Chapter Six

Disposal of Solid Wastes and Residual Matter

1.6 Ultimate Disposal

There are only two alternatives available for the long-term handling of solid wastes and residual matter: disposal on or in the earth's mantle, and disposal at the bottom of the ocean. Disposal on land is by far the most common method in use today.

Ocean dumping of municipal solid wastes was commonly used at the turn of the century and continued until 1933 when it was prohibited.

2.6 Sanitary landfill

Means an operation in which, the wastes to be disposed of are compacted and covered with a layer of soil at the end of each day's operation see Figure 1. When the disposal site has reached its ultimate capacity a final layer of 2 ft (0.60 m) or more of cover material is applied.

Another definition: a land area where municipal solid waste is buried in a manner engineered to minimize environmental degradation. Commonly the waste is compacted and ultimately covered with soil or other earthy material.

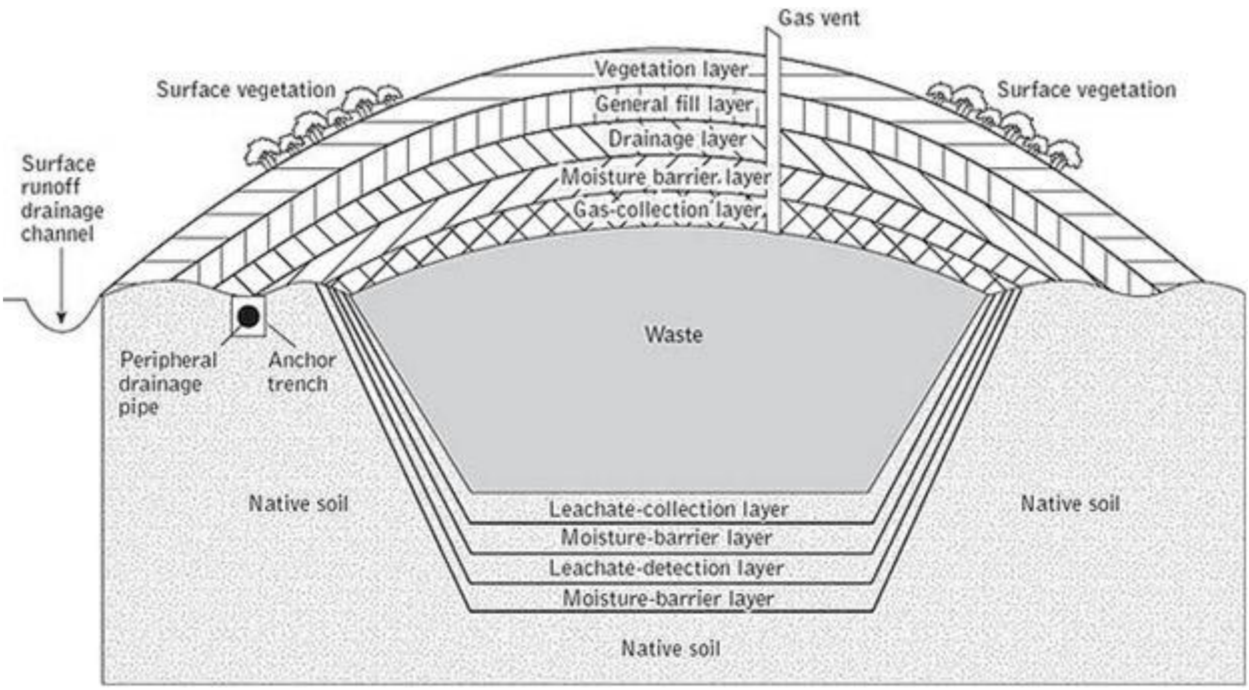


Figure. 1 Solid waste disposal

3.6 Advantages and disadvantages of sanitary landfill

Advantages:

1. Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal.
2. The initial investment is low compared with other disposal methods.
3. A sanitary landfill is a complete or final disposal method as compared to incineration and composting which require additional treatment or disposal operations for residue, quenching water, unusable materials, etc.
4. A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate processes.
5. A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment.
6. Sub marginal land may be reclaimed for use as parking lots, playgrounds, golf courses, airports, etc.

4.6 Disadvantages

1. In highly populated areas, suitable land may not be available within economical hauling distance.
2. Proper sanitary landfill standards must be adhered on daily basis or the operation may result in an open dump.
3. Sanitary landfills located in residential areas can provoke extreme public opposition
4. A completed landfill will settle and require periodic maintenance
5. Special design and construction must be utilized for buildings constructed on completed landfill because of the settlement factor
6. Methane, an explosive gas. and the other gases produced from the decomposition of the wastes may become a hazard or nuisance and interfere with the use of the completed landfill

5.6 Important Aspects in the Implementation of Sanitary Landfills

1. Site selection.
2. Landfilling methods and operations.
3. Occurrence of gases and leachate in landfills.
4. Movement and control of landfill gases and leachate.

1.5.6 Site Selection

Factors that must be considered in evaluating potential landfill sites are: (1) available land area, (2) impact of processing and resource recovery, (3) haul distance, (4) soil conditions and topography, (5) climatological conditions, (6) surface-water hydrology, (7) geologic and hydrogeologic conditions, (8) local environmental conditions, and (9) potential ultimate uses for the completed site.

تعليمات المحددات البيئية لانشاء المشاريع ومراقبة سلامة تنفيذها رقم (3) لسنة (2011)

المواقع المقترحة لطمر النفايات الصلبة البلدية حسب المادة (24) صنف (ب)

المادة-٢٤- مواقع الطمر الصحي لنفايات البلدية :المواقع المخصصة للتخلص من النفايات الصلبة غير الخطرة والمتخلفة من جميع الاستعمالات ، ويلزم لانشائها اتباع ما يأتي :

اولا- اقامتها خارج حدود البلدية بمسافة لاتقل عن (٢) كيلومترين و (١) كيلومتر واحد عن التجمعات السكانية وبمسافة لا تقل عن (١) كيلومتر واحد عن محرمات الطريق العام وبموقع مناسب.

