METHANE GENERATION POTENTIAL OF MUNICIPAL SOLID WASTE IN DUMPING SITE PANCHKULA, JALANDHAR AND AMRITSAR

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

Of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

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May – 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"METHANE GENERATION POTENTIAL OF MUNICIPAL SOLID WASTE IN DUMPING SITE PANCHKULA, JALANDHAR AND AMRITSAR"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Rishi Rana**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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16th May, 2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"METHANE GENERATION POTENTIAL OF MUNICIPAL SOLID WASTE IN DUMPING SITE, PANCHKULA, JALANDHAR AND AMRITSAR"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Himanshu Bansal (171661), Venus Chauhan (171664), Sanju (171682)** during a period from January, 2021 to May, 2021 under the supervision of **Dr. Rishi Rana** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

Though Panchkula is a well-planned city, but has an undeveloped and a poor waste management plan. The site where the daily refuse is dumped is located in 23rd sector of Panchkula. Panchkula municipal corporation area generates around 150 tons/day of daily average solid waste. But as per the waste generated, the waste management system is not much efficient. Whereas in Punjab the Punjab Local Government Department followed a different cluster approach to conduct and manage the solid waste within the state. So, they divided the state into eight clusters which comprise 8 to 26 ULBs (Urban Local Bodies) and these clusters covers all the ULB in the state. The state is divided into 8 clusters in which Jalandhar and Amritsar are two of them. The main objective of this study is to find total methane emissions in Jalandhar (Piplanwala dumping site and Warianna dumping site) and Amritsar (Bhagtanwala dumping site) through LandGem model and compare them with methane emissions in Panchkula. We found that rate of emission of Methane Gas from the Bhagtanwala Landfill is 5 times excess than the rate of emission of methane gas from Panchkula Landfill. The rate of emission of Methane Gas from the Wariana Dump is approximately 3.5 times more and rate of emission of Methane Gas from Piplanwala Landfill is approximately 4 times excess than rate of emission of methane gas from the Panchkula Landfill.

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CAA	Clean Air Act
CPCB	Central Pollution Control Board
DM	Direct Method
EPA	Environmental Protection Act
EG	Emission Guidelines
FOD	First Order Decay
GHGs	Green House Gases
GDP	Gross Domestic Product
Gg	Giga grams
IPCC	Intergovernmental Panel of Climate Change
LandGEM	Landfill Gas Emission Model
MSW	Municipal Solid Waste
MTM	Modified triangular Method
NSWMA	National Solid Waste Management Authority
NYDEC	New York state Department of Environmental control
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMOCs	Non Methane Organic Compounds
NSPS	New Source Performance Standards
SWM	Solid Waste Management
SWDS	Solid Waste Disposal Sites
UNFCCC	United Nation Framework Convention of Climate Change
USEPA	United States Environmental Protection Agency

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INTRODUCTION

1.1 Background

Activities by human beings generate waste material which is sometimes thrown away as they are counted in useless materials. These refuses produced is mainly solid; the word refuse/garbage generally suggests that the material is unnecessary and of no use. Moreover, many types of refused materials can be renewed or reused, and thus this garbage can be utilised as a resource in manufacturing Industries and generation of energy, if conducted and controlled properly. Waste management was an engineering function and still it is an engineering function. It is generally directly connected to the progression of the technical society, with all of the advantages of the mass manufacturing, which has produced significant issues for the disposal of the solid refuse. Land use and zoning is general starting point of solid refuse in a community. Although they can be classified into many numbers of source, some important and useful categories are :(1) residential, (2) agricultural, (3) industrial, (4) demolition and construction, (5) treatment plant sites, (6) municipal services, (7) institutional, and (8) commercial.**[13]**

Solid refuse conduct is a bit complicated process as it requires several technologies and several management plans. Technologies related with it are the minimisation of the generation of the waste, handling of the waste, storage of the refuse, collection of the refuse, transfer of the waste, procession techniques, and disposal of the solid wastes. Now to do all these social and legal guidelines are there, so that these processes do not put any impact on the humans as well as on the environment. Note that these all processes should be done in the aesthetics and under the allotted budged of the solid waste. The disciplines that have to be followed are the administrative disciplines, financial and legal, architectural, planning of the waste management, and some engineering functions. Now in order to make the solid waste management plan to be successful all these regulatory bodies should communicate and must contact with each one in a positive internal regulatory relationship. **[13]**

Waste management is different in different countries, for example in the developing countries the waste management system is not much effectively developed as compared to the economically well planned and developed countries, same goes with the residential and industrial areas waste management systems. Now we have always given our main concern towards the conduct of the waste which emanates from the households, but there are also some other major sources of the waste such as offices, waste from hospitals, waste from shopping malls, schools and also the waste which is collected by the sweepers from the roads. Now discussing about the residential commercial wastes which generally includes the food wastepaper waste, cardboard waste, plastics waste, textiles waste, glassy materials, metals, aches and there are special waste like bulky wastes items, electronic wastes, batteries (which can be hazardous in nature), oil, waste tires, and other household wastes that are hazardous.

In the industrial type of wastes we generally take into account the waste such as paper, plastic wastes, cardboard wastes, special solid wastes, hazardous wastes etc. If we discuss about waste from the Municipal services, we can include waste such as waste collected from the street sweeping, landscape and the organic waste from the tree trimmings, wastes collected from the parks, waste from beaches, and from the residential areas.

So, we can conclude that the major waste which is being generated include the paper wastes, cardboard waste, plastic waste glass wastes and the now talking about the hazardous wastes such as the medicines waste from the hospitals or chemist shops, discarded automobile part wastes, and the other small electronic wastes.**[13]**

1.2 Waste Generation Scenario

World population in 2020 is around 7.8 Billion (estimated) and the world produces 2.01 billion tons of solid municipal refuse every year (according to the report of the world bank).

India's population in 2020 is around 1.38 Billion (estimated) and the waste generated is around 277.1 Million annually which is likely to touch 387.8 Million per year by the year 2030 **[48]**.

Now from these scenarios we can see that waste generated by the human population is increasing at a very fast rate. It became very important to use that waste as a source of energy otherwise this waste can lead to many environmental problems which will be very difficult or we can say impossible to solve.

In India a large chunk of waste is left untreated which is a very big issue because we are not using our waste as a source of energy**.[13]**

1.3 Green House Gases

There are some gases such as Methane and Carbon dioxide which have the potential to capture the heat from the sun, which causes the greenhouse effect. Now as these gases traps heat due to which the atmospheric temperature will rise. There is approximately 76 percent of the contribution of the Carbon dioxide in the greenhouse effect**[49]**. Whereas methane gas up to

16 percent (dioxides of carbon equivalent) of the greenhouse gas emission generated from the agricultural areas, and Nitrous oxide which is emitted from the industries and agriculture, generally contributes 6 percent (carbon dioxide equivalent) in the global greenhouse gas emission. This information is sufficient to show that these are the major gases which are emitted from the landfills, and we should also note that these gases if left un trapped can cause some serious problems to the environment and as well as to the human beings. So, it is very important to start storing these gases from the landfills and start using these gases as a source of energy. Now not only the estimation and collection of these gases in important but it is also very important to spread awareness that how much important are these gases, as if these gases used in a right way, we can also slowly decrease the global warming rate in the coming years.

1.4 Landfill

Landfill is an area where the grabage from a city or town is dumped. Landfills also have some other names such as dumping ground, waste dump area, garbage dumping site etc. There are different types of landfills for different type of wastes **[41, 47]**. Different types of landfill are:

- **Sanitary Landfill**: Sanitary landfills are those landfills in which the waste is being disposed in such a way that it does not affect the environment as in this type of landfill site refuse is kept away from the environment. Waste is considered safe until it totally degraded biologically, physically and as well as chemically. Sanitary landfills use various technology to contain the waste in such a manner that there is no leaching out of the hazardous substances. Trench method and the area method is shown in the *Figure 1.1(a).*

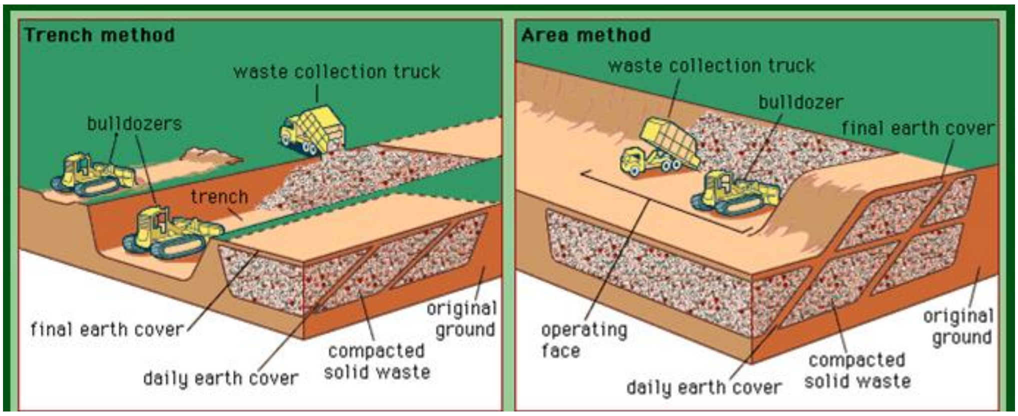


Figure 1.1(a): Sanitary Landfill **[47]**

- **Municipal Solid Waste Landfill (MSW):** These are the most common type of landfill as the waste from the household is being collected in these landfills. The guidelines and the minimum criteria have been given by the environmental Protection agency (EPA) that these landfills must fulfil. Note that some type of material is banned from being disposed in these types of landfills such as the chemicals, paint, battery wastes, pesticides etc. Some wastes from the household that can be dangerous are also banned but still being disposed in these landfills. See *Figure 1.1(b).*

Figure 1.1(b): MSW Landfill **[47]**

- **Construction and demolition Waste landfill:** As the name specified demolition and construction refuse landfills, so the wastes that are generated from the construction of buildings, as well as from the demolition of the structure are being disposed in these landfills. It includes the concrete waste, wood waste, asphalt waste, gypsum waste, metal wastes, waste from the bricks, glass wastes, plastic wastes, rock etc. See *Figure 1.1(c)*

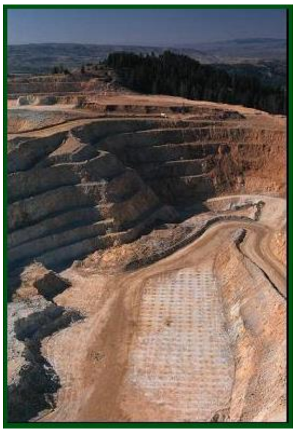


Figure 1.1(c): Demolition and Construction Landfill **[47]**

- **Industrial waste Landfills:** This type of landfill contains the most hazardous refuse produced from the Industrial areas. Special care is taken in order to dispose and treat these types of wastes. High concentration of the metallic waste can be found in these types of landfills.

1.5 Landfill Gases

Landfills are the major contributor for the emission of the Greenhouse gases. Landfill gases are formed due to the natural decomposition process of the waste in the landfills. Mostly organic waste is responsible for the landfill gas generation. Landfill produce about 50 percent of the carbon dioxide from the waste, approx. 50 % of Methane gas is generated from the landfill through the anaerobic decomposition of the refuse, this gas a primary component of the biogas, and there is very small amount of the non-methane gases that are generated from the landfills. Intrusting fact that all should know is that Methane gas is approx. 26 to 36 times more powerful and effective then carbon dioxide, that’s why it is very beneficial to calculate the methane gas from the landfill. This data is from the IPCC Latest reports (Intergovernmental Panel on Climate Change)**[48]**.

1.5.1 Methane Emission From landfill:

When the waste is dumped into the landfill, it is left open initially. The organic matter which is present in the waste react with oxygen present in the atmosphere and undergoes the aerobic decomposition. During the aerobic decomposition very small amount of methane is generated. Then when the waste is covered with the soil daily, for example the plastic cover or of any other material the presence of oxygen in the landfill decreases, within the time of one year the refuse starts to undergo the anaerobic decomposition, (without the presence of oxygen) and when this process starts, large amount of methane is generated **[13, 49]**.

In India according to the different studies from the year 2010 to 2015 around 22 trillion grams per year Methane was generated from the landfills **[13]**. Now, we can see that how we are wasting such a good source of energy without capturing it. We know that the methane is a by-product generated from the landfills so it becomes very important to not only estimate the emission rate but also to capture this gas. As it was discussed earlier, that during the first phase of the year when the waste is dumped into the landfill there is very small amount of methane that is generated during the aerobic process. When the aerobic conditions are established, large amount of methane start generating from the landfill. Note, that the kind of waste which is in landfill will decide the worth of “potential of methane generation” Lo which is additionally called as methane generation capacity. Which suggests that the sort of waste and Lo value has direct relation. The upper the cellulose concentration in the refuse, the upper the worth of Lo. The standards of obtained and theoretical Lo ranges as 6.2 to 270 m^3 /Mega gram of refuse (EPA) **[13, 49]**.

1.5.2 The Four Phases of Bacterial Decomposition of Landfill Waste:

- **Phase I**

  When the refuse is dumped into the landfill the Phase one of de-composition starts. In this phase the aerobic bacteria (these types of bacteria only live in the presence of oxygen) with the help of oxygen break down the molecular chains of the organic waste. Also, these bacteria break down the complex chains of the proteins, carbohydrates and lipids. Now during this process these bacteria consume oxygen while decomposing the waste. Phase I of the decomposition process produce Carbon dioxide gas. Note that the nitrogen gas content released from the waste in the starting will be high, but the Nitrogen content decreases as time pass and the decomposition process goes to the fourth phase. As during this process, the availability of oxygen decreases, as soon as the oxygen depleted from the surroundings the Phase I is over and next phase starts. Now this phase can last for days or months, this all depends upon the availability of oxygen in the surroundings. If the availability of oxygen is very high then this process takes time to complete. Now, the availability of the oxygen depends upon the covering technique of the waste, that how properly waste is being covered in the landfill **[49]**.

- **Phase II**

  Now after the oxygen present in the landfill is full used Phase II starts. In this phase the main role is of the anaerobic process. In this process by oxygen content is required for the decomposition of the waste. The components which were created in the aerobic process, is converted into acids such as acetic acid, lactic acid, and formic acids & alcohols like-as ethanol and methanol by the anaerobic bacteria. This makes the landfill highly acidic. Now point we should note that the moisture is also present on the landfill, so this acid combines with the vapor present and they cause dissolution of nutrients, which makes the nitrogen content and phosphorus content accessible to the different types of the bacteria in the landfill. Now, the gases which release during this procedure are CO_2 and hydrogen. Now again very entrusting point is that if Oxygen somehow makes way into the landfill (if landfill is disturbed) then the Phase one microbial process will again start **[49]**.

- **Phase III**

  Now, in Phase II there are some organic acids that were produced. So, the Phase III starts when the special type of anaerobic bacteria's start consuming the organic acids produced in the Phase II. During this consumption of organic acids these bacteria's produce the byproduct of acetate, also a type of organic acid. This is course of time where the landfill becomes neutral environment, this neutral environment is very important for the establishment of the methane producing bacteria. There is a special symbiotic relation between the Methane and bacteria which produce acid. Components for the methanogenic bacteria for the consumption process are created by the acid producing bacteria. For acid producing bacteria the carbon dioxide is toxic, so in order to eliminate these Methanogenic bacteria consumes the acetate and CO_2 **[49]**.

- **Phase IV**

  Note when both the generating rates as well as composition rates of the landfill gases become relatively constant, and then we can say that the Phase IV is started. In the Phase IV of the Landfill gas, it usually comprises of approx. 45 to 60 percent CH_4 by volume, where CO_2 is 40 to 60 percent and the other gases content id about 2 to 9 percent (sulfides). In the Phase IV the gas is produced at the stable rates, for about 15 to 20 years, note that the gas will be carry on to be produced from the landfill for about 50 to further years after the waste is dumped at the site **[49]**. Here we should keen another thing in mind is that if the organic content is more in the landfill the gas will be produced to more years. See *Figure 1.2.*

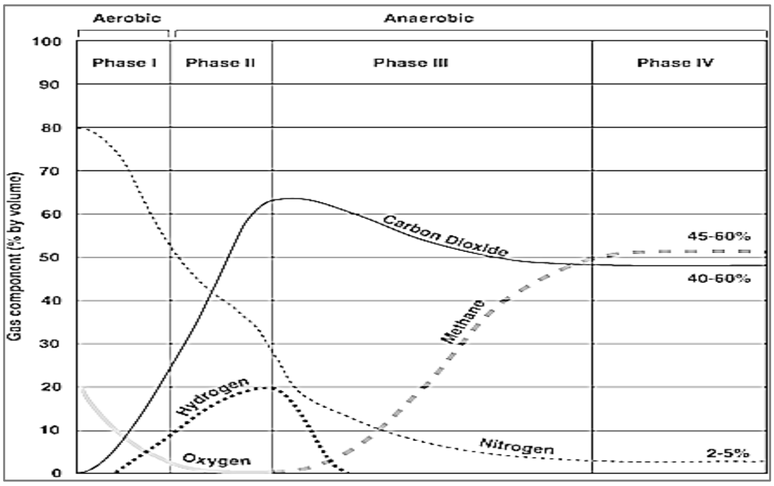


Figure 1.2: Phases of Generation of Landfill Gases **[49]**

1.5.3 Collecting and Treating Landfill Gases:

We can use the landfill gases as a renewable energy source, by capturing these gases from the landfill. Capturing the Landfill gases can reduce the problems of odour and other health issues related to the emission of the landfill gases. Collecting landfill gases can reduce the effect of the methane gas on the environment. As we know that methane gas if not collected can lead to the greenhouse effect and health related issues will also be there. It is very important that the Landfill gas collecting Projects can generate revenue and can create job opportunities. **[41].**

We should always keep in mind that Methane is a very powerful greenhouse gas. Methane is 25 times excess stronger than Carbon Dioxide in terms of seizing heat. Capturing the methane gas from the Landfill is very important. It can be burned to produce electric power, heat houses, or power garbage trucks. We can also reduce the climate related problems by capturing methane gas. *Figure 1.3 (a)* **[41]** represents how methane is collected from the landfills and converted into energy.

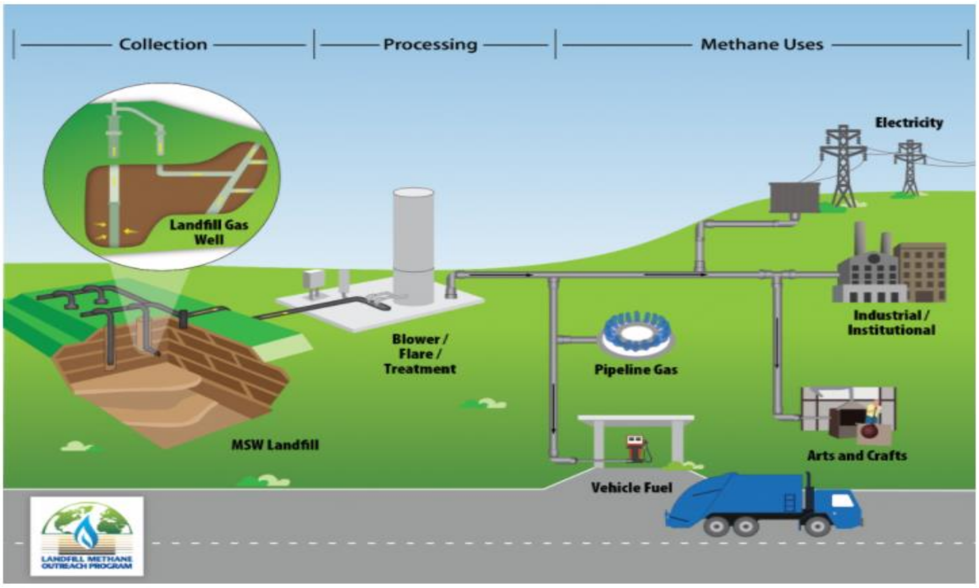


Figure 1.3(a): Capturing of Methane Gas **[41]**

From the *Figure 1.3(b)* we can depict the basic processes through which methane gas is being captured from the landfill sites. Now from the Point marked 1 in figure we can see that the trash decomposes in the landfill which produces the landfill gases (here we are only concerned about the methane gas). Now the point marked 2 in the figure we can see that the as the methane generated from the decomposition process it rises to the top and then it is collected by the pipes also called as the gas collection wells. Now, point 3 shows that the methane gas producing heat and electricity generation when burnt. **[42].**

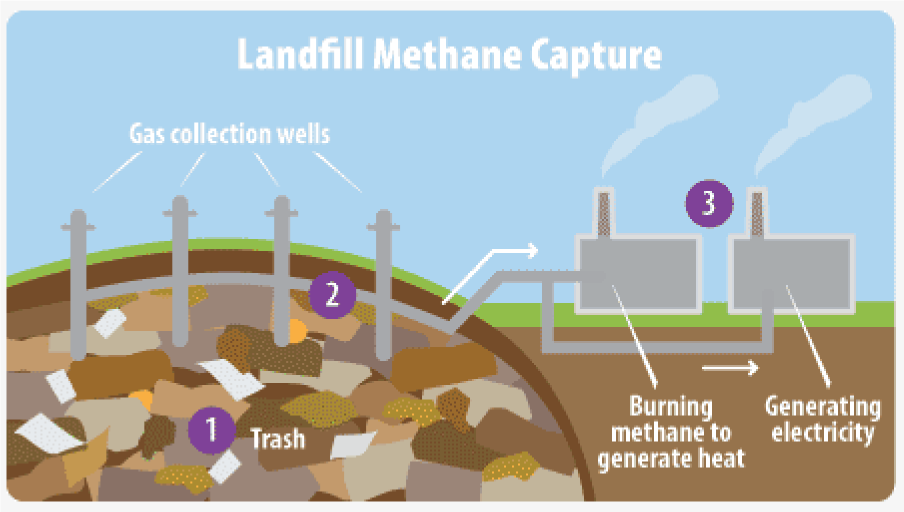


Figure 1.3(b): Landfill Methane capture **[41]**

1.6 Methane

In between the year 1776 and 1778 Alessandro volta was the one who discovered and isolated Methane. A.W.V Hofmann was the German chemist who gave the idea of naming it as methane in the year 1866. Now, if we mention about the natural gases, methane contributes to over 87% in it. As we have mentioned earlier that the Methane is emitted and produced from the degradation of the organic matter at very low pressure. According to the U.S Times 2019 reports the scientists recorded the high rise of the methane gas in the atmosphere. The main reason was that the emission of the methane gas from the industries of the fossil fuels was underestimated significantly **[46]**.

CH_4 is how the methane is written in the chemical formulation i.e., number of carbon atoms are one and four hydrogen atoms. Methane is considered in the 14th group of hydrides, as we have mentioned earlier that methane contribution in natural gas is very high as it is a from as the simplest compound alkane. As methane is in very large quantity on earth so we can say that it is very economical natural fuel. If we mention the properties of the methane, it has no colour means it is colourless, it has no smell means it is also odourless which is at the standard pressure and room temperature. Boiling point is of -161.5^{O}C atmospheric pressure one. Now, if the methane reacts it gets very difficult to control it. It is counted at very low level in its acid nature. Methane fuel is very useful when it is burned as it can be used in kilns, industrial works, rotating the turbines, in homes, heaters etc. In generating the electricity methane is very useful. It is also used by some space research organizations in the form of rocket fuel **[46]**.

1.6.1 Physical Property

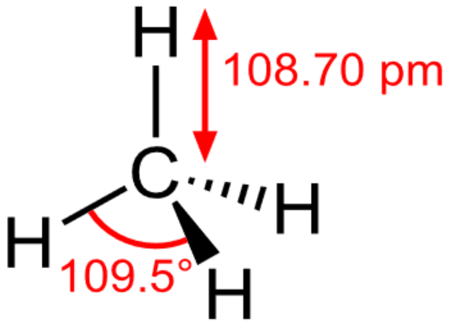


Figure 1.4: Chemical Structure of methane **[46]**

- CH_4 is a one carbon compound, in which Carbon is attached to four Hydrogen atoms with single bond.
- Methane has no colour means it is colourless, and it has also no smell means it is odourless gas which is also known with another name as mash methane gas. Methane gas is easy to burn as it captures heat very fast. The methane gas in vapour form is less heavy than air. If the methane is in the exposure of heat for long period of time it can explode. In order to make another chemical compound methane is also used and this gas has high contribution in natural form of gases.
- Methane in liquid form has boiling point below -90 degree C which is also known as the compound of cryogenic liquid. Main and important point to note is that the methane is also counted in reducing agent compounds.
- Methane has no taste means it is tasteless. Flash point of methane is -306F (NTP, 1992), it is the lowest and the minimum warmth where the chemical can be vaporised to form mix which is ignitable in air. Lower the point of flash higher the flammability.
- Methane is soluble in water (H_2O) is around 22mg/L at the temperature of 25^0C. methane is also soluble in ethyl ether, ethanol, benzene, methanol etc. Vapour pressure of methane is 258573 mm Hg which is at the temperature of 100F and 760 mm Hg temperature at -258.7F (NTP,1992). **[46]**

1.6.2 Chemical Property

- Methane is multistep oxidation reaction where one molecule of gas methane reacts with two molecule of oxygen gas under combustion condition to form one molecule of carbon dioxide gas with two molecule of water vapor and energy.

- Methane when burned only releases carbon dioxide (CO_2) and water (H_2O) it is a cleanest fuel while burning. This gas is becoming unstable when its content reaches in the range of 6 to 15% in the atmosphere.
- As we have mentioned that methane is normally chemically stable, but the energy is only emitted when the carbon and hydrogen bonds are formed or it react with other compounds.
- Important property of methane is that it is not corrosive to alloys of aluminium alloys, and the steel formed by carbon. Note that the hazardous decomposition and the reaction of methane that are hazardous are not known.
- Methane is non-acidic and it is not counted in acidic compounds. The main reason is that the hydrogen bonds are very close to carbon in the methane chemical structure and they not go out. It has a pH of around neutral point i.e., of 7. With oxygen it is combustible. **[46]**

1.6.3 Advantages

- Methane is clearer fuel as compared to petroleum-based fuels. 25 percent is the emission of CO2 which is lower than patrol, around 17 percent lesser thane propane liquid gas, around 30 percent lesser than the diesel and as compared to carbon it is 75 percent less.
- Hydrates of CH_4 could be the energy source for future; a m^3 of CH_4 hydrates contain in between 160-180 m^3 of CH_4. In the areas of permafrost beneath the ocean floor it has been calculated that more than 100000 million billion m^3 of CH_4 are present which are trapped in frame of hydrates.
- Methane is lighter than air at room temperature.
- CH_4 is a very economical gas if used in a correct way.
- It is used in homes, kilns, automobiles as a fuel.
- CH_4 (refined liquids) can be used in rockets as fuels.
- The gas can be piped to homes for the purposes of cooking & domestic heating.
- Natural gas (consists of mostly CH_4) is used in large scale hydrogen gas production.
- Methane on the planet could supply 2x energy obtained from all fossil fuel deposits.
- CH_4 does not require to get transported to petrol junction only thing which is required is the pipe connection. There is option of self-re-fueling from home-based gas system is there.

