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FORECASTING MUNICIPAL SOLID WASTE MANAGEMENT AND METHANE EMISSIONS IN GREATER CHENNAI METROPOLITAN

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ABSTRACT

Municipal Solid Waste (MSW) is a source of large scale emissions of green house gases. Methane and Carbon-di-oxide are primary drivers of climate change and global warming. Methane more specifically has 21 times the capacity to create global warming than Carbon-di-oxide. This study estimates the emission potential of Municipal Solid Waste (MSW) collected for the baseline year 2016 using UNFCCC's Clean Development Mechanism (CDM). It was found that the amount of methane that is generated from the SWDS in the baseline scenario in year 2016 is 19,527 (t CO2e/yr). This solid waste in the disposed at landfill site has capacity to emit 58,144(t CO2e/yr) in the year 2025 (after discounting the weight fraction of Methane combusted or utilized into another form). The study also identifies Seasonality and Trend of monthly Solid Waste volumes using deseasonalization of time series data. Forecasting of Monthly volumes was performed using smoothening techniques which simulated predicted and actual volumes of solid waste disposed. The fifteen administrative zones of the study area were analyzed using geo-informatics and it was observed Zone 9 (Teynampet), Zone 10 (Kodambakkam) and Zone 13 (Adyar) ranked the highest for its solid waste generation. The study recommends waste minimization, waste-to-energy mechanisms and policy interventions to reduce the volume and emission potential of solid waste disposed at site.

Keywords*: Methane Emissions, Municipal Solid Waste, Clean Development Mechanisms and Time Series Forecasting of Solid Waste Volumes.*

I. INTRODUCTION

Municipal solid waste (MSW) in the third largest anthropogenic emission source and contributed approximately 11% of global Methane (CH_4) emissions . Carbon-di-oxide (CO_2) and Methane (CH_4) are first two causative drivers of Climate Change, which has a Global Warming Potential of 25 over 100 years (IPCC, 2007a). The population increase, internal migrations for economic gains and exponential surge in Industrial enterprises has increased the amount of anthropogenic solid waste disposed, thereby substantially increasing the demand for superior solid waste management services in Chennai, India. Solid Waste Management is indeed an integral civic service that is provided by the local municipalities. Corporation of Chennai is the official government body, which through its integrated public-private partnership is managing the Municipal Solid Waste (MSW) management of the city, very effectively. Solid Waste from fifteen administrative zones of the City are cleared by Greater Chennai Corporation workers, which are further inventoried in a transfer station and then the final disposal into the city dump yard. The final destinations of the city solid waste are the two Landfill Grounds - The Kodungaiyur and the Perungudi grounds. The Kodungaiyur ground which is operational for close to 30 years is about 200 acres and handles about 2100 to 2300 Metric Tonnes of city debris, each day. The Perungudi ground operation for about 25 years is also about 200 acres and handles close to 2200 tonnes to 2400 Metric Tonnes of city debris, each day.

Table 1 Feature of Landfills in Chennai:

Characteristics	Kodungaiyur	Perungudi
Area	200 acres	200 acres
Disposal Site Launch	1980	1987
Years in Operation	30	25

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Current Old Garbage	9.03 million cubic meter	4.3 cubic million meter
Daily Contribution of Solid Waste	2200 – 2400 MT	2600 – 2800 MT

Source: Corporation of Chennai (2017)

The physical components of Municipal Solid Waste (MSW) include 68% residential household waste, 16% Commercial Waste, 14% waste from Marriage Halls, Schools and other Institutions and 2% Industrial waste. MSW includes diverse materials of waste including Green Waste and food Waste (Degradable Organic Material), Inerts, Plastic, Wood, Rubber,… (Fig 1.1).