ثانيا- العمل وفق الاسس العلمية المتبعة بعمليات الطمر الصحي للنفايات .

ثالثا- تسييج المواقع قبل المباشرة بالاستغلال مع ضرورة تشجير جوانب الموقع قدر المستطاع .

رابعا – انشاء الطرق داخل وخارج الموقع لتسهيل حركة الاليات.

خامسا-توفير المعدات و الاليات اللازمة في عملية الطمر بالطريقة الصحيحة .

سادسا- ترك الموقع بعد ملئه بالنفايات واستخدامه بعد تسوية سطح التربة كمناطق خضراء.

سابعا – معالجة انخفاض سطح التربة بعد مرور فترة مناسبة .

ثامنا – تجهيز الموقع بانابيب لتصريف الراشح المتكون من تحلل النفايات مع تبطين الموقع بمادة غير نفاذة لهذا الراشح .

تاسعا – تجهيز الموقع بانابيب تنفيس الى الجو للغاز الناتج عن التحلل العضوي للنفايات .

(1) Available land area:-

Example 1: Estimate the required landfill area for a community with a population of 31000. Assume that the following conditions apply

1. Solid waste generation is 6.4 1b/ capita/d
2. Compacted density of solid waste in the landfill 8001b/yd^3
3. Average depth of compacted solid waste 10ft

Note: The actual site requirements will be greater than the value computed, because additional land is required for site preparation, access roads, utilities, etc. Typically, this allowance varies from 20 to 40 percent.

(2) Impact of processing and resource recovery,

In the initial assessment of potential disposal sites, it is important to project the extent of resource recovery processing activities that are likely to occur in the future and determine their impact on the quantity and condition of the residual materials to be disposed of. For example if 50 percent of the paper were to be recycled, then the landfill area requirement will be reduced. It is also important to know whether the recovery facilities are to be located at the disposal site.

(3) Haul distance,

Although minimum haul, distances are desirable. Other factors should be considered in site selection. These include collection route location, local traffic patterns, and characteristics of the routes' to and from the disposal site (condition of the routes traffic patterns, and access conditions).

(4) Soil conditions and topography,

Because it is necessary to provide cover material for each day's landfill and a film layer of cover after the filling is completed, data must be obtained on the amount and characteristics of soils in the area of landfilling

(5) Climatological conditions,

Where freezing is severe, landfill cover material must be available in stockpiles, because excavation is impractical. Wind and wind patterns must be considered carefully in landfilling site selection. To avoid blowing or flying paper, windbreaks must be established. The specific form of windbreak depends on local conditions. Ideally, prevailing winds should blow toward the filling operation.

(6) surface-water hydrology,

The local surface-water hydrology of the area is important in establishing the existing natural drainage and runoff characteristics. Other conditions of flooding must also be identified.

(7) Geologic and hydrogeologic conditions

Data on these factors are required to assess the pollution potential of the proposed site and to establish what must be done to the site to ensure that the movement of leachate or gases from the landfill will not impair the quality of local ground water or contaminate other subsurface or bedrock aquifers (see Fig.2).

8) Local environment conditions,

While it was possible to build and operate landfill sites in close proximately to both residential and industrial developments extreme care must be taken in their operation if they are to be environmentally acceptable with respect to noise, odor, dust, and vector control. Flying papers and plastic films must also be controlled.

(9) Potential ultimate uses for the completed site,

One of the advantages of a landfill is that, once it is completed, a sizable area of land becomes available for other purposes. Because the ultimate use affects the design and operation of the landfill, this issue must be resolved before the layout and design of the landfill are started. For example, if the completed landfill is to be used as a park or golf course, a staged planting program should be initiated and continued as portions of landfilling.

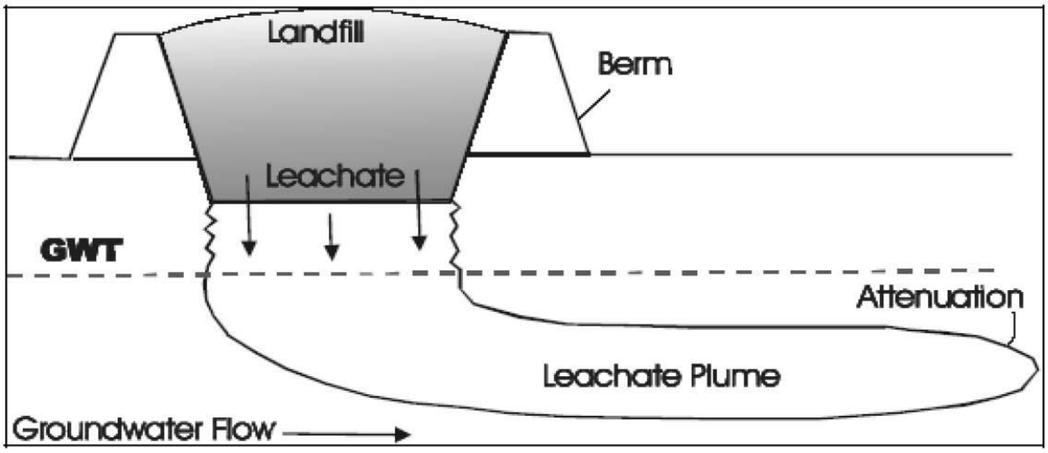


Figure (2) Schematic representation groundwater pollution by leachate.

