

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 9, September 2017

# Estimation of Methane and Carbon Dioxide Concentration at Landfill Sites in Udaipur, Rajasthan

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**ABSTRACT:** The landfilling of the waste is the significant source of greenhouse gas emission when organic part of the solid waste undergoes phases of degradation, i.e., hydrolysis, fermentation/ acidogenesis, acetogenesis and methanogenesis. The study was conducted in Titardi and Baleecha landfill sites situated in Udaipur, Rajasthan in the month of May, June and July based on the availability of waste to estimate the concentration of methane and carbon dioxide by using the flux chamber methodology the results of the investigation indicated that seasonal fluctuations, temperature, moisture, age and composition of the waste has a significant effect on generation of potent greenhouse gases. The results reveal that there was no correlation exists between the amount of generation and emission of these gases in the ambient air. These two gases trap the heat from the atmosphere and raise the temperature.

**KEYWORDS:** Landfill, greenhouse gas, organic waste, seasonal fluctuations.

### I. INTRODUCTION

The urbanization and changing consumption pattern of the growing population resulted in the increment of municipal solid waste that will be doubled worldwide by 2025 in Climate Summit (2014) [4]. Landfills are the third largest source of anthropogenic greenhouse gas emissions, i.e. 11% estimated global emission. The near and long term climatic impact of the solid waste sector, such as air pollution in cities that in turn affecting the human health. The major source of GHG emission is the landfill waste degradation mentioned in the chapter Landfill gas basics (2001) [12]. Landfill gas is the byproduct of bacterial decomposition under aerobic and anaerobic condition in the organic fraction of landfill waste. It is collected and transported in the trucks and tippers and dumped into the landfill site where it is first undergoes aerobic (oxygen) decomposition and within a time period of a few months it finally achieves an anaerobic condition where methane producing bacteria begins the process of methanogenesis and producing methane as studied by Ghosh S, et. al., (2011) [6]. Landfill gas constitutes the major amount of methane and carbon dioxide and in minimum other non methane organic compounds. Methane is more effective, i.e. 28 to 36 times than carbon dioxide in trapping atmospheric heat to raise the surface temperature as mentioned in the article USEPA, (2004) [3].

The urban population demands have increased imposed a great pressure on availability of the resources and the consumption of resources in turn generates a large volume of waste which is very difficult to manage by the municipal corporation of Udaipur and its transportation to the dump sites is also challenging task because littering on the travelled road has been creating ugly look. The total waste generated in the city per day is in the range of 200-250 tons out of which only 150 tons have been managed and dumped by the Municipal Corporation estimated by Meena R.S (2016) [1]. The waste generation rates are fluctuating seasonally due to festivals, events like the opening of restaurants, marriages, processions and so on. The unattended waste piles are commonly seen in and around the city which attenuated towards its potential hazards like transmission of diseases, fouling smell, increases surface temperature and emission of gases, which is needed to be undertaken for the investigation as it deteriorate the environmental quality and health hazard for human.

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## II. RELATED WORK

The related work had been done by many scientists across the world a study carried out by Yesiller N. (2003) & Wang Y.et.al, (2012) who has studied the effect of temperature on long term behavior of municipal solid waste degradation. The concurrent study carried out by Sunday Ighovie Efe, et. al., (2013) studied the ‘Effects of solid waste on urban warming in Warri metropolis, Nigeria’ in that investigation, they found that the gas production heat the earth's surface and increase the air temperature as the production of CO<sub>2</sub> traps the air temperature. Similar lines of research have been performed by Scarlet N. et. al, (2015), ‘An evaluation of the energy potential of Municipal Solid Waste from African urban areas’ they found that moisture plays an important role in gas production. The studies have been done by Mohammed F.M. et. al (2016) on seasonal variation of landfill methane and carbon dioxide in tropical climate. In India few researchers had done the related work, namely Akolkar A.B, et. al., (2008), ‘Assessment of methane emission from municipal solid waste disposal site’ by using the default methodology of IPCC, 2006. The concurrent study by Ghosh S, et. al., (2011), on ‘Sanitary Landfill, Encyclopedia of Life Support Systems’ (EOLSS) in which they found that potentiality of landfill gas generation and it can be better utilized as an energy resource for other sectors. Thus, the main objective of our study is to collect the emission data of these greenhouse gases from the waste disposed in the landfill by adopting an appropriate methodology in addition to this, to estimate the generation rate in seasonal fluctuations, the asses contribution of greenhouse gases in surface warming and inform future policy makers and can be further utilized as an energy resource.

