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Greenhouse Gas Emissions in Present and Proposed Municipal Solid Waste Management Plans and Technologies in India: A Comparative analysis of CO_2 Equivalent Emissions from Centralized and Decentralized Municipal Solid Waste Management

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Abstract—*The persistently rising rates of generation of municipal solid wastes in urban India are over riding its population growth. The spatiotemporal changes in the sprawl and structure of urban India indicate an exponentially growing use of the natural capital, especially land. In the current development scenario it is important to evaluate the present and proposed methods and technologies being used to manage municipal solid waste in terms of their greenhouse gas emissions, efficiency and ease of management in synchronization with the growing ecological footprint. This study uses management method specific emission factors in conjunction with the IPCC methodologies to determine the annual greenhouse gas emissions from the present and proposed, centralized and decentralized municipal solid waste management plans. These methods for municip[al solid waste management are being practiced and some have been proposed in various parts of India. The study takes Ahmedabad (Gujarat) as the reference city to compare the greenhouse gas emission results. It also evaluates the results based on sustainability pentagon analysis method and proposes a share in which the present and proposed municipal solid waste management plans be used to minimize its impact on the natural capital.*

1. INTRODUCTION

Urban settlements in urban areas especially over the past two decades have become the hotspots of greenhouse gas emissions around the globe. Amongst the rapid industrialization and urbanization in the developing countries in the world, almost every country has registered a steep rise in greenhouse gas emissions over the past two decades. A major fraction of these emissions originate due to anthropogenic activities like consumption of energy in residential, commercial and industrial sectors, transportation, municipal solid waste generation etc. and tend to absorb and emit the radiations emitted by earth's surface at particular wavelengths within the thermal infrared radiation spectrum [1,2]. The rapid economic and infrastructure development in India, post implementation of liberalization, privatization and globalization in 1991 has been a major driving force to upgrade the lifestyles of its residents and in turn create varied pressures on the natural capital of all metropolitan and urban demographic regions. This occurs due to higher population density in urban and suburban regions [3], persistently increasing urban transport and industrial activities [4], increasing consumption of power and generation of municipal solid waste in the residential sectors due to changing lifestyles [3,5-7]. The emissions from cooking, space heating and cooling, transportation and municipal solid waste generation are playing a major role as drivers of climate change [8-10].

As the change in lifestyle has changed the residential energy consumption and travel patterns, it has also been continuously changing the municipal solid waste generation over the recent years [7]. Biodegradable food and garden wastes dominate in MSW in the developing countries in comparison to the major fraction of paper products in the developed ones [11, 12]. The MSW generation in India is increasing at a rate of 1.33% per capita per year and hence resulted in 48Tg in 1997 from 6Tg in 1947 [13].). Indian urban areas produce MSW at rate of 0.5-0.7 kg/day/capita [14] and have the volatile matter content in the range of 10-30% [15]. As 75% of the MSW generated in India is being dumped into 70-90% of non scientifically managed landfills or open dumpsites [11] the emissions due to anaerobic decomposition in these areas, composing of 60% methane and 40% carbon dioxide with traces of other gases [16] have significant share in the overall greenhouse gas emissions.

Having a federal structure, the states in India play a vital role in implementing the energy generation and efficiency policies

[17]. With the inferences of the effects of the growing greenhouse gas emissions due to rapid energy demands, the importance of actions by the Urban Local Bodies in appropriate policy formations and taking steps to mitigate the pressures created by the changing climate is evident. The recent developments in assessing the scientific evidences of the growing human settlements in the urban areas have listed a series of challenges [18]. One of the most common challenge faced in the developing countries is comprehensively and accurately documenting the data regarding the spatiotemporal developments and human settlements in urban and metropolitan demographic regions [19, 20], lack of uniformity in accounting the details, varied scientific approaches and irregular and random efforts to document the pressures created on the demography have not satisfied the needs organized data collection. Thus, this study evaluates the data collected from Ahmedabad (Gujarat) regarding present and proposed methods of municipal solid waste management to determine the greenhouse gas emissions which would result from them. Hence, it is a useful tool for the Urban Local Bodies in any city, to evaluate their municipal solid waste management methods on this basis and form a composite plan which best suits their demography.

