Landfill Gas Control

Table: Potential environmental impacts of landfill gases

Impacts	Description
Explosion	Due to methane migration and accumulation in confined areas with subsequent ignition resulting in serious injury or death and/or damage to buildings or other structures.
Asphyxiation	Workers on the landfill or people or animals in the vicinity may suffer from asphyxiation due to accumulation of gas in any confined area.
Vegetation damage	Crops or other vegetation are damaged as a result of oxygen deficiency due to landfill gas migration in the root zones. Some trace components of landfill gases are toxic to plants.
Nuisance	Due to presence of malodorous gases
Water pollution	Carbon dioxide, highly soluble in water, increases the hardness, decreases the pH and the water becomes acidic.
Corrosion	Acid forming gases may cause corrosion of landfill equipment and other metallic items.
Health effect	Migration of trace compounds and emission from incomplete combustion of gases during flaring may contain dioxins and furans which cause serious health hazard.
Green house effect	Methane and carbon dioxide present in the landfill gases contribute to the green house effect.

Composition of Landfill Gas:

Table: Typical composition of landfill gases

Component	% by volume
Methane	47.7
Carbon dioxide	47
Nitrogen	3.7
Oxygen	0.8
Hydrogen	0.1
Carbon Monoxide	0.1
Hydrogen Sulfide	0.01
Trace Compounds	0.5

Stages of Landfill Gas Generation

The generation of landfill gases occurs in five district phases as shown in the following Figure.

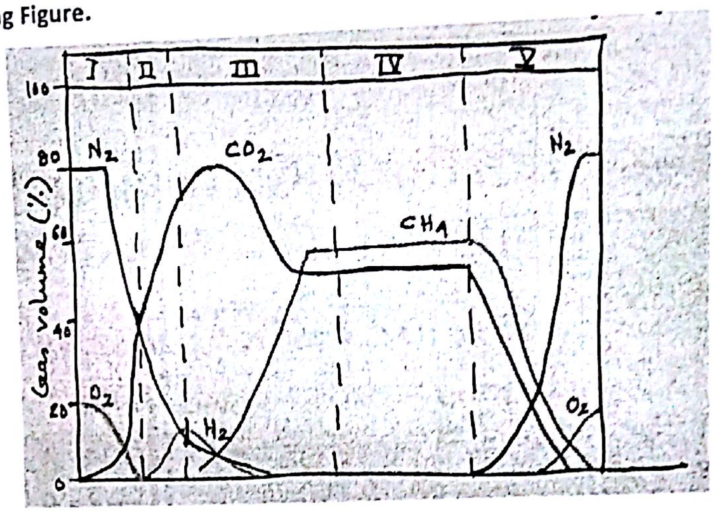


Figure: Idealistic development of landfill gases.

Duration of these phases depends upon the type of wastes, moisture content, nutrient content, pH, initial compaction level, particle size, temperature etc. Each of these phases in described below:

Phase I: This is an aerobic phase that takes place immediately after the waste is disposed off. Easily biodegradable substances are broken down by the presence of oxygen and carbon dioxide is produced.

Phase II: This is a transition phase in which oxygen is depleted and anaerobic conditions start developing. Fermentative and acidogenic bacteria produce volatile fatty acids, carbon dioxide and hydrogen.

Phase III: In this phase, methanogenic bacteria starts to grow and produce methane. Organic acids and hydrogen gas formed during phase II are converted into methane and carbon dioxide. Increasing amount of methane will be produced and the concentration of carbon dioxide will decrease.

Phase IV: This is the so-called stable methanogenic phase. It is characterized by 50-60% of methane. Hydrogen is oxidized by carbon dioxide to form methane and the concentration of CO_2 is reduced.

Phase V: During this stabilization phase, methane and carbon dioxide production will begin to decrease and the presence of atmospheric air will reintroduce aerobic conditions.

Quantity of Landfill Gas Generation

Methods of estimation are:

- Stoichiometry method
- IPCC method
- Test well method
- Rough approximation method

Stoichiometry Method:

The most common technique is to use stoichiometry. If the chemical composition of organic matter present in the wastes is known, the following equation can be used to determine the volume of principal gases in the landfill.