### Description of the study area:

Two major non sanitary landfill sites were studied in Udaipur i.e. Baleecha and Titardi. These two are located outskirts of the city and every day a large volume of the waste has been thrown into these areas the waste piles releases bad odor and gases which is polluting the nearby environment. The three months sampling had been done with the help of the static flux chamber technique are used to estimate the rate of generation of these gases.

### The description of Baleecha Landfill Site:



Fig-A: Baleecha Landfill Site

Baleecha near Savina is a non sanitary landfill site in the southern part which is situated 8.3 km from the city and has an area of 54 Ha. This site is new for open dumping of the solid waste generated in the city. Daily trucks and tippers are loaded with tons of waste and are dumped into this site. The site is full of cattle and rodents that are meant for scavenging process.

### The description of Titardi Landfill Site:



Fig-B: Titardi Landfill Site

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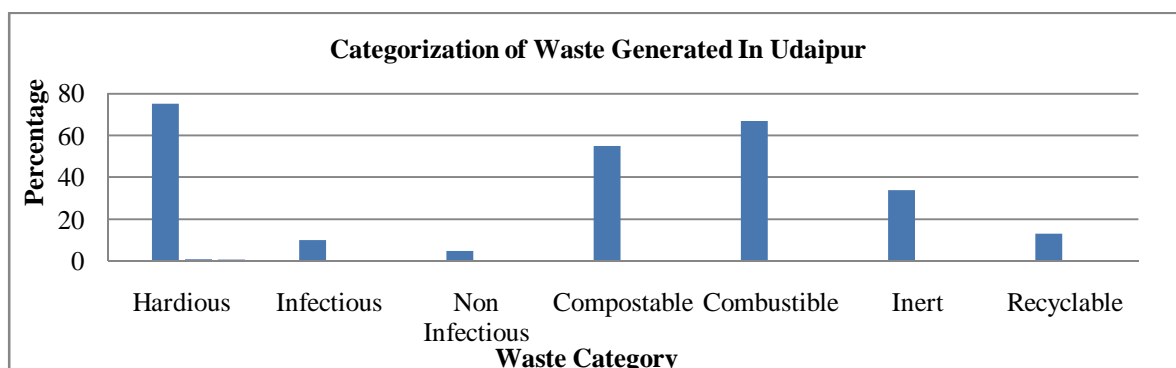
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Titardi which is located about 7.3 km from the city and has an area of 19 Ha. It is an old landfill site of the city around 10-15 years old site has been used for dumping the large volume of waste collected from the city.

**Composition of the Landfill Waste:** The landfill waste contains plastic, textile, metal, food and garden scraps, paper, ceramic, fine earth and ash and others. It is generated from different sources in the city and is categorized as **non hazardous 75%, infectious 10%, non-infectious 5%, compostable 55%, combustible 67%, inert 34% and recyclable 13%** estimated by Meena R.S. (2016) [1].



**Graph 1: The graph showing the waste category with percentage as generated in Udaipur Region**

The third parameter need consideration is **mean chemical characteristics** of MSW is under normal conditions and the data reveal that normally **pH** remains at 8.04, **calorific value** is 1765.18 calories, **compostable matter** is 67.75%, **non-volatile matter** on dry basis is 76.8%, **volatile matter** is 25.9 %, **organic carbon** on dry basis is 11.34%, **Nitrogen** on % dry basis is 2.04%, **Carbon** on% dry basis is 33%, **C/N ratio** on total dry basis is 5.7:1 and **Phosphorus** is 0.39%, **Hydrogen** % is 1.20; **Sodium** is 4.2 and lastly **Potassium** is 36% estimated by Meena R. S (2016) [1].