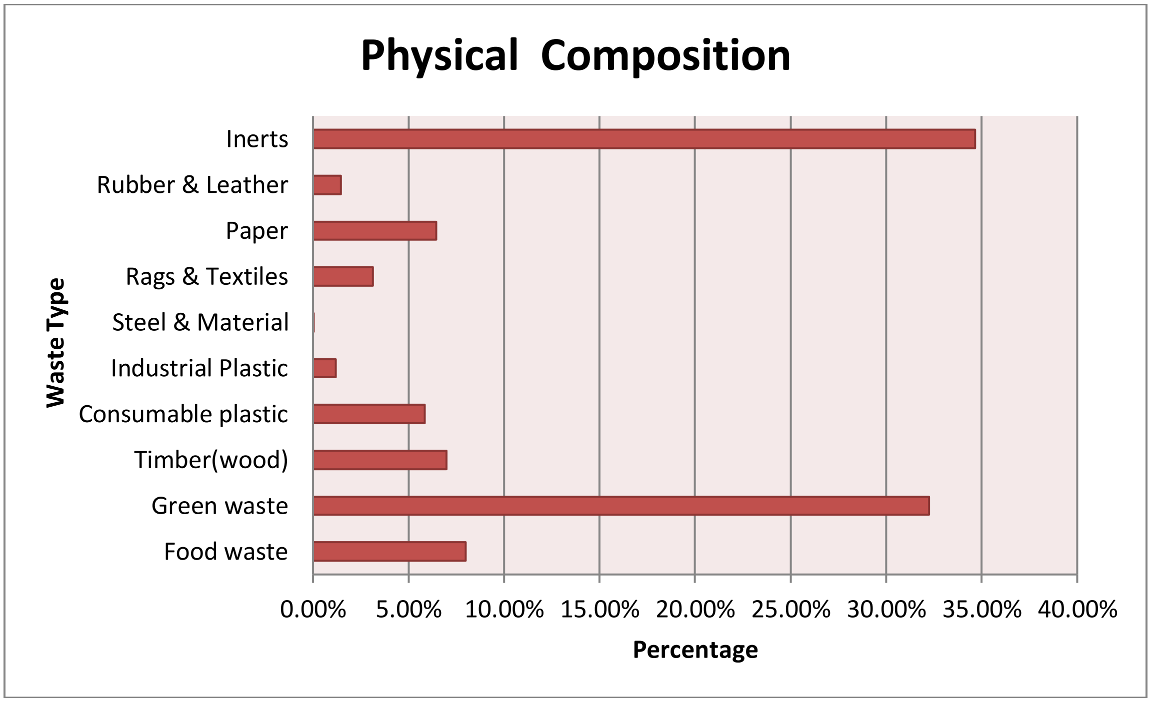

Fig 1.1 Physical Components of Municipal Solid Waste (MSW) in Chennai

Given a state of art infrastructure to effectively manage the municipal waste, there is also a need to inspect the Environmental Lifecycle Assessment of Municipal Solid Waste. Studies have confirmed that a average 60% methane (CH4), 40% Carbon dioxide (Co2) and few other trace gases like Nitrous Oxide (N2O) and perfluorocarbons (PFCs) are released into the Atmosphere from the Municipal Solid Waste (MSW) Land Fills . It should be noted that over 70% to 90% Indian Cities have their mode of disposal of municipal Solid waste into Open Dump yards or Landfill Grounds . The organic material of Solid Waste from the landfill grounds is a major contributor of Atmospheric Methane (CH4), which is a potent Green House Gas. The Anaerobic digestion of organic matter by methonogenic bacteria undergoes the process of Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis to be finally converted to Methane (CH4). Therefore, it is imperative that baseline emissions from solid waste disposed currently needs to be quantified to understand its future emission potential.

This paper tires to quantity methane emissions from current existing solid waste volumes. The estimate is performed using Clean Development Mechanism tool . UNFCCC estimates of Green House Gas Emission adopts First Order Decay (FOD) methods recommended in Revised 1996 IPCC Guidelines for National Greenhouse Gas.

Inventories (1996 Guidelines, IPCC, 1997) and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories and IPCC Fourth Assessment Report (IPCC, 2007b), based on the IPCC guideline for National Greenhouse gas Inventories . Clean Development Mechanism (CDM) is noted to compute base estimates based on broad parameters, existing methodologies of IPCC and more specifically for using core estimate equation with a clear precise understanding of the time variable, which is regarded as an inconsistency in IPCC guidelines -Annex of IPCC latest Edition .

The secondary aim of this paper is to forecast the solid waste generation of the city. The forecasting was performed based on time series analysis of data. Statistical methods of deseasonalization were performed, using R computing technology, to identify trend component, seasonal component and stochastic component. The monthly variation of these curves proved very valuable to enumerate the monthly variations and seasonal impacts of municipal waste generation.