- The waste from which CH_4 is produced can be used as a manure for plants after treatment.
- Methane is a very beneficial gas, just people in India need to realize its importance.**[46]**

1.6.4 Disadvantages

- CH_4 is a clean fuel but needs high safety precaution while operation like appropriate cylinder of fuel & inspection of the fuel system should be frequently done. Resistance to air of system and it involves storage below high pressure of about 23 MPa.
- Methane requires extra installment inspection, cylinder containers of methane takes extra area, mass of steel container, high worth of container composites, as compared to diesel, range of the car is less than 50 percent.
- Old-style cylinders of steel are heavy whereas new cylindrical containers are available which are less heavy and of very high cost.
- Tropospheric ozone, water vapor, CO_2 & abundance of other greenhouse gases are affected by atmospheric methane. Methane emission is 25% higher than previous estimate contributing to global warming suggested by recent researches.
- Tropospheric ozone level rise due to increased methane emission.
- CH4 if present in huge % age in our environment, can also result in death of people.
- This gas is a major contributor in GHG effect.
- It's a very poisonous gas that can also lead to suffocation & breathing problems.
- Methane is responsible for 40% of warming since the industrial revolution, respiratory disease, heart disease, damages airways and lung tissue, up to 15% annual yield losses of soy and wheat etc.
- In comparison to carbon dioxide, it has been observed that methane warms planet 84 times faster.
- CH_4 if allowed to escape to atmosphere, can be fatal for plants & animal as well.
- The treatment plant is expensive, that is used to generate methane. So methane generation is not much in use in India.
- People in India are unaware of its importance so, they are not much interested in using it as a source of energy.
- Methane can trap heat in the atmosphere which is harmful when released into the atmosphere. **[46]**

1.7 Need of Study

- To analyze the landfill gases (specially methane) produced from the dumping site of Panchkula, Jalandhar and Amritsar city.
- We chose Panchkula, Jalandhar and Amritsar city for our study area as these cities have almost same environmental conditions. Also, the Solid waste management system is almost same.
- To know more about the positives and negatives of methane gas.
- Study data can help the Jalandhar and Amritsar MSW management to achieve the purpose of **reducing GHGs emissions** from sources.
- The emitted methane from the dumping site can be used a source of energy and also it will be economical.

1.8 Objectives of the Study

- To calculate the emission rate of the Total Landfill gases mainly Methane, Carbon dioxide gas from the landfill area of panchkula, Jalandhar and Amritsar city.
- To analyse the GHG effect of the landfill gases on the environment using the same software results.
- To Compare the results which we will get from the IPCC modelling method (LandGem Software).

CHAPTER-2

LITERATURE REVIEW

2.1 Review of Literature

This chapter discusses the reviews related to literature both in terms of theoretical and experimental research done by the great scholars.

The study conducted by **[40]**. The solid waste condition of Jalandhar city is bad because of increasing population and changing lifestyles which is resulting in increase in solid waste day by day. Instead of improving skills to convert solid waste into useful things, more focus is on reduction of solid waste which looks a bit difficult. Solid refuse assemblage and disposal with the help of a private player in Jalandhar has turned out to be useless. Jalandhar is a very old city and has a huge population and has rapid industrialization. Jalandhar has a total area of 3401 square km. In Jalandhar there are around 2.13 lakh houses but around 1.5 lakh urban households are servicing the garbage collection facility and 0.63 lakh are unservicing. 1.5 kg is the daily garbage generation per house. In Jalandhar 500 metric tons is the garbage collection.

The Study **[38]** is based on generation, collection, transfer, disposal and conduct of the SWM in Panchkula and Mohali. 150 tons/day (0.267 Kilo gram/capita/day) is the daily average generation of the garbage from both cities. The effectiveness of the refuse collection from houses is about 60% to 70%, and from the slum areas and villages in both these satellite towns the effectiveness of the waste collection is about 10% to 20%. Solid refuse generation in the Indian cities per capita differs from 210gram/day to 850gram/day. Solid refuse production relies upon the populace of the urban area and the city economical condition **[38].**

A study **[36]** shows, that Punjab is facing waste disposal problems. Urban agencies and local governments have considered solid waste a big problem. Most of the garbage is generated from commercial and residential complexes. Jalandhar is a very specialized centre in manufacturing leather goods, sports goods, hand tools, etc. Various types of tourism are provided in tourism in Jalandhar such as medical tourism, educational tourism, historical tourism, etc. The economy of a city deteriorates due to waste management. With the growth of the city, waste also grows which puts a huge burden on the waste management system of the city. Migration increases burden on infrastructure. Solid waste consists of both homogenous material and heterogenous materials. There are three criteria for management of waste: 1. Collection 2. Transportation 3. Disposal. Around 2714 safai karmachaari, 1500 sweepers are there in Jalandhar. Sweepers work about 7 hours for 6 days in Jalandhar. 1 km length of road is given to each sweeper for cleaning. There are no automatic road sweeping machines in Jalandhar. In Jalandhar, the solid waste collection is done by municipal corporation & Jindal infra tech limited. Bins are provided by municipal corporation of 1 m^3 and 4.5 m^3. Maximum quantity of waste in Jalandhar generated from residential areas. No waste segregation is done and directly send to dumping site.

In a study **[29]** the MSW in Jalandhar has been characterized for evaluation of its suitability for different technologies of waste processing. In this study analysis of MSW collected was done to check its chemical, geotechnical and physical characteristics. Punjab generates nearly 3035 tons MSW per day. Major cities of Punjab produce around 1830 tons waste. Jalandhar is situated between Sutlej and Beas. Around 8% population of Punjab is in Jalandhar 1 million in urban areas and 1 million in rural areas and 3.8% growth rate increase per annum. Around 480 tons of MSW is generated in Jalandhar per day. Sampling of waste was done in Jalandhar by collection and transportation vehicles. Samples were segregated into veggies, plastic, paper, inert, fruits, etc. Waste was chemically characterized for accessing its potential for various techniques of waste processing such as incineration, composting, RDF, vermicomposting. Wetness content, vaporization matter content, fixed C, ash content (in %). MSW" s geotechnical properties are determined for maintaining and designing of landfills. Degree of saturation, void ratio and unit weight are determined by using average specific gravity and average moisture content. Waste is sweeped and disposed in nearest collection points by the sweepers of MCJ. Jalandhar has around 75 collection points. At various places the dustbins are overflowing. MCJ collects park and garden waste separately for composting. Around 400 tons of waste is collected by the municipality in Jalandhar. Waste management practices have to be improved in Jalandhar. Hence, MCJ has to put lot of efforts in this.

In a study **[1]** characterization of MSW is done for nearly a time period of 10 months at urali devachi landfill in Pune, India. It shows that it has 69% of decomposable organic matter. The degradation of organic materials in landfill produces landfill gas (LFG). The LFG method used to calculate the generation of LFG are based on composition of MSW, age of the waste & total MSW dumped. First order decay (FOD), default method (DM) and MTM are used. The emission of methane for 2008 using FOD (base), DM and MTM & FOD (worst), is 6.9 Gg, 10.3 Gg, 8.1 Gg and 5.1 Gg respectively. The study is useful to compare and make plans for controlling the GHG emission from landfill in metro cities in Asia. SWM is a big issue in India. Rise in population and urbanization has led to increased solid wastes. Landfill is the most used SWM method. Landfill consists nearly 60% of methane and 40% is carbon dioxide. Methane if escapes from the landfill can contribute to greenhouse effect in a major extent. Methane emission from the landfills is dependent on the quantity of solid refuse and concentration of solid waste dumped. Methane traps around twenty times more heat than carbon dioxide.

Moreover in the study **[1]**, Pune has population reaching approximately 34,00,000 is found to produce about 1400 metric tons of MSW daily. The MSW is disposed at Pune Urali Devachi landfill having an area of 64 hectares. It is working since 1999 and consists of residential, market waste, educational institutes and IT industry wastes.

From study **[9]** we came to know that Landfill gas emissions can cause serious problems, particularly when these gases escape to the atmosphere, get collected in closed spaces where these gases can produce a very serious hazard, i.e., explosion can happen. LFG monitoring is a very important thing for landfill operators & has become an important portion of the lawful necessities for the design, operation & its closure. The main purpose of landfill gas monitoring is - detecting gas attendance, & prediction of measure of gas & the location where we can expect high gas amounts. Gas monitoring activities can be classified as following:

- Monitoring of gas in soil
- Monitoring of gas in the nearby area
- Monitoring of the Emission

In a study **[34]** on the quantitative analysis of CH4 emission from MSW in India. The study found total CH4 emission with the help of IPCC- default method and FOD. In the period of 260 yr., range 1750 to 2010, the assemblage of GHG CH_4 in the env. shows a growth ranging 701 to 1809 ppb. The rate of rise detected in last some years was one to two percent each year. The MSW generation in Asia, estimated to increase up to 1.8 M TPD by the year 2025 from 1 M tons every day. Our Country, GDP growth of its of about 6.7%, is experiencing an extremely quick suburbanization and changes in the living. Generation amount of M.S.W by each person in India varies from 0.2 to 0.5kg/day. Currently, about ninety million ton of the solid refuse is produced by the country. It's found that CH4 contributes to about 29.5% of total emissions of GHGs from India, its much higher than global average which is around 15%. CH_4 release increased approx. 2.5 excess more in a time range of 10 years (1999 to2009), increment to 1084 Gigagram/Y till 2015. The increase of 246% is found from 1999 to 2011, whereas, 110%

increase was found from the year 2011 to 2015. Estimation is that total inner-city waste in country will rise to 1080 hundred tons per year by the yr. 2031 and rise to 1610 Hundred tons per year till 2041.

In a study **[5]** which is about to find year wise potential of methane from landfill, IPCC and various models, Shell Canyon model and LandGem are used. LFG models receive huge criticism for their bad correctness and insufficient authentication. Thomson et al. (2009) has related different techniques for methane release from different landfills & reached to a conclusion that Land Gem model has estimated methane emission better than the other models. It depends on 2 important factors, i.e., the methane potential (Lo) & decay rate (k) of the landfill refuse. The key determination of this study was to find the Land Gem model as per the Indian environmental variations and its refuse characteristics. The physical examination of the refuse showed that around 55.3% of the refuse comprises of biodegradable elements, about 8.9% of refused paper and remaining 36% of inert refuse. Land Gem is a model which is used in predicting the LFG releases for a time range of 20 yr. In this study, the Land Gem model has been transformed by using Indian set up. The Method has been developed and established in U.S.

In a study **[39]**, we come to know that World energy consumption raised from 50% to 181,000 GWh/year by the year 2020. According to the IPCC, fossil fuel ignition adds up to 57% of releases that lead to global warming. Methane can be collected and can be used as energy. Profits of anaerobic systems related to aerobic systems include: (1) Making of useful energy (2) Reduction in air pollution and GHGs (3) Less functional value.

Limitations of Anaerobic Process: (1) Requirements needed for post- treatment (2) Sensitivity to lower temperatures (3) Attention needed while start-up time. While the degradation process which is anaerobic by bacteria it has the process of the breakdown of polymer, generation of acids production of acetic acid and methane releases. Environmental conditions influencing the release rate of methane include the warmth in landfill, vapours presence, pH & conc. Of substances which are toxic.

Study **[24]**, shows waste management scenario in Punjab. According to the annual report of CPCB, the generation of MSW in Punjab from 1999 to 2000 is nearly around 1266 TPD and has grown to about 2793 tpd in 2011. According to the CPCB hazardous waste inventory report 2009, Punjab had total 3023 hazardous waste generation units, which generated around 180k tons of hazardous waste. In class 1 cities, the sewage generation was around 1528 MLD and

411 MLD was the treatment capacity. Whereas the generation and treatment capacity in class 2 cities were 157.4 MLD and 42.8 MLD respectively. The waste generation per capita is said to increase by 1 to 1.33% every year. In Punjab, the daily waste generated is to increase by 128% by the year 2041. Punjab is divided into 8 clusters: 1. Patiala 2. Jalandhar 3. Ludhiana 4. Amritsar 5. Bathinda 6. Ferozpur 7. Pathankot 8. GMADA. And moreover, Punjab has 143 ULBs. And it also has 4 Municipal Corporations, ie, Patiala, Jalandhar, Amritsar and Ludhiana.

2.2 Summary of Literature Reviews

- From these Literature Reviews we have come to know a lot about methane gas. We have learnt about its advantages, disadvantages, its generation and many more things related to it. Seriously, these literature reviews have helped us a lot.
- A major amount of methane is generated by landfills. Landfill's gases consist of about 60% methane & rest consists of CO_2. CH_4 is extremely powerful gas which can trap heat around 20 times more than CO_2. Still in India methane generation is not much in use because people here do not realize its importance. But methane generation is very much in use in other foreign countries.
- Methane is used as fuel for water heaters, homes, ovens, automobiles, etc. Superior liquid methane is used as a rocket fuel. Methane is a great source of energy, and can be used for electricity generation. Along with the advantages, methane also has many disadvantages. Methane if goes into the atmosphere can majorly contribute in greenhouse effect resulting in global warming. Moreover, methane is very dangerous to the human body as in high concentration in air can result in suffocation. Methane if left un-trapped, can be very explosive.
- Methane generation is very economical method. Also, the waste used for methane generation acts as a manure for plants. Methane is very important source of energy. People in India just need to tap its potential. Hence, by adopting methane generation method, we can derive its benefits as an energy and moreover, we can play a very important part in reducing greenhouse effect. So, as per my opinion, methane generation should be followed in India.

CHAPTER-3

IPCC LANDFILL GAS ESTIMATION METHODS

3.1 Introduction

In the Dumps and Landfills when the solid waste is disposed, high amount of the organic material will be degraded with a period of time and that period of time can be longer or shorter, it can be in the duration smaller than a single year to hundred yr. over time. The process by which the organic solid waste is decomposed is bio-degradation and this is the main process behind the degradation over the period of time.

When the solid waste is disposed in the dumping site, it goes under two process of biodegradation and these processes are Aerobic and Anaerobic (largely depend upon the condition of the site in which the waste is disposed) **[49]**.

So, it depends strongly upon the landfill site situations where the solid refuse is dumped/disposed that the biodegradation process will be- aerobic / anaerobic. Here we have intrusting point that during the aerobic process the products released after degradation are generally water, warmth in the form of heat and Carbon Dioxide, but during the anaerobic process products formed/released are the Methane gas and Carbon-Dioxide **[48, 49]**.

The CH_4 emitted from the landfill and freed into the open atmosphere largely adds to the increase in the environment temperature causes Global warming and the release/emission of this gas from the various sources should be computed or estimated and the results should be handover or reported to the inventories of greenhouse gas, "United nations Framework Convention of Climate Change" (UNFCCC). Basically, the majority of the Carbon Dioxide generates from the refuse such as food refuse, paper waste, from garden etc., and these are biogenic sources. That's why its emission is not needed to be in the national records **[49]**.

The range of the estimation of the annual emission globally of CH_4 from the disposal sides of the solid waste is around 20 million tons to 40 million tons (we can see that it is very high amount of methane), Methane emission mostly comes from industrialised countries (according to UNFCC). This contribution is estimated to be in the range of five to twenty percent (approx.) of the worldwide human caused CH_4, which is generally equivalent to about/approx. 1% to 4% of total Greenhouse gas generated by the human actions **[48, 49]**.

Point to be noted that the gases emission from the countries that are developing and the countries whose economy is not too good will increase with very high rate in the coming years due to the increase the population in the urban areas, due to the growth of the refuse generated by the individual as there is increase in the economy and the enhanced management practices for the conduct of the solid refuse.

3.2 IPCC methods to estimate Landfill Gases

The IPCC Guidelines has given two main methods for assessment of the CH_4 productions from the solid refuse disposal.

3.2.1 IPCC Default Method

The basic Default technique/method of IPCC is basic and simple calculation of the mass balance which basically calculates the CH_4 generation rate which is being produced from the Dumping sites of the solid waste. Basic assumption in this method is that all the methane i.e., CH_4 which is releases the same year in which the waste is dumped or disposed off and it estimate the whole CH_4 emission from the dumping site in one go.**[8][26]**

3.2.2 First Order Decay Method (FOD)

In the First Order Decay Method (FOD) takes the factors/aspects of time and the degradation process of the waste process into its considerations, and then produces the results of the annual emission estimates of the dumping ground gases or landfill gases, now this process can be long term or can be short term. We should keep in mind and should also note that there is no comparison between the modelling methods. The First Order Decay Method (FOD) gives better estimation results on annual emissions of the landfill gases, whereas if we talk about the IPCC default method which is sometime generally it is taken as an alternative has also qualities e.g., in studies which compares the different aspects to diminish the CH_4 releases from the landfill sites by alternative waste treatment methods. **[8], [26]**

While Using the IPCC "default method" (DM) and "First Order Decay Method" (FOD) it requires the input if the Solid Waste Disposal (SWD) data which further includes the info. on the various Composition of the refuse which is dumped in the site and also the landfill site conditions generally known as Solid Waste Disposal Sites (SWDS).

In the IPCC "default method" (DM), we generally require this data only for the Working years of the landfill called as the inventory years, whereas in the FOD method we require the landfill data for the past twenty to twenty-five or more years. Also, we have to determine and enter the degradation rate of refuse dumped at SWDS in the FOD method. Now we should note that the

IPCC regulations comprises of some values which are default considerations for most of the things/data which we need to use the default method, whereas in the FOD method there are also some constant values given by the IPCC but they are insufficient and still research is going on for the constant values also called as default values **[8], [26]**.

Generally, in various countries there are uncertainties in the emission estimates of the Landfill gases by both methods given by IPCC i.e., Default Method of gas emission estimation and First Order Decay method of gas emission estimation **[8], [26]**.

Countries having Good Solid Waste disposal data based upon the amount of disposal and on the sampling of the waste can generally use these methods easily to calculate the emission rates per year. Whereas in some developing countries does not have good Solid Waste management systems, So the data is not easily available that's why IPCC has given the constants which can be used in place of the non-availability of the data. So, it is advised to use the default parameters in order to estimate gas emission rate in that condition **[8], [26]**.

Countries in which the waste is burnt open, more frequent aerobic decomposition etc may cause much lower emission rates of the gases from the Solid wastes as compared to the industrial countries, so it becomes very important to enhance the Solid Refuse conduct/management systems in the developing countries in order to get the correct and sufficient data of the solid waste from the dumping area. Also, IPCC updates their default parameters according to the conditions of the countries and we can also add the parameters by calculation the separately through various modelling method then can be used in the IPCC methods **[8], [26].**

3.3 METHODOLOGICAL ISSUES

3.3.1 SELECTION OF METHOD:

The IPCC Regulations have described about two core methods:

- The first one is **default I.P.C.C** procedure (it is basically used as alternative method some time) That is it generally relies upon the theoretic gas produce (a mass balance equation).
- Theoretical **First Order method** (kinetic procedures), from which the IPCC Regulations introduces and gives the method which is known as "First-order- of-decay model" (FOD).

Now discussing about their main differences, the first method that is Default process does not show the time disparity in the disposal of the solid refuse (SW) and the progression of degradation which occurs with time in landfill as in this method it assumes that all potential methane which is there in the landfill is freed or emitted in the same year the SW is disposed. Here we know that the degradation process is not short-term process it is a long-term process so, in the second method given and described by the IPCC is First Order Decay Method, it basically shows/reflects the timing if the genuine emissions of the landfill gases from the landfill. It shows the year wise emission rate of the gases.

Note that if there is a constant rate of the waste disposed composition as well as the disposed waste practices for a long period of time yearly, then the Default method is preferred as it can give fairly more good results as compared to the FOD method. Here another point is that the increasing amount or massive amount of the refuse that is being disposed into the site daily or annually can lead to a high estimation or incorrect estimation of the landfill gases; On the other hand, the lesser the rate of the waste disposal can lead to the low estimation of the landfill gases from the site.

IPCC First Order Decay method is more preferred to get estimation on the yearly bases as this method gives the fair result on the yearly estimation of the landfill gases. Here many nations may have some difficulties in receiving or analysing the required figures and information (data such as constant rate for decay, previous year Solid Waste disposal etc) to get the proper estimation through the FOD method, so that it accurate and acceptable **[8].**

3.3.2 IPCC Default Method

The basic equation for default method is given as under; **[8]**

$$\text{Methane emissions (Gg/yr)} = (MSW_T * MSW_F * MCF * DOC * DOC_F * F * \frac{16}{12} - R) * (1 - OX)$$

[8]

Where:

MSW$_T$: It is the overall amount of MSW produced (Giga gram/year)

MSW$_F$: It is the amount of MSW thrown or dumped in the solid refuse dumping sites.

MCF: It is the factor of the Methane Correction.

DOC: It is defined as degradable organic carbon (kilo gram C/ kilo gram SW)

DOC$_F$: Dissimilated DOC factor fraction

F: In landfill gases the fraction Methane, CH_4 is defined by F (default value is around 0.5)

16/12: conversion factor of Carbon to Methane

R: Methane-CH_4 recovery (Giga gram/year)

OX: factor of oxidation (fraction default value is 0)

As it was earlier discussed that the Default method estimate the methane emission on one go, which means that it takes into consideration that all of the methane (methane potential) CH_4 emission from the refuse in landfill is freed into env. in the same year in which the refuse is disposed in the site.

This method is generally simple and we require only the restricted set of the constraints for the input, IPCC has given their regulatory values for the default values to be entered in this method, Where countries specified data is tough to get or calculate or not available.

IPCC has given various recommendations for the default parameters specially for the countries which does not have enough Solid Waste Disposal Data **[8], [26].**

MSW_T: The general figure values for the MSW which is generated which should be national specific are provided. Having general units in Kg/capita/day. Now, for those countries which are under developed or still developing the information is still missing in some regions.

MSW_F: This figure is also having units as kg/capital/day, Municipal solid waste disposal figures which should be national specified in provided here.

MCF: General default value is taken as 0.6 and depending upon the disposal site management the default standards are ranging from 1 to 0.4.

DOC: It is more limiting selection then from MSW_T and MSW_F. The DOC value in MSW which should be nation specified is selected. This equation is also provided with the sefault values as well as the region or country specified. Based on MSW

DOC_F: the specified theoretical equivalence $DOC_F = 0.014T + 0.28$, in which T = temperature which is used to determine the standard. And IPCC general default standard is 0.77 as recommended by Bingemerr and Crutzen (1987).

F: 0.5 is the IPCC specified default standard.

OX: 0 is the IPCC specified default standard.

The least national standards required are: **[8], [26]**

- National Figures for Municipal Solid Refuse (MSW) quantities based upon the Solid Waste Disposal Sites, generally depends upon the amount of the non-rural inhabitants in the nation which is then multiplied with a particular rate of the national Municipal Solid Waste figure and upon them.
- Amounts of Landfill gas recovered throughout the country.

- Now talking about the developing countries where there is very less or negligible amount of gas production and recapture, the only value required during the estimate is the number of the people in the nation (population), mainly we pay attention on the non-rural area population.

3.3.3 First Order Method Decay Methodologies (Theoretical)

Guidelines according to IPCC

Three equations are used to present this model effectively. For one or specified number of landfills the first equation comes in use **[8], [26].**

$$Q = Lo * R * (e^{-kc} - e^{-kt})$$

Where: **[8]**

Q: Specified year in which the methane gas is generated, units (m^3 /yr).

Lo: Potential of the generation of the methane, units (m^3 /Mega gram).

R: It is the average of the yearly rate of the waste which is accepted in landfill in the working years or throughout the life of the landfill, unit (Mega gram/year)

k: rate of methane production constant, unit (l/yr.)

c: Dumping site closure year, unit (year)

t: Dumping site period of opening years (time), unit in (year).

Whenever estimating the following equation is used while calculating the regional or national values, for methane generation in year T from all of the solid refuse land filled in one let's suppose x specific year (Rx) can be used:

$$Q_{T,x} = k * R_x * Lo * e^{-k\,(T-x)}$$

Where: **[8]**

$Q_{T,x}$: It is the total quantity of the methane which is generated in specified year T by refuse R_X

x: it is the specific year of the refuse input.

R_X: it is the Total quantity in Mega Grams the refuse is dumped in the year x.

T: existing/recent year

In account to evaluate the all-total productions in the year T from refuse that is dumped of in preceding years, All of the Overhead Equation for the basic values of Rx can be solved and the result can be estimated using the succeeding equation:

$$Q_T = \sum Q_{T,x}$$

For x = initial year to T

Where: **[8]**

Q_T : It is the overall emissions of the gases from the refuse dumped in the preceding years also in account of the year T.

Here we found that there are no specific recommendations given by IPCC on the default values for the Lo and k, they have specified the wide range of values for Lo ranging from 100 to -200 Nm^3 /Mg and for the values of k, IPCC has specified the range from 0.005 to 0.4. There is very limited information provided in the guidelines. Now another point is that there is no reduction value provided due to recapture of gas or some factor of oxidation. Still IPCC advice to use these equations for the estimation of the landfill gases even though there is no sufficient data for the evaluation of the land fill gases from the Landfill inventories **[8], [26].**

3.4 Land GEM Software

(Version 3.02)

"United States environmental Protection Agency (USEPA) with the help of IPCC has developed a Modelling tool Land GEM (Landfill Gas Emission Model) Which is an automated tool, it is in the form of excel sheets, which help in estimating the Landfill gases such as Methane, Carbon Dioxide, non – methane organic compounds (NMOCs), and other individual pollutants of air from the Landfill (Municipal Solid Refuse)" **[26]**.

If no detailed data of the site is available then there are various standard parameters provided in the Land GEM software by the IPCC Guidelines or if the data in detail is available then there is also an option in the software to input the known data and then software estimate the gas emission accordingly.

Land GEM comprises of two set of standard parameters and we can select from those two default parameters. Two standard parameters are C.A.A defaults and Inventory Defaults **[26].**

CAA Defaults – As we can see from the name itself these defaults are given by the Clean Air Act based on the requirements of the Conduct of the Solid refuse that is laid on the land fill. Not only CAA but these defaults are also given by NSPS/EG and NESHAP. These set of standard parameters work upon the conservation calculation of the released gases from the landfill which is subjected to the controlled basic necessities of NSPS/EG or NESHAP **[26].**

Defaults Standards of Inventory – This Landfill Default given by Inventory Default with the exemption of the damp Landfill is based upon the discharge factors in the "U.S. Environmental Protection Agency" (EPA's) with the collection of Factors of Pollutants into Air (AP-42). Now these standards given by Inventory Defaults produces the average releases and also, they can be useful to estimate the production rate of the inventories in the air allows in the absence of the site-detailed data. These values are also mentioned in AP-42 for the various evolving countries and in inventories of state emission. From the more recent field tests conducted by EPA they have updated the default parameters recently according to the specified data. We know that in the Wet landfills the decomposition rate of the organic waste is high **[26].**

3.4.1 Understanding Land GEM:

First Order Decay method is the method of IPCC on which the Land GEM software is made. Land GEM works on the 1^{st} Order decay equation of decomposition rate for the estimation of the Landfill gases. This software has very simple interface and the approach of estimation of landfill gases is also very simple and easy. As discussed earlier this Software has default parameters which are provided by the CAA and the Inventory defaults. These default parameters are provided by the study conducted on the landfills of the United States. If we want then the field specified data can also be used in place of the default parameters.