**The methodology used to estimate the Gaseous Emission:** The sampling of gases at both landfill sites had been done by using the flux chamber technique; it is developed by US EPA as mentioned in the project report of Radian Corporation, (1986) [2] for landfill gas surface monitoring. Flux chamber is a rectangular flux box having dimensions 60 cm × 33 cm × 70 cm. It consists of a hole on the top the chamber for the collection of Land Fill Gas samples with 50 ml polyethylene syringe. The syringe is coupled with three way plastic vials which operate in the closed and open position. At a time of 5-15 minutes only 40 ml gas sample is collected from the flux chamber. The flux chamber was placed on a flat surface at the landfill site and sealed with soil along the periphery to prevent the ingress of air. To measure the flux it is the emission rate per area or mass per unit time per area. Whereas the emission rate is the mass per unit time. The emission flux rate can be calculated by multiplying (mass/time/area) by the surface area responsible for emission event by Akolkar A.B, et. al., (2008) [5]. The gas samples are analyzed with gas analyzer which is provided with sensor probe and graphic LCD to detect the concentration of carbon dioxide and methane gas in the gas samples. The temperature reading was recorded by using a digital temperature sensor.

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### III. RESULT AND DISCUSSION

**Table1: Studied parameters during the month of May, June and July (at Baleecha Landfill Site)**

Sample	Methane Conc.	Carbon Dioxide Conc.	Time (Sec.)	Rate of Generation (DC/DT)		Flux $\mu\text{g}/\text{m}^2\cdot\text{sec}$	
				CH <sub>4</sub>	CO <sub>2</sub>	CH <sub>4</sub>	CO <sub>2</sub>
<b>A</b>	May	May					
1A	46.3 $\mu\text{g}/\text{m}^3$	39.2 $\mu\text{g}/\text{m}^3$	300	0.0313	0.0336	0.0219	0.0235
2A	52.2 $\mu\text{g}/\text{m}^3$	48.9 $\mu\text{g}/\text{m}^3$	600				
3A	65.1 $\mu\text{g}/\text{m}^3$	59.4 $\mu\text{g}/\text{m}^3$	900				
<b>B</b>	June	June					
1B	69.2 $\mu\text{g}/\text{m}^3$	57.9 $\mu\text{g}/\text{m}^3$	300	0.061	0.069	0.0427	0.0487
2B	81.4 $\mu\text{g}/\text{m}^3$	79.6 $\mu\text{g}/\text{m}^3$	600				
3B	105.8 $\mu\text{g}/\text{m}^3$	99.7 $\mu\text{g}/\text{m}^3$	900				
<b>C</b>	July	July					
1C	57.8 $\mu\text{g}/\text{m}^3$	49.6 $\mu\text{g}/\text{m}^3$	300	0.0193	0.0148	0.0135	0.0103
2C	64.2 $\mu\text{g}/\text{m}^3$	50.8 $\mu\text{g}/\text{m}^3$	600				
3C	69.4 $\mu\text{g}/\text{m}^3$	58.5 $\mu\text{g}/\text{m}^3$	900				

The above results obtained at Baleecha landfill site showing the temporal variations in the concentration of methane and carbon dioxide, which is maximum in June than July and minimum in May due to certain reasons as illustrated in result I, II, III & IV.

