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Characterization and Energy Generation of Sharda Landfill at Agra

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ABSTRACT
Most of the global municipal solid waste is dumped in non regulated landfills and the generated methane is emitted to the atmosphere which has global warming potential. Some of the modern regulated landfills attempt to capture and utilize landfill gas. An attempt has been made in this study for the recovery of energy potential of Shadra site. This includes different methodologies to determine the feasibility of recovery project. The laboratory results show that the percentage by volume of methane is 51%. The landfill gas (LFG) generation is very low (i.e. low-range recovery scenario) and it is un-economical to recover such low flow gases produced in landfill. So, this reveals that flaring is only the option to reduce the global warming potential (GWP) and also the problems of odour in the vicinity of landfill.

Key Words: Landfill, Methane generation and odour problem.

I. INTRODUCTION

Open dumping approach still remains the predominant waste disposal alternative in developing countries causing nuisance and environmental problems. With the accelerated generation of waste caused by increasing population, urbanisation, and industrialisation, the problem has become even worse. Most Asian countries are facing resembling problems, e.g. in India more than 90% of landfills is just open dumps until recent years [1].

Sanitary Landfills are the most popular method of ultimate disposal of solid waste. It is a land disposal site employing an engineered method of disposing of solid waste on land in a manner that minimize volume, and applying and compaction cover material at the end of each day [3]. As mentioned above, the impacts from inappropriate sanitary landfill can be minimized by controlled leachate generation and gas emission from the landfill site. Leachate is the most polluted liquid generated in a landfill due to the water content that enters the landfill from external sources, surface drainage, rainfall, groundwater, and water from waste material. Leachate characteristics and leachate generation depend on the type and depth of solid waste, age of landfill, the rate of water application, landfill design and operation [4].Alternative methods used to manage leachate from the landfill are leachate recycling, leachate evaporation, treatment followed by disposal and discharge to municipal wastewater collection systems [2]. However, the treatment systems need financial support and technician skill to control and operate the system, thus the other alternative is leachate minimization; waste composition and the type of pretreatment can minimize the characteristics of leachate [5].

Landfill gas is produced from the decomposition of the organic fraction of Municipal Solid Waste (MSW). The principal components of gas emissions from the municipal landfill sites are Methane, Carbon dioxide, Hydrogen, Oxygen and Nitrogen. Methane and Carbon dioxide are the major gases produced in MSW from anaerobic decomposition of biodegradable organic waste [6]. Methane is the one of the greenhouse effect gases, which has 23-times potential compared to Carbon dioxide. It can explode; thus, it considered being a dangerous gas. In Thailand methane emissions from landfills using IPCC value was 0.701 Tg/year, in 1994 [7]. Typically, the methods for the management of landfill gas are flared or energy to recovery. Flaring of landfill gases is a method for treating landfill gas by thermal destruction and this method can generate other air pollution such as sulphur dioxide, oxide of nitrogen and trace gas (VOCs). Landfill gas energy recovery systems usually convert gas from landfills to electricity; however, it is an expensive technique as the landfill site is small and has low gas production.

1.1 Objectives and Scope of the study

This study is focused on the investigation of the following aspects:

i) To characterize the gases produced in the landfill.
ii) To proposed energy capture or flaring.

Landfilling is commonly being developed as a renewable source of energy through the systematic recovery and utilization of biogas generated during anaerobic decomposition of municipal solid wastes. In India there is good scope for the development of landfill gas technology as municipal solid waste contains a high proportion of degradable organic matter. Biogas generation from various sources is also seen as a key renewable energy source.

Methane emissions from the solid waste sector in India are projected to increase significantly over the next 15 years. Reusing landfill methane gas for energy purposes has the potential to mitigate 5.5 million metric tons of carbon dioxide equivalents, which is equal to the annual emissions from one million vehicles [8]. Currently, there are no operational landfill gas-to-energy projects in India but several large sites in Delhi, Mumbai and other cities could support the clean energy projects. In India, the labour-oriented solid waste management systems concentrate more on the collection and transportation stages. Disposal is mostly limited to uncontrolled filling of low-lying areas. As the solid waste contains a good proportion of degradable organic matter, and there is a growing energy demand in every sector of the economy, there is good scope for controlled landfill gas generation, recovery and utilization. People may be exposed to landfill gases either at the landfill or in their communities. As discussed above that, landfill gases may migrate from the landfill either above or below ground. Gases can move through the landfill surface to the ambient air. Once in the air, the landfill gases can be carried to the community with the wind. Odours from day-to-day landfill activities are indicative of gases moving above ground. Gases may also move through the soil underground and enter homes or utility corridors on or adjacent to the landfill. The levels of gases that migrate from a landfill and to which people are exposed are dependent on many factors such as diffusion, pressure, permeability of soil etc. If a collection or control system is in place and operating properly, migration and exposures should be minimal. So, it is necessary to conduct study for gas generation and adopt either flaring or energy recovery according to the availability of gas in the landfill.