Note that better the input provided in the Land GEM Software better will be the results. The major limitation is that if there is variation in the accessible data about the refuse quantity and composition over the time, then it can put impact on the emission potential rates estimated by the software. Note that the data provided of the wet Landfill in the Land GEM software the emission rate will be very fast as the waste decompose in faster rate in the wet conditions. So these changes can also lead to the variation the Land GEM provided results. So the defaults for these types of conditions are provided in the software by the CAA Agency so that there is less or no variation in the results. So, the CAA applicability is very important in the Land GEM Software **[26]**.

3.4.2 First Order Decomposition Rate Equation

Land GEM basically works upon the following decomposition rate equation of 1st order, to calculate the yearly production/emission of the Methane gas over a period of time which is specified by user.

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_0 \left[\frac{M_i}{10}\right] e^{-kt_{i,j}}$$

[8], [26]

Where:

Q_{CH4} = Total yearly methane generated from landfill of the yr. which is being calculated, units in(m^3/yr.)

i = increment of 1 yr. period,

n = it is estimated as considered calculated year – starting years in which the waste is thrown in Landfill

j = increase of time 0.1-year,

k = rate of the methane gas produced from the Landfill, unit in ($yr.^{-1}$)

L_o = capacity of the methane production potential methane, unit in (m^3/Mega gram)

M_i = i^{th} year in which the waste is gained (mass) (Mg)

t_{ij} = time at j^{th} component of the waste mass in which the Mi is accepted in the time of the i^{th} year. In the decimal years **[8], [26].**

SOFTWARE REQUIREMENTS

In order to run the Land GEM, it is essential to have Microsoft Excel 97 or latest versions of Excel. Note that the previous types of the Microsoft excel can't run the Software, So latest version is very important to be installed in your system. As there are macros which are embedded in the Software.

- **Enable Macros**-When we Open the Land GEM software the very first thing, we should do is to Enable Macros when it Prompt up, it basically allows the Land GEM package to use the macros which are already installed in the file. Note that Land GEM software is free of viruses and it is carefully screened by the company **[26].**
- **Macros Security Settings-** It is advised to set your Security level of the functions to Standard before if you are using older version of Microsoft Excel or Excel 2002 (Note

that it should be in the package of the Microsoft XP) to allow the enable macro-option which we have to select. Now the pop-up message which is shown in *Figure 3.1* will pop up if the Security of Macros level is at the high setting when we first time open this modelling software. If we want, we can regulate the function level security in Excel and the steps to do so is, in excel select the Macro security in the Tools Menu and click on the Medium radio button available. Even though the Land GEM software can be operated with the Low-level Security of the Macro, and this setting is also sometime the default setting which is recommended by the Microsoft.**[26]**

Figure 3.1: Macro Security Warning Message **[26]**

- **Memory Requirements**- Memory requirements are, the (RAM) Random Access Memory of the system should be minimum of 64 Mega Bytes (MB). And there should be at least 2 Mega Bytes (MB) free space in the Hard Drive of the System. These requirements of memory should be fulfilled in order to run the Land GEM Software in your System.**[26]**
- **Read Only Feature**- Land GEM is a onetime read file; we have the save a copy of the Land GEM with another name while running the different Landfill scenarios. This feature of read only is to guard the main file from the exploitation or written-over. Now if it is necessary the make changes, we can eliminate this constraint of read only by altering the file properties in the Files menu management program for example windows explorer.**[26]**
- **Password Protection Feature**- This is a very use full feature available in the Land GEM software is that we can password protect our file so that there is no modification in the model by other user. We can also password protect the spreadsheets available in the Land GEM software individually **[26].**
- **Screen Resolution**- In order to View Land GEM 1024 by 768 pixels are the optimum screen resolution. Now to change the screen resolution, go to start menu open control panel, then open folder of display, click on the settings tab at topmost of the window so

that it is selected, and then adjust the screen resolution. (it basically depends upon the windows versions installed in the different systems) **[26].**

3.4.3 Spread sheet Design

Worksheet name and function are defined as following **[26]:**

- **INTRO** – In the intro sheet of the Land GEM it contains only the overview (general information) of the model and it also contains the important notes about the usage of the software.
- **USER INPUTS** – In this Spread sheet the users provide inputs in the software, inputs such as Landfill characteristics, Model parameters which can be default or user specified, we can select the 4 gases or contaminants from the overall landfill gases, methane, Carbon dioxide, NMOCs, and the other 46 air pollutants, and also we have to enter the waste acceptance rate of the landfill every year.
- **POLLUTANTS** – In the Land GEM it allows user to edit the pollutant concentrations and also allows entering the molecular weights of the pollutants and we can also add up new pollutant parameters if the data is available for the specified area.
- **INPUT REVIEW** – Now in the input review user can review and at the same time user can print the inputs for the future reference.
- **METHANE** – First Order Decay method is used by the software to approximate the emission rate of methane specified by the IPCC.
- **RESULTS** – Results in the Land GEM software are shown in the tabular form. User can check the results up to the four specified pollutants at a time. The results of the emission rate of the landfill gases are shown on the per year basis. Units are in mega Gram per year, Cubic Meter per Year, and operator choice unit option is also available which is a third unit of measure such as average cubic feet per minute, cubic feet per year, or short tons per year.
- **GRAPHS** – Land GEM gives the graphical representation of the estimated Total landfill gases/pollutants on the per year basis. In the units of Mega Gram per Year, cubic Meter per year and third operator specified unit.
- **INVENTORY** – User can check the amount of the emission rate of the gases in the tabular form for the single year specified.
- **REPORT** – In the last Spreadsheet of the Land GEM software it allows user to view and print the results. Also, user can print the inputs and summary report at the same time.

CHAPTER-4

METHANE GENERATION POTENTIAL OF MUNICIPAL SOLID WASTE IN DUMPING SITE PANCHKULA

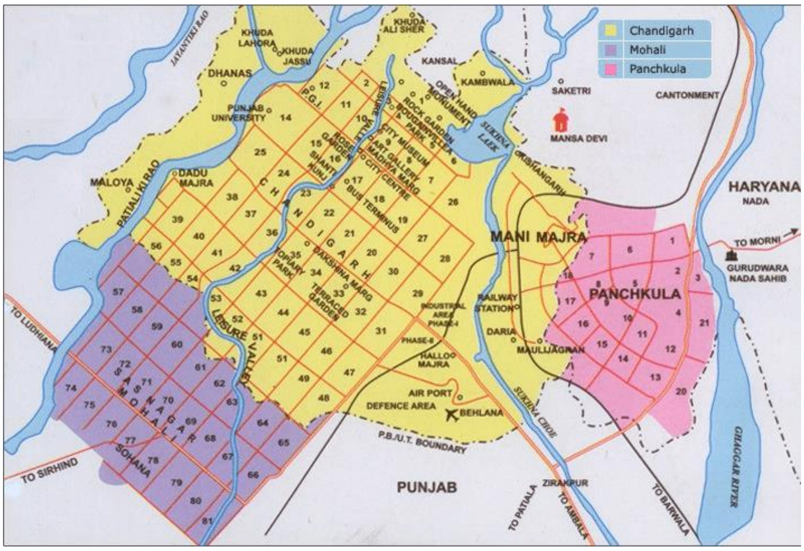
4.1 Introduction

The Panchkula city in Haryana is a very well-planned city, and it comes under the Ambala division in Haryana. The Panchkula name basically came from the place where the (Panch means five) 5 canal joins which is used for the irrigation purpose. Panchkula shares its boundaries with Zirakpur, Mohali and Chandigarh. City headquarters is in district Panchkula **[38].**

Highlighting about the distances from the nearby areas Panchkula city is approximately 4 kilometres from Chandigarh capital of Punjab and Haryana, it is approximately 105 kilometres from Shimla which is capital of Himachal Pradesh, Ambala to Panchkula distance is of 44 kilometres, and from New Delhi the distance of Panchkula is about 259 kilometres.

According to the Google Maps Panchkula lies within the longitudinal and latitudinal coordinates of 30.74000^0 N, 76.8000^0 E and is a very well-planned city. Total area of Panchkula city is 816 Km^2 with a people count of approximately five lakhs fifty thousand in the year 2011 according to the census of India (National Census Report, 2011) **[38].**

Figure 4.1(a) **Figure 4.1(b)**



(c)

Figure 4.1 (a) Panchkula city Location on Indian Map, **(b)** Panchkula city map, **(c)**Panchkula city Sector-wise Map

Estimated Population of Panchkula city year wise is

year 2014- population 651,326,

in year 2015 – population 682,903,

in year 2016 – population 710,002,

in year 2017 – population 732,441,

in year 2018 – population 761,558.

Year 2019 – population 783,604 (estimated).

4.1.1 Waste Generation and Characterization

In Panchkula the uptown areas, commercial areas, institutions and offices are the main sources of the City Solid Refuse. According to the reports that we study we found that the Panchkula city generates overall refuse of approximately 150 tons every day which is equivalent to 0.267 kilo grams per person every day. Where, around 350 kg/m^3 is the estimated density of the refuse in the panchkula city. *Table 4.1* shows the source of Municipal Solid waste in the Panchkula city, as through this table we can find that the major waste is from the house hold, market and commercial areas.

Table 4.1: Source of Municipal Solid refuse in Panchkula

Source of waste	Panchkula (%)
Household waste	34.9
Street sweeping	20.7
Institutional waste	13.2
Market and Commercial waste	31.2

4.1.2 Waste Collection and Storage of MSW

In the Panchkula city the city solid refuse is mostly contains high organic refuse content, plastic content, paper content, polythene, glass and some other materials. Now in Panchkula the workers of the city corporation collect the solid refuse on the repeatedly basis with the employing method that is by collecting the waste from the houses and by cleaning the streets daily. After reading the research papers we found that each sector in Panchkula is allotted with maximum two sweepers. In order to clean the streets, roads and lanes and also to collect the refuse the sweepers are equipped with the brooms, tricycles and carts. After collecting the waste, the sweepers throw the refuse in an open area before the refuse is being transferred to the dumping site **[38].**

As in the Panchkula city the major content of refuse is organic so, the refuse collecting workers collects the refuse from houses daily. But the collection process is not very proper, as sometimes the workers does not collect the waste effectively, means the efficiency of refuse collection sometimes goes below 60%. The main reason behind this that the number of workers are less who collects the refuse daily. Another main reason is that the workers are less educated and are less aware of the negative effects of the waste on the human health as well as on the environment **[38]**.

The refuse which is daily collected by the workers are thrown in an open area before being transferred to the dumping site, this is because in Panchkula there are no storage contains installed for the refuse in any sector. The refuse which is collected by the street sweepers from the domestic areas are stored in temporary bins, and the bins are installed at various areas within the sector. The location points of the bins are fixed in every sector of the city. They are positioned in such a way that each sector gets at least 4 bins. **[38].**

The number of vehicles which are given to the workers to collect and transfer the refuse from the collection point to the dumping ground are 45 include tractors and dumping pacer, and the capacity of around 2 to 4 tons. From the recent reports the number of vehicles and the dustbin has been increased to increase the refuse collection and efficiency of storage in panchkula city. Also new solid waste management rules has been implemented in the recent years which state that the waste generators have to segregate the waste and even deal with the dispoisal of the collected waste**[38].**

Figure 4.2: Panchkula MC staff distributing segregation bins.

4.1.3 Waste Disposal (Dumping site sector 23 Panchkula)

The site for the dumping of the waste in the city is in Sector 23 of Panchkula. This os the site which is in use from last 17 years in order to dump the refuse which is collected daily by the sweepers. The area of this site is approximately 12 acres. From the reports of the M.C Panchkula around 90 to 95 percent of the overall refuse which is generated in the city is disposed at this site. The process of segregation is done by the rag pickers after the waste is thrown in this dumping ground. The cover of soil on the refuse is provided daily by the street sweepers and the drainage cleaning is also done. Note that there is no treatment facility to treat the refuse in Panchkula **[38].**

Now due to the lack of workers and large amount of refuse is thrown in this site the people who live in nearby area always complain about the foul smell, they also complain that sometime the waste is being burnt in open environment which also increase the air pollution of that area. So, According to the latest reports the municipal corporation is going to turn the dumping ground of sector 23 in Panchkula into a park with disposal plant facility**[38].**

But objective of our project is to estimate the methane generated from this landfill area from last 18 years. (Note our result does not depend upon that the landfill is currently open or not).

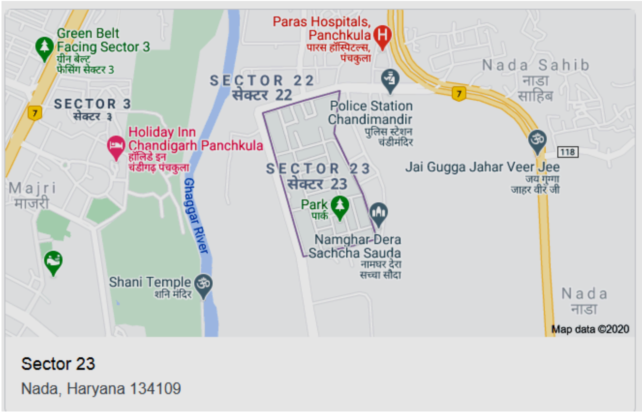


Figure 4.3: Map view of sector 23

4.2 Gas Emission from Dumping Site (Land GEM) Sector 23 Panchkula

4.2.1 Description

Modelling tool we are using to estimate the gases which are produced from the landfill is Land GEM this software is known as the Model of Landfill Gas Release. This model takes in considerations of the time factor while calculating the generation rate of the gases from the MSW landfills. This model basically estimates the mass of the production/generation of CH_4 per year using the generation capacity of methane and the group of the refuse that is deposited at the landfill site. First order decomposition equation which is used by the Land GEM software is given below:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_0 \left[\frac{M_i}{10}\right] e^{-kt_{i,j}}$$

Where: **[8][26]**

Q_{CH4} = Total yearly methane generated from landfill of the yr. which is being calculated, units in(m^3/yr.)

i = increment of 1 yr. period,

n = it is estimated as considered calculated year – starting years in which the waste is thrown in Landfill

j = increase of time 0.1-year,

k = rate of the methane gas produced from the Landfill, unit in ($yr.^{-1}$)

L_o = capacity of the methane production potential methane, unit in (m^3/Mega gram)

M_i = i^{th} year in which the waste is gained (mass) (Mg)

t_{ij} = time at j^{th} component of the waste mass in which the Mi is accepted in the time of the i^{th} year. In the decimal years.**[8][26]**

4.2.2 Model Inputs

- **Opening and Closure Year of landfill:** Landfill Opening Year is a compulsory input. In our case the landfill open year is 2002. Landfill Closure Year in Land GEM of landfill capacity any one is optional so; we have used the Landfill shut down year as our input. So, in the year, as according to the latest reports the municipal corporation is going to turn the dumping ground of sector 23 into park with disposal plant facility. So, in order to run this model, we have taken the landfill closure year as 2019.
- **Annual Waste Acceptance Rates:** The yearly refuse capacity is a critical Land GEM model setting.

Table 4.2: Year wise population of panchkula city (estimated)

Year	Population
2011 (census)	561,293
2014	651,326
2015	682,903
2016	710,002
2017	732,441
2018	761,558
2019	783,604

in order to input the data of the Waste acceptance data of the landfill per year from the opening year to the shutdown year we have estimated the data and estimated data is shown in *Table 4.3*.

Table 4.3: Estimated waste generated per year in panchkula city

Year	Waste Generated (tons/day)	Total Weight (tons/year) (approx)
2002	110	38142.5
2007	130	45077.5
2011	150	52012.5
2016	180	62415
2019	190	65882.5

Now we have entered this data in LandGEM Software Figure 4.2.2(a) Shows the data which we have entered year wise.

4: ENTER WASTE ACCEPTANCE RATES

Input Units: Mg/year

Year	Input Units (Mg/year)	Calculated Units (short
2002	39,000	42,900
2003	39,000	42,900
2004	39,000	42,900
2005	39,000	42,900
2006	39,000	42,900
2007	46,000	50,600
2008	46,000	50,600
2009	46,000	50,600
2010	46,000	50,600
2011	53,000	58,300
2012	53,000	58,300
2013	53,000	58,300
2014	53,000	58,300
2015	53,000	58,300
2016	63,000	69,300
2017	63,000	69,300
2018	63,000	69,300
2019	66,000	72,600

Figure 4.4(a): Waste acceptance rate data entered in LandGEM Software Year wise (Mega Gram per Year)

- **Methane Generation Rate, k (year^{-1}):** We can estimate or calculate the value of Methane Generation Rate k by using the following equation.

$$k = 3.1 * 10^{-5}\ (annual\ mean\ rainfall) + 0.01$$

[8], [26]

Or we can Also use the constant values provided of Methane Generation Rate, k (year^{-1}) as shown in the *Table 5.5*.

We have used the CAA Conventional Constants throughout our study.

- **Potential methane generation capacity L_0 (m^3/mg):** The methane generation potential capacity symbolized as L_o rely largely on the sort/kind of refuse that is disposed in the landfill. We should keep in consideration that the methane generation potential, L_o standards will be higher for refuse comprising lot of cellulose in it **[8][26]**. See *Table 5.6.*

We have used CAA Conventional default constant value for L_0 throughout our study.

- **Organic Compounds that are Non-Methanic (NMOC) Concentration:** This generally depends upon the waste characteristics. IPCC default values are six hundred ppmv for landfills having the waste from the house and some of other kind in the landfill. We have taken CAA default values in our study report **[8][26].**
- **Methane Content (% by volume):** Default CAA value is 50% by volume. And we have taken the same constant value.
- **Selected Gas / Pollutants:** while modelling LandGEM gives us the option to pick any four gases or the pollutants of air at one time for modelling [**8][26].** *Figure 4.4(b) and Table 5.7***.**

Figure 4.4(b) Shows the selected gas and pollutants which is being used by model.

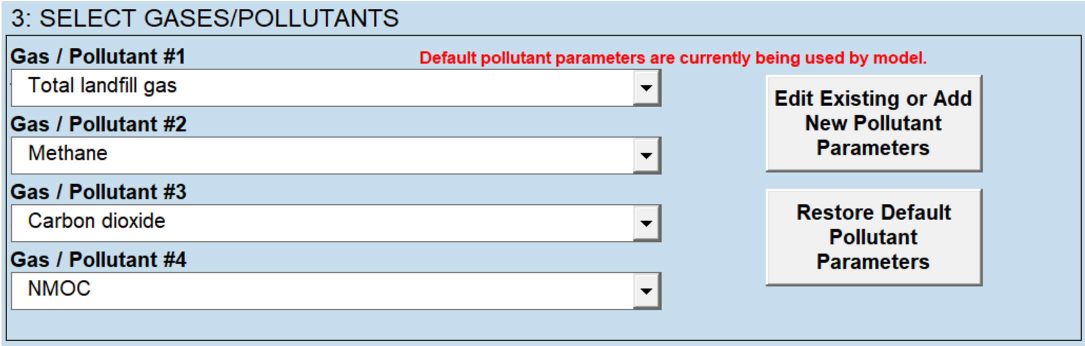


Figure 4.4(b): Selected Gases and pollutants

Now we can edit here the pollutant parameters if we have calculated or we can also use the default considerations. We have selected priority Total landfill gases, for methane, then for carbon dioxide estimation and at last for the NMOCs. We can also edit the pollution parameters.

4.2.3 Results:

Table 4.4 (a) shows the result of the quantity/amount of the waste that is thrown off in the landfill during the 17 years in which the landfill was open.

Table 4.4 (a)

Years	Waste Accepted		Waste in Place	
	(Mg/year)	(Short tons/year)	(Mg/year)	(Short tons/year)
2002	39,000	42,900	0	0
2003	39,000	42,900	39,000	42,900
2004	39,000	42,900	78,000	85,800
2005	39,000	42,900	1,17,000	1,28,700
2006	39,000	42,900	1,56,000	1,71,600
2007	46,000	50,600	1,95,000	2,14,500
2008	46,000	50,600	2,41,000	2,65,100
2009	46,000	50,600	2,87,000	3,15,700
2010	46,000	50,600	3,33,000	3,66,300

2011	53,000	58,300	3,79,000	4,16,900
2012	53,000	58,300	4,32,000	4,75,200
2013	53,000	58,300	4,85,000	5,33,500
2014	53,000	58,300	5,38,000	5,91,800
2015	53,000	58,300	5,91,000	6,50,100
2016	63,000	69,300	6,44,000	7,08,400
2017	63,000	69,300	7,70,000	7,77,700
2018	63,000	69,300	7,70,000	8,47,000
2019	66,000	72,600	8,33,000	9,16,300

Table 4.4 (b) shows the trend of the Total landfill gases Methane gas emission every year at the waste disposal site. (This table is generated by the LandGEM software in the result spreadsheet).

Table 4.2.3 (b)

Year	Total Landfill Gases		Methane	
	(Mg/year)	(short tons/year)	(Mg/year)	(short tons/year)
2002	0	0	0	0
2003	8.096E+02	8.906E+02	2.163E+02	2.379E+02
2004	1.580E+03	1.738E+03	4.220E+02	4.642E+02
2005	2.312E+03	2.544E+03	6.177E+02	6.794E+02
2006	3.009E+03	3.310E+03	8.038E+02	8.842E+02
2007	3.672E+03	4.039E+03	9.809E+02	1.079E+03
2008	4.448E+03	4.893E+03	1.188E+03	1.307E+03
2009	5.186E+03	5.705E+03	1.385E+03	1.524E+03
2010	5.888E+03	6.477E+03	1.573E+03	1.730E+03
2011	6.556E+03	7.211E+03	1.751E+03	1.926E+03
2012	7.336E+03	8.070E+03	1.960E+03	2.156E+03
2013	8.079E+03	8.887E+03	2.158E+03	2.374E+03
2014	8.785E+03	9.664E+03	2.347E+03	2.581E+03
2015	9.457E+03	1.040E+04	2.526E+03	2.779E+03
2016	1.010E+04	1.111E+04	2.697E+03	2.966E+03
2017	1.091E+04	1.200E+04	2.915E+03	3.206E+03

2018	1.169E+04	1.286E+04	3.122E+03	3.434E+03
2019	1.243E+04	1.367E+04	3.319E+03	3.651E+03
2020	1.319E+04	1.451E+04	3.523E+03	3.875E+03
2021	1.255E+04	1.380E+04	3.351E+03	3.686E+03
2022	1.193E+04	1.313E+04	3.188E+03	3.506E+03
2023	1.135E+04	1.249E+04	3.032E+03	3.335E+03
2024	1.080E+04	1.188E+04	2.884E+03	3.173E+03
2025	1.027E+04	1.130E+04	2.744E+03	3.018E+03
2026	9.771E+03	1.075E+04	2.610E+03	2.871E+03
2027	9.294E+03	1.022E+04	2.483E+03	2.731E+03
2028	8.841E+03	9.725E+03	2.362E+03	2.598E+03
2029	8.410E+03	9.251E+03	2.246E+03	2.471E+03
2030	8.000E+03	8.800E+03	2.137E+03	2.350E+03
2031	7.609E+03	8.370E+03	2.033E+03	2.236E+03
2032	7.238E+03	7.962E+03	1.933E+03	2.127E+03
2033	6.885E+03	7.574E+03	1.839E+03	2.023E+03
2034	6.550E+03	7.205E+03	1.749E+03	1.924E+03
2035	6.230E+03	6.853E+03	1.664E+03	1.831E+03
2036	5.926E+03	6.519E+03	1.583E+03	1.741E+03
2037	5.637E+03	6.201E+03	1.506E+03	1.656E+03
2038	5.362E+03	5.899E+03	1.432E+03	1.576E+03
2039	5.101E+03	5.611E+03	1.362E+03	1.499E+03
2040	4.852E+03	5.337E+03	1.296E+03	1.426E+03
2041	4.615E+03	5.077E+03	1.233E+03	1.356E+03
2042	4.390E+03	4.829E+03	1.173E+03	1.290E+03
2043	4.176E+03	4.594E+03	1.116E+03	1.227E+03
2044	3.973E+03	4.370E+03	1.061E+03	1.167E+03
2045	3.779E+03	4.157E+03	1.009E+03	1.110E+03
2046	3.594E+03	3.954E+03	9.601E+02	1.056E+03
2047	3.419E+03	3.761E+03	9.133E+02	1.005E+03
2048	3.252E+03	3.578E+03	8.688E+02	9.556E+02
2049	3.094E+03	3.403E+03	8.264E+02	9.090E+02

2050	2.943E+03	3.237E+03	7.861E+02	8.647E+02
2051	2.799E+03	3.079E+03	7.477E+02	8.225E+02
2052	2.663E+03	2.929E+03	7.113E+02	7.824E+02
2053	2.533E+03	2.786E+03	6.766E+02	7.442E+02
2054	2.409E+03	2.650E+03	6.436E+02	7.079E+02
2055	2.292E+03	2.521E+03	6.122E+02	6.734E+02
2056	2.180E+03	2.398E+03	5.823E+02	6.406E+02
2057	2.074E+03	2.281E+03	5.539E+02	6.093E+02
2058	1.973E+03	2.170E+03	5.269E+02	5.796E+02
2059	1.876E+03	2.064E+03	5.012E+02	5.514E+02
2060	1.785E+03	1.963E+03	4.768E+02	5.245E+02
2061	1.698E+03	1.868E+03	4.535E+02	4.989E+02
2062	1.615E+03	1.777E+03	4.314E+02	4.746E+02
2063	1.536E+03	1.690E+03	4.104E+02	4.514E+02
2064	1.461E+03	1.608E+03	3.904E+02	4.294E+02
2065	1.390E+03	1.529E+03	3.713E+02	4.085E+02
2066	1.322E+03	1.455E+03	3.532E+02	3.885E+02
2067	1.258E+03	1.384E+03	3.360E+02	3.696E+02
2068	1.196E+03	1.316E+03	3.196E+02	3.516E+02
2069	1.138E+03	1.252E+03	3.040E+02	3.344E+02
2070	1.083E+03	1.191E+03	2.892E+02	3.181E+02
2071	1.030E+03	1.133E+03	2.751E+02	3.026E+02
2072	9.796E+02	1.078E+03	2.617E+02	2.878E+02
2073	9.318E+02	1.025E+03	2.489E+02	2.738E+02
2074	8.864E+02	9.750E+02	2.368E+02	2.604E+02
2075	8.432E+02	9.275E+02	2.252E+02	2.477E+02
2076	8.020E+02	8.822E+02	2.142E+02	2.357E+02
2077	7.629E+02	8.392E+02	2.038E+02	2.242E+02
2078	7.257E+02	7.983E+02	1.938E+02	2.132E+02
2079	6.903E+02	7.593E+02	1.844E+02	2.028E+02
2080	6.567E+02	7.223E+02	1.754E+02	1.929E+02
2081	6.246E+02	6.871E+02	1.668E+02	1.835E+02