II. METHOD & MATERIAL

Data on Solid Waste for fifteen zones from years 2015 to 2017 was collected from Corporation of Chennai. The methane emission from landfills of Chennai was computed from the baseline year 2016 using Clean Development Mechanism (CDM) which is inclusive of IPCC First of Decay (FOD) Methodology and has greatly regarded for being inclusive of the time variability. There are many ways to estimate green house gases, but Clean Development Mechanism (CDM) is an more appropriate method to estimate atmospheric emissions, for United Nations Framework for Climate Change includes simplified approaches to First Order Decay (FOD) methodology while also addressing the time variability (an inconsistency considered with IPCC Guidelines of 2006) in terms of Constant Solid Waste Decay rates, waste streams of solid waste at disposed at site over the time period… United Nations Framework for Climate Change also have evolved the CDM methodology to address emissions trading (ET) between Annexure-1 and Non- Annexure 1 developing countries, joint implementation (JI) for sustainable energy recovery and structured Intergovernmental Frameworks for project implementation. It's capability to forecast time-dependent, real scenario of Environmental Lifecycle of Methane Emissions for the Solid Waste Disposed at Site (SWDS) for the given time period, made UNFCCC's Clean Development Mechanism (CDM) as a choice for method for this study. The algorithm for estimating Methane Emissions given by Clean Development Mechanism (CDM) is given as:

$$BE_{CH4,y} = \varphi_y \cdot (1 - f_y) \cdot GWP_{CH4} \cdot (1 - OX) \cdot \frac{16}{12} \cdot F \cdot DOC_{f,y} \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j \cdot (y-x)} \cdot (1 - e^{-k_j})$$

Based on the data for the year 2016, the average waste disposed for future years was extrapolated by considering yearly growth rate (Compounding effect). Fraction of methane contributed from Solid Waste Disposal Site (SWDS), which is combusted and utilized in another manner was subtracted from the closing year emissions. Global Warming Potential (GWP), Oxidation Factor (1-OX), Fraction of degradable organic carbon (DOC fy) that decomposes under specific conditions and fraction of degradable organic carbon present in solid waste type as weight fraction (DOCj) were given the default input values of 21, 0.1, 0.5, 20% respectively. The year of year solid waste decay rate was calculated at the average of 0.4 per year. An overall normalization was performed using Methane Correction Factor for the closing emission year and a model correction factor to account for First Order Decay (FOD) computational uncertainties.

The amount of Municipal Solid Waste collected for the Baseline year from fifteen zones of Chennai was 65288 Metric Tonnes annually which would amount to 178.3 Metric Tonnes per day. The computations for the Emission components with baseline value are tabulated in table 2.

Table 2: Emission Factors of Baseline Year

Period	Municipal Solid Waste						
	Wj,x	DOCj	kj	e-kj	(1-e-kj)	kj(y-x)	(e-kj(y-x))
2016	65288	0.2	0.4	0.670320046	0.329679954	0	1

The amount of solid waste disposed in the Landfill side will have a compounding effect, except the fraction of aforesaid combusted or utilized being discounted from the overall weight fractions. This compounding effect is extrapolated for its emission values for until nine years, so to compute the green house gas emissions (GHG) for up to ten years. The computations for the Emission components with baseline value are tabulated in table 2.

Table 3: Emission Factor of 2025 of MSW of Baseline Year

Period	Municipal Solid Waste						
	Wj,x	DOCj	kj	e-kj	(1-e-kj)	kj(y-x)	(e-kj(y-x))
2016-2025	65288	0.2	0.4	0.670320046	0.329679954	3.6	0.027323722
2016-2024	65288	0.2	0.4	0.670320046	0.329679954	3.2	0.040762204
2016-2023	65288	0.2	0.4	0.670320046	0.329679954	2.8	0.060810063
2016-2022	65288	0.2	0.4	0.670320046	0.329679954	2.4	0.090717953
2016-2021	65288	0.2	0.4	0.670320046	0.329679954	2	0.135335283
2016-2020	65288	0.2	0.4	0.670320046	0.329679954	1.6	0.201896518
2016-2019	65288	0.2	0.4	0.670320046	0.329679954	1.2	0.301194212
2016-2018	65288	0.2	0.4	0.670320046	0.329679954	0.8	0.449328964
2016-2017	65288	0.2	0.4	0.670320046	0.329679954	0.4	0.670320046
2016	65288	0.2	0.4	0.670320046	0.329679954	0	1

From the above values we have computed the amount of methane that is generated from the SWDS in the baseline scenario in year 2016 is 19,527 (t CO2e/yr). The compounded year on year value of the solid waste disposed in the base line year would amount to 58,144(t CO2e/yr) for the year 2025.

