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Research Article

Study of Green House Gas Emissions in Solid Waste Landfills of Puducherry using WARM software

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Abstract

Solid waste management is one of the challenging and important global concern today especially in developing countries due to its adverse impacts on the environment. Solid waste disposal sites that include both open dumps and landfills are recognized as the major GHG emission sources in developing countries by the researchers. This paper is an attempt to study the Green House Gas emissions from the Municipal Solid Waste disposal sites in Puducherry, India; compared with the reduction that can be brought by using alternative methods of treatment of solid waste .This study compares the greenhouse gas emissions from the unscientific method of landfilling adopted in the area with proposed scientific alternative for each category of waste using the software Waste Reduction Model (WARM) developed by US EPA. This study involves secondary data collected from the Puducherry Union territory and suggests various scientific approaches that can be implemented by the NGO's and Government to reduce the greenhouse gas emissions due to solid waste disposal.

Keywords: Waste Reduction Model; Green House Gas; Landfill; Puducherry; Solid Waste Disposal; LFG Recovery.

Introduction

Municipal solid waste is defined as commercial and residential waste generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes [1,2]. The proper management of the municipal solid waste has become exigent due to the rapid urbanization and exponential growth in population. A typical MSW management system consists of source reduction, segregation, composting, recycling and landfilling [3,4]. There has been notable increase in the generation of MSW in India over the past decades with a daily generation of about 0.1 million tonnes. In this condition more than 25% of the MSW is not collected at all and 70% of the Indian cities are doing inappropriate MSW management due to inadequate facilities for collection, transport and scientific landfills [5].

This current scenario of mismanagement calls for a legitimate solid waste management system to be adopted in the country which can also limit down the greenhouse gas emissions from the landfills. India is the third biggest GHG emitter with its contribution 5.3% behind countries such as China and the USA [6]. The net GHG emissions in 2007 was 1727.71 million tonnes of CO2 equivalent, of which CO2 emission was 1221.76 million tonnes ,CH_4 emission was 20.56 million tonnes and N_2O emission was 0.24 million tonnes. The combined annual growth rate of emission of these greenhouse gases in India is 6.3% (CO_2), 1.2% (CH_4), and 3.3% (N_2O), respectively [7]. These research works identifies the need for a system which could reduce the direct and indirect impacts of improper solid waste disposal.

The present paper aims at studying the greenhouse gas emissions from the present state of Solid waste disposal in the Union Territory of Puducherry and compare them with alternate scenarios. Puducherry earlier known as Pondicherry is one among the seven Union territories of India. It has an area of 492 square kilometers which comprises of small districts of Puducherry, Karaikal, Yanam and Mahe spread across the states of Tamil Nadu, Andhra Pradesh and Kerala. The Puducherry district of the Puducherry Union Territory covers an area of 293 square kilometer with a population of 9,

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50,289 as per 2011 census [8]. This study uses secondary data to assess GHG emission reductions that can be achieved by implementing scientific waste management practices. The present paper uses Waste Reduction Model (WARM) created by the U.S. Environmental Protection Agency (EPA) to help solid waste planners and organizations estimate greenhouse gas (GHG) emission reductions from various waste management practices.

Material and methods

The present study is intended to compare the merits and GHG emission reductions that can be attained by adopting different waste management techniques in Puducherry. WARM calculates and totals the relative GHG emission and energy impacts of prevalent and alternative materials management practices–source reduction, recycling, combustion, composting, and landfilling–using emission factors that EPA has developed based on a materials life-cycle approach [9]. The model can calculate GHG emissions in metric tons of carbon equivalent (MTCE), metric tons of carbon dioxide equivalent ($MTCO_2E$), and energy units (million BTU) across a wide range of 50 material types commonly found in municipal solid waste (MSW). The four basic steps involved in the GHG analysis using WARM are given below.

a. Input of baseline waste generation characteristics.
b. Alternative management scenario input.
c. Landfill characteristics.
d. Waste Transport characteristics.