2082	5.942E+02	6.536E+02	1.587E+02	1.746E+02

Table 4.4 (c) Shows the CO_2 and NMOCs emission rate per year from the Panchkula dumping site. (This table is generated by Land GEM software)

Table 4.4(c)

Year	**Carbon Dioxide**		**NMOCs**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
2002	0	0	0	0
2003	5.934E+02	6.527E+02	9.295E+00	1.023E+01
2004	1.158E+03	1.274E+03	1.814E+01	1.995E+01
2005	1.695E+03	1.864E+03	2.655E+01	2.920E+01
2006	2.205E+03	2.426E+03	3.455E+01	3.800E+01
2007	2.691E+03	2.960E+03	4.216E+01	4.638E+01
2008	3.260E+03	3.586E+03	5.107E+01	5.617E+01
2009	3.801E+03	4.181E+03	5.954E+01	6.549E+01
2010	4.315E+03	4.747E+03	6.760E+01	7.436E+01
2011	4.805E+03	5.285E+03	7.527E+01	8.279E+01
2012	5.377E+03	5.914E+03	8.423E+01	9.265E+01
2013	5.921E+03	6.513E+03	9.275E+01	1.020E+02
2014	6.438E+03	7.082E+03	1.009E+02	1.109E+02
2015	6.931E+03	7.624E+03	1.086E+02	1.194E+02
2016	7.399E+03	8.139E+03	1.159E+02	1.275E+02
2017	7.997E+03	8.797E+03	1.253E+02	1.378E+02
2018	8.565E+03	9.422E+03	1.342E+02	1.476E+02
2019	9.106E+03	1.002E+04	1.427E+02	1.569E+02
2020	9.666E+03	1.063E+04	1.514E+02	1.666E+02
2021	9.195E+03	1.011E+04	1.440E+02	1.584E+02
2022	8.746E+03	9.621E+03	1.370E+02	1.507E+02
2023	8.320E+03	9.152E+03	1.303E+02	1.434E+02
2024	7.914E+03	8.705E+03	1.240E+02	1.364E+02
2025	7.528E+03	8.281E+03	1.179E+02	1.297E+02

2026	7.161E+03	7.877E+03	1.122E+02	1.234E+02
2027	6.812E+03	7.493E+03	1.067E+02	1.174E+02
2028	6.479E+03	7.127E+03	1.015E+02	1.117E+02
2029	6.163E+03	6.780E+03	9.655E+01	1.062E+02
2030	5.863E+03	6.449E+03	9.184E+01	1.010E+02
2031	5.577E+03	6.135E+03	8.737E+01	9.610E+01
2032	5.305E+03	5.835E+03	8.310E+01	9.141E+01
2033	5.046E+03	5.551E+03	7.905E+01	8.696E+01
2034	4.800E+03	5.280E+03	7.520E+01	8.272E+01
2035	4.566E+03	5.023E+03	7.153E+01	7.868E+01
2036	4.343E+03	4.778E+03	6.804E+01	7.484E+01
2037	4.131E+03	4.545E+03	6.472E+01	7.119E+01
2038	3.930E+03	4.323E+03	6.157E+01	6.772E+01
2039	3.738E+03	4.112E+03	5.856E+01	6.442E+01
2040	3.556E+03	3.912E+03	5.571E+01	6.128E+01
2041	3.383E+03	3.721E+03	5.299E+01	5.829E+01
2042	3.218E+03	3.539E+03	5.041E+01	5.545E+01
2043	3.061E+03	3.367E+03	4.795E+01	5.274E+01
2044	2.911E+03	3.203E+03	4.561E+01	5.017E+01
2045	2.769E+03	3.046E+03	4.338E+01	4.772E+01
2046	2.634E+03	2.898E+03	4.127E+01	4.540E+01
2047	2.506E+03	2.756E+03	3.926E+01	4.318E+01
2048	2.384E+03	2.622E+03	3.734E+01	4.108E+01
2049	2.267E+03	2.494E+03	3.552E+01	3.907E+01
2050	2.157E+03	2.373E+03	3.379E+01	3.717E+01
2051	2.052E+03	2.257E+03	3.214E+01	3.535E+01
2052	1.952E+03	2.147E+03	3.057E+01	3.363E+01
2053	1.856E+03	2.042E+03	2.908E+01	3.199E+01
2054	1.766E+03	1.942E+03	2.766E+01	3.043E+01
2055	1.680E+03	1.848E+03	2.631E+01	2.895E+01
2056	1.598E+03	1.758E+03	2.503E+01	2.753E+01
2057	1.520E+03	1.672E+03	2.381E+01	2.619E+01

2058	1.446E+03	1.590E+03	2.265E+01	2.491E+01
2059	1.375E+03	1.513E+03	2.154E+01	2.370E+01
2060	1.308E+03	1.439E+03	2.049E+01	2.254E+01
2061	1.244E+03	1.369E+03	1.949E+01	2.144E+01
2062	1.184E+03	1.302E+03	1.854E+01	2.040E+01
2063	1.126E+03	1.239E+03	1.764E+01	1.940E+01
2064	1.071E+03	1.178E+03	1.678E+01	1.846E+01
2065	1.019E+03	1.121E+03	1.596E+01	1.756E+01
2066	9.691E+02	1.066E+03	1.518E+01	1.670E+01
2067	9.219E+02	1.014E+03	1.444E+01	1.589E+01
2068	8.769E+02	9.646E+02	1.374E+01	1.511E+01
2069	8.341E+02	9.175E+02	1.307E+01	1.437E+01
2070	7.935E+02	8.728E+02	1.243E+01	1.367E+01
2071	7.548E+02	8.302E+02	1.182E+01	1.301E+01
2072	7.179E+02	7.897E+02	1.125E+01	1.237E+01
2073	6.829E+02	7.512E+02	1.070E+01	1.177E+01
2074	6.496E+02	7.146E+02	1.018E+01	1.119E+01
2075	6.179E+02	6.797E+02	9.680E+00	1.065E+01
2076	5.878E+02	6.466E+02	9.208E+00	1.013E+01
2077	5.591E+02	6.150E+02	8.759E+00	9.635E+00
2078	5.319E+02	5.851E+02	8.332E+00	9.165E+00
2079	5.059E+02	5.565E+02	7.926E+00	8.718E+00
2080	4.813E+02	5.294E+02	7.539E+00	8.293E+00
2081	4.578E+02	5.036E+02	7.171E+00	7.889E+00
2082	4.355E+02	4.790E+02	6.822E+00	7.504E+00

Figure 4.5 Shows the yearly variation of Landfill Gases rate of production generated by the LandGEM Software for the dumping site in Sector 23 Panchkula. (In the form of Graph).

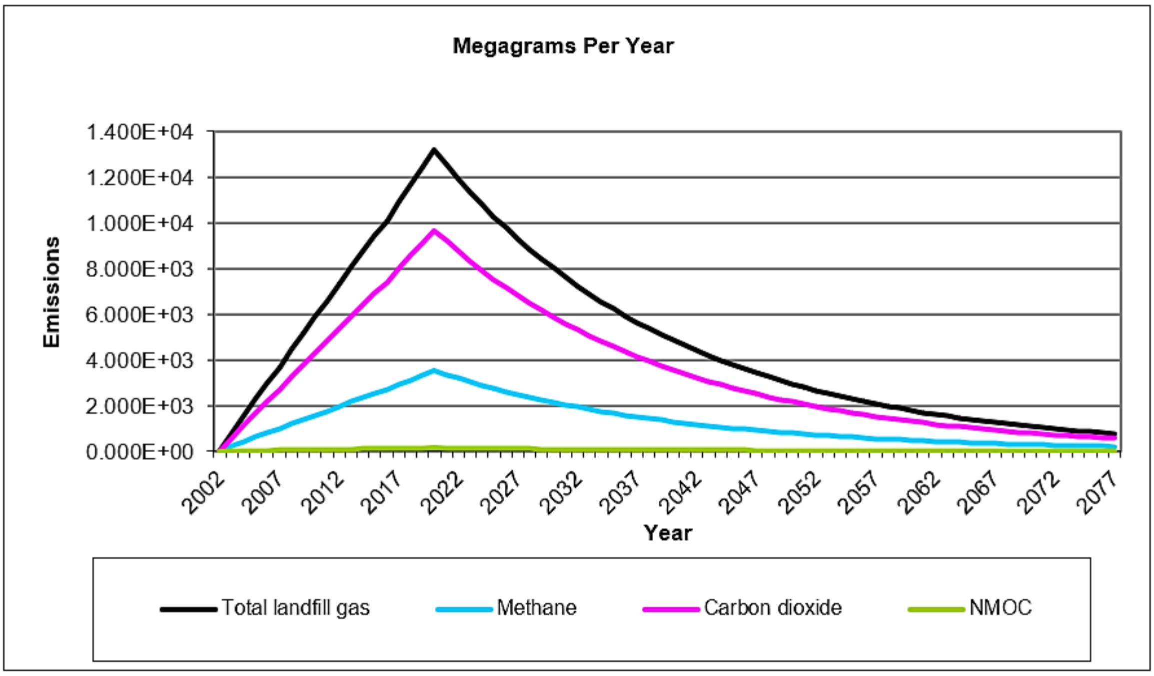


Figure 4.5: Annual total landfill Gas Graph result by LandGEM in Mg/year (Panchkula)

4.2.4 Discussion:

During the first year of the garbage/refuse in Landfill the Land GEM assumes that there is no decomposition process started and there is no biogas produced during that period.

After reading the literatures there it was mentioned that the methanogenesis steps starts in minimum 6 months after refuse is disposed in site. Refuse degradation generally rely upon many conditions and situations such as refuse type, moisture content in the refuse, climatic provisions changed during that period of time, refuse covering material in the landfill, etc., The Land GEM software don't take into consideration of all of these provisions in order to start the initial phases of methanogenesis process and examine these all parameters after 52 weeks, all of these things are considered at the starting of this phase.

As we see the *Table 4.4(b)* and *Figure 4.5*, we can see that from Sector 23 Dump Panchkula in the year 2003 the total Methane gases which was generated was around $2.163 * 10^2$ Mg/year which is increased to $3.5 * 10^3$ Mg /year by the year 2020 which is a peak value.

CHAPTER-5

METHANE GENERATION POTENTIAL OF MUNICIPAL SOLID WASTE IN DUMPING SITE OF JALANDHAR AND AMRITSAR

5.1 Introduction

Amritsar and Jalandhar cities are located in the state of Punjab in India which is in northern Part of India. The Punjab state has boundaries with Jammu Kashmir (union territory) to the north, with Himachal Pradesh state to the northern and northeast, with Haryana in south and south east, and with Chandigarh at east. Punjab share its International boundaries with Pakistan. The area of Punjab state is approx. 50,362 square kilometers. Population of Punjab was approx. 2.77 crores according to the census held in 2011 of India. Which is now increased to approx. 3 crores by the year 2020 as per the Indian census growth rate report **[24][26].**

Now, if we discuss about the waste generation scenario in the state of Punjab, as reported in the Board of central Pollution Control (CPCB) annual report, in the past year of 1999-2000 Punjab state generated approx. 1,266 tons of refuse per day (TPD). Due to increase in the population of Punjab in the next decade the waste generated was approx. 2,793 TPD by the year 2011 according to the 2012 reports of CPCB. As per CPCB reports when the Punjab state was not divided into clusters for the Control and conduct of Solid Municipal Refuse, all the Solid waste which was generated during that time was disposed into unscientific landfill disposal sites. If we read the Hazardous waste inventory report by CPCB of the year 2009, the Punjab was having 3023 HW (Hazardous Waste) generating units and it generated approx. 1,80,000 tons of HW on an annual basis. Which was 13601 tons landfillable, 14831 non-recyclable and 89481 tons recyclable **[24][26].**

According to The Tribune reports by the year 2030 the waste generated in tons per day in Punjab will be approx. 5 thousand (5000T/day). And also, by the year 2041 approximately 6400 T/day. The reason that they mentioned for this rapid increase in the waste generated per day is majorly the urban population which is increasing in the very fast rate. If we conclude in this in one line, we can say that the daily waste which is generated in Punjab is anticipated to rise to around 128% in the year of 2041.

5.1.1 Municipal Solid Waste Management Plan/Model Punjab

National Urban Sanitary Policy (NSUP) of 2008 states that all the strategies of the municipal refuse conduct must be done and organized at the small level under the Cleanness Plan of City and the State of Sanitation Strategy. Now, this policy is being introduced in order to check and certify that the change in the type and amount of the City refuse in Solid is properly recognized and the steps which are taken for solid refuse handling is appropriate or not. This implementation can also help to resolve the issues like Land Acquisitions for the purpose of the waste conduct and problems with stake holders at local level can be resolved more precisely as the individuals who make decisions are local and they know how to handle the situation effectively in their own region **[26].**

Urban local bodies are accountable for the conduct of handling and managing the solid refuse in Punjab state. They also handle all the things related to the waste management i.e., collection of the refuse, carriage of the waste, waste storage, processing of the waste, and its disposal into the respective landfills and dumping areas. Now with accordance to the articles and the reports of CPCB, Punjab pollution Control Board, and the 2014 Punjab Model of managing and conduct of Solid Waste Plan in the year of 2014 there was around 146 ULBs in Punjab which includes 4 Municipal Corporations i.e., Amritsar in punjab, Jalandhar in punjab, Ludhiana in punjab and Patiala in punjab. All the ULBs has an authority to make the laws and can also charge the user to manage the solid refuse within their area. Now, these ULBs has been increased to 163 which includes 10 Municipal Corporations 95 Municipal Council and 58 Nagar Panchayat.**[60]** [**24] [26].**

The Punjab Local Government Department followed a different cluster approach to conduct and manage the solid waste within the state. So, they a-parted the state into eight clusters which comprise 8 to 26 ULBs (Urban Local Bodies) and these clusters covers all the ULB in the state. As in period year of 2014 when the Punjab Board which control the pollution released its report on the cluster approach progress in Punjab, they mentioned that there are around 146 ULBs in Punjab and from these ULBs the daily waste which is generated is around 4250 tons. So, that’s why in the resent years in order to make the managing and conduct of Waste which is Solid in the Punjab more efficient the Punjab Government has decided to increase the number of ULBs in the state. In this report they also mentioned that the Punjab Local Government Department has planned to run these clusters on the PPP model (Public Private Partnership) and similarly the conduct of the solid refuse will be carried out in all the ULBs within the state, which is designed and formed at small level with the local adaption at the small level of clusters.

In the four clusters i.e., Jalandhar in punjab, Bathinda in punjab, Ludhiana in punjab and Ferozepur in punjab the Partners that are individual i.e., private been selected. Rest of the clusters i.e., GMADA, Patiala, Pathankot and Amritsar the Private Partners bidding is still under implementation stage **[24][26].**

Table 5.1: Cluster Approach of Punjab Government

Name of Cluster	No. of ULBs covered/ Areas covered	Capacity in Tons per Day (TPD)	Disposal and Processing Facility	Project Cost (Rs. In Crores)
Amritsar Cluster	8 ULBs	650 TPD	21 acres at Bagtanwala	116.00
Bathinda Cluster	16 ULBs	350 TPD	36.11 acres of land at village mandi Khurad	66.46
GMADA Cluster	18 ULBs	350 TPD	50 acres of land at Samgauli	80.00
Jalandhar Cluster	27 ULBs	750 TPD	20 acers of land at village Jamsher	133.33
Ludhiana Cluster	14 ULBs	1125 TPD	49.5 acres of land Jamalpur; 33 acres of land at jaipur	97.85
Pathankot Cluster	13 ULBs	250 TPD	Site at village Deriwal – 40 acres	55.00
Patiala Cluster	25 ULBs	500 TPD	Site at village Simgauli	95.00
Ferozpur Cluster	18 ULBs	300 TPD	20 acres of land in village Beer Chahal	66.46

[24]

Table Source: Board of Control Of Pollution In Punjab 2014.

The **GMADA** Cluster in the Punjab is basically the combination of different Municipal Corporation and other remaining 14 ULB’s. Municipal Corporation of Mohali includes the Nagar of Sahibjada Ajit Singh and 14 other ULB’s combines to form this GMADA Cluster. These ULB’s are divided as: Zirakpir, Mohali, Naya Gaon, Lalru, Kharar, Banur, Dera Bassi, comes under Nagar of Sahibjada Ajit Singh District; Rajpur comes under the Patiala District; Sirhind-Fatehgarh Sahib, Bassi Pathana, Mandi Gobindgarh comes under District of Fatehgarh Sahib, and Chamkaur Sahib, Morinda, Ropar comes under the part of district of Rupnagar.

5.1.2 Punjab Conduct of MSW Plan Principles:

These are the following principles which are adopted and taken during the Punjab Conduct of Solid Refuse Waste in an area implementation: **[24][26]**

- Effective segregation of the waste during collecting it from source as well as segregation of the waste during the processing period and transportation.
- Maximum resource recovery.
- Effective handling of the refuse.
- Safe disposal of the refuse.
- Polluters to pay.

5.1.3 Punjab Waste Control and Management Plan:

- **Door to Door Collection and Segregation of Waste:** In the Door-to-door Collection of the Conduct of Solid waste Houses will be equipped with the separate two bins or containers, one for the damp waste also known as the biodegradable waste (green color) and other for the dry waste which also known as the Non-Biodegradable waste (white color). This will help to do the primary segregation of the refuse at the collection place. The refuse from houses will be collected through the rickshaws, auto rickshaws, big vehicles etc. which have the compartment containers. Cities will be divided into the different zones and these zones will be sub divided further into beats. Time for Door-to-Door collection will be from morning 7:30AM to the afternoon 2:00PM. These timings can be decided by the Corporation authority also. Now it depends upon the population for the placement of the bins, approximately 200 to 400 number of litter bins having capacity of 20 liters to 50 liters are to be placed at the desired locations for the waste keeping which is generated from the street sweepers. Approximately 300 to 500 workers will be deployed by the Company for the carrying of the work. It is also mentioned in the plan that whenever the owner's wants, they can adopt the Container free or Bin-less system by eliminating the secondary collection points **[26].**

- **Regulatory Measures for Waste generators:** These regulatory measures include from the **Residents** they are not allowed to throw the waste on streets, neighborhood, open spaces etc. They will not dispose the wet waste in the plastic carry bags. Regulatory measures for **Vegetable/Fruit Market Waste** are that the containers of large size to collect waste should be closed with lid. And these large containers will be removed during night time also known as the non-peak hours' time from the market. The collection of the waste from the **Marriage Hall /Mandaps/Community Halls** would be done on the daily basis and on the full cost recovery basis. For the waste generated from the **Hospital/Nursing Homes/Health Care Centers/Pathological Laboratories** the Board of Control of Pollution in Punjab has directed that these establishments should not throw biodegradable waste (medical waste) on the open spaces or streets as well as they will not throw the bio-medical waste into the given desired area dust bins or other collection sites. The Punjab Govt. has given desired direction in their code laws for the storage and treatment of the medical waste. The waste from the **Construction and Demolition** would accumulate a partly from the MSW. The charges per ton waste from the Construction and Demolition is fixed by the govt. and would be charged from the person generating it. The waste from the **Garden** would accumulate in the different vehicles. The private partners who collect these wastes has full independence to start a plant for composting **[26].**

- **Management of storage points in the city:** The waste collected from the households, shops and establishments through the primary Collection System would be taken to the disposal or the processing site directly with the help of the large vehicles so that the waste from these sources of the generation is transported to the desired location in the reasonable time. PPCB also mentions that out of hundred percent maximum of 10% of storage Depots Points in the city are allowed. There should be hygienic and good conditions around the waste bins. The waste collecting bins should be out of the reach of the animals, in terms of distance they should be easily accessible, covered with lid etc. **[26].**

- **Transportation of the Collected Waste:** The transfer station would be planned and provided based on the availability and the requirement of the waste. Waste collected would be transported in the safe and covered vehicles like dumper pacer/refuse compactor etc. The waste from the primary collection system would be directly transported in the covered vehicle to the waste shifting points. The route for the transfer of the waste can be decided by the Public Private Partner. Now if required the waste can be transferred twice or thrice a day before the bin's stars to overflow. The number of vehicles which are required to transfer the waste depends upon the amount of the waste generated in a zone **[26].**

5.1.4 Punjab Municipal Solid Waste Management Plan Silent Features:

- Door to Door assemblage of the waste which is done daily.
- Two waste collector (bin) method to be selected for the segregation of the refuse at the place of collection into the Non-Biodegradable and Biodegradable waste.
- Wherever feasible the Bin Free system is to be adopted.
- Latest technologies such as Incineration, Composting, Power/Energy generation from refuse, Refuse (RDF) originated Fuel Plants, etc. to be installed.
- In the well maintained and designed properly Sanitary Landfill, not more than 25% of the refuse to be thrown.
- For the conduct of the solid refuse in an area householder would have to pay and those who will violate the law will be finned. And this is done by adopting the principle of polluters have to pay. For the execution of the project a special fund would be created at the state level.
- Multi-tier management System: Implementation cells and Monitoring commissions at state, local and small area level; an independent engineer and an expert agency to monitor the project **[26].**

5.2 Methodology

5.2.1 Description of Study area – Jalandhar

Jalandhar is an Indian city which is Punjab state. This city lies alongside the GT Road (Grand Trunk Road) and also has a well-connected road and rail junction. Jalandhar is basically situated between the Sutlej and Beas rivers. It is of approx. 350 Km road length from the Delhi.

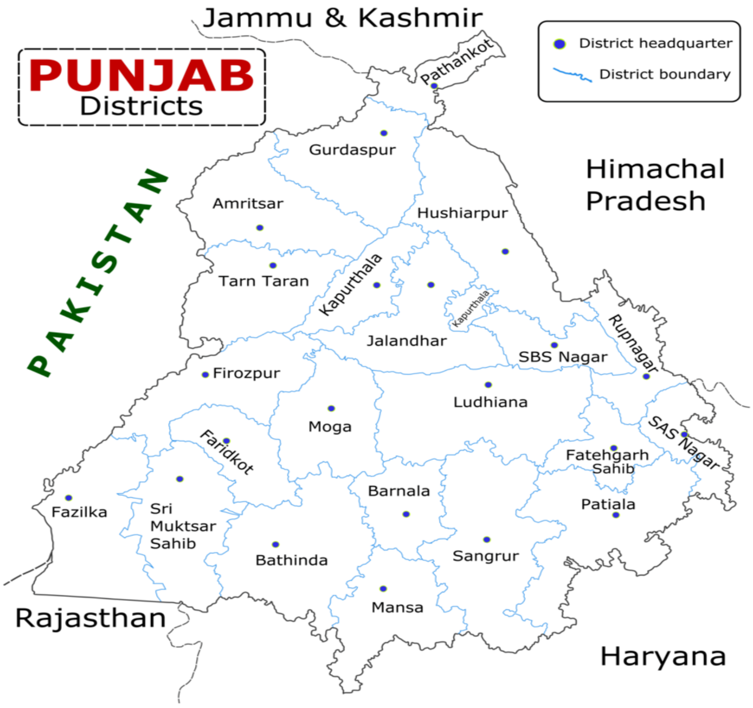
The Jalandhar city is 82.5 km South east of Amritsar which is also in Punjab, 146 Km in the north side of Chandigarh (Punjab and Haryana Capital).

According to the Google map the Jalandhar Lies withing the Latitude and Longitude of 31.3260^0N, 75.5762^0E. Area of Jalandhar city is approx. 110 Km^2 with the people count of approx. 873,725 in the year 2011, with male population of 463.975 and female population of 409,750 according to the Indian census report (National Census Report, 2011). The Jalandhar district possesses around 8.1% of the overall populace of the Punjab state as per the report of the census 2011.

If we discuss about the climate of the Jalandhar city, it has a subtropical humid climate with the long high temperature summers and unheated winters. Winters from year month November till February and Summers from April to June. The temperature in winter varies from 19^0C to -7^0C and in summer the temperature varies from 48^0C to 35^0C. And the average annual rainfall in centimeters is about 70cm.

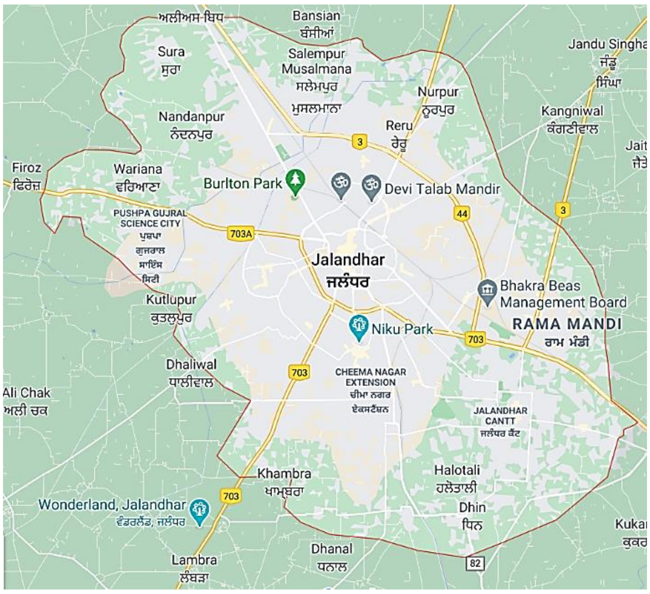
(a)

Figure 5.1(a): Shows the Place of the Jalandhar on Indian Map (Source of the image is from Wikipedia)



(b)

Figure 5.1(b): Shows the District Map of Punjab and the Place of Jalandhar in Punjab. (Source Google maps)



(c)

Figure 5.1(c): Shows the Jalandhar city Map (source Google Maps)

5.2.2 Waste Generation and Characterization

Considering the reports that we have read and studied the total area of the Jalandhar includes 80%-85% of the residential zone, 10% of the industrial one, and 5%-10% of the mixed zones. Now according to the Jalandhar Municipal Corporation reports of 2011 during the census year the Jalandhar district generated approx. 450 tons – 480 tons of the Waste per day. Now this number has been increased from approx. 250 tons / day over the last ten years. The solid refuse which is generated from the non-rural areas of the Jalandhar contributes to approx. fifteen percent of the overall refuse that is produced in Punjab. Now, approximately 50 tons of the refuse is produced from vegetables, fruits and grain markets. The waste in the built-up regions of Jalandhar contains the market waste, institutional, domestic waste, and some small amount of the industrial waste. From the year 2003 to 2009 the waste generated by each or per person has raised from 0.427 kilo gram/ day to 0.5 kilo gram/day **[29], [36].**

There was around total 60 wards in Jalandhar when the Punjab Government adopted the cluster approach for the Conduct of the solid refuse in Punjab. Now, the number of wards has been increased to 63. According to the Jalandhar Municipal corporation report of 2014 the waste generation per house in Jalandhar is approx. 1.5 kg. *Table 5.2* shows the type of the city solid refuse generated in the Jalandhar city.