2. METHODOLOGY

CO_2 equivalent emissions from the landfills and non-scientifically monitored sites constitute a major fraction of emissions from the waste sector. They form 3-4% of the anthropogenic CO_2 equivalent emissions globally every year. IPCC methodology of quantifying these emissions describe the method wherein methane and carbon dioxide are the major gases emitted from the first order decay of municipal solid wastes, which decay in the dumpsites at a comparatively slower pace than they are treated. The methane emissions from the waste decomposition keep on descending with the age of the waste as the degradable carbon in the municipal wastes gets consumed by the bacteria. The extent of emissions from the municipal wastes would depend on the fraction of food, garden and other wastes being recycled, the segregation of the organic recyclables from the waste, temperature and climate of the region [21]. Thus, in order to study the CO_2 equivalent emissions from the present dumping, disposal and treatment techniques for municipal solid waste management and to compare these with the CO_2 equivalent emission debits and credits which would result in a scenario when any of the two proposed technologies for efficient municipal solid waste management are implemented, a comprehensive and comparative excel freeware developed by Institute of Energy and Environmental Research (IFEU- Institut für Energie- und Umweltforschung Heidelberg GmbH gemeinnütziges ökologisches Forschungsinstitut) had been used.

3. RESULTS AND DISCUSSION

The calculation of greenhouse gas emissions as tones of CO_2 equivalent released from the dumping, disposal and treatment of municipal solid wastes have been calculated under three different scenarios. 'Status Quo', refers to the methods currently in practice, "Waste to Energy" refers to the waste to energy plants proposed to the urban local bodies, which include processes like gas collection, incineration and other efficient practices, "Decentralized MSW Treatment" refers to the proposed establishment of compact decentralized composting units with respect to the population density, aimed to treat the organic fraction of waste at source and thereby enhance the efficiency of segregation of wastes. The minor fraction of wastes which cannot be recycled or composted efficiently can then be sent to scientifically managed landfills.

Note: The estimates regarding various parameters in this section, referred as 'Author's Estimates' have been made after studying and evaluating the management and disposal practices and techniques at present and the ones which would be adopted in the two proposed scenarios.

The wastes are primarily divided into two major categories: the waste materials like plastics, glass etc. classified under dry waste and waste containing a relatively high organic content (mainly food and garden waste) classified under wet waste [22]. In order to calculate the greenhouse gas emissions generated by the municipal solid wastes, it is important to know their composition with respect to the subject area [23]. Fig. 1 shows the composition of municipal solid wastes in Ahmedabad.

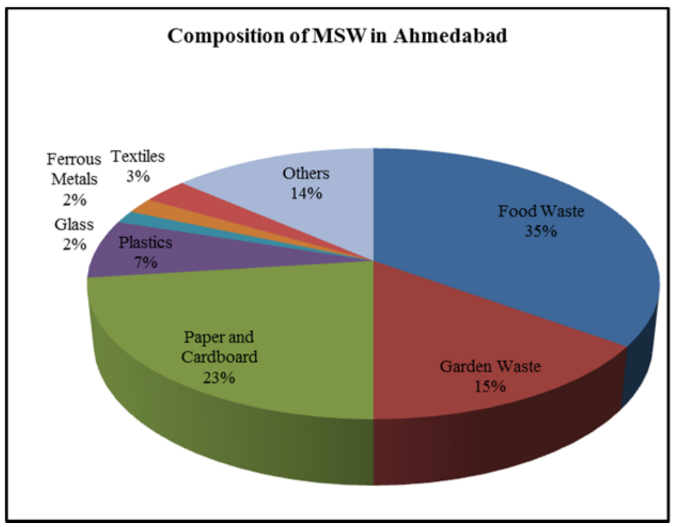

Fig. 1: Composition of Municipal Solid Waste in Ahmedabad Source: Author's Estimates.

In the current scenario, the waste generated per capita is 0.69 kg/day, making the total annual waste generation for Ahmedabad city to be 1,609,650 tones. Food and garden waste constitute almost half a fraction of the total waste generated in the city. In this scenario, the recycling of wastes is of prime importance as it mitigates a major fraction of greenhouse gas emissions which would be generated in case where they are dumped or land filled. Moreover, it is important to know the proportion of total waste being recycled in order to calculate the greenhouse gas emissions related to the municipal solid waste generation and disposal, as the efficiency of recycling of various components of wastes mitigate the emissions that would occur otherwise [24]. Fig. 2 shows the percentage of each type of waste being recycled at present and the percentage which would be recycled in the proposed scenarios.