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

where $C_aH_bO_cN_d$ is the chemical composition of the municipal solid wastes.

IPCC method:

IPCC (Intergovernmental Panel on Climate Change) has suggested guidelines to estimate the quantity of methane generated from municipal solid wastes as follows:

CH_4 emission= $\Sigma\ MSW_i * FDOC_i * FD_i * MEF_i * CR_i$

Where MSW_i = Amount of municipal solid wastes disposed off

$FDOC_i$ = Fraction of degradable organic carbon

FD_i = Fraction of total degradable organic carbon which actually degrades (about 0.75)

MEF_i = Methane emission factor (about 0.5)

CR_i = Methane carbon conversion rate (16/12)

The method gives a fair prediction of the potential of gas generation in a landfill.

Test Well Method:

- This is the most reliable method for estimating the gas production from an existing landfill.
- It involves construction of a gas well at the landfill site and monitoring of quantity and quality of gas received.
- The number of test wells required for this purpose depends upon the size of landfill as well as characteristics waste.

Rough Approximation Method:

- This method is used to assess the quantity of gas generated based on the volume of waste disposed off in a landfill.
- It is assumed that about $6m^3$ of gas is generated every year from each ton of wastes.
- Estimation from this method may vary by as much as 50%.

Pb. Estimate the theoretical volume of methane and carbon dioxide gasses that would be expected from the anaerobic digestion of a ton of waste having the composition $C_{50}H_{100}O_{40}N$.

Solution:

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

a = 50, b = 100, c = 40, d = 1

$$C_{50}H_{100}O_{40}N + 5.75\ H_2O \rightarrow 27.125\ CH_4 + 22.875\ CO_2 + NH_3$$

(1354) (103.5) (434) (1006.5) (17)

The weight of CH_4 gas produced per ton of the waste
= (434/1354) x 1000 kg/ton = 320.5 kg/ton
The weight of CO_2 gas produced per ton of the waste
= (1006.5/1354) x 1000 kg/ton = 743.4 kg/ton

Density of CH_4 gas at STP = 0.7167 kg/m^3
Density of CO_2 gas at STP = 1.9783 kg/m^3
Volume of methane gas = = 447.2 m^3/ton
Volume of carbon dioxide gas = = 375.8 m^3/ton

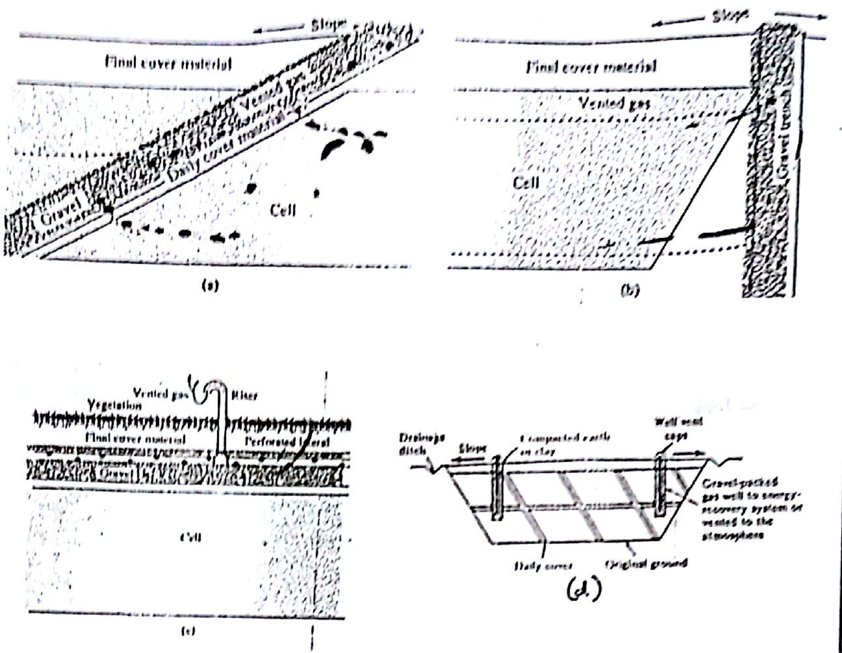
Comments: In practice, a portion of the waste would be used for the synthesis of cell tissue. Hence, the actual volume of gas would be about 0.85 times the value determined.