In the present scenario, many projects have been in running position in India, but few of them have a potential of energy recovery. Major Project’s sites including Dhapa Disposal Site (Kolkata), Deonar Landfill (Mumbai), Bhalswa Landfill (New Delhi), Gazipur Landfill (New Delhi), Okhla Landfill (Delhi), Pirana Landfill (Ahmedabad), Uruli Devachi Landfill (Pune).

1. 2 Landfill Gas incidents

The concentration level at which gas has the potential to explode is called the explosive limit. The potential for a gas to explode is determined by its lower explosive limit (LEL) and upper explosive limit (UEL). The LEL and UEL are measures of the percent of a gas in the air by volume. At concentrations below its LEL and above its UEL, a gas is not explosive. However, an explosion hazard may exist if a gas is present in the air between the LEL and UEL and an ignition source is present.

Table 1 Landfill Gas Fire /Explosions cases

IN DEVELOPED COUNTRIES, Although landfill gas explosions are by no means common occurrences, a number of incidents known or suspected to have been caused by landfill gas explosions have been documented. [39]	
1999	An 8-year-old girl was burned on her arms and legs when playing in an Atlanta playground. The area was reportedly used as an illegal dumping ground many years ago. (Atlanta Journal-Constitution 1999)
1994	While playing soccer in a park built over an old landfill in Charlotte, North Carolina, a woman was seriously burned by a methane explosion. (Charlotte Observer 1994)
1987	Off-site gas migration is suspected to have caused a house to explode in Pittsburgh, Pennsylvania.(EPA 1991)
1984	Landfill gas migrated to and destroyed one house near a landfill in Akron, OHIO. Ten houses were temporarily evacuated. (EPA 1991)
1983	An explosion destroyed a residence acrossthe street from a landfill in Cincinnati, Ohio. Minor injuries were reported. (EPA 1991)
1975	In Sheridan, Colorado, landfill gas accumulated in a storm drain pipe that ran through a landfill. An explosion occurred when several children playing in the pipe lit a candle, resulting in serious injury to all the children. (USEPA 1984)

Table 2: below summarizes the potential explosion hazards posed by the important constituents of landfill gas. Keeping in mind that methane is the most likely landfill gas constituent to pose an explosion hazard. Other flammable landfill gas constituents are unlikely to be present at concentrations high enough to pose an explosion hazard. However, the flammable NMOCs do contribute to total explosive hazard when combined with methane in a confined space.

Table 2 Explosion Hazards from Landfill Gas Components [39]

Component	**Potential to Pose an Explosion Hazard**
Methane	Methane is highly explosive when mixed with air at a volume between its LEL of 5% and its UEL of 15%. At concentrations below 5% and above 15%, methane is not explosive. At some landfills, methane can be produced at sufficient quantities to collect in the landfill or nearby structures at explosive levels.
Carbon dioxide	Carbon dioxide is not flammable or explosive.
Nitrogen dioxide	Nitrogen dioxide is not flammable or explosive.
Oxygen	Oxygen is not flammable, but is necessary to support explosions.
Ammonia	Ammonia is flammable. Its LEL is 15% and its UEL is 28%. However, ammonia is unlikely to collect at a concentration high enough to pose an explosion hazard.
NMOCs	Potential explosion hazards vary by chemical. For example, the LEL of benzene is 1.2% and its UEL is 7.8%. However, benzene and other NMOCs alone are unlikely to collect at concentrations high enough to pose explosion hazards.
Hydrogen sulphide	Hydrogen sulphide is flammable. Its LEL is 4% and its UEL is 44%. However, in most landfills, hydrogen sulphide is unlikely to collect at a concentration high enough to pose an explosion hazard.