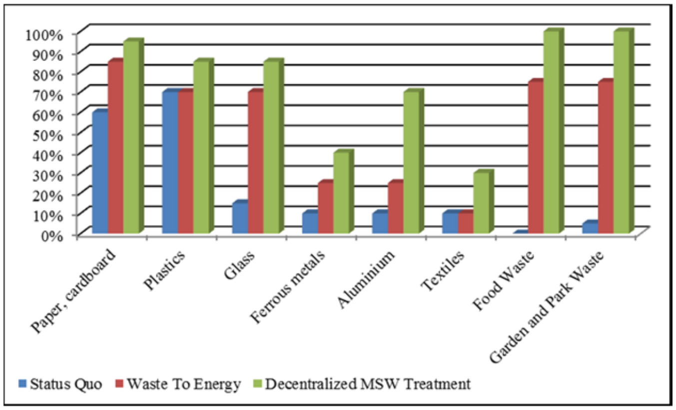

Fig. 2: Percentage of type of waste being recycled at present and would be recycled in the proposed scenarios.
Source: Author's Estimates

If, total waste generated for a particular type (paper, plastics, glass, etc.) = y

Then, percentage of type of waste recycled = x% of y and percentage of type of waste to be disposed = (100-x)% of y

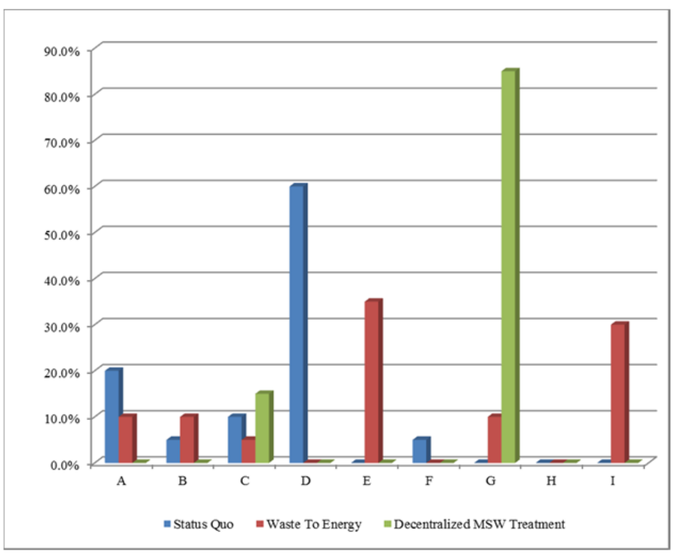

Fig. 3: Percentage of type of waste to be disposed subjected to particular dumping, disposal or treatment processes.

After the classification, segregation and recycling of wastes, it is important to observe the treatment process which the remaining proportion of waste is put in. There are several practices and techniques by which the remaining proportion of waste is being disposed or would be treated. Fig. 3 shows the percentage by which the remaining portion of the waste gets treated or disposed in the present scenario or would undergo in the proposed scenarios.

The rows 'A to I' in the Fig. 3 represent the disposal methods or treatments that the municipal solid wastes undergo after the fraction from each type of waste is sent for recycling. The disposal methods or treatments (A to I), can be described as follows,

A: Localized dumping of wastes or scattered waste which is not burnt.

This refers to the scattered waste being thrown away at particular sites in the near vicinity of any residential area. Although there are no noticeable greenhouse gas emissions from the waste as it is deposited in relatively very small quantities and undergoes aerobic decomposition, but these practices must be avoided in order to avoid health hazards and epidemic diseases [25].

B: Open burning of wastes

This refers to the open burning of wastes by the residents or open burning of wastes in localized and centralized dump sites.

C: Localized wild dump/disposal sites

These are uncontrolled or unmanaged landfill sites. The greenhouse gas emissions from these have been assumed to be equivalent to the emissions from the landfill sites without gas collection as in both cases the dumped waste goes under anaerobic decomposition almost at the same rate [11, 25].

D: Controlled dump sites or centralized landfill sites without gas collection

It refers to a centralized dump site or disposal facility.

E: Well maintained sanitary landfill with efficient gas collection

The efficiency of gas collection has been assumed to be between 10 to 40%. It has been observed that 2/3rd fraction of greenhouse gas emissions from a landfill, take place in the first decade (when the landfill is active), of which methane emissions constitute a major proportion.

If a landfill is well maintained and scientifically managed then 1/3rd of the gases emitted in the first decade and almost 2/3rd of the emissions after the first decade can be collected efficiently [26, 27].

F: Biological stabilization processes in the landfill

It refers to simple biological stabilization processes performed on the MSW and dumping them thereafter in order to lower the greenhouse gas emissions being generated otherwise [28].

G: Landfill after Mechanical and biological treatment processes

These refer to putting the wastes through advanced segregation to separate the metallic and alloy components for recycling purposes and treating the organic waste with different biological treatments. These processes help in increasing the recycling efficiency, separation of refuse derived fuel and hence efficiently reduce greenhouse gas emissions [21,28].

H: Mechanical, biological and physical processes used for stabilization of MSW

It refers to the separation of metals and alloys and putting the remaining fraction of the dumped MSW through physical and biological stabilization processes [29].