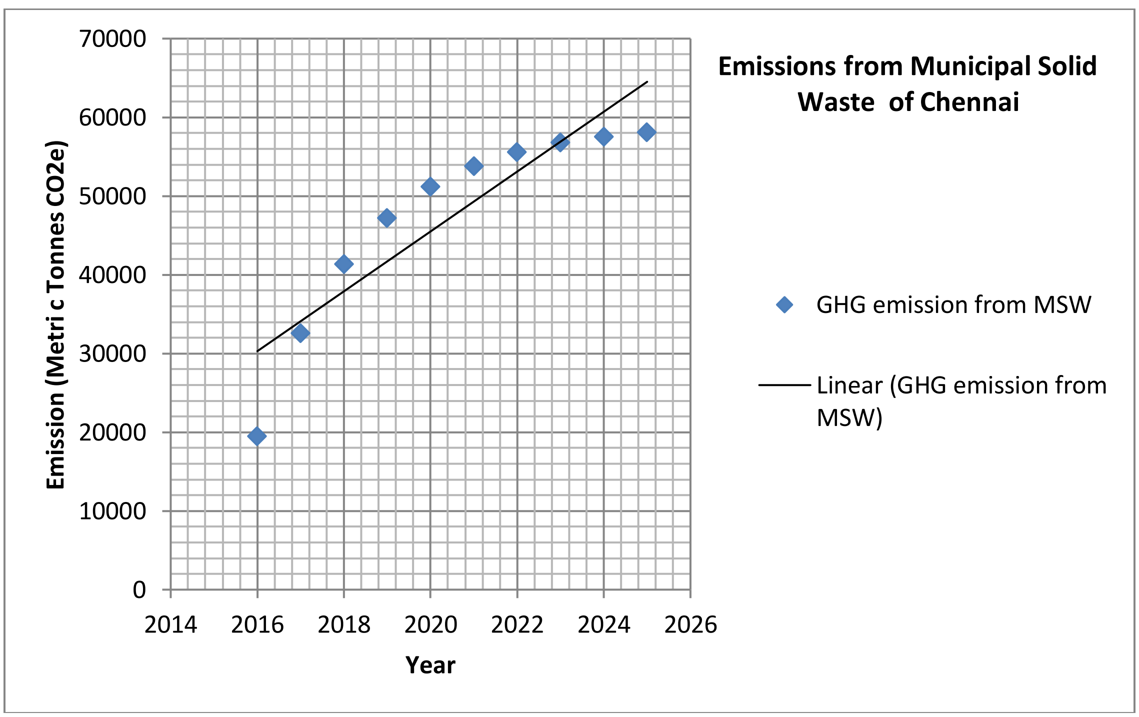

Figure 2: Methane Emission Potential of SWDS for 2016 baseline year

For forecasting the solid waste generation of the city a model on current trends was developed using Time series analysis. The Monthly daily average volumes of solid waste disposed at site (SWDS) from the year 2016 to 2017

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were used to identify trend, seasonality and stochastic components. The time series analysis was applied using Deseaonalize model, in which the seasonal mean was removed from individual metric data and then dividing them individually by the seasonal standard deviation. The need for seasonal adjustments in the regional municipal data was imperative, for the volume of solid waste disposed can largely fluctuate by shorter periodic factors. This extra influx of solid waste due to extraneous seasonal components needs to be identified for it will be exclusive of a masked time-series, devoid of stochastic error component. Hence, a more appropriate method to estimate time-series forecasting, that does not include the white noise was adopted in this study. The daily average municipal solid waste metric data point (Yt) for a frequency of 12 intervals (time t) from the years 2015 to 2017 were first analyzed for Seasonality (St) and Trend (Tt). The average mean of the three year data was 5327, median was 5240 and Standard Deviation was 4928.5. The metric (Yt) plotted on Time series data (Fig 3) indicated Seasonal variations indicated an increasing trend for months from July to November of each year.