Source: ATSDR (Agency for toxic substances and disease registry)

1.3 Site Description

The Site is located at Shadra, Agra, in the state of Uttar Pradesh. The climate in Agra is classified as continental. The 24-hour average temperature is 25.6 degrees C (78 degrees F). Average annual precipitation in Agra is 710 mm (28 inches), most of which falls in the monsoon months of July through September [2]. The Shadra Dump Site is divided into two phases. Phase I is owned by the ADA (Agra Development Authority), and Phase II is disputed over the local public. The disposal site operated from approximately 1979 until 2009 as an open dump site and has approximately 473,450 metric tons (Mg) of solid waste in-place. Waste in Phase I was not compacted or covered while in operation, but since its closure in 2009 it has been compacted and capped with soil. Phase II is uncapped and ungraded but is expected to be covered with a synthetic cap [17-19].

1.4 Waste Disposal Rates at site

The disposal site area was calculated and it is found to be 34,195 m2 for Phase I and 16,296 m2 for Phase II (total of 50,491 m2). The volume of MSW was calculated by multiplying the area with a reported maximum depth of 12 m, and it is found to be approximately 344,548 m3 for Phase I and 128,904 m3 for Phase II (total of 473,450 m3). In-place waste density was estimated to be 1.0 Mg/m3 after accounting for waste decay. Applying this density to the estimated waste volume results in an estimated total of 473,450 Mg of waste in place. Waste disposal reportedly occurred between 1979 and April 2009. The estimated total amount of waste in place, and opening and closing years were used to develop an annual disposal history. For the purpose of estimating the current efficiency of total waste transportation from the city, the site was physically observed by the local governing body from 6:00AM in the morning to & 12:00 noon in the evening for seven consecutive days .Each and every vehicle reaching the site were noted in a log book and weighed for tare and load weight and estimation of quantity is arrived thereafter.

1.5 Source of Solid Waste Generation

The waste generated from the city includes household waste, commercial waste, clinical waste and industrial waste.

Following are the major sources of generation of waste at city level:

- Local residents,
- Hotels, Restaurants
- Bazaar and vegetable markets,
- Hospital and dispensaries,
- Others

About 628MT of solid waste is generated every day in the city, which comes out to be about 492 grams per capita per day. As per the NEERI Strategy Paper on SWM in India, (February 1996) the per capita waste generation in the city with population range of 10-20 lakhs should be 270 grams per capita per day. The average waste generated from the city is 492 grams per capita per day, which is higher than the standard/norms prescribed in the Manual on Municipal Solid Waste Management; Ministry of Urban Development & Poverty Alleviation, Government of India; 20001 (270 grams per capita per day for city with population in between 10 lakhs and 20 lakhs).

I. Waste from Petha industry

Agra is famous for its petha sweet and petha making produces substantial quantity of organic waste. It also produces large quantity of vegetable waste mainly peelings, seeds and fleshy part around the seeds. There are around 400 petha industry units. The situation is worst in the Petha industry area, as the petha waste attracts flies, mosquitoes and strays too. In some areas the garbage waste is recklessly burnt in open dump yards placed on the main highway road.

Waste Composition Data

Due to improper solid waste management taking place in the city, the received solid waste is heterogeneous in nature. The population of Agra is increasing exponentially, so solid waste collection, transportation and disposal is not being done as per MSW rules This is due to unavailability of equipments & tools, vehicles, workers, lack of awareness among the peoples of the city or due to the unavailability of funds.Waste composition and moisture conditions in a Disposal Site are primary considerations when estimating LFG for model Lo and k values. The waste composition data were provided by Agra Municipal Corporation (AMC).The estimated waste composition percentages are summarized in Table 3:

Table 3 Composition of Solid Waste at Shadra landfill site [20-25]

COMPONENT	WET MASS (Kg)	DRY MASS (Kg)
FOOD	50	15
GARDEN WASTE	5	2
CONSTRUCTION AND DEMOLITION WASTE	28.5	26.22
PAPER	2.5	2.35
METALS	1.0	1.0
PLASTICS	5.0	5.0
GLASS AND CERAMICS	0.5	0.5
TEXTILES	2.5	2.25
WOOD WASTES	5	4

Source : Nagar Nigam Agra (NNA)

II. METHODOLOGY

The investigation was conducted to predict the gas generation and to characterize the gases from landfill by different operational techniques. The different operational techniques include i) Stoichiometric Analysis ii) Field Investigations iii) Laboratory Analysis.