Table 5.2: Percentage of the MSW generated daily in Jalandhar

Waste Type	Waste generated daily (%)
Residential waste	42.4%
Commercial waste	24.8%
Institutional waste	2.6%
Hotel and Resorts	15.8%
Recreational and Landscaping waste	1.4%
Street Sweeping	13%

(Source – Municipal Corporation Jalandhar 2015)

As we can see that the majority of the waste in the Jalandhar comes from the residential and Commercial areas. In Jalandhar the municipal corporation workers collects the Solid waste on the regularly basis with the employing method of house-to-house collection of refuse and by sweeping the streets.

In Jalandhar in consideration to the Municipal Corporation the majority of Paper waste, card board waste, and organic matter waste comes from the residential and open spaces. From the Commercial and street sweeping mostly the genre of waste which is collected by the workers are Paper waste, Plastic waste, inorganic waste and organic waste. The Toxic waste or the hazardous waste and organic waste comes from the industrial areas in Jalandhar **[29], [36]**.

5.2.3 Waste Collection and Storage of MSW

In the Jalandhar city in consideration to (MCJ) Municipal Corporation Jalandhar there are around 2720 workers (safai sewak) including the tipper truck drivers, and there are around 1500 sweepers which are employed by the MC Jalandhar. Infra technological Jindal limited and Municipal Corporation Jalandhar are accountable for the conduct and collection of the solid refuse in Jalandhar. The Jindal Infra tech has also employed man power to collect the solid waste **[29], [36].**

In Jalandhar sweepers work for around 7 hours a day, for 6 days a week. The assigned road length given for each sweeper is approx. 1km. it should also be noted that there is no automatic sweeping machine in Jalandhar. Municipal and Infra technological Jindal limited tippers cover estimated 85% to 95% of the city area. In Jalandhar the segregation of the scrap/refuse is not conducted at source, at transfer station and also not at the refuse dump site. Bins allotted in Jalandhar by municipal Corporation are of volume $1m^3$ and $4.5m^3$ and according to the reports at some places there are four wall concrete structures provided which act as waste collection dump **[29], [36]**.

In the recent reports we found that the Jalandhar City Municipal Corporation with the help of the private contractors are implementing new rules and regulation for effective assemblage and storage of the solid refuse. Steps which they will take in future such as: increasing the number of vehicles to collect the waste and transport at the fast rate to the dumping site, Increasing the workers so that the door-to-door assemblage of the refuse is more effective, increasing the number of the bins in some areas as still in some areas the numbers of bins are less and the workers have to travel long distance to throw the waste which they have collected in the collection bins. Jalandhar municipal corporation is also thinking about the segregation of the refuse at the collection point by installing different bins for biodegradable waste and for non-biodegradable refuse. Jalandhar city is still lacking behind in the effective collection of the waste. Still, they are not following properly the Punjab Solid waste management action plan.

Figure 5.2: Municipal Corporation Jalandhar (M.C.J) Waste collection vehicle.**[50]**

5.2.4 Waste Disposal (Wariana Dumping Site Jalandhar)

In the Jalandhar city for conduct of solid refuse disposal the site which was in use before the Punjab state adopted the Cluster approach was in village Wariana. This Wariana Dump site is not a sanitary Landfill. The total area of this site is approx. 14 acres which is around 0.057 km^2, this site is in use from the last 40 to 50 years for the waste disposal in Jalandhar. In Wariana dump the scrap/refuse is dumped directly without segregation, without proper segregation and without compaction, and this cause unpleasant smell and non-hygienic conditions. In this dumping site daily soil covers are also not applied on the dumped waste. As we know that this site is not an well designed landfill scrap site so there are no provisions for the leachate collection system by Municipal Corporation Jalandhar **[29][36].**

Now if we discuss about the present status of the dumping site according to Hindustan Times article and the reports which we have studied, this site is so far full to its volume. The daily refuse is just stacked up on the already existing refuse. As this dump area is full to its volume some time the daily waste (approx. 480 metric tons) is thrown/discarded at the two ponds at Jugral and Qadian Villages and in the scheduled areas of the city periphery **[29], [36]**.

We are only concerned about the methane gas which is generated from this dumping area. Our modeling software results does not depend upon that the site is currently open or not.

Figure 5.3 (a): Map view of the Wariana village (red bounded area) in Jalandhar,

Figure 5.3(b): Wariana Dumping ground image (Source: The Tribune Photo)

5.3 Gas Emission from Landfill (Land GEM) Wariana Dump Jalandhar

5.3.1 Description

Modelling tool we are using to estimate the gases which are produced from the landfill is Land GEM this software is known as the Model of Landfill Gas Release. This model takes in considerations of the time factor while calculating the generation rate of the gases from the MSW landfills. This model basically estimates the mass of the production/generation of CH_4 per year using the generation capacity of methane and the group of the refuse that is deposited at the landfill site. First order decomposition equation which is used by the Land GEM software is given below:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_0 \left[\frac{M_i}{10}\right] e^{-kt_{i,j}}$$

Where: **[8], [26]**

$\mathbf{Q_{CH4}}$ = Total yearly methane generated from landfill of the yr. which is being calculated, units in(m^3/yr.)

i = increment of 1 yr. period,

n = it is estimated as considered calculated year – starting years in which the waste is thrown in Landfill

j = increase of time 0.1-year,

k = rate of the methane gas produced from the Landfill, unit in ($yr.^{-1}$)

$\mathbf{L_o}$ = capacity of the methane production potential methane, unit in (m^3/Mega gram)

$\mathbf{M_i}$ = i^{th} year in which the waste is gained (mass) (Mg)

$\mathbf{t_{ij}}$ = time at j^{th} component of the waste mass in which the Mi is accepted in the time of the i^{th} year. In the decimal years **[8], [26].**

To do our study, the important required inputs which we have entered are mentioned in the *section 5.3.2*.

5.3.2 Model inputs

- **Opening and Closure Year of landfill:** Landfill opening Year is a compulsory entry. In our case the landfill open year is 1970. Landfill Closure Year in Land GEM or landfill capacity any one is optional so, we have used the Landfill shut down year as our input. Now, according to the Hindustan Times Articles and other reports which we have studies the Wariana dump has exhausted its capacity before the Punjab state adopted the Cluster approach strategy for the waste management in Punjab. So, in order to run this model, we have taken the closure year of landfill is taken as 2010 **[29].**
- **Annual Waste Acceptance Rates:** The yearly refuse capacity is a critical land GEM model setting.

Table 5.3: Year Wise Population of Jalandhar (census data)

Year	**Population** (approx.)
1970	290,000
1971 (census)	299,000
1981 (census)	411,000
1991 (census)	515,000
2001 (census)	719,000
2011 (census)	880,000

Table 5.3 shows the population of Jalandhar city according to Indian Census. In order to calculate the Waste which is taken in by the landfill every year, this data is very important. In consideration to the reports and CPCB data during the year of 2005 to 2010 in Jalandhar the per day waste which was generated was approx. 400 to 450 tons per day. Also, with accordance the reports around 90% to 95% of the overall refuse that is generated in Jalandhar is dumped in the landfill. Now in order to input the data of the Waste acceptance data of the landfill per year from the opening year to the shutdown year we have estimated the data and estimated data is tabulated in *Table 5.4*.

Table 5.4: Estimated waste generated per year in Jalandhar

Year	**Waste generated (tons/day)**	**Total Weight (tons/year) (approx.)**
1970	250	86687.5
1975	275	95356.25
1980	300	104025
1985	325	112693.75
1990	350	121362.5
1995	375	130031.25
2000	400	131400
2005	425	147368
2010	450	156037.5

Now, we have entered this data in LandGEM Software *Figure 5.4 (a)* Shows the data which we have entered year wise.

4: ENTER WASTE ACCEPTANCE RATES

Input Units: Mg/year

Year	Input Units (Mg/year)	Calculated Units (short tons/year)
1970	86,688	95,356
1971	86,688	95,356
1972	86,688	95,356
1973	86,688	95,356
1974	86,688	95,356
1975	95,356	1,04,892
1976	95,356	1,04,892
1977	95,356	1,04,892
1978	95,356	1,04,892
1979	95,356	1,04,892
1980	1,04,025	1,14,428
1981	1,04,025	1,14,428
1982	1,04,025	1,14,428
1983	1,04,025	1,14,428
1984	1,04,025	1,14,428
1985	1,12,694	1,23,963
1986	1,12,694	1,23,963
1987	1,12,694	1,23,963
1988	1,12,694	1,23,963
1989	1,12,694	1,23,963
1990	1,21,363	1,33,499
1991	1,21,363	1,33,499
1992	1,21,363	1,33,499
1993	1,21,363	1,33,499
1994	1,21,363	1,33,499
1995	1,30,031	1,43,034
1996	1,30,031	1,43,034
1997	1,30,031	1,43,034
1998	1,30,031	1,43,034
1999	1,30,031	1,43,034
2000	1,31,400	1,44,540
2001	1,31,400	1,44,540
2002	1,31,400	1,44,540
2003	1,31,400	1,44,540
2004	1,31,400	1,44,540
2005	1,47,368	1,62,105
2006	1,47,368	1,62,105
2007	1,47,368	1,62,105
2008	1,47,368	1,62,105
2009	1,47,368	1,62,105
2010	1,56,038	1,71,641

Figure 5.4(a): Waste acceptance rate data entered in LandGEM Software Year wise (Mega Gram per Year)

- **Methane Generation Rate, k (year^{-1}):** We can estimate or calculate the value of Methane Generation Rate k by using the following equation.

$$k = 3.1 * 10^{-5}\ (annual\ mean\ rainfall) + 0.01$$

[8], [26]

Or we can Also use the constant values provided of Methane Generation Rate, k ($year^{-1}$) as shown in the *Table 5.5*.

Table 5.5: Constant values for k ($year^{-1}$)

C.A.A Conventional	0.05
Arid area C.A.A	0.02
Inventory Standard Conventional	0.04
Arid Area inventory	0.02
Inventory Wet	0.7

[26]

We have used the CAA Conventional Constants throughout our study.

- **Potential methane generation capacity L_0 (m^3/mg):** The methane generation potential capacity symbolized as L_o rely largely on the sort/kind of refuse that is disposed in the landfill. We should keep in consideration that the methane generation potential, L_o standards will be higher for refuse comprising lot of cellulose in it **[8][26]**. The five default L_o values given for household waste are given in *Table 5.6*.

Table 5.6: Values for the potential methane generation capacity

Emission Type	Landfill Type	L_o value (m^3/mg)
Clean Air Act	Conventional	170 (default)
CAA	Area is Arid	170
Inventory	Conventional	100
Inventory defaults	Area is Arid	100
Inventory defaults	Wet	96

[26]

We have used CAA Conventional default constant value for L_0 throughout our study.

- **Organic Compounds that are Non-Methanic (NMOC) Concentration:** This generally depends upon the waste characteristics. IPCC default values are six hundred ppmv for landfills having the waste from the house and some of other kind in the landfill. We have taken CAA default values in our study report **[8][26].**

- **Methane Content (% by volume):** Default CAA value is 50% by volume. And we have taken the same constant value.
- **Selected Gas / Pollutants:** while modelling LandGEM gives us the option to pick any four gases or the pollutants of air at one time for modelling [**8**][**26**]. Now, the data with the pollutants and gases is Shown in the table below;

Table 5.7: Data Associated with Gases/Pollutants

Gas/Pollutant	Concentration (ppmv)	Molecular Weight
Gases		
Total landfill gas	Not Applicable	30.03
Methane	Not Applicable	16.04
Carbon Dioxide	Not Applicable	44.01
NMOCs	4,000 for CAA 600 for Inventory No or Unknown Co-Disposal 2,400 for Inventory Co-disposal	86.8
Pollutants		
1,1,1-Trichloroethane (methyl chloroform)	0.48	133.41
1,1,2,2-Tetrachloroethane	1.1	167.85
1,1-Dichloroethane (ethylidene dichloride)	2.4	98.97
1,1-Dichloroethene (vinylidene chloride)	0.20	96.94
1,2-Dichloroethane (ethylene dichloride)	0.41	98.96
1,2-Dichloropropane(prop.)	0.18	112.99
2-Propanol (isopropyl alcohol)	50	60.11
Acetone	7.0	58.08
Acrylonitrile	6.3	53.06

Benzene	1.9 for No or Unknown Co-disposal or 11 for Co-disposal	78.11
Bromodichloromethane	3.1	163.83
Butane	5.0	58.12
Carbon disulfide	0.58	76.13
Carbon monoxide	140	28.01
Carbon tetrachloride	$4.0 * 10^{-3}$	153.84
Carbonyl sulfide	0.49	60.07
Chlorobenzene	0.25	112.56
Chlorodifluoromethane	1.3	86.47
Chloroethane (ethyl chloride)	1.3	64.52
Chloroform	0.03	119.39
Chloromethane	1.2	50.49
Dichlorobenzene	0.21	147
Dichlorodifluoromethane	16	120.91
Dichlorofluoromethane	2.6	102.92
Dichloromethane (methylene chloride)	14	84.94
Dimethyl sulfide (methyl sulphide)	7.8	62.13
Ethane	890	30.07
Ethanol	27	46.08
Ethyl mercaptan (ethanethiol)	2.3	62.13
Ethylbenzene	4.6	106.16
Ethylene dibromide	$1.0 * 10^{-3}$	187.88
Fluorotrichloromethane	0.76	137.38
Hexane	6.6	86.18
Hydrogen sulfide	36	34.08
Mercury (total)	$2.9 * 10^{-4}$	200.61
Methyl ethyl ketone	7.1	72.11
Methyl isobutyl ketone	1.9	100.16

Methyl mercaptan	2.5	48.11
Pentane	3.3	72.15
Perchloroethylene (tetrachloroethylene)	3.7	165.83
Propane	11	44.09
t-1,2-Dichloroethene	2.8	96.94
Toluene	39 for No or Unknown Co-disposal	92.13
	170 for Co-disposal	
Trichloroethylene (trichloroethene)	2.8	131.40
Vinyl chloride	7.3	62.50
Xylenes	12	106.16

[8], [26]

Figure 5.4 (b) Shows the selected gas and pollutants which is being used by model.

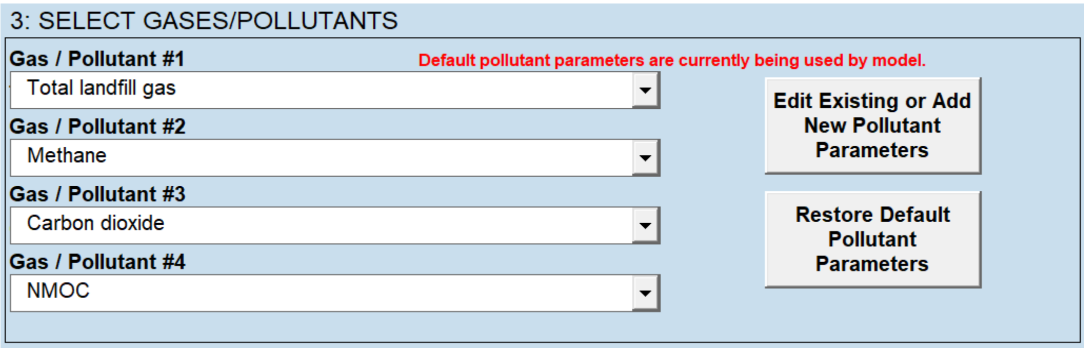


Figure 5.4(b): Selected Gases and pollutants

Now we can edit here the pollutant parameters if we have calculated or we can also use the default considerations. We have selected priority Total landfill gases, for methane, then for carbon dioxide estimation and at last for the NMOCs. We can also edit the pollution parameters.

5.3.3 Results:

Table 5.8(a) shows the result of the quantity/amount of the waste that is thrown off in the landfill during the 50 years in which the landfill was open.

Table 5.8(a)

Year	**Waste Accepted**		**Waste-In-Place**	
	(Mg/year)	**(short tons/year)**	**(Mg)**	**(short tons)**
1970	86,688	95,356	0	0
1971	86,688	95,356	86,688	95,356
1972	86,688	95,356	1,73,375	1,90,713
1973	86,688	95,356	2,60,063	2,86,069
1974	86,688	95,356	3,46,750	3,81,425
1975	95,356	1,04,892	4,33,438	4,76,781
1976	95,356	1,04,892	5,28,794	5,81,673
1977	95,356	1,04,892	6,24,150	6,86,565
1978	95,356	1,04,892	7,19,506	7,91,457
1979	95,356	1,04,892	8,14,863	8,96,349
1980	1,04,025	1,14,428	9,10,219	10,01,241
1981	1,04,025	1,14,428	10,14,244	11,15,668
1982	1,04,025	1,14,428	11,18,269	12,30,096
1983	1,04,025	1,14,428	12,22,294	13,44,523
1984	1,04,025	1,14,428	13,26,319	14,58,951
1985	1,12,694	1,23,963	14,30,344	15,73,378
1986	1,12,694	1,23,963	15,43,038	16,97,341
1987	1,12,694	1,23,963	16,55,731	18,21,304
1988	1,12,694	1,23,963	17,68,425	19,45,268
1989	1,12,694	1,23,963	18,81,119	20,69,231
1990	1,21,363	1,33,499	19,93,813	21,93,194
1991	1,21,363	1,33,499	21,15,175	23,26,693
1992	1,21,363	1,33,499	22,36,538	24,60,191
1993	1,21,363	1,33,499	23,57,900	25,93,690
1994	1,21,363	1,33,499	24,79,263	27,27,189
1995	1,30,031	1,43,034	26,00,625	28,60,688

1996	1,30,031	1,43,034	27,30,656	30,03,722
1997	1,30,031	1,43,034	28,60,688	31,46,756
1998	1,30,031	1,43,034	29,90,719	32,89,791
1999	1,30,031	1,43,034	31,20,750	34,32,825
2000	1,31,400	1,44,540	32,50,781	35,75,859
2001	1,31,400	1,44,540	33,82,181	37,20,399
2002	1,31,400	1,44,540	35,13,581	38,64,939
2003	1,31,400	1,44,540	36,44,981	40,09,479
2004	1,31,400	1,44,540	37,76,381	41,54,019
2005	1,47,368	1,62,105	39,07,781	42,98,559
2006	1,47,368	1,62,105	40,55,149	44,60,664
2007	1,47,368	1,62,105	42,02,517	46,22,769
2008	1,47,368	1,62,105	43,49,885	47,84,874
2009	1,47,368	1,62,105	44,97,253	49,46,979
2010	1,56,038	1,71,641	46,44,621	51,09,083
2011	0	0	48,00,659	52,80,725

Table 5.8(b) shows the trend of the Total landfill gases Methane gas emission every year at the waste disposal site. (This table is generated by the LandGEM software in the result spreadsheet).

Table 5.8(b)

Year	**Total Landfill Gases**		**Methane**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
1970	0	0	0	0
1971	1.800E+03	1.980E+03	4.807E+02	5.288E+02
1972	3.511E+03	3.863E+03	9.379E+02	1.032E+03
1973	5.140E+03	5.654E+03	1.373E+03	1.510E+03
1974	6.689E+03	7.358E+03	1.787E+03	1.965E+03
1975	8.162E+03	8.978E+03	2.180E+03	2.398E+03
1976	9.744E+03	1.072E+04	2.603E+03	2.863E+03
1977	1.125E+04	1.237E+04	3.004E+03	3.305E+03
1978	1.268E+04	1.395E+04	3.387E+03	3.725E+03

1979	1.404E+04	1.544E+04	3.750E+03	4.125E+03
1980	1.534E+04	1.687E+04	4.096E+03	4.506E+03
1981	1.675E+04	1.842E+04	4.473E+03	4.921E+03
1982	1.809E+04	1.990E+04	4.832E+03	5.315E+03
1983	1.937E+04	2.130E+04	5.173E+03	5.690E+03
1984	2.058E+04	2.264E+04	5.498E+03	6.047E+03
1985	2.174E+04	2.391E+04	5.806E+03	6.387E+03
1986	2.302E+04	2.532E+04	6.148E+03	6.763E+03
1987	2.423E+04	2.666E+04	6.473E+03	7.120E+03
1988	2.539E+04	2.793E+04	6.782E+03	7.461E+03
1989	2.649E+04	2.914E+04	7.076E+03	7.784E+03
1990	2.754E+04	3.029E+04	7.356E+03	8.092E+03
1991	2.872E+04	3.159E+04	7.670E+03	8.437E+03
1992	2.984E+04	3.282E+04	7.969E+03	8.766E+03
1993	3.090E+04	3.399E+04	8.254E+03	9.079E+03
1994	3.191E+04	3.510E+04	8.524E+03	9.376E+03
1995	3.288E+04	3.616E+04	8.781E+03	9.659E+03
1996	3.397E+04	3.737E+04	9.074E+03	9.982E+03
1997	3.501E+04	3.852E+04	9.353E+03	1.029E+04
1998	3.601E+04	3.961E+04	9.618E+03	1.058E+04
1999	3.695E+04	4.064E+04	9.870E+03	1.086E+04
2000	3.785E+04	4.163E+04	1.011E+04	1.112E+04
2001	3.873E+04	4.260E+04	1.034E+04	1.138E+04
2002	3.957E+04	4.352E+04	1.057E+04	1.163E+04
2003	4.037E+04	4.440E+04	1.078E+04	1.186E+04
2004	4.112E+04	4.524E+04	1.098E+04	1.208E+04
2005	4.185E+04	4.603E+04	1.118E+04	1.230E+04
2006	4.287E+04	4.715E+04	1.145E+04	1.259E+04
2007	4.383E+04	4.822E+04	1.171E+04	1.288E+04
2008	4.476E+04	4.923E+04	1.195E+04	1.315E+04
2009	4.563E+04	5.020E+04	1.219E+04	1.341E+04
2010	4.647E+04	5.111E+04	1.241E+04	1.365E+04

2011	4.744E+04	5.218E+04	1.267E+04	1.394E+04
2012	4.513E+04	4.964E+04	1.205E+04	1.326E+04
2013	4.292E+04	4.722E+04	1.147E+04	1.261E+04
2014	4.083E+04	4.491E+04	1.091E+04	1.200E+04
2015	3.884E+04	4.272E+04	1.037E+04	1.141E+04
2016	3.695E+04	4.064E+04	9.869E+03	1.086E+04
2017	3.514E+04	3.866E+04	9.387E+03	1.033E+04
2018	3.343E+04	3.677E+04	8.929E+03	9.822E+03
2019	3.180E+04	3.498E+04	8.494E+03	9.343E+03
2020	3.025E+04	3.327E+04	8.080E+03	8.888E+03
2021	2.877E+04	3.165E+04	7.686E+03	8.454E+03
2022	2.737E+04	3.011E+04	7.311E+03	8.042E+03
2023	2.604E+04	2.864E+04	6.954E+03	7.650E+03
2024	2.477E+04	2.724E+04	6.615E+03	7.277E+03
2025	2.356E+04	2.591E+04	6.292E+03	6.922E+03
2026	2.241E+04	2.465E+04	5.986E+03	6.584E+03
2027	2.132E+04	2.345E+04	5.694E+03	6.263E+03
2028	2.028E+04	2.230E+04	5.416E+03	5.958E+03
2029	1.929E+04	2.122E+04	5.152E+03	5.667E+03
2030	1.835E+04	2.018E+04	4.901E+03	5.391E+03
2031	1.745E+04	1.920E+04	4.662E+03	5.128E+03
2032	1.660E+04	1.826E+04	4.434E+03	4.878E+03
2033	1.579E+04	1.737E+04	4.218E+03	4.640E+03
2034	1.502E+04	1.652E+04	4.012E+03	4.413E+03
2035	1.429E+04	1.572E+04	3.817E+03	4.198E+03
2036	1.359E+04	1.495E+04	3.630E+03	3.993E+03
2037	1.293E+04	1.422E+04	3.453E+03	3.799E+03
2038	1.230E+04	1.353E+04	3.285E+03	3.613E+03
2039	1.170E+04	1.287E+04	3.125E+03	3.437E+03
2040	1.113E+04	1.224E+04	2.972E+03	3.270E+03
2041	1.059E+04	1.164E+04	2.827E+03	3.110E+03
2042	1.007E+04	1.108E+04	2.690E+03	2.958E+03

2043	9.578E+03	1.054E+04	2.558E+03	2.814E+03
2044	9.111E+03	1.002E+04	2.434E+03	2.677E+03
2045	8.666E+03	9.533E+03	2.315E+03	2.546E+03
2046	8.244E+03	9.068E+03	2.202E+03	2.422E+03
2047	7.842E+03	8.626E+03	2.095E+03	2.304E+03
2048	7.459E+03	8.205E+03	1.992E+03	2.192E+03
2049	7.095E+03	7.805E+03	1.895E+03	2.085E+03
2050	6.749E+03	7.424E+03	1.803E+03	1.983E+03

Table 5.8(c) Shows the CO_2 and NMOCs emission rate per year from the wariana dumping site. (This table is generated by Land GEM software)

Table 5.8(c)

Year	**Carbon Dioxide**		**NMOCs**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
1970	0	0	0	0
1971	1.319E+03	1.451E+03	2.066E+01	2.273E+01
1972	2.574E+03	2.831E+03	4.032E+01	4.435E+01
1973	3.767E+03	4.144E+03	5.901E+01	6.491E+01
1974	4.902E+03	5.392E+03	7.679E+01	8.447E+01
1975	5.982E+03	6.580E+03	9.371E+01	1.031E+02
1976	7.141E+03	7.855E+03	1.119E+02	1.231E+02
1977	8.244E+03	9.068E+03	1.291E+02	1.421E+02
1978	9.292E+03	1.022E+04	1.456E+02	1.601E+02
1979	1.029E+04	1.132E+04	1.612E+02	1.773E+02
1980	1.124E+04	1.236E+04	1.761E+02	1.937E+02
1981	1.227E+04	1.350E+04	1.923E+02	2.115E+02
1982	1.326E+04	1.458E+04	2.077E+02	2.285E+02
1983	1.419E+04	1.561E+04	2.224E+02	2.446E+02
1984	1.508E+04	1.659E+04	2.363E+02	2.599E+02
1985	1.593E+04	1.752E+04	2.496E+02	2.745E+02
1986	1.687E+04	1.856E+04	2.643E+02	2.907E+02