**Table 2: Studied Parameters During the month of May, June and July (at Titardi Landfill Site)**

Sample	Methane	Carbon Dioxide	Time (Sec.)	Rate of Generation (DC/DT) $\mu\text{g}/\text{m}^3\cdot\text{sec}$		Flux $\mu\text{g}/\text{m}^2\cdot\text{sec}$	
				CH <sub>4</sub>	CO <sub>2</sub>	CH <sub>4</sub>	CO <sub>2</sub>
<b>D</b>	May	May					
1D	54.4 $\mu\text{g}/\text{m}^3$	48.3 $\mu\text{g}/\text{m}^3$	300	0.0156	0.018	0.0109	0.0126
2D	59.6 $\mu\text{g}/\text{m}^3$	47.9 $\mu\text{g}/\text{m}^3$	600				
3D	63.8 $\mu\text{g}/\text{m}^3$	58.7 $\mu\text{g}/\text{m}^3$	900				
<b>E</b>	June	June					
1E	74.9 $\mu\text{g}/\text{m}^3$	70.2 $\mu\text{g}/\text{m}^3$	300	0.0721	0.0723	0.0504	0.0506
2E	93.4 $\mu\text{g}/\text{m}^3$	89.2 $\mu\text{g}/\text{m}^3$	600				
3E	118.2 $\mu\text{g}/\text{m}^3$	113.6 $\mu\text{g}/\text{m}^3$	900				
<b>F</b>	July	July					
1F	49.7 $\mu\text{g}/\text{m}^3$	44.2 $\mu\text{g}/\text{m}^3$	300	0.0281	0.0251	0.0197	0.0175
2F	59.4 $\mu\text{g}/\text{m}^3$	52.6 $\mu\text{g}/\text{m}^3$	600				
3F	66.6 $\mu\text{g}/\text{m}^3$	59.3 $\mu\text{g}/\text{m}^3$	900				

The above results obtained at Titardi landfill site showing the temporal variations in the concentration of methane and carbon dioxide, which is maximum in June than July and minimum in May due to certain reasons as illustrated in result I, II, III & IV.

$$\text{Formulas: Flux} = \frac{\text{Volume}}{\text{Area}} \times \text{DC/DT}$$

DC /DT =slope of the linear regression of volumetric gas concentration on time (Sec<sup>-1</sup>)

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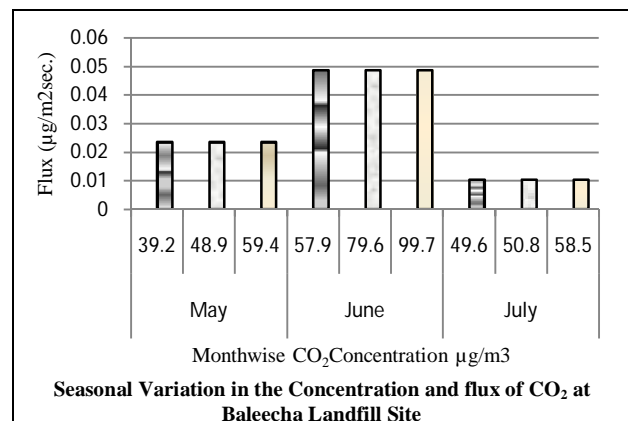
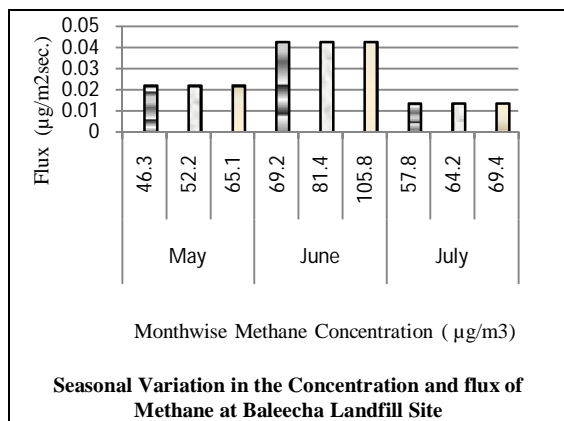
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$$\text{Methane concentration} = \frac{\text{Peak area of unknown sample}}{\text{Peak area of methane standard}} \times \text{Concentration of methane in standard}$$