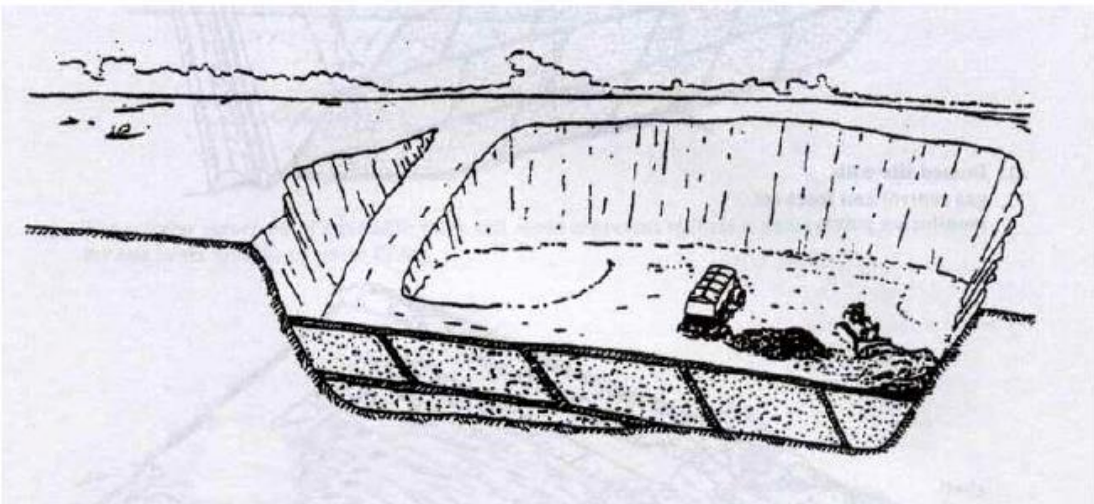
7.6 Construction methods for a sanitary landfill

The construction method and subsequent operation of a sanitary landfill are mainly determined by the topography of the terrain, although they also depend on the type of soil and the depth of the water table. There are three basic ways of making a sanitary landfill.

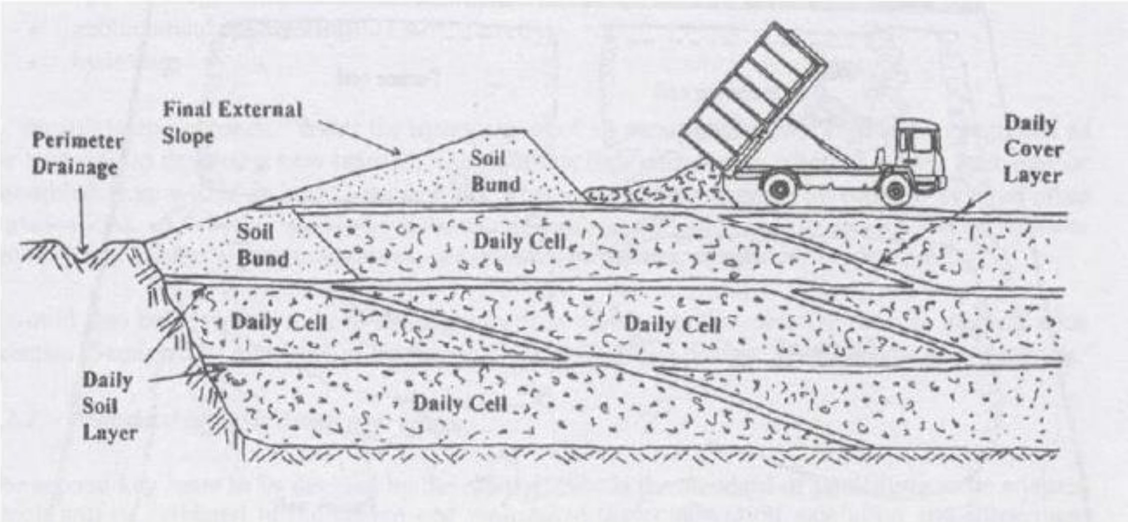
1. Area
2. Trench
3. Depression

The Area Method: The filling operation is usually started by building an earthen levee against which wastes are placed in thin layers and compacted. Each layer is compacted as the filling progress until the thickness of the compacted wastes reaches a height varying from 6 to 10 feet (1.83-3.05 m) at that time, at the end of each day operation a 6 to 12in (0.15-0.30 m) layer of cover material is placed over the completed fill. The cover material must be hauled in by truck or earth-moving equipment from adjacent land. A completed lift including the cover is called a cell. Successive lifts are placed on top of one another until the final grade in the ultimate plan is reached. A final layer of cover material is used when the fill reaches the final design height.

Area landfilling



Daily cover



The cell is the building unit of the landfill contains waste that has been compressed and covered, preferably not less than 75 meters in length, 25 meters in width and thickness of 3.2 meters, covered with a layer of soil not less than 25 cm in thickness, The size of the cell must take into consideration the quantity of waste and the number of waste trucks expected to reach the landfill daily to unload the load at one time. The height of the cell between 2-3 meters, but the conditions of some sites may impose a lower rise. The number of adjacent cells with a uniform height comprised one layer. The landfill can consist of several layers and may rise up to 15-20 m above the ground surface nearby.