1987	1.776E+04	1.954E+04	2.782E+02	3.061E+02
1988	1.861E+04	2.047E+04	2.915E+02	3.207E+02
1989	1.942E+04	2.136E+04	3.042E+02	3.346E+02
1990	2.018E+04	2.220E+04	3.162E+02	3.478E+02
1991	2.105E+04	2.315E+04	3.297E+02	3.627E+02
1992	2.187E+04	2.405E+04	3.425E+02	3.768E+02
1993	2.265E+04	2.491E+04	3.548E+02	3.902E+02
1994	2.339E+04	2.573E+04	3.664E+02	4.030E+02
1995	2.409E+04	2.650E+04	3.774E+02	4.152E+02
1996	2.490E+04	2.739E+04	3.900E+02	4.290E+02
1997	2.566E+04	2.823E+04	4.020E+02	4.422E+02
1998	2.639E+04	2.903E+04	4.134E+02	4.547E+02
1999	2.708E+04	2.979E+04	4.242E+02	4.666E+02
2000	2.774E+04	3.051E+04	4.345E+02	4.780E+02
2001	2.838E+04	3.122E+04	4.446E+02	4.891E+02
2002	2.900E+04	3.190E+04	4.543E+02	4.997E+02
2003	2.958E+04	3.254E+04	4.634E+02	5.098E+02
2004	3.014E+04	3.315E+04	4.722E+02	5.194E+02
2005	3.067E+04	3.374E+04	4.804E+02	5.285E+02
2006	3.142E+04	3.456E+04	4.921E+02	5.414E+02
2007	3.213E+04	3.534E+04	5.033E+02	5.536E+02
2008	3.280E+04	3.608E+04	5.138E+02	5.652E+02
2009	3.344E+04	3.679E+04	5.239E+02	5.763E+02
2010	3.405E+04	3.746E+04	5.335E+02	5.868E+02
2011	3.477E+04	3.824E+04	5.447E+02	5.991E+02
2012	3.307E+04	3.638E+04	5.181E+02	5.699E+02
2013	3.146E+04	3.461E+04	4.928E+02	5.421E+02
2014	2.992E+04	3.292E+04	4.688E+02	5.157E+02
2015	2.847E+04	3.131E+04	4.459E+02	4.905E+02
2016	2.708E+04	2.978E+04	4.242E+02	4.666E+02
2017	2.576E+04	2.833E+04	4.035E+02	4.438E+02
2018	2.450E+04	2.695E+04	3.838E+02	4.222E+02

2019	2.331E+04	2.564E+04	3.651E+02	4.016E+02
2020	2.217E+04	2.439E+04	3.473E+02	3.820E+02
2021	2.109E+04	2.320E+04	3.303E+02	3.634E+02
2022	2.006E+04	2.207E+04	3.142E+02	3.457E+02
2023	1.908E+04	2.099E+04	2.989E+02	3.288E+02
2024	1.815E+04	1.997E+04	2.843E+02	3.128E+02
2025	1.727E+04	1.899E+04	2.705E+02	2.975E+02
2026	1.642E+04	1.807E+04	2.573E+02	2.830E+02
2027	1.562E+04	1.718E+04	2.447E+02	2.692E+02
2028	1.486E+04	1.635E+04	2.328E+02	2.561E+02
2029	1.414E+04	1.555E+04	2.214E+02	2.436E+02
2030	1.345E+04	1.479E+04	2.106E+02	2.317E+02
2031	1.279E+04	1.407E+04	2.004E+02	2.204E+02
2032	1.217E+04	1.338E+04	1.906E+02	2.097E+02
2033	1.157E+04	1.273E+04	1.813E+02	1.994E+02
2034	1.101E+04	1.211E+04	1.725E+02	1.897E+02
2035	1.047E+04	1.152E+04	1.640E+02	1.805E+02
2036	9.961E+03	1.096E+04	1.560E+02	1.717E+02
2037	9.475E+03	1.042E+04	1.484E+02	1.633E+02
2038	9.013E+03	9.915E+03	1.412E+02	1.553E+02
2039	8.574E+03	9.431E+03	1.343E+02	1.477E+02
2040	8.155E+03	8.971E+03	1.278E+02	1.405E+02
2041	7.758E+03	8.533E+03	1.215E+02	1.337E+02
2042	7.379E+03	8.117E+03	1.156E+02	1.272E+02
2043	7.019E+03	7.721E+03	1.100E+02	1.210E+02
2044	6.677E+03	7.345E+03	1.046E+02	1.151E+02
2045	6.351E+03	6.987E+03	9.950E+01	1.094E+02
2046	6.042E+03	6.646E+03	9.465E+01	1.041E+02
2047	5.747E+03	6.322E+03	9.003E+01	9.903E+01
2048	5.467E+03	6.013E+03	8.564E+01	9.420E+01
2049	5.200E+03	5.720E+03	8.146E+01	8.961E+01
2050	4.947E+ 03	5.441E+03	7.749E+01	8.524E+01

Figure 5.5 Shows the yearly variation of Landfill Gases rate of production generated by the LandGEM Software for the dumping site in Wariana village Jalandhar. (In the form of Graph).

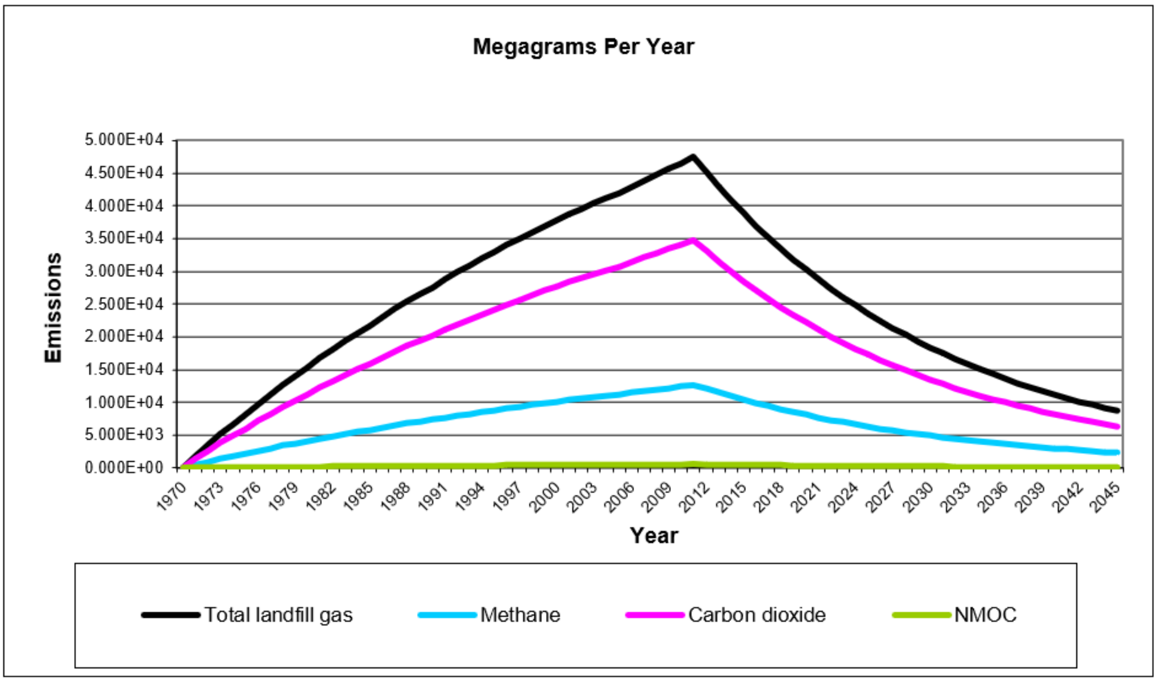


Figure 5.5: Annual total landfill Gas Graph result by LandGEM in Mg/year (Wariana Dump Jalandhar)

5.3.4 Discussion:

During the first year of the garbage/refuse in Landfill the Land GEM assumes that there is no decomposition process started and there is no biogas produced during that period.

After reading the literatures there it was mentioned that the methanogenesis steps starts in minimum 6 months after refuse is disposed in site. Refuse degradation generally rely upon many conditions and situations such as refuse type, moisture content in the refuse, climatic provisions changed during that period of time, refuse covering material in the landfill, etc., The Land GEM software don't take into consideration of all of these provisions in order to start the initial phases of methanogenesis process and examine these all parameters after 52 weeks, all of these things are considered at the starting of this phase.

As we see the *Table 5.8(b)* and *Figure 5.5*, we can see that from Wariana Dump Jalandhar in the year 1971 the total Landfill gases which was generated was around $1.800*10^3$Mg/year which is increased to $4.744*10^4$Mg/year by the year 2011 which is a peak value.

And if we see the generated CH_4 in the year 1971 it was around $4.807*10^2$Mg/year and by the year 2011 it increased to $1.267*10^4$Mg/year peak value in graph.

5.4 Gas Emission from Dumping site (Land GEM) Piplanwala Landfill Jalandhar

5.4.1 Description

Modelling tool we are using to estimate the gases which are produced from the landfill is Land GEM this software is known as the Model of Landfill Gas Release. This model takes in considerations of the time factor while calculating the generation rate of the gases from the MSW landfills. This model basically estimates the mass of the production/generation of CH_4 per year using the generation capacity of methane and the group of the refuse that is deposited at the landfill site. First order decomposition equation which is used by the Land GEM software is given below:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_0 \left[\frac{M_i}{10}\right] e^{-kt_{i,j}}$$

Where: **[8], [26]**

Q_{CH4} = Total yearly methane generated from landfill of the yr. which is being calculated, units in(m^3/yr.)

i = increment of 1 yr. period,

n = it is estimated as considered calculated year – starting years in which the waste is thrown in Landfill

j = increase of time 0.1-year,

k = rate of the methane gas produced from the Landfill, unit in ($yr.^{-1}$)

L_o = capacity of the methane production potential methane, unit in (m^3/Mega gram)

M_i = i^{th} year in which the waste is gained (mass) (Mg)

t_{ij} = time at j^{th} component of the waste mass in which the Mi is accepted in the time of the i^{th} year. In the decimal years **[8], [26].**

To do our study, the important required inputs which we have entered are mentioned in the section 5.4.2.

5.4.2 Model inputs

- **Opening and Closure Year of landfill:** Landfill opening Year is a mandatory entry. The opening year of Piplanwala landfill was 2010 when the MC Jalandhar started dumping the waste in this landfill. This landfill is designed for approx. 30 years from now according to board of Control of Pollution in Punjab reports. So, the closing year of landfill is taken as 2040. And the waste data which is entered in the Land GEM software is till the year 2019 **[36], [29].**

- **Annual Waste Acceptance Rates:** The year wise refuse capacity is a critical Land GEM model setting.

Table 5.9: Yearly population of Jalandhar City (estimated)

Year	Population (approx..)
2010	863,000
2011 (census)	880,000
2013	917,000
2015	955,000
2017	994,000
2019	1,034,000

Table 5.9 shows the population of Jalandhar city according to Indian Census and the estimated. In order to calculate the waste which is accounted in the landfill annually this data is very important. In considerations of reports and CPCB data during period of 2010 in Jalandhar the per day waste which was generated was approx. 450 tons per day in the resent years the waste generated is approx. 500 tons per day. Also, in considerations with reports around 95% of the overall waste that is generated in Jalandhar is dumped in the landfill. Now in order to input the data of the Waste acceptance data of the landfill per year from the opening yr. to the shutdown yr. we have estimated the data and estimated data is tabulated in Table 5.10.

Table 5.10: Estimated waste generated per year in Jalandhar

Year	Waste generated (tons/day)	Total Weight (tons/year) (approx.)
2010	450	156037.5
2015	480	166440

Now, we have entered this data in Land GEM Software *Figure 5.6* Shows the data which we have entered year wise.

4: ENTER WASTE ACCEPTANCE RATES

Input Units: Mg/year

Year	Input Units (Mg/year)	Calculated Units (short tons/year)
2010	1,56,038	1,71,641
2011	1,56,038	1,71,641
2012	1,56,038	1,71,641
2013	1,56,038	1,71,641
2014	1,56,038	1,71,641
2015	1,66,440	1,83,084
2016	1,66,440	1,83,084
2017	1,66,440	1,83,084
2018	1,66,440	1,83,084
2019	1,66,440	1,83,084

Figure 5.6 Waste acceptance rate data entered in Land GEM Software Year wise (Mega Gram per Year)

- **Methane Generation Rate, k (year^{-1}):** We can estimate or calculate the value of Methane Generation Rate k by using the following equation.

$$k = 3.1 * 10^{-5} \, (annual\ mean\ rainfall) + 0.01$$

[8], [26]

Or we can Also use the constant values provided of Methane Generation Rate,

For k (year^{-1}) values check *Table 5.5*.

We have used the CAA Conventional Constants throughout our study.**[8], [26]**

- **Potential methane generation capacity L_0 (m^3/mg):** The CH_4 generation potential capacity symbolized as L_o rely largely on the sort/kind of refuse that is disposed in the landfill. We should keep in consideration that the methane generation potential, L_o standards will be higher for refuse comprised of lot of cellulose in it. The five default L_o standards for household refuse are shown in *Table 5.6*. We have used CAA Conventional default constant value for L_0 throughout our study.

- **Compounds that are Non-Methanic (NMOC) Concentration:** This generally depends upon the waste characteristics. IPCC default values are six hundred ppmv for landfills having the waste from the house and some of other kind in the landfill. We have taken CAA default values in our study report **[8], [26].**
- **Methane Content (% by volume):** Default CAA value is 50% by volume. And we have taken the same constant value **[8], [26].**
- **Selected Gas / Pollutants:** We can pick any four air pollutants or gases to be modelled at one time. Check *Table 5.7.* and check *Figure 4.4(b)* to see the Gas and pollutants which we have selected.

5.4.3 Results:

Table 5.11(a) Shows the Waste in Place at the Piplanwala Landfill. This table is from Land GEM software:

Table 5.11(a)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2010	1,56,038	1,71,641	0	0
2011	1,56,038	1,71,641	1,56,038	1,71,641
2012	1,56,038	1,71,641	3,12,075	3,43,283
2013	1,56,038	1,71,641	4,68,113	5,14,924
2014	1,56,038	1,71,641	6,24,150	6,86,565
2015	1,66,440	1,83,084	7,80,188	8,58,206
2016	1,66,440	1,83,084	9,46,628	10,41,290
2017	1,66,440	1,83,084	11,13,068	12,24,374
2018	1,66,440	1,83,084	12,79,508	14,07,458
2019	1,66,440	1,83,084	14,45,948	15,90,542
2020	1,66,440	1,83,084	16,12,388	17,73,626
2021	1,66,440	1,83,084	17,78,828	19,56,710
2022	1,66,440	1,83,084	19,45,268	21,39,794
2023	1,66,440	1,83,084	21,11,708	23,22,878
2024	1,66,440	1,83,084	22,78,148	25,05,962
2025	1,66,440	1,83,084	24,44,588	26,89,046

2026	1,66,440	1,83,084	26,11,028	28,72,130
2027	1,66,440	1,83,084	27,77,468	30,55,214
2028	1,66,440	1,83,084	29,43,908	32,38,298
2029	1,66,440	1,83,084	31,10,348	34,21,382
2030	1,66,440	1,83,084	32,76,788	36,04,466
2031	1,66,440	1,83,084	34,43,228	37,87,550
2032	1,66,440	1,83,084	36,09,668	39,70,634
2033	1,66,440	1,83,084	37,76,108	41,53,718
2034	1,66,440	1,83,084	39,42,548	43,36,802
2035	1,66,440	1,83,084	41,08,988	45,19,886
2036	1,66,440	1,83,084	42,75,428	47,02,970
2037	1,66,440	1,83,084	44,41,868	48,86,054
2038	1,66,440	1,83,084	46,08,308	50,69,138
2039	1,66,440	1,83,084	47,74,748	52,52,222
2040	0	0	49,41,188	54,35,306

Table 5.11(b) shows the trend of the Total landfill gases Methane gas emission every year at the Piplanwala Landfill Jalandhar. (This table is generated by the Land GEM software in the result spreadsheet).

Table 5.11(b)

Year	**Total Landfill gases**		**Methane**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
2010	0	0	0	0
2011	3.239E+03	3.563E+03	8.653E+02	9.518E+02
2012	6.321E+03	6.953E+03	1.688E+03	1.857E+03
2013	9.252E+03	1.018E+04	2.471E+03	2.718E+03
2014	1.204E+04	1.324E+04	3.216E+03	3.538E+03
2015	1.469E+04	1.616E+04	3.924E+03	4.317E+03
2016	1.743E+04	1.917E+04	4.656E+03	5.121E+03
2017	2.004E+04	2.204E+04	5.352E+03	5.887E+03
2018	2.251E+04	2.477E+04	6.014E+03	6.615E+03
2019	2.487E+04	2.736E+04	6.643E+03	7.308E+03

2020	2.711E+04	2.982E+04	7.242E+03	7.967E+03
2021	2.925E+04	3.217E+04	7.812E+03	8.593E+03
2022	3.128E+04	3.440E+04	8.354E+03	9.189E+03
2023	3.321E+04	3.653E+04	8.869E+03	9.756E+03
2024	3.504E+04	3.855E+04	9.360E+03	1.030E+04
2025	3.679E+04	4.047E+04	9.826E+03	1.081E+04
2026	3.845E+04	4.229E+04	1.027E+04	1.130E+04
2027	4.003E+04	4.403E+04	1.069E+04	1.176E+04
2028	4.153E+04	4.568E+04	1.109E+04	1.220E+04
2029	4.296E+04	4.726E+04	1.148E+04	1.262E+04
2030	4.432E+04	4.875E+04	1.184E+04	1.302E+04
2031	4.562E+04	5.018E+04	1.218E+04	1.340E+04
2032	4.685E+04	5.153E+04	1.251E+04	1.376E+04
2033	4.802E+04	5.282E+04	1.283E+04	1.411E+04
2034	4.913E+04	5.404E+04	1.312E+04	1.444E+04
2035	5.019E+04	5.521E+04	1.341E+04	1.475E+04
2036	5.120E+04	5.632E+04	1.368E+04	1.504E+04
2037	5.215E+04	5.737E+04	1.393E+04	1.532E+04
2038	5.307E+04	5.837E+04	1.417E+04	1.559E+04
2039	5.393E+04	5.933E+04	1.441E+04	1.585E+04
2040	5.476E+04	6.023E+04	1.463E+04	1.609E+04
2041	5.209E+04	5.730E+04	1.391E+04	1.530E+04
2042	4.955E+04	5.450E+04	1.323E+04	1.456E+04
2043	4.713E+04	5.184E+04	1.259E+04	1.385E+04
2044	4.483E+04	4.932E+04	1.198E+04	1.317E+04
2045	4.265E+04	4.691E+04	1.139E+04	1.253E+04
2046	4.057E+04	4.462E+04	1.084E+04	1.192E+04
2047	3.859E+04	4.245E+04	1.031E+04	1.134E+04
2048	3.671E+04	4.038E+04	9.804E+03	1.078E+04
2049	3.492E+04	3.841E+04	9.326E+03	1.026E+04
2050	3.321E+04	3.653E+04	8.871E+03	9.759E+03
2051	3.159E+04	3.475E+04	8.439E+03	9.283E+03

2052	3.005E+04	3.306E+04	8.027E+03	8.830E+03
2053	2.859E+04	3.145E+04	7.636E+03	8.399E+03
2054	2.719E+04	2.991E+04	7.263E+03	7.990E+03
2055	2.587E+04	2.845E+04	6.909E+03	7.600E+03
2056	2.460E+04	2.707E+04	6.572E+03	7.229E+03
2057	2.340E+04	2.575E+04	6.252E+03	6.877E+03
2058	2.226E+04	2.449E+04	5.947E+03	6.541E+03
2059	2.118E+04	2.330E+04	5.657E+03	6.222E+03
2060	2.014E+04	2.216E+04	5.381E+03	5.919E+03
2061	1.916E+04	2.108E+04	5.118E+03	5.630E+03
2062	1.823E+04	2.005E+04	4.869E+03	5.356E+03
2063	1.734E+04	1.907E+04	4.631E+03	5.094E+03
2064	1.649E+04	1.814E+04	4.405E+03	4.846E+03
2065	1.569E+04	1.726E+04	4.191E+03	4.610E+03
2066	1.492E+04	1.642E+04	3.986E+03	4.385E+03
2067	1.420E+04	1.562E+04	3.792E+03	4.171E+03
2068	1.350E+04	1.485E+04	3.607E+03	3.968E+03
2069	1.284E+04	1.413E+04	3.431E+03	3.774E+03
2070	1.222E+04	1.344E+04	3.264E+03	3.590E+03
2071	1.162E+04	1.278E+04	3.104E+03	3.415E+03
2072	1.106E+04	1.216E+04	2.953E+03	3.248E+03
2073	1.052E+04	1.157E+04	2.809E+03	3.090E+03
2074	1.000E+04	1.100E+04	2.672E+03	2.939E+03
2075	9.516E+03	1.047E+04	2.542E+03	2.796E+03
2076	9.052E+03	9.957E+03	2.418E+03	2.660E+03
2077	8.610E+03	9.471E+03	2.300E+03	2.530E+03
2078	8.190E+03	9.009E+03	2.188E+03	2.406E+03
2079	7.791E+03	8.570E+03	2.081E+03	2.289E+03
2080	7.411E+03	8.152E+03	1.979E+03	2.177E+03
2081	7.049E+03	7.754E+03	1.883E+03	2.071E+03
2082	6.706E+03	7.376E+03	1.791E+03	1.970E+03
2083	6.378E+03	7.016E+03	1.704E+03	1.874E+03

2084	6.067E+03	6.674E+03	1.621E+03	1.783E+03
2085	5.772E+03	6.349E+03	1.542E+03	1.696E+03
2086	5.490E+03	6.039E+03	1.466E+03	1.613E+03
2087	5.222E+03	5.744E+03	1.395E+03	1.534E+03
2088	4.968E+03	5.464E+03	1.327E+03	1.460E+03
2089	4.725E+03	5.198E+03	1.262E+03	1.388E+03
2090	4.495E+03	4.944E+03	1.201E+03	1.321E+03

Table 5.11(c) Shows the CO_2 and NMOCs emission rate per year from the Piplanwala Landfill site. (This table is generated by Land GEM software).

Table 5.11(c)

Year	**Carbon dioxide**		**NMOCs**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
2010	0	0	0	0
2011	2.374E+03	2.611E+03	3.719E+01	4.091E+01
2012	4.632E+03	5.096E+03	7.257E+01	7.982E+01
2013	6.780E+03	7.459E+03	1.062E+02	1.168E+02
2014	8.824E+03	9.706E+03	1.382E+02	1.521E+02
2015	1.077E+04	1.184E+04	1.687E+02	1.855E+02
2016	1.277E+04	1.405E+04	2.001E+02	2.201E+02
2017	1.468E+04	1.615E+04	2.300E+02	2.530E+02
2018	1.650E+04	1.815E+04	2.585E+02	2.843E+02
2019	1.823E+04	2.005E+04	2.855E+02	3.141E+02
2020	1.987E+04	2.186E+04	3.113E+02	3.424E+02
2021	2.143E+04	2.358E+04	3.358E+02	3.694E+02
2022	2.292E+04	2.521E+04	3.591E+02	3.950E+02
2023	2.434E+04	2.677E+04	3.812E+02	4.194E+02
2024	2.568E+04	2.825E+04	4.023E+02	4.425E+02
2025	2.696E+04	2.966E+04	4.224E+02	4.646E+02
2026	2.818E+04	3.100E+04	4.414E+02	4.856E+02
2027	2.934E+04	3.227E+04	4.596E+02	5.055E+02

2028	3.044E+04	3.348E+04	4.768E+02	5.245E+02
2029	3.149E+04	3.463E+04	4.932E+02	5.426E+02
2030	3.248E+04	3.573E+04	5.089E+02	5.597E+02
2031	3.343E+04	3.677E+04	5.237E+02	5.761E+02
2032	3.433E+04	3.777E+04	5.378E+02	5.916E+02
2033	3.519E+04	3.871E+04	5.513E+02	6.064E+02
2034	3.601E+04	3.961E+04	5.641E+02	6.205E+02
2035	3.678E+04	4.046E+04	5.762E+02	6.338E+02
2036	3.752E+04	4.127E+04	5.878E+02	6.466E+02
2037	3.822E+04	4.205E+04	5.988E+02	6.587E+02
2038	3.889E+04	4.278E+04	6.093E+02	6.702E+02
2039	3.953E+04	4.348E+04	6.192E+02	6.811E+02
2040	4.013E+04	4.415E+04	6.287E+02	6.916E+02
2041	3.817E+04	4.199E+04	5.980E+02	6.578E+02
2042	3.631E+04	3.994E+04	5.689E+02	6.257E+02
2043	3.454E+04	3.800E+04	5.411E+02	5.952E+02
2044	3.286E+04	3.614E+04	5.147E+02	5.662E+02
2045	3.125E+04	3.438E+04	4.896E+02	5.386E+02
2046	2.973E+04	3.270E+04	4.657E+02	5.123E+02
2047	2.828E+04	3.111E+04	4.430E+02	4.873E+02
2048	2.690E+04	2.959E+04	4.214E+02	4.636E+02
2049	2.559E+04	2.815E+04	4.009E+02	4.410E+02
2050	2.434E+04	2.678E+04	3.813E+02	4.195E+02
2051	2.315E+04	2.547E+04	3.627E+02	3.990E+02
2052	2.202E+04	2.423E+04	3.450E+02	3.795E+02
2053	2.095E+04	2.305E+04	3.282E+02	3.610E+02
2054	1.993E+04	2.192E+04	3.122E+02	3.434E+02
2055	1.896E+04	2.085E+04	2.970E+02	3.267E+02
2056	1.803E+04	1.984E+04	2.825E+02	3.107E+02
2057	1.715E+04	1.887E+04	2.687E+02	2.956E+02
2058	1.632E+04	1.795E+04	2.556E+02	2.812E+02
2059	1.552E+04	1.707E+04	2.431E+02	2.675E+02

2060	1.476E+04	1.624E+04	2.313E+02	2.544E+02
2061	1.404E+04	1.545E+04	2.200E+02	2.420E+02
2062	1.336E+04	1.469E+04	2.093E+02	2.302E+02
2063	1.271E+04	1.398E+04	1.991E+02	2.190E+02
2064	1.209E+04	1.330E+04	1.894E+02	2.083E+02
2065	1.150E+04	1.265E+04	1.801E+02	1.981E+02
2066	1.094E+04	1.203E+04	1.713E+02	1.885E+02
2067	1.040E+04	1.144E+04	1.630E+02	1.793E+02
2068	9.896E+03	1.089E+04	1.550E+02	1.705E+02
2069	9.414E+03	1.036E+04	1.475E+02	1.622E+02
2070	8.955E+03	9.850E+03	1.403E+02	1.543E+02
2071	8.518E+03	9.370E+03	1.334E+02	1.468E+02
2072	8.102E+03	8.913E+03	1.269E+02	1.396E+02
2073	7.707E+03	8.478E+03	1.207E+02	1.328E+02
2074	7.331E+03	8.065E+03	1.149E+02	1.263E+02
2075	6.974E+03	7.671E+03	1.092E+02	1.202E+02
2076	6.634E+03	7.297E+03	1.039E+02	1.143E+02
2077	6.310E+03	6.941E+03	9.885E+01	1.087E+02
2078	6.002E+03	6.603E+03	9.403E+01	1.034E+02
2079	5.710E+03	6.281E+03	8.945E+01	9.839E+01
2080	5.431E+03	5.974E+03	8.508E+01	9.359E+01
2081	5.166E+03	5.683E+03	8.093E+01	8.903E+01
2082	4.914E+03	5.406E+03	7.699E+01	8.469E+01
2083	4.675E+03	5.142E+03	7.323E+01	8.056E+01
2084	4.447E+03	4.891E+03	6.966E+01	7.663E+01
2085	4.230E+03	4.653E+03	6.626E+01	7.289E+01
2086	4.024E+03	4.426E+03	6.303E+01	6.933E+01
2087	3.827E+03	4.210E+03	5.996E+01	6.595E+01
2088	3.641E+03	4.005E+03	5.703E+01	6.274E+01
2089	3.463E+03	3.809E+03	5.425E+01	5.968E+01
2090	3.294E+03	3.624E+03	5.161E+01	5.677E+01

Figure 5.7 Shows the yearly rate of generation of Total landfill gases made by the LandGEM Software for the Landfill site in Piplanwala Jalandhar. (In the form of Graph).