2.1 Landfill Gas Characterization

Landfill gas characterization is the measuring of the concentration of gases from the interior of the landfill. Landfill gas characterization is typically done to quantify the concentrations of methane, carbon dioxide, sulphide etc. in raw landfill gas. LFG samples are collected from within the waste mass. Landfill gas characterization is performed to aide in the design of a landfill gas control system and aide in the routine balancing of an active landfill gas control system. Landfill gas characterization data is required for certain air quality permitting, and can be important for modeling landfill gas emissions and determining the feasibility of a potential post closure use at a landfill.

2.2 Hydrogen Sulphide

Hydrogen sulphide is found naturally in the environment and is also produced from man-made processes. Hydrogen sulphide is produced by landfilling of solid waste, especially construction and demolition waste. Sulphides are naturally occurring gases that often give a landfill gas mixture its rotten egg smell. Sulphides can cause unpleasant odours even at very low concentrations. Hydrogen sulphide is a colourless, flammable gas and is one of the most common sulphides responsible for landfill odours. Some people can smell hydrogen sulphide (individual’s odour threshold) at concentrations as low as 0.5 parts per billion (ppb) or 0.005 ppm. However, the odour threshold can vary significantly among individuals based on the olfactory sensitivity of the person. For many compounds, including hydrogen sulphide, there is a wide variability in published odour thresholds. Odours alone cannot be relied upon as providing an early warning for elevated concentrations of hydrogen sulphide. "At concentrations around 100 ppm,” (parts per million) “no odour is detected due to a loss of olfactory sensation, resulting in loss of warning properties at lethal levels." (Integrated Risk Information System (IRIS) [8]. Hydrogen sulphide is more dense than air, and therefore, more likely to pool at lower elevations under still conditions, depending upon topography.

The concentration of hydrogen sulphide detected in landfill gas samples at solid waste landfills that receive construction and demolition (C&D) waste i.e. 28.5% at Shadra landfill site, is usually much higher than at landfills that do not accept C&D. The higher concentrations of hydrogen sulphide are believed to be associated with the gypsum board component (e.g. wallboard) present in C&D material. The combination of gypsum, organic material, moisture and anaerobic conditions present in C&D landfills is believed to provide a favourable mixture and environment for bacteria to produce hydrogen sulphide gas.

Field investigation of hydrogen sulphide has indicated that under anaerobic conditions, no more sulphide is formed and maximum concentrations were recorded as 3.6 ppm. It may be due to maximum reaction occurs during the initial degradation of gypsum from construction and demolition waste. The factors contributing to hydrogen sulphide production are anaerobic conditions, pH, moisture, organic matter content, in the presence of sulphate.

2.3 Stoichiometric Analysis

The organic matter of MSW can be characterised by the following approximate chemical composition:

$$C_aH_b\,O_c\,N_d + \left(\frac{4a-b-2c+3d}{4}\right)H_2O \rightarrow \left(\frac{4a+b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b+2c+3d}{48}\right)CO_2 + dNH_3$$

Equation 1: Source: Peavy ,Rowe and Tchobanoglous

2.4 Field Investigations

Landfill gas characterization samples are typically collected in Tedlar bag, from landfill gas vents installed as part of a landfill gas control system. If a landfill gas control system is not in place, landfill gas samples are collected from shallow probes/wells installed within the waste mass.

Landfill gas characterization, including samples for major gases i.e. Methane and Carbon Dioxide, is typically analyzed using a combination of field equipment and laboratory analysis. First, field equipment such as H_2S Analyser (Jerome meters) are used for quantifying hydrogen sulphide concentrations in landfill gas and then samples are collected for laboratory analysis of Methane and Carbon Dioxide. For hydrogen sulphide concentrations ,the choice of which field equipment to use depends on the detection limits of equipment and the concentrations of hydrogen sulphide detected in the raw landfill gas. Multigas meters typically have the detection range of 1 ppm - 2000 ppm for hydrogen sulphide compared with a Jerome meter, which has the detection range of 0.003 ppm to 50 ppm. Jerome meter is used (a portable hydrogen sulphide meter manufactured by Arizona Instrument LLC, which has a detection range of 0.003 ppm to 50 ppm) for field analysis of H_2S concentration [10].