Control of Gas Movement:

The gases generated from a landfill should be either vented to the atmosphere or in larger landfills, collected for the production of energy.

Gas venting:
The methods of gas venting are:
(1) Cell vent
(2) trench vent
(3) perforated-pipe vent, and
(4) well vent, as shown in the next slide.

- **The cell vent, composed of gravel, is put directly above the daily cover.**
- **In a trench vent, a trench is dug as deep as the solid wastes and filled with gravel.**
- **In the perforated pipe vent, perforated pipes are used to collect and convey the gases to riser pipes for gas venting.**
- **The well vent composed of gravel packed gas well is installed in deeper landfill to collect and vent the gases to the atmosphere.**



Gas Recovery:

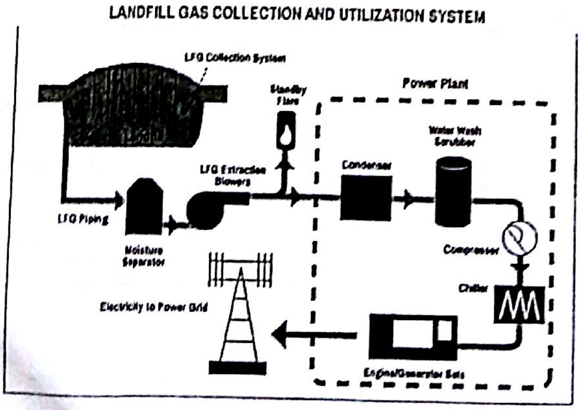
The objections of gas recovery is

- to prevent migration and accumulation of landfill gases
- to use it as an energy source
- to reduce the emission of green house gases

The methane gas has a high calorific value and can be utilized for recovery of energy.

A typical gas recovery system is shown in the following figure

LANDFILL GAS COLLECTION AND UTILIZATION SYSTEM



- Active extraction systems link collection wells with piping and extract the gas under vacuum created by a central blower. Landfill gas if not available is sufficient quantity or found of poor quality is not feasible for energy recovery. In such cases, gas should be burnt off by standby flare.
- Gas collected from landfill contains various impurities especially water vapor and hydrogen sulfide, which are removed for efficient energy recovery. The purified gas is used to generate electricity using a generator and the electricity is supplied to the power grid or locally used.

Resource Recovery from Solid Waste:

The processes of resource recovery may be classified into two groups:

- Recovery by materials separation
- Recovery by materials conversion

Recovery by materials separation is the sorting of the groups of materials contained in the waste stream without changing their physical and chemical properties. It can be done either through separation at the source or through mixes waste separation at some control locations.

Recovery by materials conversion is the recovery of products for transformation and their use as raw materials or sources of energy as well as harnessing of the energy released during transformation.

Options for utilization of recovered resources are:

- re-use of useable items in house hold wastes e.g. glass bottles, plastic bottles, metal containers, etc.;
- direct application of wastes on land;
- recycling through materials recovery processes;
- energy recovery through thermal combustion, incineration etc.;
- composting or other chemical or biological processes.

Recycling Process in Bangladesh:

In Bangladesh, wastes having some market value are being reclaimed or salvaged in three stages.

- In the first stage, housewives/maids separate refuse of higher market value such as papers, bottles, fresh containers old clothes, shoes etc. and sell them to street hawkers.
- Mostly children of slum dwellers known as "Tokai" carry out the second stage of salvaging. They collect different items of low market value from waste collection bins. The items include broken glass, cans, cardboard, waste papers, rags, plastics, metals and miscellaneous commercial wastes discarded by households.
- Scavengers at the final disposal sites do the third stage of salvaging when municipal trucks unload fresh refuse.

The reclaimed materials reach the old materials shops through the street hawkers and waste collectors. The salvaged materials require intermediate processing like washing, drying and sorting.

The refuse dealers separate the material and sell them to shops for direct use or supply them to appropriate processing factories for reuse as raw materials.