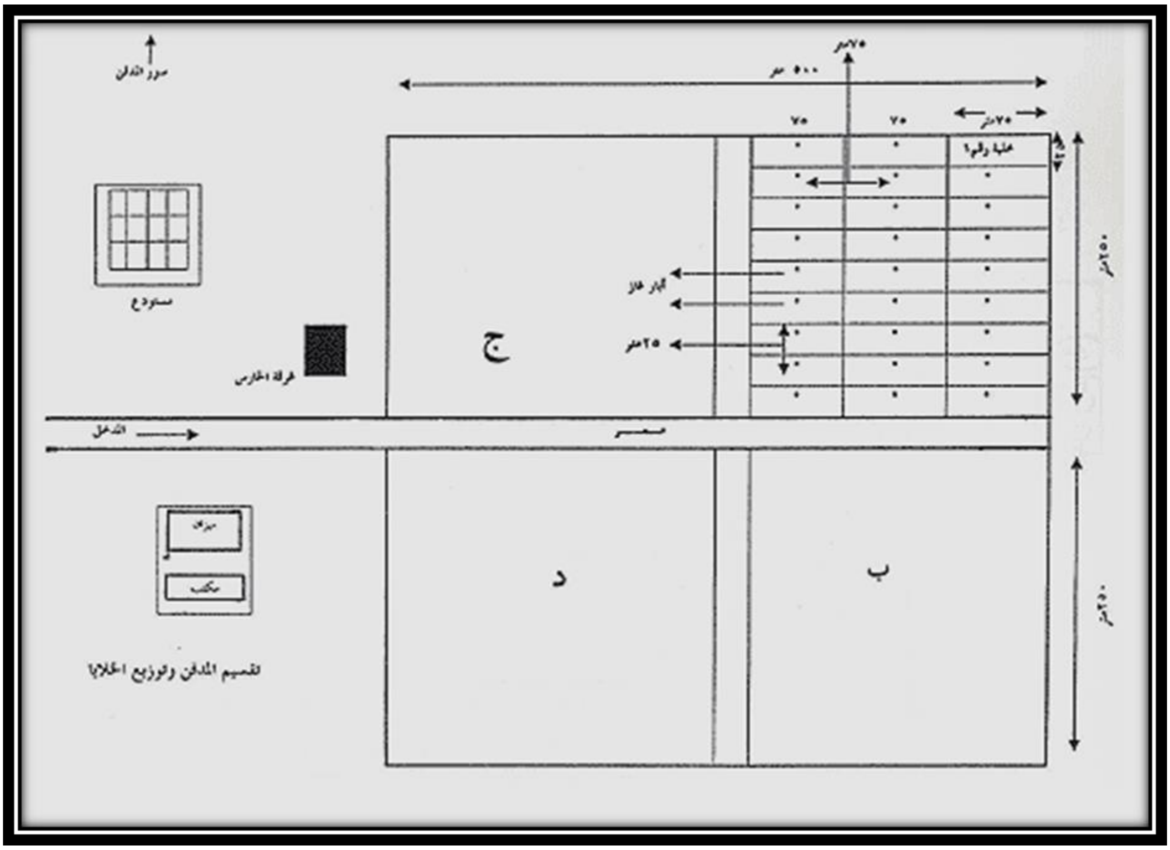


Fig. 3 Suggested design for some landfill

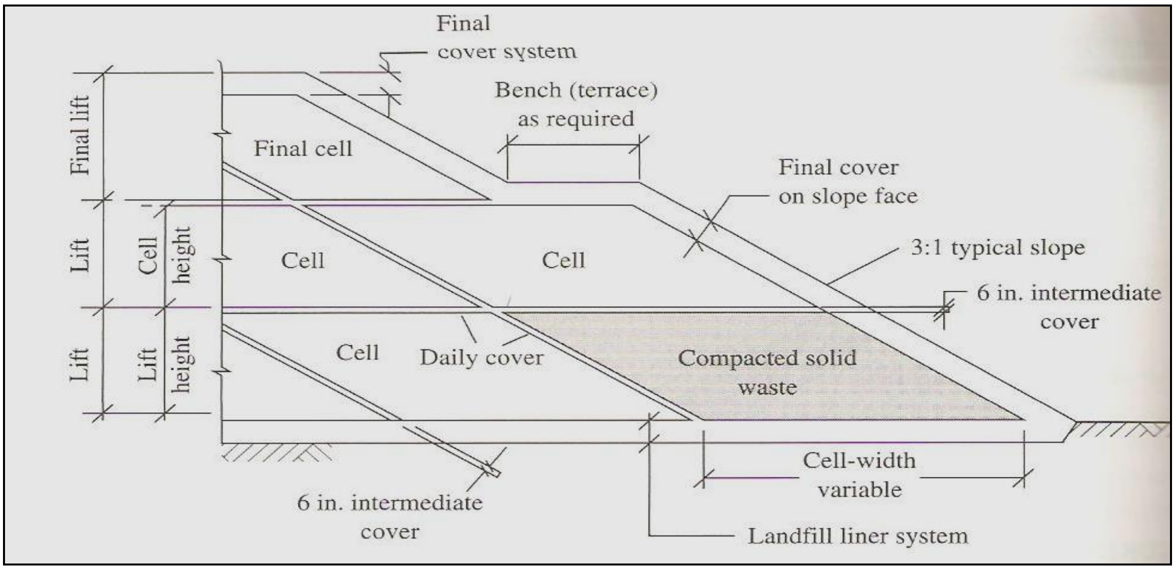


Fig. 4 Sectional view through a sanitary landfill

The Trench Method: is ideally suited to areas where water table is well below the surface. A portion of the trench is dug with a bulldozer and the dirt is stock piled to form an embankment behind the first trench. The width of trench ranging from (25-40) m and the length ranging from (80-150) m. Wastes are then placed at the trench spread into thin layers and compacted. The operation continues until the desired level is reached. Cover material is obtained by excavating an adjacent trench.

The Depression Method: Where artificial depression occurs, it is often possible to use them effectively for landfilling operations. The techniques to place and compact solid wastes in depression landfills vary with the characteristics of the site. The availability of adequate material to cover the individual lifts and to provide a final cover over the entire landfill is very important. Some pits and abandoned quarries may not contain sufficient soil for intermediate cover, so that it may have to be imported.

8.6 Reactions occurrence of gases and Leachate in Landfills

The following biological, physical and chemical events occur when solid wastes are placed in a sanitary landfill:

1. Biological decay of organic materials either aerobically or anaerobically, with evolution of gases and liquids
2. Chemical oxidation of waste materials
3. Escape of gases from the fill
4. Movement of liquids caused by differential heads
5. Dissolving and leaching of organic and inorganic by water and Leachate moving through the fill
6. Movement of dissolved material by concentration gradients and osmosis
7. Uneven settlement caused by consolidation of material into voids.

9.6 Decomposition in Landfills

The organic biodegradable components in solid wastes begin to undergo bacterial decomposition as soon as they are placed in a landfill. Initially, bacterial decomposition occurs under aerobic conditions because a certain amount of air is trapped within the landfill. However, the oxygen in the trapped air is soon exhausted, and the long-term decomposition occurs under anaerobic conditions. The principal source of both the aerobic and anaerobic organisms responsible for the decomposition is the soil material that is used as a daily and final cover.

10.6 Gases in Landfills

Gases found in landfills include air, ammonia, carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide methane nitrogen and oxygen. Carbon dioxide and methane are the principal gases produced from the anaerobic decomposition of the organic solid-waste components.