The first step in WARM is to input the quantity of waste generated corresponding to each material type [7]. The waste generation rate of Puducherry is 370 t/d in 2009, with a waste generation factor of 0.59 kg/capita/day. The MSW of Puducherry consisted of a major amount of yard waste (38.4%) and paper waste (30%) followed by plastics (10.4%) and the remaining comprise of other wastes (Table 1). The quantity of waste generated per day in each material category is calculated by multiplying the waste generation rate per day (370 t/d) and the percentage composition of the material in MSW (Table 1). Also, the annual waste generation in each category is obtained by multiplying 365 days with the waste generation rate per day.

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Table 1. Solid Waste Quantity

Sl. No.	Waste type	Percentage composition (%)	Quantity of waste generated (t/day)	Quantity of waste generated (t/year)
1	Plastics	10.4	38.48	14045.2
2	Rubber and Leather	2.5	9.25	3376.25
3	Textile	4.5	16.65	6077.25
4	Metals	4.1	15.17	5537.05
5	Paper	30	111	40515
6	Food Waste	3.6	13.69	4996.85
7	Glass	5	18.5	6752.5
8	Yard Waste	38.4	142.08	51859.2
9	Wood	1.5	5.55	2025.75

Source: Pattnaik and Reddy, 2009 [7]

The third step is the landfill characteristic with five options such as national average, no landfill gas (LFG) recovery, LFG recovery, recover for energy, and flare. The “No LFG recovery” option was selected because in India landfills are neither designed for it nor equipped with these systems [5]. The final step involves waste transport characteristics which calculates the emissions during transport of materials to the management facility. An average distance of 5-10 miles is used in this study.

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Results and discussion

Analysis of baseline scenario

Baseline analysis using the WARM calculated the current emissions in terms of metric tonnes of Carbon dioxide emitted ($MTCO_2E$). In WARM the data collected can be analyzed under four categories namely recycling, landfilling, combustion and composting. Since, MSW generated in Puducherry are currently landfilled at Karuvadikuppam; they are entered in the landfill category for analysis using WARM.

The Tables 2 and 3, gives the current GHG emissions in Karuvadikuppam landfill site on a daily and yearly basis. In both tables 3 and 4, the positive sign in the total $MTCO_2E$ column indicates that the corresponding waste material type add emissions to the environment. Similarly, negative sign indicates that the corresponding waste type reduce GHG emissions. Thus, from the analysis results it has been found that there is a daily GHG emission of 213 $MTCO_2E$ and a yearly GHG emission of 77,880 $MTCO_2E$.

Currently, source segregation of compostable waste from the mainstream waste is not done at the level of waste generation and collection in Puducherry, which causes a major amount of waste to be dumped in the landfill [10].

Table 2. Daily GHG Emission for Baseline Scenario

GHG Emissions from Baseline Waste Management Scenario ($MTCO_2E$): 213					
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Glass	0	19	0	N/A	1
Food Waste (Non-meat)	N/A	14	0	0	21
Yard Trimmings	N/A	142	0	0	14
Branches	N/A	6	0	0	-1
Mixed Paper (general)	0	111	0	N/A	177
Mixed Metals	0	15	0	N/A	1
Mixed Plastics	0	38	0	N/A	1
Carpet	0	17	0	N/A	1
Tyres	0	9	0	N/A	0

Source: As obtained from WARM (Version 13)

Table 3. Yearly GHG Emission for Baseline Scenario

GHG Emissions from Baseline Waste Management Scenario ($MTCO_2E$): 77880					
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Glass	0	6,753	0	N/A	248
Food Waste (Non-meat)	N/A	4,997	0	0	7,676
Yard Trimmings	N/A	51,859	0	0	4,971
Branches	N/A	2,026	0	0	-524
Mixed Paper (general)	0	40,515	0	N/A	64,445
Mixed Metals	0	5,537	0	N/A	203
Mixed Plastics	0	14,045	0	N/A	515
Carpet	0	6,077	0	N/A	223
Tyres	0	3,376	0	N/A	124

Source: As obtained from WARM (Version 13)

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Analysis of alternative scenario

The alternative scenario calculates the GHG emission reductions and energy savings from proper and scientific management of the waste generated [10]. Mixed paper, mixed metals, mixed metals which cannot be source reduced due to the diverse nature can be recycled effectively to reduce 2,46,845 tonnes of GHG emissions per year. The food waste, yard and wood waste can be composted which can reduce 58,851 tonnes of landfilling per year. The Tables 4 and 5 shows the daily and annual GHG emissions for alternative scenarios.

