especially for *E*-waste. Active involvement of media, NGOs, schools and other educational institutes could play an important role.

Threats: Mixed fraction of waste reduced the overall energy content of the MSW. Weak implementation of various rules and schemes related to waste sector. Lack of awareness among waste handlers about occupational health hazards. Environmental pollution due to generation of leachate and landfill gases from the open dumping site.

Guerrero *et al.* (2013) highlighted that waste management involved large number of different stakeholders, with different fields of interest. Considering this, assessment of internal strengths and weaknesses of the management system including the external opportunities and challenges that can be faced by the various stakeholders are shown in Table 3. The stakeholders were divided into three sectors that included public, private and community sector. Municipal authorities were found usually to be responsible for waste management in the cities, however to provide an effective and efficient system of waste management all stakeholders (public, private and community) need to play a key role. This would also ensure a healthy environment and well being of the local communities.

Prospectus of sustainable waste management: Strategic review and planning could play an significant role in reducing the direct and indirect impact of waste on the environment. Review of existing waste management practices infer that source segregation of waste should be encouraged using color coded bins (Ravindra *et al.,* 2015). Segregation of combustible material at source would ensure that RDF processing plant generate good quality and quantity of RDF. Several studies suggest that composting or vermi-composting can play a key role in organic waste management (Sundberg and Navia 2014, Ponmani *et al.,* 2014)). In-house or community composting should be promoted by MCC. Dry leaves generated during specific season could be densified to reduce the volume for transportation and used in paper industries or for the production of charcoal. Household batteries, discarded medicines and other hazardous material should be segregated and disposed off separately. Special provision should be made in SSKs to collect household hazardous waste separately. Since *E*-Waste (WEEE) Management and Handling Rules (2011) have been implemented recently in May, 2012 and more efforts should be made to make people aware about the sound management of *E*-Waste.

Recently, Government of India has initiated the 'Swach Bharat Mission' campaign with main motive of Clean India, such efforts at large scale are important to create awareness among the masses about effective waste management. However, ensuring that each fraction of waste is treated and disposed scientifically should be the main focus of 'Swach Bharat Mission'.

Alternatives to current practices could be made feasible only if the community subscribes to them and hence local communities and private sector should be involved in strategic decisions. Further, stakeholder-based SWOT analysis could help to explore new ways and means of converting the existing 'threats' into 'opportunities' and shifting the 'weaknesses' into 'strengths' of MSW management programme. Hence, municipal corporations may start appreciation award to promote good waste management practice in various sectors involving local communities. Further, the study conclude that there is no single technology for complete management of waste (e.g. RDF plant in Chandigarh) and hence, city-specific combination of technologies (RDF, bio-methanation plant, vermi-composting and recycling plant etc.) should be adopted for sustainable waste management and as an aid to sustainable cities.

Acknowledgments

RK would like to thank Department of Health Research (DHR), Indian Council of Medical Research (ICMR), Ministry of Health and Family Welfare for providing the Fellowship Training Programme in Environmental Health under Human Resource Development Health Research Scheme.

References

Achudume, A.C. and J.T. Olawale: Microbial pathogens of public health significance in waste dumps and common sites. *J. Environ. Biol.,* **28**, 151-154 (2007).

Allesch, A. and P.H. Brunner: Assessment methods for solid waste management: A literature review. *Waste Manage. Res*., **32**, 461-47 (2014).

Annepu, R.K.: Open dumping of solid wastes in India, Sustainable Solid Waste Management in India; Master of Science in Earth Resources Engineering, Columbia University, New York; pp: 1-230 (2012).

Atasoylu, G., E.D. Evci, E. Kaya,, F. Ergin, D. Tikir and E. Beser: The household garbage in the western coast region of Turkey and its relationship with the socio-economic characteristics. *J. Environ. Biol.,*, **28**, 225-229 (2007).

Central Pollution Control Board (CPCB): Municipal Solid Waste generation and Composition Report of major cities of India (2005).

City Development Plan Report of 'Chandigarh' (CDPR): Chandigarh administration. Jawahar Lal Nehru Urban Renewable Mission. Ministry of Urban Development, GOI, pp. 50-110 (2010).

Chen, C. K., S. L. Lo and T. Y. Chen: Regeneration and reuse of leachate from a municipal solid waste landfill. *J. Environ. Biol.,* **35**, (2014).

Greene, K.L and D.J. Tonjes: Quantitative assessments of municipal waste management systems: Using different indicators to compare and rank programs in New York State. *Waste Manage.,* **34**, 825-836 (2014).

Gómez, G., M. Meneses, L. Ballinas and F. Castells: Seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico. *Waste Manage*., **29**, 2018–2024 (2009).

Guerrero, L. A., G. Maas and W. Hoglan: Solid waste management challenges for cities in developing countries. *Waste Manage.*, **33**, 220-232 (2013).

Kaur K., S. Mor and K. Ravindra: Waste Management Policies in India: Can we address the implementation challenges? *Waste Manage.*, **37**, I-III (2015).

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

Khajuria, K., Y. Yamamoto and T. Morioka: Estimation of municipal solid waste generation and landfill area in Asian developing countries. *J. Environ. Biol.,* **31**, 649-654 (2010).

Mor, S., K., Ravindra, R.P., Dahiya, A., Chandra: Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. *Environ. Monitor. Assess*., **118,** 435-456 (2006a).

Mor, S., Ravindra, K., A. De Visscher, R.P. Dahiya and A. Chandra: Municipal solid waste characterization and its assessment for potential methane generation: A case study. *Sci. Total Environ.,* **371**, 1-10 (2006b).

Mor, S., K. Kaur and K. Ravindra: Growth behavior studies of bread wheat plant exposed to municipal landfill leachate.. *J. Environ. Biol.,* **34**, 1083-1087 (2013).

MacRae, G: Solid waste management in tropical Asia: what can we learn from Bali? *Waste Manage. Res.,* **30**, 72-79 (2012).

NEERI (National Environmental Engineering Research Institute) Comprehensive characterization of municipal solid waste at Calcutta, India. (2005).

Pattnaik, S. and M. V. Reddy: Assessment of municipal solid waste management in Puducherry (Pondicherry), India. *Resou. Conserv. and Recy.*, **54**, 512-520 (2010).

Ponmani, S., C. Udayasoorian, R.M.Jayabalakrishnan and K.V.Kumar Vermicomposting of paper mill solid waste using epigeic earthworm *Eudrilus eugeniae*, *J. Environ. Biol*., **35**, 617-622 (2014).

Ravindra, K., K. Kaur and S. Mor: System analysis of municipal solid waste management in Chandigarh and minimization practices for cleaner emissions. *J. Clean Prod.,* **89**, 251-256 (2015).

Sharholy, M., K. Ahmad, G. Mahmood and R.C. Trivedi: Municipal solid waste management in Indian cities-A review. *Waste Manage.*, **28**, 459-467 (2008).

Srivastava, P.K., K. Kulshreshtha, C.S. Mohanty, P. Pushpangadan and A. Singh: Stakeholder-based SWOT analysis for successful municipal solid waste management in Lucknow, India. *Waste Manage.*, **25**, 531-537 (2005).

Sundberg, C. and R. Navia: Is there still a role for composting? *Waste Manage. Res.,* **32**, 459-460 (2014).

Tchobanoglous, G., Kreith, F. Handbook of Solid Waste Management, second ed. McGraw Hill (2002).