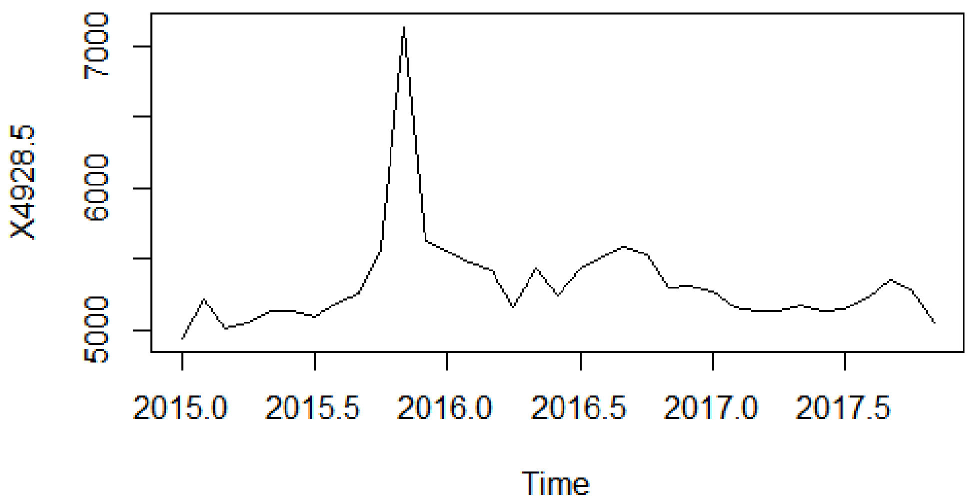

Figure 3: Monthly Municipal SWDS Volume daily average in Metric Tonnes (2015, 2016 & 2017)

However, a modest Trend fluctuation (Tt) over the period of time (t), with one high kurtosis in December 2015 was evident in the model. This high Kurtosis can be attributed to the additional 1500 daily average Metric Tonnes disposed due to the disaster event of Chennai Floods. In the second phase, this Seasonality (St) and Trend (Tt) were removed to estimate the irregular stochastic component. This estimation was performed by calculating simple moving average of time series (Yt) on which additive time series was performed (Yt – Tt). The additive time series was further decomposed to estimate the seasonal component, trend component and stochastic random component, of the average daily municipal solid waste disposed in Metric Tonnes (Fig 4). The decomposed time series plot indicated a strong increase in seasonality (third from top) from July to November of 2016 and 2017. The seasonality plot also showed that the month of April in all three years was lowest, in terms volume of daily average solid waste volume collected.

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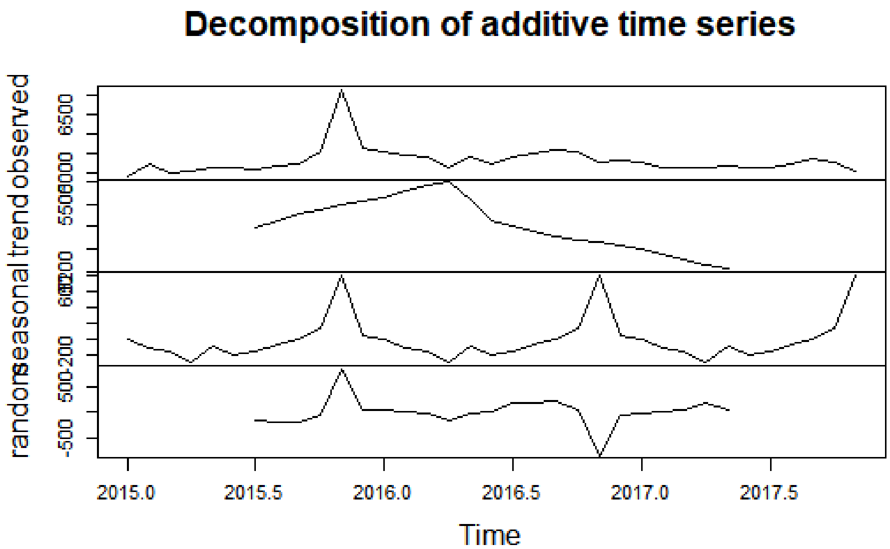

Figure 4: Seasonality & Trend of daily average SWDS in Metric Tonnes (2015, 2016 & 2017)

The daily average municipal solid waste metric data points (Yt) on trend plot pointed an outlier in December 2015 metric point, an causative factor of city's flood disaster event. The outlier point was removed from the total 36 metric data points and smoothening technique was performed. Removing the random variation from the historical data points allowed forecasting simulation of predicted values and actual values.