For the purpose of quantifying the landfill gas samples for laboratory analysis, it recommends that, prior to the collection of landfill gas samples, Tedlar bag should be checked for any intrusion of atmospheric gases. The presence of high concentrations of oxygen in the laboratory sample may be an indicator of atmospheric contamination of the sample. As always, proper collection procedures and holding times for the particular test method need to be followed. Additionally, the laboratory data can be used in Model study in order to ensure the quantification of methane gas generation. After analyzing the landfill gas with field equipment, a gas sample for laboratory analysis is typically collected in a Tedlar bag.

2.5 Laboratory Analysis

Landfill gas is produced through bacterial decomposition, volatilization and chemical reactions. Most landfill gas is produced by bacterial decomposition that occurs when organic waste solids, food, vegetables, garden waste (i.e. leaf and yard waste), wood and paper products, are broken down by bacteria naturally present in the waste and in soils. Chemical reactions occur when different waste materials are mixed together during disposal operations. Additionally, moisture plays a large role in the speed of decomposition. Generally, the more moisture, the more landfill gas is generated, both during the aerobic and anaerobic conditions.

From the laboratory investigation from Spectro Analytical Labs., the composition of landfill gas is composed primarily of 51 percent methane and 44 percent carbon dioxide and other gases produced at less than 5 percent. Methane and carbon dioxide are generated through the biological decomposition of waste. Methane is naturally occurring flammable, colourless and odourless gas and is the principal explosive component of concern in landfill gas. Carbon dioxide is naturally found at low concentrations in the atmosphere. Carbon dioxide is colourless, odourless, and slightly acidic.

III. RESULTS AND DISCUSSION

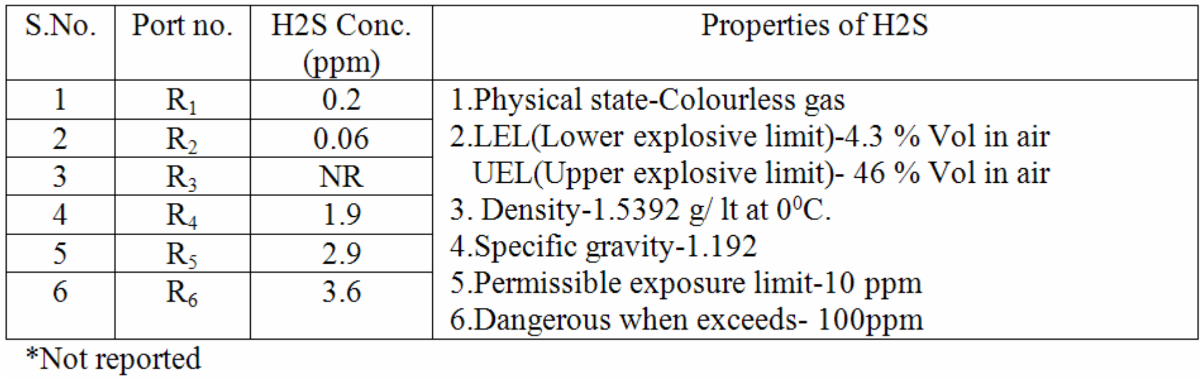
This section illustrates the results coming out from different methodologies. The results include field analyses, Laboratory analyses and Stoichiometric analyses. From all of the above methodologies.

3.1 Field Analyses Results

Field analyses can be used to get an initial estimate of conditions at the site. Field analyses is also used for periodic monitoring during the operation and maintenance phase of the project to determine what adjustments need to be made to the LFG collection and treatment system. For field investigation, use H_2S analyser and Tedlar bag. H_2S Analyser directly gives the H_2S concentration (as shown in Table 4) while Tedlar bag (for the collection of gas sample at site) is brought to Laboratory for further investigation. The Tedlar bag sample are sent to off-site labs (sample is analysed in Spectro Analytical labs) and analyzed according to specified methods and collected gas samples were analysed using gas chromatography-mass spectrometry (GC-MS) in accordance with the analytical procedure described in USEPA Method 18.