Table 4. Daily GHG Emission for Alternative Scenario

GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): -566							
Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt-Base) $MTCO_2E$
Glass	0	19	0	0	N/A	-5	-6
Food Waste (Non- meat)	0	N/A	0	0	14	-2	-23
Yard Trimming	0	N/A	0	0	142	-18	-31
Branches	0	N/A	0	0	6	-1	1
Mixed Paper (general)	N/A	111	0	0	N/A	-392	-568
Mixed Metals	N/A	15	0	0	N/A	-66	-67
Mixed Plastics	N/A	38	0	0	N/A	-40	-41
Carpet	0	17	0	0	N/A	-39	-40
Tyres	0	9	0	0	N/A	-4	-4

Source: As obtained from WARM (Version 13)

Table 5. Yearly GHG Emission for Alternative Scenario

GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): -2,06,714							
Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt- Base) $MTCO_2E$
Glass	0	6,753	0	0	N/A	-1,878	-2,125
Food Waste (Non-meat)	0	N/A	0	0	4,997	-772	-8,447
Yard Trimming	0	N/A	0	0	51,859	-6,468	-11,440
Branches	0	N/A	0	0	2,026	-253	272
Mixed Paper (general)	N/A	40,515	0	0	N/A	-1,42,922	-2,07,367
Mixed Metals	N/A	5,537	0	0	N/A	-24,238	-24,441
Mixed Plastics	N/A	14,045	0	0	N/A	-14,522	-15,037
Carpet	0	6,077	0	0	N/A	-14,352	-14,575
Tyres	0	3,3076	0	0	N/A	-1,309	-1,433

Source: As obtained from WARM (Version 13)

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From the WARM analysis results it is clear and evident that proper waste management strategies effectively help in reducing GHG emissions as well as reduce the volume of waste being dumped into the landfills [11]. The total change in GHG emission obtained is 780 $MTCO_2E$ per day and 2, 84,594 $MTCO_2E$ per year. The annual reductions in GHG emissions from WARM analysis when used as input for “US EPA Greenhouse Gas Equivalencies Calculator”, gives a clearer picture of the impacts via the quantification of the equivalents in terms of numbers or units that are easier to relate to, by the general public. The reduction of 2, 84,594 $MTCO_2E$ of GHG that can be achieved by proper management is equivalent to reducing annual GHG emissions from 59,915 passenger vehicles, reducing CO_2 emissions from 3, 20, 23,630 gallons of gasoline, reducing CO_2 emissions from 30, 56, 86,359 pounds of coal burned, reducing CO_2 emissions from 3,767 tanker trucks’ worth of gasoline, reducing CO2emissions from the electricity use of 39,146 homes for 1 year, carbon sequestered by 72, 97,282 tree seedlings grown for 10 years and GHG emissions avoided by recycling 1, 02,005 tonnes of waste instead of sending it to the landfill.

Conclusions

The results from WARM analysis advocates the need for proper solid waste management system in Puducherry. If the MSW is recycled or composted, a huge annual reduction of 2, 84,594 MTCO2E of GHG emission can be achieved in Puducherry. The equivalents of GHG emission given by the “US EPA Greenhouse Gas Equivalencies Calculator” will help to create a public awareness about the adverse impact of the current practices of MSW management and encourage social entrepreneurs to fabricate efficient solid waste management systems. This study proves that WARM is an efficient tool to aid the solid waste managers streamline the prevailing MSW treatment systems.

Conflicts of Interest

Authors declare no conflict of interest.

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