I: Incineration

It refers to incineration in a modern MSW incineration plant. The waste has to be thoroughly tested for its qualification of being put through this process. Self sustaining incineration usually requires a minimum calorific value of about 6MJ/kg waste (PD Dr.-Ing. habil. Abdallah Nassour, 2015). Though, low impact flue gas emissions arise from the process, these processes considerably reduce the greenhouse gas generated otherwise to produce equivalent energy (Munish K Chandel et. al., 2012).

Table 1: Total waste generated, amount of waste recycled and amount of waste subjected to various dumping, disposal and treatment processes in the present and proposed scenarios.

	Status Quo	Waste To Energy	Decentralized MSW Treatment
Total waste	1,609,650	1,609,650	1,609,650
Recycled Waste	312,514	1,026,554	1,299,551
thereof			
Food waste	0	422,533	563,378
Garden & park waste	0	181,086	241,448
Paper, cardboard	222,132	314,687	351,709
Plastics	78,873	78,873	95,774
Glass	3,622	16,901	20,523
Ferrous metals	3,058	7,646	12,233
Aluminium	0	0	0
Textiles	4,829	4,829	14,487
Disposed of waste	1,297,136	583,096	310,099
thereof			
A	259,427	58,310	0
B	64,857	58,310	0
C	129,714	29,155	46,515
D	778,282	0	0
E	0	204,083	0
F	64,857	0	0
G	0	58,310	263,584
H	0	0	0
I	0	174,929	0

Thus, on the basis of the inferences from Fig. 2 and 3, the amount of each type of waste being recycled or being disposed of by specific technologies mentioned above has been comprehended in Table 1.

On the basis of the above calculations the greenhouse gas emission debits and credits have been calculated for the present and proposed scenarios (refer methodology). Fig. 4 shows the greenhouse gas emissions as tones of CO_2 equivalent emitted with respect to the amount of msw being recycled and disposed in the present and proposed scenarios and Fig. 5 shows the greenhouse gas emissions as tones of CO_2 equivalent emitted in the present and proposed scenarios.

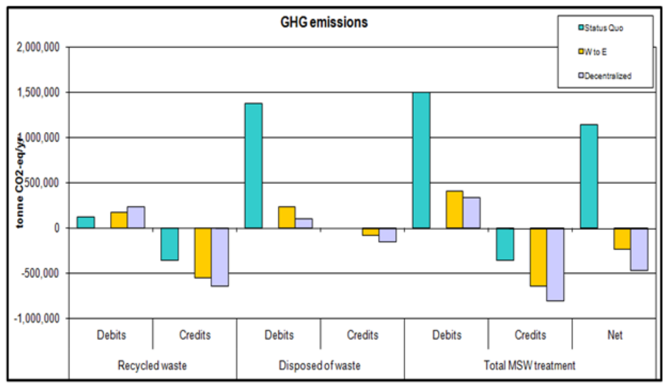

Fig. 4: Greenhouse gas emissions (tCO_2 equivalent) debits and credits due to recycling, dumping/disposal/treatment of disposed waste in present and proposed scenarios.

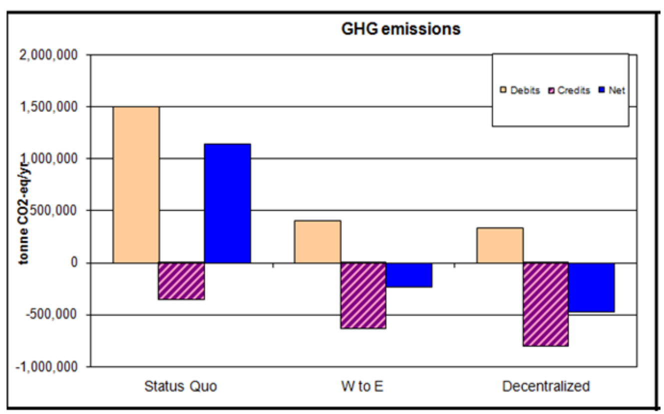

Fig. 5: Greenhouse gas emissions (tCO_2 equivalent) debits and credits in present and proposed scenarios.

4. CONCLUSION

From the above results, it is evident that the 'decentralized' management model for efficient handling, treatment and disposal of municipal solid waste creates the least pressure on the natural capital. Inspite of the ease of handling municipal solid wastes in the 'decentralized' management model, the need of the other technologies cannot be ruled out. Thus, an 'optimal share' of methods used to manage municipal solid waste should be designed in a manner where in the organic fraction gets treated in a decentralized model, a part of the inorganic fraction is sent to the recycling stations/plants, a part of the inorganic fraction (which cannot be recycled) is treated with the 'waste to energy' techniques and the reminder fraction of the above technologies gets landfiled.

5. ACKNOWLEDGEMENTS

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