Table 4 H_2S Field Test Results

The Table. 4 above and graph 1 shows the H_2S concentrations at different gas collection ports made up of PVC pipes.



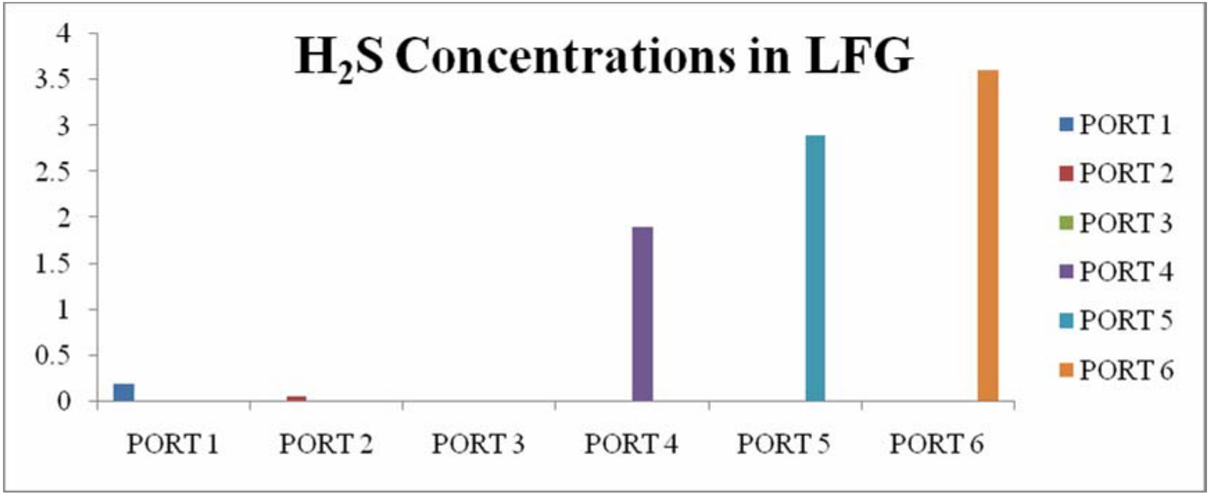
S.No.	Port no.	H2S Conc. (ppm)	Properties of H2S
1	R_1	0.2	1.Physical state-Colourless gas 2.LEL(Lower explosive limit)-4.3 % Vol in air UEL(Upper explosive limit)- 46 % Vol in air 3. Density-1.5392 g/ lt at 0^0C. 4.Specific gravity-1.192 5.Permissible exposure limit-10 ppm 6.Dangerous when exceeds- 100ppm
2	R_2	0.06	
3	R_3	NR	
4	R_4	1.9	
5	R_5	2.9	
6	R_6	3.6	

*Not reported

Field test results of hydrogen sulphide concentrations shows that there is a large variation of concentrations. The concentration of hydrogen sulphide in port no 1 and 2 is very low. But in port no 4, 5 and 6; the hydrogen sulphide concentration is 1.9, 2.9 and 3.6 respectively. This is because of the maximum concentration of construction and demolition waste in the vicinity of ports given higher values of H_2S. Port no 3 doesn't show any concentration of hydrogen sulphide. It may be due to two reasons-

- The concentration of construction and demolition waste nearby this port i.e. 3 is negligible.
- The concentration of H_2S is above 50 ppm and analyser doesn't record it (the detection limit of H_2S analyser is 0.03 to 50 ppm).