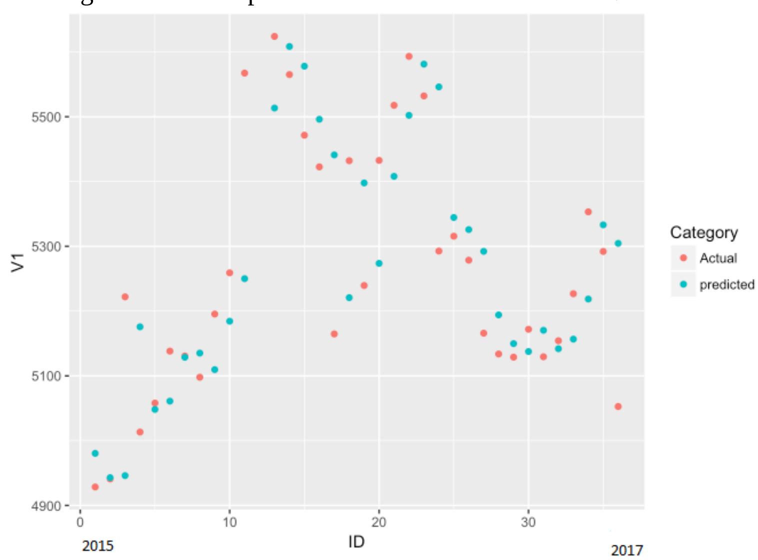

Figure 5: Forecasting SWDS in Metric Tonnes using Smoothening moving average (2015, 2016 & 2017)

The collection of Municipal Solid Waste (MSW) from fifteen administrative zones of Chennai, for the years 2015 to 2017 was mapped on GIS and analyzed for its variation in volume of waste material.

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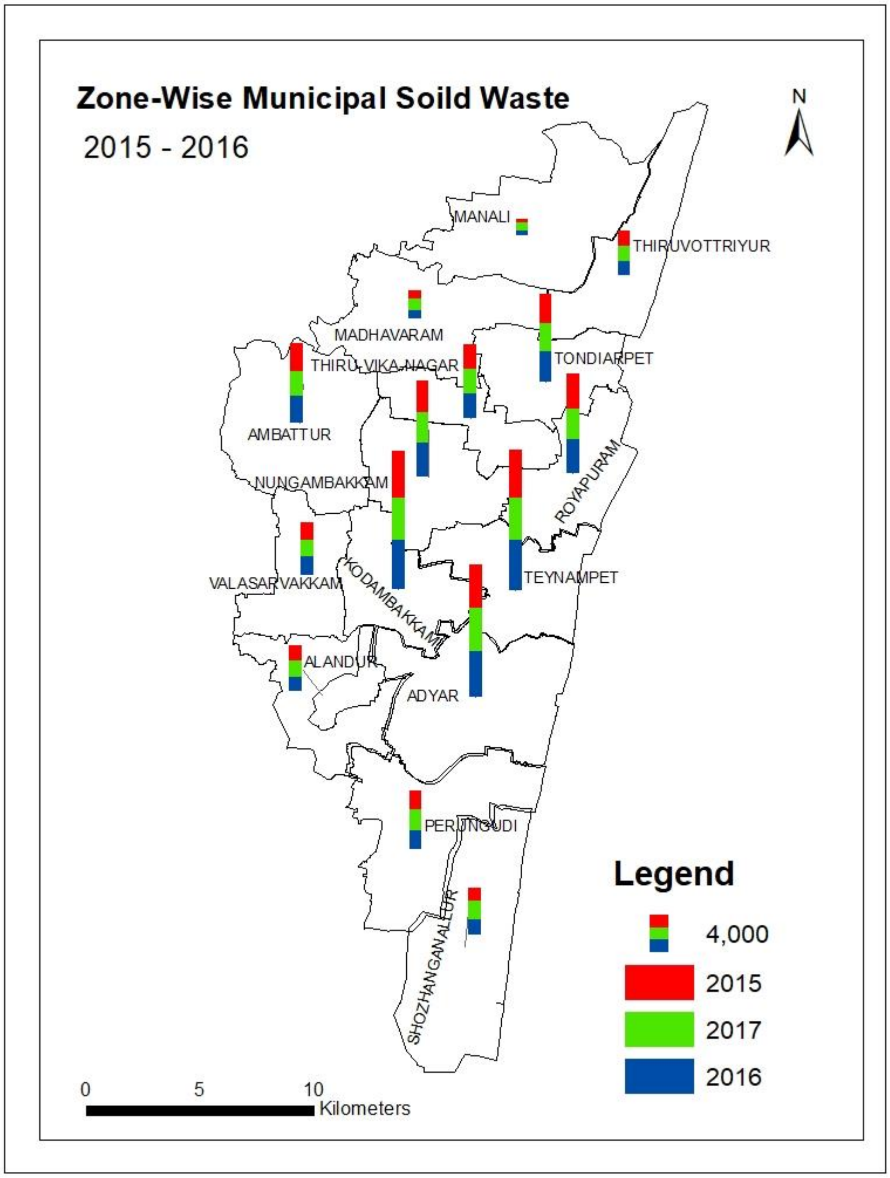