- I. The significant changes in the LFG generation due to seasonal fluctuations had been considered important very similar studies have been done by Mohammed F.M. et.al (2016) on seasonal variation of landfill methane and carbon dioxide in tropical climate [10]. The dry summer season and wet rainy season are the most favorable for the generation of landfill gases. Thus, the concentration of methane and carbon dioxide in the waste surface in June and July was more as compared to May. The maximum and minimum methane concentration in June were 118.2  $\mu\text{g}/\text{m}^3$  and 69.2  $\mu\text{g}/\text{m}^3$ , respectively, whereas the carbon dioxide levels were 113.6  $\mu\text{g}/\text{m}^3$  and 57.9  $\mu\text{g}/\text{m}^3$  respectively. Similarly, in July the maximum and minimum concentration of methane were 69.4  $\mu\text{g}/\text{m}^3$  and 49.7  $\mu\text{g}/\text{m}^3$ , respectively, whereas the maximum and minimum carbon dioxide concentration were 59.3  $\mu\text{g}/\text{m}^3$  and 44.2  $\mu\text{g}/\text{m}^3$  respectively. The concentration of both the gases in the month of May i.e. for methane were 65.1  $\mu\text{g}/\text{m}^3$  and 46.3  $\mu\text{g}/\text{m}^3$  whereas the carbon dioxide maximum and minimum were 59.4  $\mu\text{g}/\text{m}^3$  and 39.2  $\mu\text{g}/\text{m}^3$  respectively.



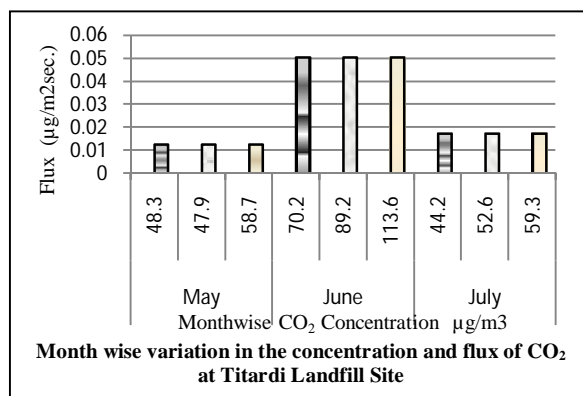
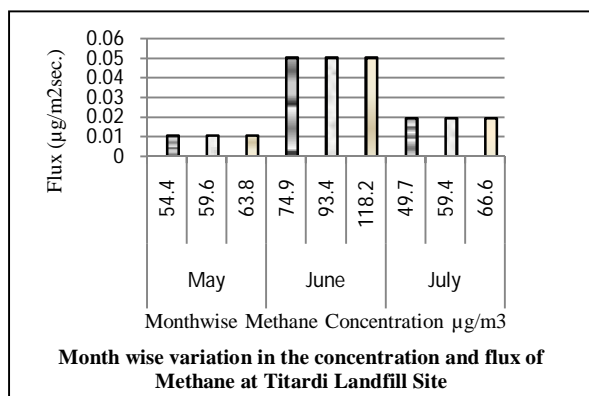
- II. The maximum concentration of methane and carbon dioxide was observed due to temperature increase as it accelerates the degradation activity and promote the gas production concurrent investigation have been carried out by Yesiller N. (2003) & Wang Y.et.al, (2012) who has studied the effect of temperature on long term behavior of municipal solid waste degradation [8,9] under anaerobic condition at the Titardi landfill site in June i.e., 118.2  $\mu\text{g}/\text{m}^3$  and 113.6  $\mu\text{g}/\text{m}^3$  respectively. Similarly, at the Baleecha landfill site the concentration of methane was 105.8  $\mu\text{g}/\text{m}^3$  and 99.7  $\mu\text{g}/\text{m}^3$  of carbon dioxide.