Table 1. Typical landfill gas composition

Constituent		Typical concentrations (percentage v/v)	Trace components
Methane	CH_4	50 – 60	Hydrogen sulphide, non-methane volatile organic carbons (NMVOCs) and halo-carbons
Carbon Dioxide	CO_2	30 – 50	
Nitrogen (from air)	N_2	0 – 15	
Oxygen (from air)	O_2	0 – 2	
Hydrogen	H_2	0 – 2	
Trace components		0 – 1	
Water vapour	H_2O	Saturated	

11.6 Leachate in Landfills

Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it. The liquid portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquid that has entered the landfill from external sources, such as rain and ground water. The high initial percentage of carbon dioxide is the result of aerobic decomposition. Aerobic decomposition continues to occur until the oxygen in the air initially present in the compacted wastes is depleted. Thereafter, decomposition will proceed anaerobically. After about 18 months, the composition of the gas remains reasonably constant.

12.6 Settlement of Landfills

The settlement of landfills depends on the initial compaction, characterization of the wastes, degree of decomposition, and effects of consolidation when the leachate and gases are formed in the landfill. The height of the completed fill will also influence the initial compaction and degree of consolidation. It has been found in various studies that about 90% of ultimate settlement occurs within the first 5 yr. The placement of concentrated loads on completed landfills is not recommended.

13.6 Gas Movement

Under ideal condition, the gas generated from a landfill should be either vented to the atmosphere or in larger landfills collected for the production of energy. Over 90% of the gas volume produced from the decomposition of solid wastes consists of methane and carbon dioxide. When methane concentration present in the air between 5-15%, it is explosive. However, there is no oxygen in the landfill when methane concentration in it reach this critical concentration and so there is no danger of explosion

If vented into the atmosphere in an uncontrolled manner methane can accumulate (because its specific gravity is less than that of the air) below buildings or in other enclosed spaces on, or close to a sanitary landfill. With proper venting methane should not pose a problem.

Because CO_2 is about 1.5 times as dense as air and 2.8 times as dense as methane, it tends to move toward the bottom of the landfill. As a result the concentration of CO_2 at the bottom of the landfill may be high for years.

Ultimately, because of its density carbon dioxide will also move downwards through the under laying formation until it reaches the ground water. Because carbon dioxide is readily soluble in water, it usually lowers the pH which in turn can increase the hardness and mineral content of the ground water through the solubilization of calcium and magnesium carbonates.

$CO_2 + H_2O$ ------- H_2CO_3

$H_2CO_3 + CaCO_3$-------$Ca^{+2} + 2H_2CO_3$

14.6 Control of Gas Movement

The movement of gases in landfills can be controlled by construction of vents and barriers and by gas recovery system as will discussed later.

15.6 Leachate Movement

Under normal conditions, leachate is found in the bottom of the landfill and will percolate the underlying strata. Many of chemical and biological constituents originally contained in it will be removed by the filtration and adsorptive action of the material composing the strata.

The use of clay has been the favored method in reducing or eliminating the percolation of leachate. Membrane liners has also been used but they are expensive and require care so that they will not be damaged during the filling operations. The use of appropriate surface slop (1 to 2 percent) and adequate drainage surface infiltration can be used effectively. Table 2. Shows the composition of landfill leachate.

Table 2. Composition of landfill leachate

Constituent	Value ($mg \cdot L^{-1}$) New Landfill (< 2 years) Range	Typical	Mature Landfill (>10 years)
BOD_5 (5-day biochemical oxygen demand)	2000–30,000	10,000	100–200
TOC (total organic carbon)	1500–20,000	6000	80–160
COD (chemical oxygen demand)	3000–60,000	18,000	100–500
Total suspended solids	200–2000	500	100–400
Organic nitrogen	10–800	200	80–120
Ammonia nitrogen	10–800	200	20–40
Nitrate	5–40	25	5–10
Total phosphorus	5–100	30	5–10
Ortho phosphorus	4–80	20	4–8
Alkalinity as $CaCO_3$	1000–10,000	3000	200–1000
pH (no units)	4.5–7.5	6	6.6–7.5
Total hardness as $CaCO_3$	300–10,000	3500	200–500
Calcium	200–3000	1000	100–400
Magnesium	50–1500	250	50–200
Potassium	200–1000	300	50–400
Sodium	200–2500	500	100–200
Chloride	200–3000	500	100–400
Sulfate	50–1000	300	20–50
Total iron	50–1200	60	20–200

16.6 Landfill Liner and Cover Systems

Geosynthetics

In general, geosynthetics are fabric like material made from polymers such as polyester, polyethylene, polypropylene, polyvinyl chloride (PVC), nylon, chlorinated polyethylene, and others. The term geosynthetics includes the following:

1. Geotextiles
2. Geomembranes
3. Geonets
4. Geocomposites

Each type of geosynthetic performs one or more of the following five major functions:

1. Separation
2. Reinforcement
3. Filtration
4. Drainage
5. Moisture barrier

Geotextiles

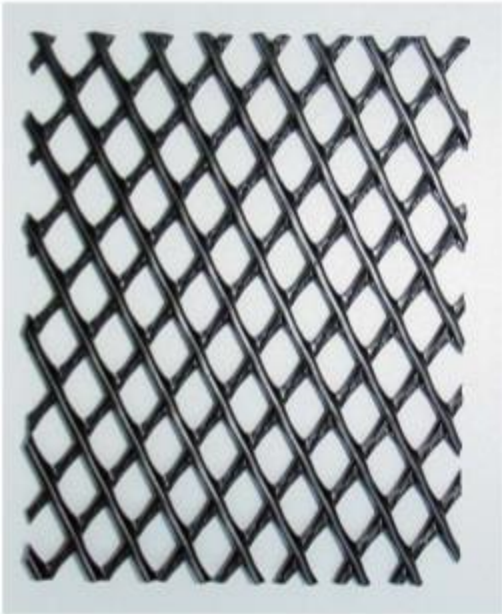
Are fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. Typically made from polypropylene or polyester.