III. RESULT & DISCUSSION

The amount of methane that is generated from the SWDS in the baseline scenario in year 2016 is 19,527 (t CO2e/yr). This solid waste in the disposed at landfill site has capacity to emit 58,144(t CO2e/yr) in the year 2025 (after discounting the weight fraction of Methane combusted or utilized into another form. It should be noted that this valued assed, as per UNFCCC's Clean Development Mechanism (CDM) method, is the minimum emission guaranteed in 2025, if the solid waste disposed at site (SDWS) is not recycled or treated to be converted into energy. The additional year on year Municipal Solid Waste discarded actually into the landfill, will even further add to the baseline volume of solid waste, thereby aggravating the burden of emissions exponentially. This study has quantified the potential surge in Methane emissions from municipal solid waste, so for the stakeholders to be aware the possible vulnerability of toxic Air Quality, which may eventually lead the citizens to be negatively impacted by Climate Change.

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The study also observed that there were seasonal variations in the volume of Solid Waste disposed and collected from Municipal Authorities. Hence, deseasonalization or trend decomposition was performed on time series data. The results identified trend, seasonality and stochastic components of the Monthly daily average volumes of solid waste disposed at site (SWDS) from the year 2016 to 2017. It was observed that July to November saw an overall increase in municipal solid waste (MSW) volume disposed at sight. The highest volume of municipal solid waste (MSW) was collected in the month of October and the lowest was collected in the month of March. This could be largely be attributed to generous moisture content (MC) available through retreating monsoons of South India, thereby increasing the water holding capacity and volume of municipal solid waste (MSW). The municipal solid waste (MSW) volumes forecasting performed using smoothing time series analysis, predicted the month on month volume in Metric Tonnes with an average residual of ±300 Metric Tonnes. The geo-informatics analysis on Greater Chennai Corporation (15 administrative Zones), showed that there is increased Municipal Solid Waste generated from Zone 9 (Teynampet), Zone 10 (Kodambakkam) and Zone 13 (Adyar). The Solid Waste data also showed that Inert Waste (34.65%) and Green Waste (32.25%) were the major physical components in Solid Waste disposed at landfill sites.

IV. CONCLUSION

The study has brought out the Chennai Municipality's potential of Methane emissions for the solid waste disposed at site (SWDS) for the baseline year 2016. It should be noted that Methane has twenty one times global warming capacity than Carbon-di-oxide and other green house gases. In practice, 65% to 80% energy content of organic waste can be recovered as heat or electricity . Hence, it is important that waste to energy mechanisms which recovers heat or electricity before solid waste is disposed at dump yard sites, are adopted by the municipality. It is also important that sustainable environmental practices of waste segregation at source, Reuse and Recycling which minimizes waste at source are propagated. Policy Interventions from Central, State and Local Bodies are required for effective implementation of a holistic and an Integrated Solid Waste strategy

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