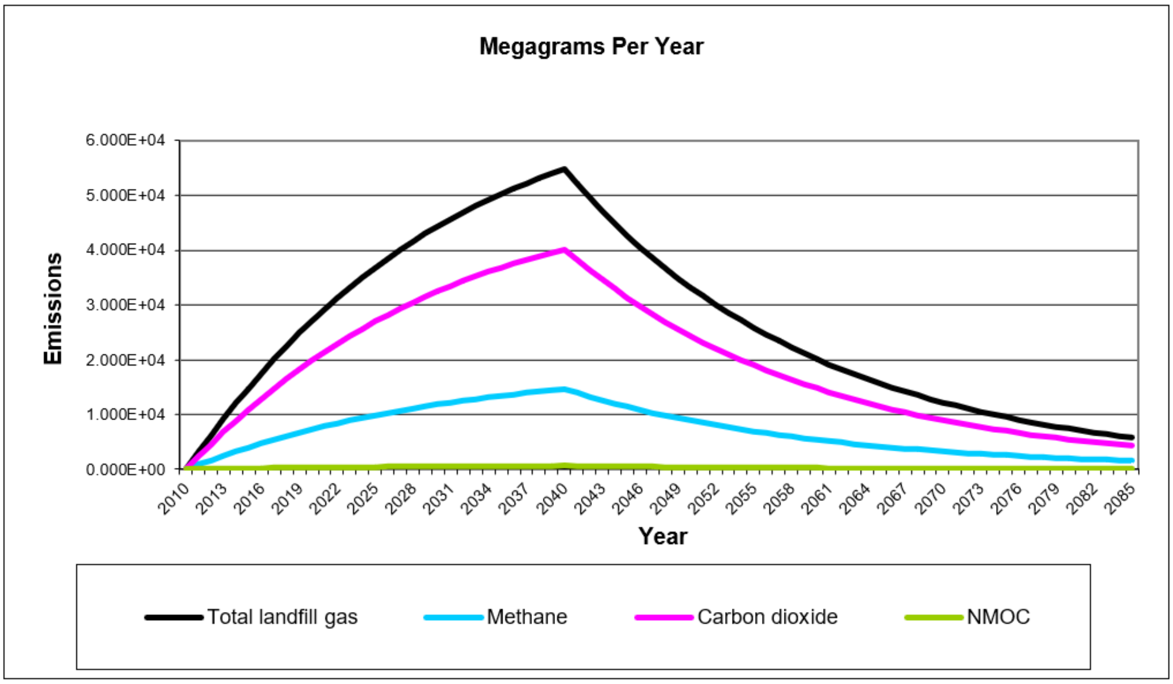


Figure 5.7: Annual total landfill Gas Graph result by LandGEM in Mg/year (Piplanwala landfill Jalandhar)

5.4.4 Discussion:

From the *Table 5.11(b)* and *Figure 5.7* we can see that from the Piplanwala Landfill which is opened in 2010 the Total landfill gases generation rate in 2011 was $3.239*10^3$Mg/year. Now according to Land GEM software, the Total Landfill Gases generation in 2040 will be approx..$5.476*10^4$Mg/year.

If we discuss about the Methane generation scenario it was around $8.653*10^2$ Mg/year in the year 2011 and by the year 2040 it will be around $1.43*10^4$Mg/year.

We can see that the large quantity of methane and other gases has been generated in the landfill at Piplanwala which if used efficiently can reduce the Green House Gas effect on the environment on that area by these toxic and harmful gases.

5.5 Methodology (Amritsar)

5.5.1 Description of Study Area – Amritsar

Amritsar is the 2nd largest city of Punjab & an administrative headquarter of Amritsar district. Amritsar is situated at Majha region of Punjab. Historically, Amritsar called as Ambarsar. It is approximately 217 km Northwest of Chandigarh, 455 km NW of New-Delhi, 47 km NE of Lahore. Wagah Border is 28 km far. Amritsar is among 10 municipal corporations of Punjab. Amritsar lies at 31.63 N, 74.87 E & is a planned city. Its area is 139 Km2, having a population of 11,32,760 in 2011 as per the latest Indian census report (National Census Report, 2011)

Estimated Population of Amritsar city year wise is

in year 2014 - population 12,50,000

in year 2015 – population 12,72,000

in year 2016 – population 12,93,000

in year 2017 – population 13,15,000

in year 2018 – population 13,37,000

in year 2019 – population 13,57,000

in year 2020 – population 13,78,000

Figure 5.8: Amritsar on Indian map

5.5.2 Waste Generation and characterization:

Major sources of MSW in Amritsar municipal corporation areas are residents, marriage hall, hospital, demolition and construction refuse, garden waste, dairy and cattle-shed refuse. Amritsar generates the total waste of 438 TPD, i.e., 0.45 kg/capita/day. Amritsar is among filthiest big city in the country which scored 48% i.e. 2406 out of 5000 points in the 2019 survey and 50% i.e.2039 out of 4000 points in 2018 survey in more than one lakh population category.

At the dumping site of Amritsar, it was observed that 12-15 lakh ton of solid waste was dumped within 25 acres area, out of which few tons are managed through trammel, ballistic separator, and vibro screen machines. Smart dustbin for smart disposal in Amritsar has started the process of installing modern garbage bins, a Chennai based company has been handed the contract of installation. Each bin will have two containers with the capacity to hold 1800kg of waste **[24].**

5.5.3 Waste Disposal:

Bhagtanwala Dump is the site which is allotted for the disposal of the waste in the Amritsar city. The total area of this site is approx.. 25 acre in which there is MSW facility to process the refuse and a designed landfill facility. This city has been allotted with the disposal and processing facility. In 2014 the authorities who manage the refuse in Amritsar planned to start plant for the solid refuse conduct/management. The landfill site in Amritsar has caused many problems for the people in the nearby area. It is of big concern because approx. fifty thousand people live in that area. This area is very nearby to the very famous wheat trading market. The site is of 10 acres in which the daily refuse is dumped from approx. 9 ULBs. There are approx. 60 rickshaws for the daily waste collection given to rag pickers. With the facility of dry and wet waste bins. The daily refuse collection from door to door is also done daily **[24].**

Figure 5.9 shows Bhagtanwala Dump in Amritsar.

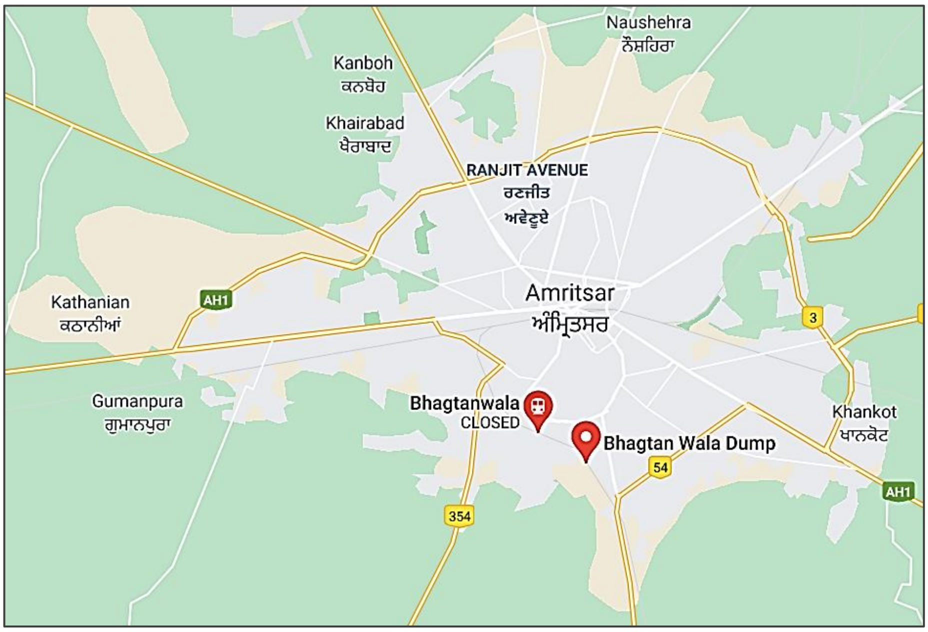


Figure 5.9: Bhagtanwala Dump in Amritsar (Source Google maps)

5.6 LFG Emission Model (Land GEM) Bhagtanwala dumping site Amritsar

5.6.1 Description

Modelling tool we are using to estimate emission of LFG is Land GEM. This software is also called LFG Emission Model. This model takes in considerations of the time factor while calculating the production rate of the gases' from MSW landfills. The model basically estimates the mass of the CH_4 generation per year using the generation volume of methane & Mass of the refuse that is deposited at the landfill site. First order decomposition equation which is used by the Land GEM software is written below:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_0 \left[\frac{M_i}{10}\right] e^{-k t_{i,j}}$$

Where: **[8], [26]**

Q_{CH4} = Total yearly methane generated from landfill of the yr. which is being calculated, units in(m^3/yr.)

i = increment of 1 yr. period,

n = it is estimated as considered calculated year – starting years in which the waste is thrown in Landfill

j = increase of time 0.1-year,

k = rate of the methane gas produced from the Landfill, unit in ($yr.^{-1}$)

L_o = capacity of the methane production potential methane, unit in (m^3/Mega gram)

M_i = i^{th} year in which the waste is gained (mass) (Mg)

t_{ij} = time at j^{th} component of the waste mass in which the Mi is accepted in the time of the i^{th} year. In the decimal years.**[8], [26]**

5.6.2 Model inputs

- **Opening and Closure Year of landfill:** Landfill opening Year is a mandatory entry. In our case the landfill open year is 1995. Landfill Shutdown Year in Land GEM or landfill capacity any one is optional so; we have shut down yr. of landfill as our input. So, in order to run this model, we have taken the Shutdown yr. of landfill is taken as 2030 as this Landfill is designed so that it can accumulate waste till 2030.

- **Annual Waste Acceptance Rates:** The yearly refuse capacity is a critical Land GEM model setting.

Table 5.12: Year Wise Population of Amritsar (estimated)

Year	Population (approx.)
1995	824,000
1996	853,000
2001 (census)	1,009,000
2006	1,096,000
2011(census)	1,190,000
2016	1,292,000
2021	1,400,000

Now in order to input the data of the Waste acceptance data of the landfill per year from the open yr. to shut down yr. we have estimated the data and estimated data in *Table 5.13*.

Table 5.13: Estimated waste generated per year in Amritsar

Year	Waste generated (tons/day)	Total Weight (tons/year) (approx.)
1995	400	138,700
2000	450	156,038
2005	475	164,706
2010	500	173,375
2015	550	190,712
2019	575	199,381

Now, we have entered this data in Land GEM Software *Figure 5.10* Shows the data which we have entered year wise.

4: ENTER WASTE ACCEPTANCE RATES		
Input Units:	Mg/year	
Year	**Input Units** ***(Mg/year)***	**Calculated Units** ***(short tons/year)***
1995	1,38,700	1,52,570
1996	1,38,700	1,52,570
1997	1,38,700	1,52,570
1998	1,38,700	1,52,570
1999	1,38,700	1,52,570
2000	1,56,038	1,71,642
2001	1,56,038	1,71,642
2002	1,56,038	1,71,642
2003	1,56,038	1,71,642
2004	1,56,038	1,71,642
2005	1,64,706	1,81,177
2006	1,64,706	1,81,177
2007	1,64,706	1,81,177
2008	1,64,706	1,81,177
2009	1,64,706	1,81,177
2010	1,73,375	1,90,713
2011	1,73,375	1,90,713
2012	1,73,375	1,90,713
2013	1,73,375	1,90,713
2014	1,73,375	1,90,713
2015	1,90,713	2,09,784
2016	1,90,713	2,09,784
2017	1,90,713	2,09,784
2018	1,90,713	2,09,784
2019	1,99,381	2,19,319

Figure 5.10: Waste acceptance rate data entered in Land GEM Software Year wise (Mega Gram per Year)

- **Methane Generation Rate, k (year^{-1}):** We can estimate or calculate the value of Methane Generation Rate k with the help of the equation mentioned below:

$$k = 3.1 * 10^{-5}\,(annual\ mean\ rainfall) + 0.01$$

[8], [26]

Or we can Also use the constant values provided of Methane generation Rate,

For k (yr^{-1}) values check *Table 5.5*.

We have used the CAA Conventional Constants throughout our study.

- **Potential methane generation capacity L_0 (m^3/mg):** The CH_4 generation potential capacity symbolized as L_o rely largely on the sort/kind of refuse that is disposed in the landfill. We should keep in consideration that the methane generation potential, L_o standards will be higher for refuse comprising lot of cellulose in it. The five default L_o

standards given for household refuse are in *Table 5.6*. We have used CAA Conventional default constant value for L_0 throughout our study. **[8][26]**

- **Compounds that are Non-Methanic (NMOC) Concentration:** This generally depends upon the waste characteristics. IPCC default values are six hundred ppmv for landfills having the waste from the house and some of other kind in the landfill. We have taken CAA default values in our study report. **[8][26]**
- **Methane Content (% by volume):** Default CAA value is 50% by volume. And we have taken the same constant value. **[8][26]**
- **Selected Gas / Pollutants:** We can choose 4 air pollutants and gases to be modelled at one time. Check *Table 5.7*. and check *Figure 5.4(b)* to see the Gas and pollutants which we have selected.

5.6.3: Results:

Table 5.14 (a) Shows the Waste in Place at the Bhagtanwala Landfill in amritsar. This table is from Land GEM software:

Table 5.14 (a):

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
1995	1,38,700	1,52,570	0	0
1996	1,38,700	1,52,570	1,38,700	1,52,570
1997	1,38,700	1,52,570	2,77,400	3,05,140
1998	1,38,700	1,52,570	4,16,100	4,57,710
1999	1,38,700	1,52,570	5,54,800	6,10,280
2000	1,56,038	1,71,642	6,93,500	7,62,850
2001	1,56,038	1,71,642	8,49,538	9,34,492
2002	1,56,038	1,71,642	10,05,576	11,06,134
2003	1,56,038	1,71,642	11,61,614	12,77,775
2004	1,56,038	1,71,642	13,17,652	14,49,417
2005	1,64,706	1,81,177	14,73,690	16,21,059
2006	1,64,706	1,81,177	16,38,396	18,02,236
2007	1,64,706	1,81,177	18,03,102	19,83,412
2008	1,64,706	1,81,177	19,67,808	21,64,589
2009	1,64,706	1,81,177	21,32,514	23,45,765
2010	1,73,375	1,90,713	22,97,220	25,26,942
2011	1,73,375	1,90,713	24,70,595	27,17,655
2012	1,73,375	1,90,713	26,43,970	29,08,367
2013	1,73,375	1,90,713	28,17,345	30,99,080
2014	1,73,375	1,90,713	29,90,720	32,89,792
2015	1,90,713	2,09,784	31,64,095	34,80,505
2016	1,90,713	2,09,784	33,54,808	36,90,289
2017	1,90,713	2,09,784	35,45,521	39,00,073

2018	1,90,713	2,09,784	37,36,234	41,09,857
2019	1,99,381	2,19,319	39,26,947	43,19,642
2020	1,99,381	2,19,319	41,26,328	45,38,961
2021	1,99,381	2,19,319	43,25,709	47,58,280
2022	1,99,381	2,19,319	45,25,090	49,77,599
2023	1,99,381	2,19,319	47,24,471	51,96,918
2024	1,99,381	2,19,319	49,23,852	54,16,237
2025	1,99,381	2,19,319	51,23,233	56,35,556
2026	1,99,381	2,19,319	53,22,614	58,54,875
2027	1,99,381	2,19,319	55,21,995	60,74,195
2028	1,99,381	2,19,319	57,21,376	62,93,514
2029	1,99,381	2,19,319	59,20,757	65,12,833
2030	0	0	61,20,138	67,32,152

Table 5.14(b) shows the trend of the Total landfill gases and Methane gas emission every year at the waste disposal site (Bhagtanwala Amritsar). (This table is generated by the LandGEM software in the result spreadsheet).

Table 5.14(b)

Year	**Total Landfill Gases**		**Methane**	
	(Mg/year)	**(Short Tons/year)**	**(Mg/year)**	**(Short Tons/year)**
1995	0	0	0	0
1996	2.879E+03	3.167E+03	7.691E+02	8.460E+02
1997	5.618E+03	6.180E+03	1.501E+03	1.651E+03
1998	8.224E+03	9.046E+03	2.197E+03	2.416E+03
1999	1.070E+04	1.177E+04	2.859E+03	3.144E+03
2000	1.306E+04	1.437E+04	3.488E+03	3.837E+03
2001	1.566E+04	1.723E+04	4.183E+03	4.602E+03
2002	1.814E+04	1.995E+04	4.845E+03	5.329E+03
2003	2.049E+04	2.254E+04	5.474E+03	6.021E+03
2004	2.273E+04	2.501E+04	6.072E+03	6.679E+03
2005	2.486E+04	2.735E+04	6.641E+03	7.305E+03
2006	2.707E+04	2.978E+04	7.231E+03	7.954E+03
2007	2.917E+04	3.209E+04	7.791E+03	8.570E+03
2008	3.117E+04	3.428E+04	8.325E+03	9.157E+03
2009	3.306E+04	3.637E+04	8.832E+03	9.715E+03
2010	3.487E+04	3.836E+04	9.314E+03	1.025E+04
2011	3.677E+04	4.045E+04	9.822E+03	1.080E+04
2012	3.858E+04	4.243E+04	1.030E+04	1.133E+04
2013	4.029E+04	4.432E+04	1.076E+04	1.184E+04
2014	4.193E+04	4.612E+04	1.120E+04	1.232E+04
2015	4.348E+04	4.783E+04	1.161E+04	1.278E+04
2016	4.532E+04	4.985E+04	1.211E+04	1.332E+04
2017	4.707E+04	5.178E+04	1.257E+04	1.383E+04
2018	4.873E+04	5.361E+04	1.302E+04	1.432E+04
2019	5.032E+04	5.535E+04	1.344E+04	1.478E+04
2020	5.200E+04	5.720E+04	1.389E+04	1.528E+04

2021	5.360E+04	5.896E+04	1.432E+04	1.575E+04
2022	5.513E+04	6.064E+04	1.473E+04	1.620E+04
2023	5.658E+04	6.224E+04	1.511E+04	1.662E+04
2024	5.796E+04	6.375E+04	1.548E+04	1.703E+04
2025	5.927E+04	6.520E+04	1.583E+04	1.742E+04
2026	6.052E+04	6.657E+04	1.617E+04	1.778E+04
2027	6.171E+04	6.788E+04	1.648E+04	1.813E+04
2028	6.284E+04	6.912E+04	1.678E+04	1.846E+04
2029	6.391E+04	7.030E+04	1.707E+04	1.878E+04
2030	6.493E+04	7.143E+04	1.734E+04	1.908E+04
2031	6.177E+04	6.794E+04	1.650E+04	1.815E+04
2032	5.875E+04	6.463E+04	1.569E+04	1.726E+04
2033	5.589E+04	6.148E+04	1.493E+04	1.642E+04
2034	5.316E+04	5.848E+04	1.420E+04	1.562E+04
2035	5.057E+04	5.563E+04	1.351E+04	1.486E+04
2036	4.810E+04	5.291E+04	1.285E+04	1.413E+04
2037	4.576E+04	5.033E+04	1.222E+04	1.344E+04
2038	4.353E+04	4.788E+04	1.163E+04	1.279E+04
2039	4.140E+04	4.554E+04	1.106E+04	1.217E+04
2040	3.938E+04	4.332E+04	1.052E+04	1.157E+04
2041	3.746E+04	4.121E+04	1.001E+04	1.101E+04
2042	3.564E+04	3.920E+04	9.519E+03	1.047E+04
2043	3.390E+04	3.729E+04	9.055E+03	9.960E+03
2044	3.224E+04	3.547E+04	8.613E+03	9.474E+03
2045	3.067E+04	3.374E+04	8.193E+03	9.012E+03
2046	2.918E+04	3.209E+04	7.793E+03	8.573E+03
2047	2.775E+04	3.053E+04	7.413E+03	8.155E+03
2048	2.640E+04	2.904E+04	7.052E+03	7.757E+03
2049	2.511E+04	2.762E+04	6.708E+03	7.379E+03
2050	2.389E+04	2.628E+04	6.381E+03	7.019E+03
2051	2.272E+04	2.499E+04	6.069E+03	6.676E+03
2052	2.161E+04	2.378E+04	5.773E+03	6.351E+03
2053	2.056E+04	2.262E+04	5.492E+03	6.041E+03
2054	1.956E+04	2.151E+04	5.224E+03	5.746E+03
2055	1.860E+04	2.046E+04	4.969E+03	5.466E+03
2056	1.770E+04	1.947E+04	4.727E+03	5.200E+03
2057	1.683E+04	1.852E+04	4.496E+03	4.946E+03
2058	1.601E+04	1.761E+04	4.277E+03	4.705E+03
2059	1.523E+04	1.675E+04	4.068E+03	4.475E+03
2060	1.449E+04	1.594E+04	3.870E+03	4.257E+03
2061	1.378E+04	1.516E+04	3.681E+03	4.049E+03
2062	1.311E+04	1.442E+04	3.502E+03	3.852E+03
2063	1.247E+04	1.372E+04	3.331E+03	3.664E+03
2064	1.186E+04	1.305E+04	3.169E+03	3.485E+03
2065	1.128E+04	1.241E+04	3.014E+03	3.315E+03
2066	1.073E+04	1.181E+04	2.867E+03	3.154E+03
2067	1.021E+04	1.123E+04	2.727E+03	3.000E+03
2068	9.712E+03	1.068E+04	2.594E+03	2.854E+03

2069	9.238E+03	1.016E+04	2.468E+03	2.714E+03
2070	8.788E+03	9.667E+03	2.347E+03	2.582E+03
2071	8.359E+03	9.195E+03	2.233E+03	2.456E+03
2072	7.951E+03	8.747E+03	2.124E+03	2.336E+03
2073	7.564E+03	8.320E+03	2.020E+03	2.222E+03
2074	7.195E+03	7.914E+03	1.922E+03	2.114E+03
2075	6.844E+03	7.528E+03	1.828E+03	2.011E+03

Table 5.14(c) Shows the CO_2 and NMOCs emission rate per year from the Bhagtanwala (Amritsar) Landfill site. (This table is generated by Land GEM software).