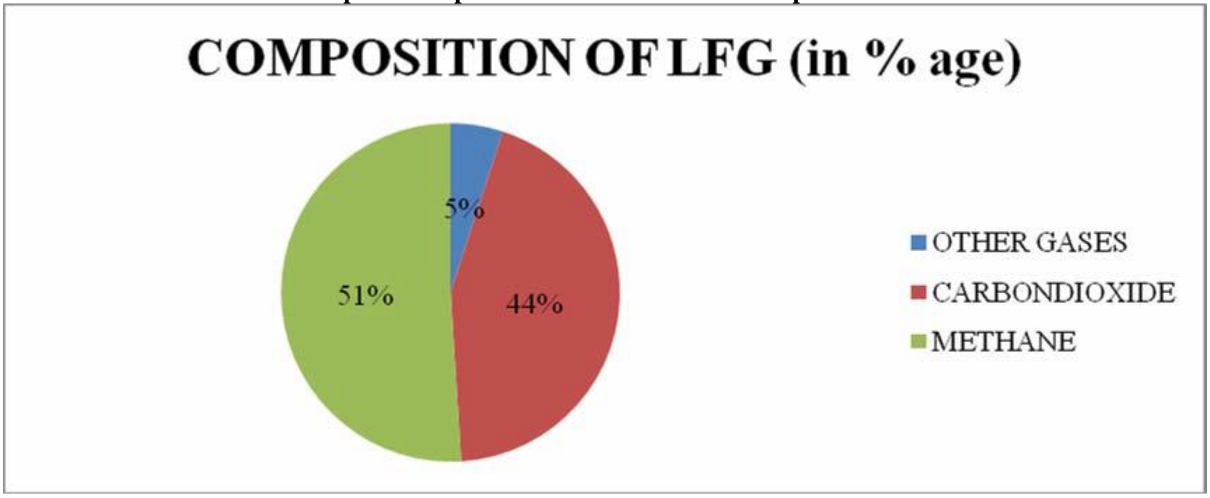
Graph.1 H_2S Concentration in Shadra Landfill



3.2 Laboratory test results

The Tedlar bag sample is analysed in Spectro Analytical labs using gas chromatography-mass spectrometry (GC-MS) in accordance with the analytical procedure described in USEPA Method 18.The Laboratory test results shows that the composition of Methane is 51 % by volume and Carbon dioxide is 44 % by volume and 5% by volume is other gases as shown in graph 2. The laboratory result shows that the energy potential gas (i.e. Methane) composition is high and there is a possibility of using LFG for energy generation.

Graph.2 Composition of LFG at Shadra disposal site.



3.3 Stoichiometric Analysis Results

The theoretical CH4 generation capacity (L0) can be determined by a Stoichiometric method that is based on a gross empirical formula representing the chemical composition of the waste. If a waste contains carbon, hydrogen, oxygen, nitrogen and sulphur its decomposition to gas is shown as equitation 1. However, this method is of limited use because it provides an estimate of the total amount of gas generated and does not provide information on the rate of generation. It also requires knowledge of the chemical composition of the waste. From the results of Stoichiometric analysis the methane generation potential is comes out to be 384 m3/tonnes which are too high. The Stoichiometric analysis results are as shown below:

IV. CONCLUSION AND SUGGESTIONS

Capturing methane from landfills for energy utilisation has been shown to be economically viable in many countries. In India, methane from solid waste disposal is predicted to rise significantly. As such, LFGE (landfill gas to energy) projects appears to be an excellent near-term energy and environmental solution for India, and the only limitation is the huge funds required for adopting these projects.

From the Experimental, Laboratory tests and Field results obtained from the study of Shadra landfill site, the following conclusions can be drawn.

- ✓ It was concluded that the project is not feasible for energy recovery as methane generation rate is very low.
- ✓ That's why flaring is only the option.
- ✓ The Shadra site is unlined arid-zone landfills site, have potential to contaminate groundwater.
- ✓ As trash decomposes it compacts and settles, and there may be a chances of landfills to sink.
- ✓ Methane efficiency can be increased significantly when waste was covered quickly with a synthetic cover.
- ✓ Methane from solid waste disposal on land is one of the major sources of greenhouse gas (GHG) emissions. It's capture and oxidation to carbon dioxide results in an environmental benefit.
- ✓ LFG energy projects reduce global methane emissions and local air pollution, and create jobs, revenues, and cost savings.
- ✓ Information on landfill gas recovery rates critical for finding suitable project sites and sizing equipment
- ✓ Analysis can be done for single sites or all sites in the country
- ✓ Follow-up studies at potential project sites may be warranted
- o Field testing
- o Feasibility studies
- ✓ Model accuracy improved by field studies

V. SUGGESTIONS AND RECOMMENDATIONS

From the study it is being recommended to construct all the landfills in scientific way i.e. it has both bottom and top liner, leachate collection system, gas collection system so that ground water contamination is minimum and consequently methane recovery is also increases. Also, it is recommended that the present disposal site should have proper maintenance and operation throughout the year.

To avoid the negative effect, a proper management system is required to facilitate maintenance and thus afford improved gas control system.

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