Geomembranes

Geomembranes are impermeable liquid or vapor barriers made primarily from continuous polymeric sheets that are flexible. The type of polymeric material used for gconrembrernes may be thermoplastic or thermoset. The thermoplastic polymers include PVC, polyethylene, chlorinated polyethylene, and polyamide. The thermoset polymers include ethylene vinyl acetate, polychloroprene, and isoprene-isobutylene. Sheets 23 -35' wide, 60 -80 mm thick.

Geonets

Geonets are formed by the continuous extrusion of polymeric ribs at acute angles to each other. They have large openings in a netlike configuration. The primary function of geonets is drainage. Substitute for sand or gravel.



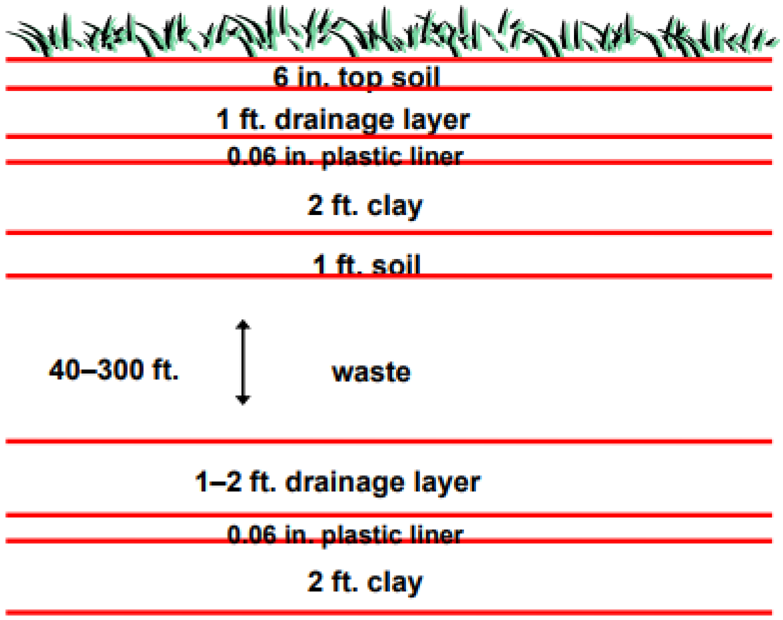
Geocomposites

A combination of any of the above

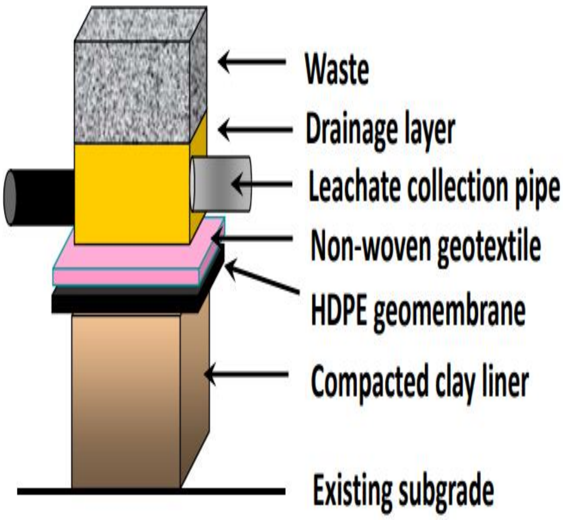
Lining layers:

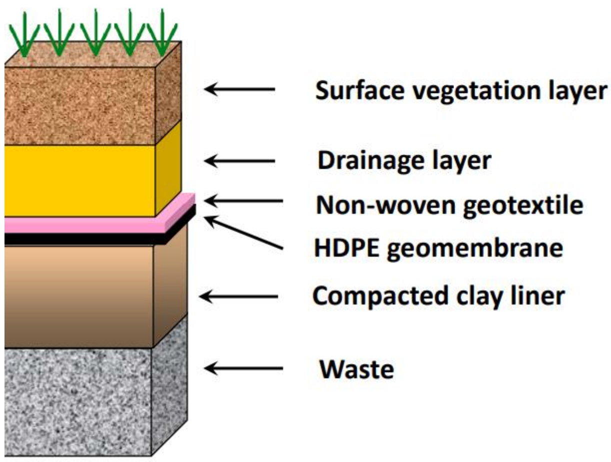
The lining system for S.L.F is composed of the following layers as shown in Figs. below:

Landfill Design



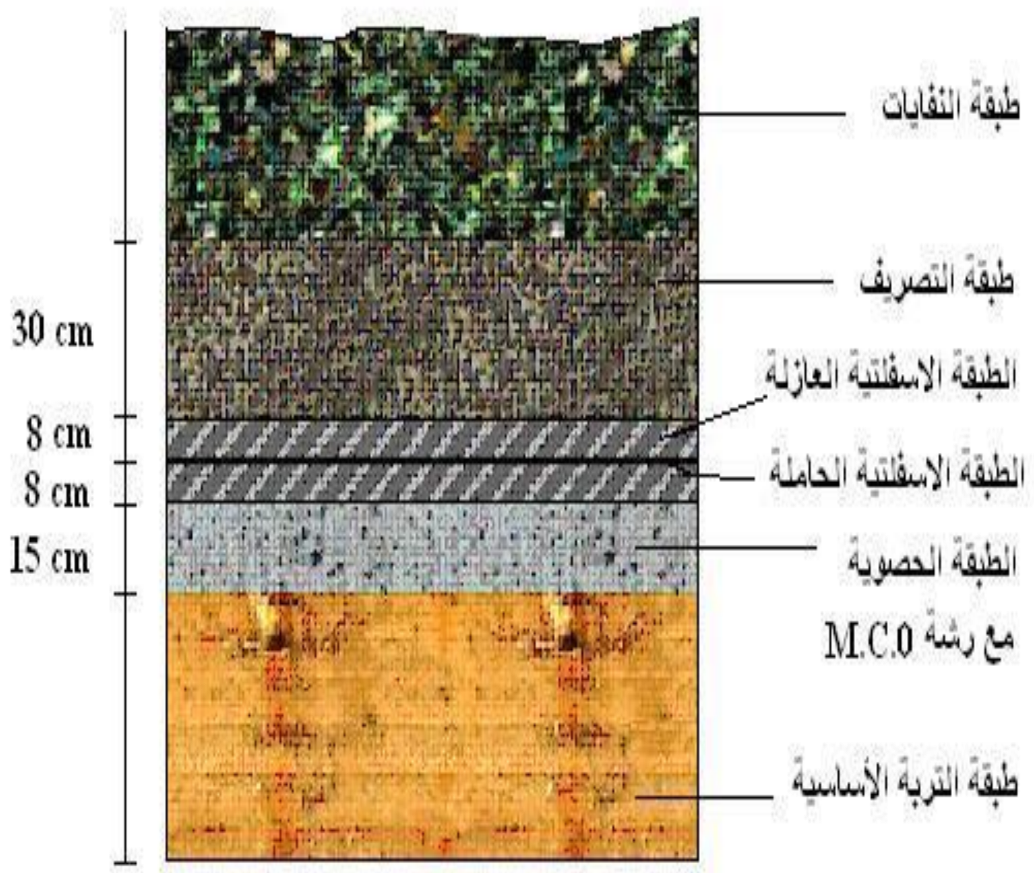

Sanitary Landfill
Waste dump in thin layers compacted
285 gsm geo-textile
300 mm thick drainage media with 160/200 OD HDPE pipes
285 gsm geo-textile
1.5 mm thick HDPE liner
Compacted clay liner 900 mm thick with permeability 1 x 10-7 cm/sec
Compacted earth
Bottom Liner
Gas vent to atmosphere
450 mm soil with grass beeding
150 mm drainage media
500 mm thick clay layer
100 mm thick soil cover
Waste dump in thin layers compacted
Top Cover


Waste
Drainage layer
Leachate collection pipe
Non-woven geotextile
HDPE geomembrane
Compacted clay liner
Existing subgrade


Surface vegetation layer
Drainage layer
Non-woven geotextile
HDPE geomembrane
Compacted clay liner
Waste

The ground insulation and drainage system for sanitary landfills isolated by asphalt is composed of the following layers from top to bottom:

- Protection layer and filter thickness of 30 cm
- A layer of asphalt with a thickness of 8 cm, the size of the voids is less than 3% and the layer of asphalt with a thickness of 8 cm.
- A layer of pure, broken gravel material (0-5 cm) with a thickness of 15 cm with a layer of asphalt (MC_0) of 2.5 kg per square meter to be distributed regularly on the gravel layer.
- Compacted Soil Layer



16.7 Wastewater (leachate) collection system

- A layer of gravel discharge
- Drainage pipes for the collection and transport of wastewater
- Basic drainage pipes for the collection and discharge of wastewater to the collection pit.
- Vaporizing and microbiological treatment plants within a biological treatment plant.
- Pump and drip network to recycle the excess wastewater within the landfill.

The recirculation of the wastewater to the landfill is carried out by pumping the discharged water from the collecting basin to the upper surface of the waste under the insulation layers during periods of non-rainfall and relative drought for waste, where the leakage of leachate is used on the surface of the landfill. The aim of this process is to increase the activity of the bacteria within the landfill and thus to analyze the materials and convert them into compost materials.

The water collection and discharge system consists of 30 cm of gravel (16/32 mm) and pipes of high impedance polyethylene with a diameter of 25 mm. The pipes are placed at distances of 30 meters each. The required slope of the discharge layer is 2% and the pipe is 1.5%.

Design of water drainage system

- The ground surface shall be fitted with longitudinal and transverse slops in order to ensure water flow.

The discharge pipes must meet the following conditions:

- Be straight
- Distance between two pipes not more than 30 m
- The maximum dimension of the end of the landfill 15 m
- The length of the pipe shall not exceed 400 m
- The diameter of the pipe shall not be less than 250 mm
- Longitudinal slopes are greater than 1.5 %