Table 5.14(c)

Year	**Carbon Dioxide**		**NMOCs**	
	(Mg/year)	**(short tons/year)**	**(Mg/year)**	**(short tons/year)**
1995	0	0	0	0
1996	2.110E+03	2.321E+03	3.306E+01	3.636E+01
1997	4.118E+03	4.529E+03	6.450E+01	7.096E+01
1998	6.027E+03	6.630E+03	9.442E+01	1.039E+02
1999	7.843E+03	8.628E+03	1.229E+02	1.352E+02
2000	9.571E+03	1.053E+04	1.499E+02	1.649E+02
2001	1.148E+04	1.263E+04	1.798E+02	1.978E+02
2002	1.329E+04	1.462E+04	2.082E+02	2.291E+02
2003	1.502E+04	1.652E+04	2.353E+02	2.588E+02
2004	1.666E+04	1.833E+04	2.610E+02	2.871E+02
2005	1.822E+04	2.004E+04	2.855E+02	3.140E+02
2006	1.984E+04	2.182E+04	3.108E+02	3.419E+02
2007	2.138E+04	2.351E+04	3.349E+02	3.684E+02
2008	2.284E+04	2.512E+04	3.578E+02	3.936E+02
2009	2.423E+04	2.666E+04	3.796E+02	4.176E+02
2010	2.556E+04	2.811E+04	4.004E+02	4.404E+02
2011	2.695E+04	2.964E+04	4.222E+02	4.644E+02
2012	2.827E+04	3.110E+04	4.429E+02	4.872E+02
2013	2.953E+04	3.248E+04	4.626E+02	5.089E+02
2014	3.073E+04	3.380E+04	4.814E+02	5.295E+02
2015	3.187E+04	3.505E+04	4.992E+02	5.491E+02
2016	3.321E+04	3.654E+04	5.203E+02	5.724E+02
2017	3.450E+04	3.795E+04	5.404E+02	5.944E+02
2018	3.572E+04	3.929E+04	5.595E+02	6.155E+02
2019	3.688E+04	4.056E+04	5.777E+02	6.354E+02
2020	3.811E+04	4.192E+04	5.970E+02	6.567E+02
2021	3.929E+04	4.321E+04	6.154E+02	6.770E+02
2022	4.040E+04	4.444E+04	6.329E+02	6.962E+02
2023	4.147E+04	4.561E+04	6.496E+02	7.145E+02
2024	4.248E+04	4.672E+04	6.654E+02	7.320E+02
2025	4.344E+04	4.778E+04	6.805E+02	7.485E+02

2026	4.435E+04	4.879E+04	6.948E+02	7.643E+02
2027	4.522E+04	4.975E+04	7.085E+02	7.793E+02
2028	4.605E+04	5.066E+04	7.214E+02	7.936E+02
2029	4.684E+04	5.152E+04	7.338E+02	8.071E+02
2030	4.759E+04	5.235E+04	7.455E+02	8.201E+02
2031	4.527E+04	4.979E+04	7.091E+02	7.801E+02
2032	4.306E+04	4.737E+04	6.746E+02	7.420E+02
2033	4.096E+04	4.506E+04	6.417E+02	7.058E+02
2034	3.896E+04	4.286E+04	6.104E+02	6.714E+02
2035	3.706E+04	4.077E+04	5.806E+02	6.387E+02
2036	3.525E+04	3.878E+04	5.523E+02	6.075E+02
2037	3.354E+04	3.689E+04	5.253E+02	5.779E+02
2038	3.190E+04	3.509E+04	4.997E+02	5.497E+02
2039	3.034E+04	3.338E+04	4.754E+02	5.229E+02
2040	2.886E+04	3.175E+04	4.522E+02	4.974E+02
2041	2.746E+04	3.020E+04	4.301E+02	4.731E+02
2042	2.612E+04	2.873E+04	4.091E+02	4.501E+02
2043	2.484E+04	2.733E+04	3.892E+02	4.281E+02
2044	2.363E+04	2.600E+04	3.702E+02	4.072E+02
2045	2.248E+04	2.473E+04	3.522E+02	3.874E+02
2046	2.138E+04	2.352E+04	3.350E+02	3.685E+02
2047	2.034E+04	2.237E+04	3.186E+02	3.505E+02
2048	1.935E+04	2.128E+04	3.031E+02	3.334E+02
2049	1.840E+04	2.025E+04	2.883E+02	3.171E+02
2050	1.751E+04	1.926E+04	2.743E+02	3.017E+02
2051	1.665E+04	1.832E+04	2.609E+02	2.870E+02
2052	1.584E+04	1.743E+04	2.482E+02	2.730E+02
2053	1.507E+04	1.658E+04	2.361E+02	2.597E+02
2054	1.433E+04	1.577E+04	2.245E+02	2.470E+02
2055	1.363E+04	1.500E+04	2.136E+02	2.350E+02
2056	1.297E+04	1.427E+04	2.032E+02	2.235E+02
2057	1.234E+04	1.357E+04	1.933E+02	2.126E+02
2058	1.174E+04	1.291E+04	1.838E+02	2.022E+02
2059	1.116E+04	1.228E+04	1.749E+02	1.924E+02
2060	1.062E+04	1.168E+04	1.663E+02	1.830E+02
2061	1.010E+04	1.111E+04	1.582E+02	1.741E+02
2062	9.608E+03	1.057E+04	1.505E+02	1.656E+02
2063	9.139E+03	1.005E+04	1.432E+02	1.575E+02
2064	8.694E+03	9.563E+03	1.362E+02	1.498E+02
2065	8.270E+03	9.097E+03	1.295E+02	1.425E+02
2066	7.866E+03	8.653E+03	1.232E+02	1.356E+02
2067	7.483E+03	8.231E+03	1.172E+02	1.289E+02
2068	7.118E+03	7.830E+03	1.115E+02	1.227E+02
2069	6.771E+03	7.448E+03	1.061E+02	1.167E+02
2070	6.440E+03	7.085E+03	1.009E+02	1.110E+02
2071	6.126E+03	6.739E+03	9.597E+01	1.056E+02
2072	5.828E+03	6.410E+03	9.129E+01	1.004E+02
2073	5.543E+03	6.098E+03	8.684E+01	9.552E+01

2074	5.273E+03	5.800E+03	8.260E+01	9.086E+01
2075	5.016E+03	5.517E+03	7.858E+01	8.643E+01

Figure 5.11 Shows total annual landfill gases at Bhagtanwala Amritsar.

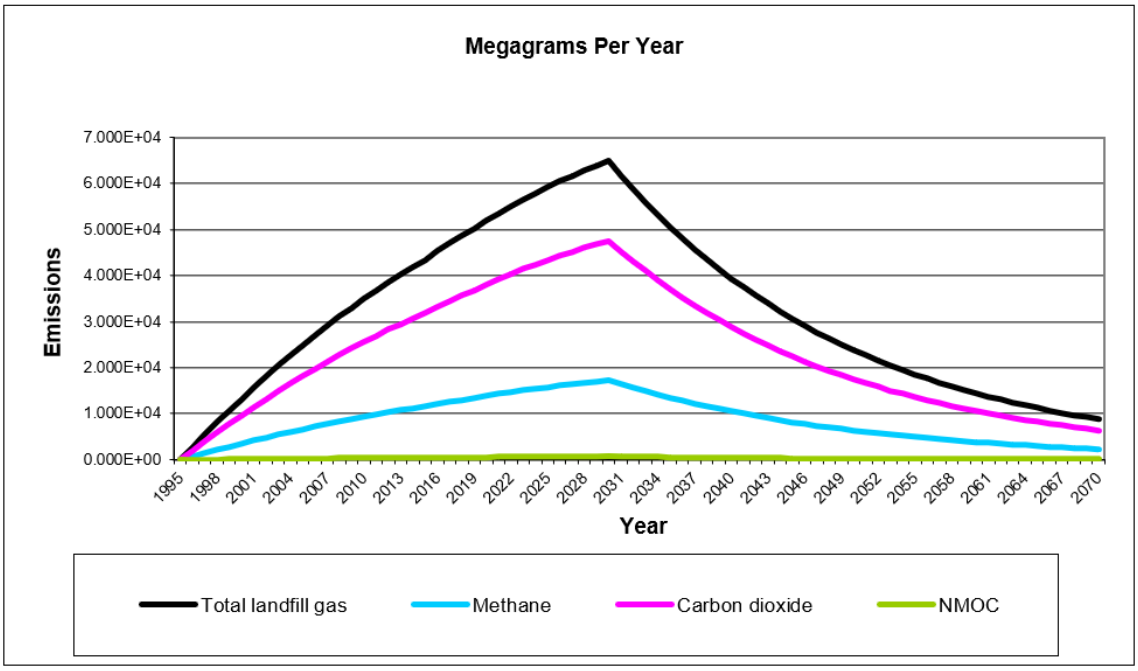


Figure 5.11: Annual total landfill Gas Graph result by LandGEM in Mg/year (Bhagtanwala Amritsar)

5.6.4 Discussion:

During the first year of the garbage/refuse in Landfill the Land GEM assumes that there is no decomposition process started and there is no biogas produced during that period.

After reading the literatures there it was mentioned that the methanogenesis steps starts in minimum 6 months after refuse is disposed in site. garbage degradation generally rely upon many conditions and situations such as refuse type, moisture content in the refuse, climatic provisions changed during that period of time, refuse covering material in the landfill, etc., The Land GEM software don't take into consideration of all of these provisions in order to start the initial phases of methanogenesis process and examine these all parameters after 52 weeks, all of these things are considered at the starting of this phase.

As we see the *Table 5.14(b)* and *Figure 5.11*, we can see that from Bhagtanwala Amritsar in the year 1996 the total Landfill gases which was generated was around $2.879*10^3$Mg/year which is increased to $6.493*10^4$Mg/year by the year 2030 which is a peak value. And see the CH_4 generation in yr. 1996 it was around $7.691*10^2$Mg/year and by year 2030 it increased to $1.734*10^4$Mg/year peak value in the graph.

CHAPTER-6

FINAL COMPARISON AND CONCLUSION

6.1Panchkula:

6.1.1 Environmental Conditions

Panchkula lies nearly 338 metres above the sea level and has a warm climate. Rainfall is more in summers as compared to winters. Panchkula has an average annual temperature of about 22.7 deg. C (72.8 deg. F). Panchkula receives an annual precipitation of 792 millimetre's (31.2 inches). November is the mostly dry month with the rain of 6 mm and maximum precipitation is in July about 195 millimetres. June is hottest with average temperature of 31 deg. C, whereas, January is coldest with 11.9 deg. C. (Source- CLIMATE-DATA.ORG).

6.1.2 Soil Conditions-

Panchkula has light loam soils. The underground water is suitable for irrigation. (Source: Wikipedia)

6.2 Jalandhar:

6.2.1 Climatic Conditions-

Jalandhar lies nearly 242 metres above the sea level and has a warm climate. Rainfall is more in summers as compared to winters. Jalandhar has an average annual temperature of about 23.1^0 Celsius (73.6^0 Fahrenheit). Jalandhar receives an annual precipitation of 957 millimetre's (37.7 inches). November is the mostly dry month with the rain of 15 mm and maximum precipitation is in July about 243 millimetres. June is hottest with average temperature of 32.1 deg. C, whereas, January is coldest with 11.5 deg. C. (Source- CLIMATE-DATA.ORG).

6.2.2 Soil Conditions-

Jalandhar has Tropical arid brown soil found in major parts of Jalandhar district, and Arid brown soil in south western part of the district. (Source: cgwb.gov.in).

6.3Amritsar:

6.3.1 Environmental Conditions-

Amritsar lies nearly 232 metres above the sea level and has a warm climate. Rainfall is more in summers as compared to winters. Amritsar has an average annual temperature of about 23.4^0 Celsius (74.1^0 Fahrenheit). Amritsar receives an annual precipitation of 786 milimetres (30.9 inches). November is the mostly dry month with the rain of 12 mm and maximum precipitation is in July about 201 millimetres. June is hottest with average temperature of 32.8 deg. C, whereas, January is coldest with 11.6 deg. C. (Source- CLIMATE-DATA.ORG).

6.3.2 Soil Conditions-

The western region has calcareous, coarse loamy soils. And central region has calcareous, well drained and fine loamy soil. (Source: cgwb.gov.in).

6.4 Result Comparison:

This result shows the comparative analysis between 4 Landfills that are Landfill in sector 23 Panchkula (Haryana), Wariana Dump Jalandhar (Punjab), Piplanawla Landfill Jalandhar (Punjab), and Bhagtanwala Landfill Amritsar (Punjab).

We have done the comparison on the basis of FOD Method which is used in Land GEM software, these resulting graphs shows the comparison of Total Landfill Gases, Methane, Carbon Dioxide and NMOCs (Non Methanic Organic Compounds) which are released from the Landfills mentioned above.

6.4.1 Total Landfill Gases

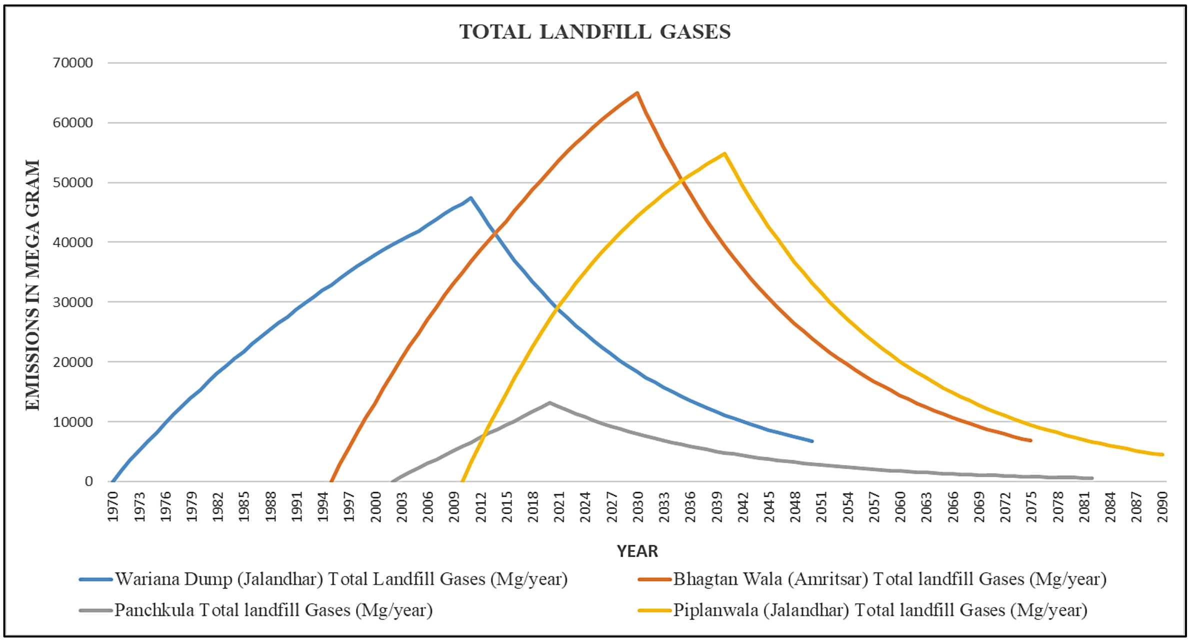


Figure 6.1: Total Landfill Gases Emission Rate Comparison Graph

This graph in the *Figure 6.1* is showing the emission rate variation of the Total landfill gases from the Landfills (Wariana Dump, Piplanwala Landfill, Bhagtanwala Landfill, and Landfill in Panchkula sector 23).

After analysing the graph, we found that the highest emission rate of Total Landfill gases is from Bhagtanwala Landfill Amritsar shown by orange color line in graph. Max value will be approx. $6.5*10^4$Mg/year by the year 2030.

The Lowest Peak in Graph of black Color is representing Panchkula sector 23 Landfill Gas emissions. There is less emission of the Total Landfill gases from this landfill is due to less waste generation in Panchkula (150 tons/day) as compared to Bhagtanwala (600 tons /day) and the population data also varies in between these two cities (Panchkula and Amritsar). The peak value of release rate of the total landfill gases from the Panchkula landfill is $1.3 * 10^4$ Mg/year in year 2020.

Now, the Blue Line in Graph starting from the year 1970 is representing wariana dump in Jalandhar. Highest emission rate of Landfill Gases from wariana Dump was in year 2011 of approx. $4.7*10^4$ Mg/year. The Total Landfill Gases emission rate from Piplanwala Landfill Jalandhar is represented by Yellow line in the Graph, the peak value will be in year 2040 as this Landfill is still in use for dumping purpose value is $5.5*10^4$Mg/year.

Now, if we compare the peak emission rate values from the graph, we can say that, the rate of emission of the Total landfill gases from the Bhagtanwala Landfill Amritsar is 5 times excess than the emission rate of Total Landfill Gases from the Landfill in sector 23 Panchkula. Also, the generation rate of the total Landfill gases from the wariana dump Jalandhar is 3.5 times and Piplanwala landfill Jalandhar is 4 times high/excess than the Panchkula Landfill.

6.4.2 Methane

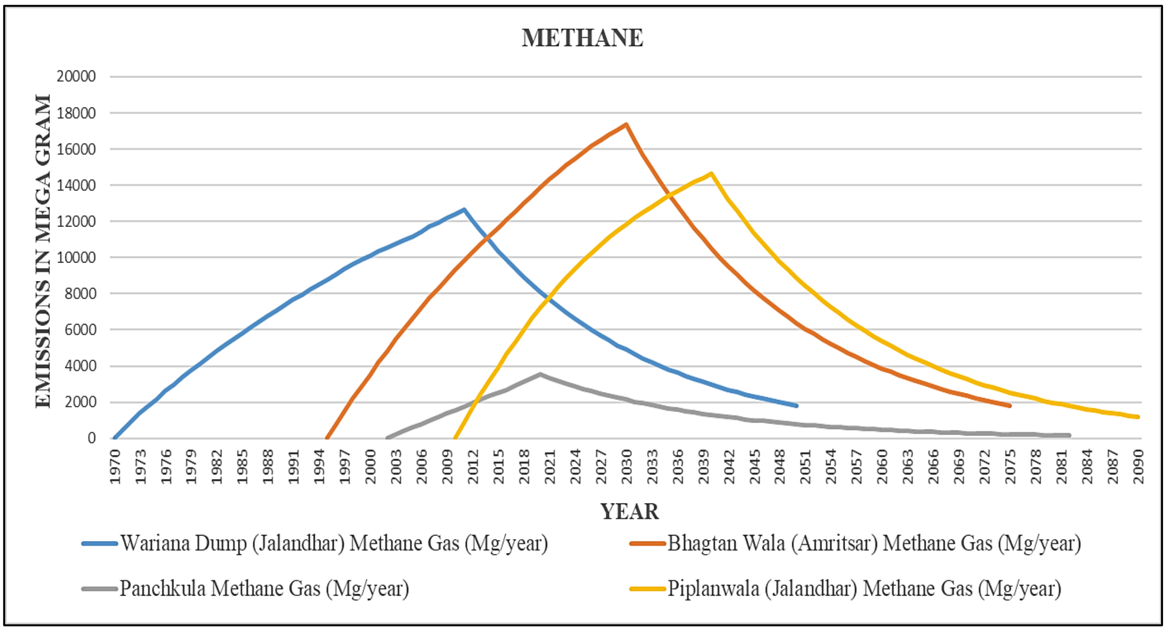


Figure 6.2: Methane Gas emission rate Comparison Graph

Figure 6.2 is representing the Comparison data of the rate of emission of the Methane Gas from the Landfills (Wariana Dump, Piplanwala Landfill, Bhagtanwala Landfill, and Landfill in Panchkula sector 23) in the graphical form.

After analyzing the graph the highest Methane gas emission rate is from Bhagtanwala Landfill Amritsar (Due to its high population and daily waste generation is also greater than the others). The Bhagtanwala Landfill Methane Gas emission rate is represented by orange color in the Graph. Peak value will be in the year 2030 approx. $1.7*10^4$Mg/year.

We got the Lowest peak (represented by black color line in graph) in the Methane Gas emission rate from the Panchkula sector 23 landfill in the year 2020 of value $3.5*10^3$Mg/year.

Rate of emission of methane from Wariana Dump in Jalandhar is represented by the blue color line in the graph the peak value of $1.3*10^4$Mg/year in year 2011. And the yellow line the graph represents the rate of release of Methane Gas from the Piplanwala Landfill Jalandhar having peak value of $1.5*10^4$Mg/year which will be in year 2040.

The rate of emission of Methane Gas from the Bhagtanwala Landfill is 5 excess times than the Methane gas emission rate from the Panchkula Landfill. The Methane gas emission rate from the Wariana Dump is approx. 3.5 times more and the Methane gas emission rate from the Piplanwala Landfill is approx. 4 excess times than Methane gas emission rate from the Panchkula Landfill.

6.4.3 Carbon Dioxide

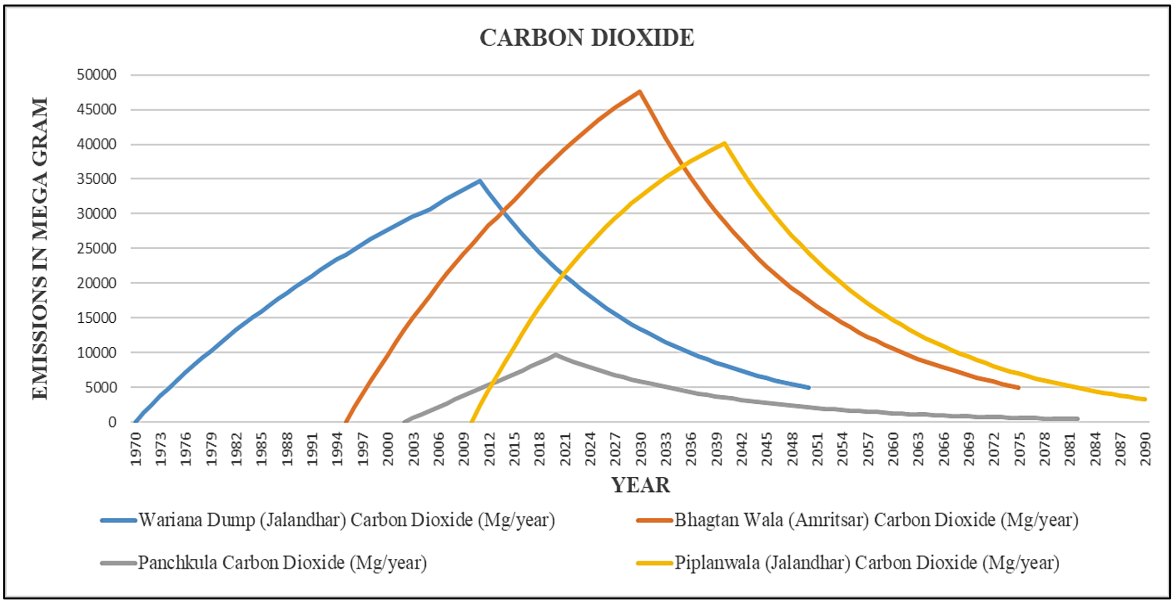


Figure 6.3 Carbon Dioxide Gas emission rate Comparison Graph

Figure 6.3 Shows the Comparison data of the Corbon Dioxide Gas Emission rate from the Landfills (Wariana Dump, Piplanwala Landfill, Bhagtanwala Landfill, and Landfill in Panchkula sector 23) in the graphical form.

The rate of emission of the Carbon dioxide gas from the Panchkula landfill ($9.7*10^3$Mg/year) is the lowest if we compare it with others. The rate of the emission of the Carbon dioxide from the Bhagtanwala Landfill (represented by the orange color line in graph). It will achieve its peak value of $4.8*10^4$ Mg/year by the year 2030.

The rate of emission of the Carbon Dioxide Gas from the Wariana dump is approx. $3.5*10^4$Mg/year (peak value) in 2011. Whereas, the rate of emission of the Carbon Dioxide Gas from the Piplanwala Landfill is approx. $4.0*10^4$ Mg/year (peak value) and this value will be in 2040.

The rate of emission of the carbon dioxide from the Bhagtanwala landfill Amritsar is 5 times excess, from the Wariana dump Jalandhar it is 3.5 excess times and from the Piplanwala Landfill Jalandhar it is 4 excess times than the rate of emission of the carbon dioxide from the Sector 23 Landfill in Panchkula.

6.4.4 Non Methanic Organic Compounds (NMOCs)

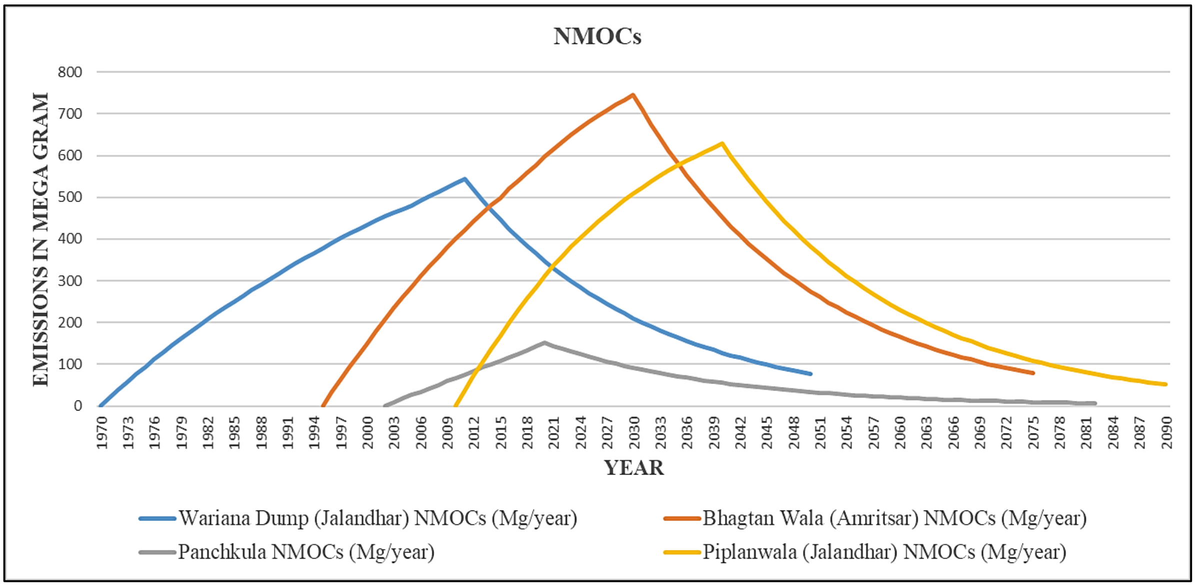


Figure 6.4 Rate of Emission of Non Methanic Organic Compounds

The *Figure 6.4* Shows the Comparison data of the Rate of Emission of Non Methanic Organic Compounds from the Landfills (Wariana Dump, Piplanwala Landfill, Bhagtanwala Landfill, and Landfill in Panchkula sector 23) in the graphical form.

Highest rate of emission of NMOCs is from the Bhagtanwala Landfill in Amritsar (represented by the orange color line in graph) of approx. 745.5Mg/year and this peak value will be in the year of 2030. And the lowest peak is from the Panchkula Landfill in 2020, peak value of 151.4Mg/year represented by the Black color line in the graph.

The blue color line in the graph represents the rate of emission of NMOCs from the Wariana Dump Jalandhar of approx. peak value of 544.6Mg/year in 2011. And the yellow color line in the graph represents the rate of emission of NMOCs from the Piplanwala Landfill Jalandhar. By the year 2040 it will achieve its peak value of approx. 628.7Mg/year.

Now, if we compare this data from the Sector 23 Landfill in Panchkula. We can conclude that the rate of emission of NMOCs from the Bhagtanwala landfill Jalandhar is 5 times excess, from the Wariana dump Jalandhar it is 3.5 times excess and from the Piplanwala Landfill Jalandhar it is 4 times excess than the rate of emission of the carbon dioxide from the Sector 23 Landfill in Panchkula.

6.5 CONCLUSION:

From this Project Work we can Conclude many things that

- After this study we can conclude that India is still in the category of developing nation. Still in India people are less aware about the natural sources of energy. Population of India say a drastic increase from last few years. So Solid garbage conduct is still facing problems for the efficiency of the waste collection. In order to boost Indian economy, we should start thinking about the Gases produced from the Landfills.

- Methane gas is a very powerful and is of explosive in nature. This gas majorly contributes in the greenhouse gas effect. This gas is used in different ways to generate energy. So, from here we can conclude that this gas is very energy efficient.

- Methane if used wisely can be very economical gas and can be used as a source of energy. But these landfill gases are not much used in India because people are not well aware of these landfill gases and their useful nature.

- Only way to decrease the effect of the gases of green house such as methane and CO_2, we should start thinking about the estimation process and collection of these gases. If India starts using these gases as a source of fuel then India may have upper hand in the energy production through gases.

- The rate of emission of the Total landfill gases from the Bhagtanwala Landfill Amritsar is 5 times excess than the emission rate of Total Landfill Gases from the Landfill in sector 23 Panchkula. Also, the generation rate of the total Landfill gases from the wariana dump Jalandhar is 3.5 times and Piplanwala landfill Jalandhar is 4 times high/excess than the Panchkula Landfill.

- The Methane Gas emission rate from the Bhagtanwala Landfill is 5 excess times than the Methane Gas emission rate from the Panchkula Landfill. The Methane Gas emission rate from the Wariana Dump is approx. 3.5 times more and the Methane Gas emission rate from the Piplanwala Landfill is approx. 4 excess times than the Methane Gas emission rate from the Panchkula Landfill.

- The MSW management workers of Panchkula as well of the Jalandhar and Amritsar are not well aware of these gases which are emitted from the landfill as they sometime burn the waste openly and also there are several health-related problems associated with it, if they come in contact with these gases.

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