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- III.** In July the concentration of both the gases were recorded higher as compared to results obtained in May due to the availability of moisture on the very similar lines of research has been performed by Scarlat N. Et.al, (2015), an evaluation of the energy potential of Municipal Solid Waste from African urban areas [14] that also plays an important role in gas production, i.e., 66.6 µg/m<sup>3</sup> (CH<sub>4</sub>) and 59.3 µg/m<sup>3</sup> (CO<sub>2</sub>) and at Baleecha landfill sites 69.4 µg/m<sup>3</sup> (CH<sub>4</sub>) and 58.9 µg/m<sup>3</sup> (CO<sub>2</sub>).
- IV.** Another factor that influences the gas production rate is the quantity, age and composition of the waste the fact is also confirmed by the experiment conducted as mentioned in the chapter landfill gas basics (2001) [12]. The waste placed in the Titardi landfill site is 10-15 year old and the rate of decomposition in old waste as well as freshly dumped waste is so varied, we had obtained maximum concentration of methane and carbon dioxide was recorded at Titardi as compared to the Baleecha landfill site as this site is new for this operation.

**Table 3: Temperature record of Landfill Sites**

Baleecha Landfill Site			
Parameter	May	June	July
<b>Waste Temperature</b>			
Morning	40°C	42°C	37°C
Afternoon	41°C	45°C	39°C
Titardi Landfill Site			
Parameter	May	June	July
<b>Surface Temperature</b>			
Morning	38°C	41°C	36°C
Afternoon	41°C	44°C	38°C

The waste temperature recorded at Baleecha and Titardi Landfill site in morning and evening hours AS illustrated in result IV below

- V.** The flux of methane was 0.504 µg/m<sup>2</sup>sec and carbon dioxide was 0.506 µg/m<sup>2</sup>sec by using a flux box methodology which was suitable as the flux of carbon dioxide was recorded higher as compared to methane in June at peak temperature of 44°C. The gas production heat the surface and increase the air temperature as the production of CO<sub>2</sub> traps the air temperature according to Sunday Ighovie Efe, et. al., (2013) "Effects of solid waste on urban warming in Warri metropolis, Nigeria" [7].

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## IV. CONCLUSION

The variation in the concentration of carbon dioxide and methane has been influenced by some of the factors which can be considered important as clearly indicated by the above results and observations. These factors are seasonal fluctuations in which time plays an important role at which sampling is done, the temperature and moisture content are another important parameters on which the gaseous emission depends and the quantity, age and composition of the waste higher the decomposition more will be the generation of both the gases moreover, it is difficult to locate the zone of decomposition in the landfill site. There was no correlation exists between the generation and emission of these gases. Thus, emission of both gases has focused attention for its environmental consequences as contributing in temperature rising so need to be controlled. Unmanaged open dumping without soil cover should be restricted and reclaimed as a sanitary landfill site with disposal of inert and non biodegradable waste. The biodegradable waste should be utilized for biogas production as an energy resource for other sectors.

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## BIOGRAPHY

Dr. Nidhi Rai is working as a professor in the Department of Environmental Sciences in Mohan Lal Sukhadia University, Udaipur, Rajasthan, India since last 20 years. She is consistently engaged in research with more than forty publications in journals of National and International repute. She has also presented papers and has been a keynote speaker in more than thirty conferences. She has produced eight Ph.Ds in the department. She is actively involved in research and her major thrust areas are vermiculture, toxicology, remote sensing and GIS, air, water and soil pollution. She has already computed one major research project funded by U.G.C. The students are working under her supervision. Under her guidance one postdoctoral fellow is also working on heavy metal pollution.

Ms Priyanka Dwivedi is pursuing Ph.D under the supervision of Prof. Nidhi Rai on the topic of Green House Gas estimation in organic fraction of solid waste. She did M.Sc. Environmental Sciences in 2007. For last 10 years she has been working as environmental professional in the field of environmental consultancy and now she is engaged in research work.