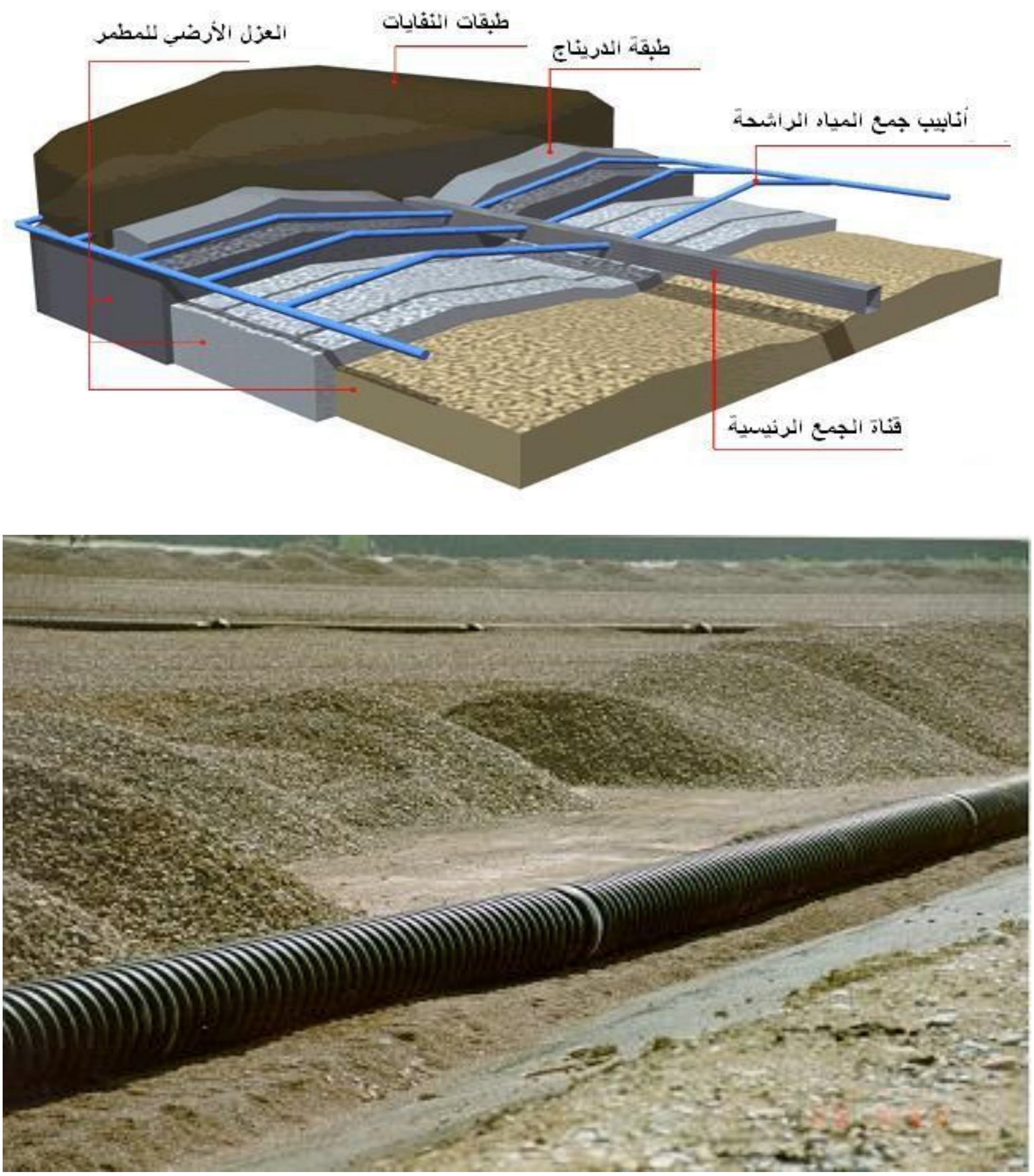


Fig. 5 Leachate (wastewater) collection system

Fig.6 Reusing of Collection water

Fig. 7 Wastewater collection Pipes net works

16.8 Gases collection system

Biodegradation in sanitary landfills produces explosive and combustible gases that easily escalate with foul odors. In addition, these gases contribute to global warming and thus damage the climate. Gases emitted from sanitary landfill sites may cause fires or may accumulate to reach explosive concentrations.

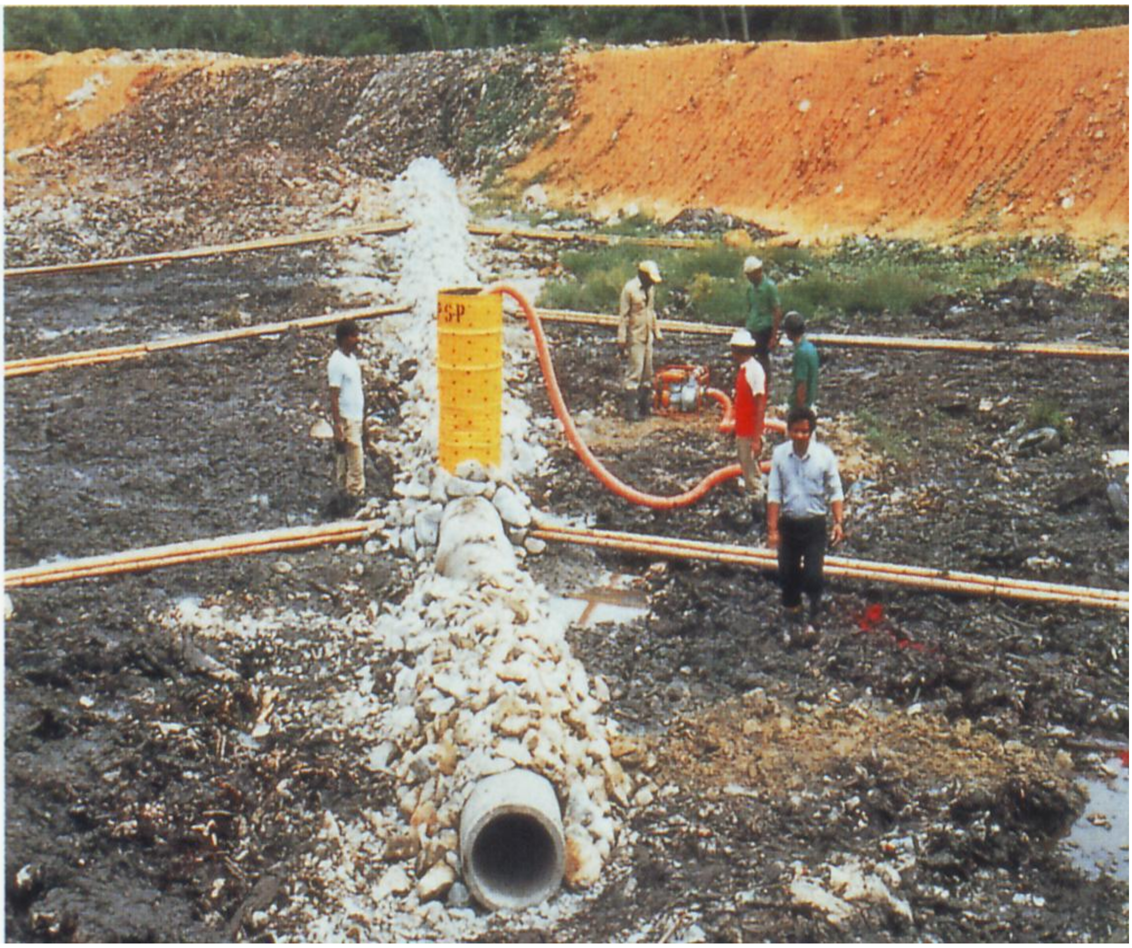
The emission of gases from small landfills can be allowed directly to the air. Landfills serving an area of 500,000 inhabitants or more, with a waste of more than 10 meters in the landfill, must be installed in the short and long term to collect, separate and burn the gases emitted from the SLF. Such design should also take into account the estimated quantities of gases emitted. In general, these gases can be used to generate energy in large landfills, yet the initial technical and economic cost is high. Therefore, a system should be installed to prevent fire during the period of the landfilling using gas wells and chimneys.

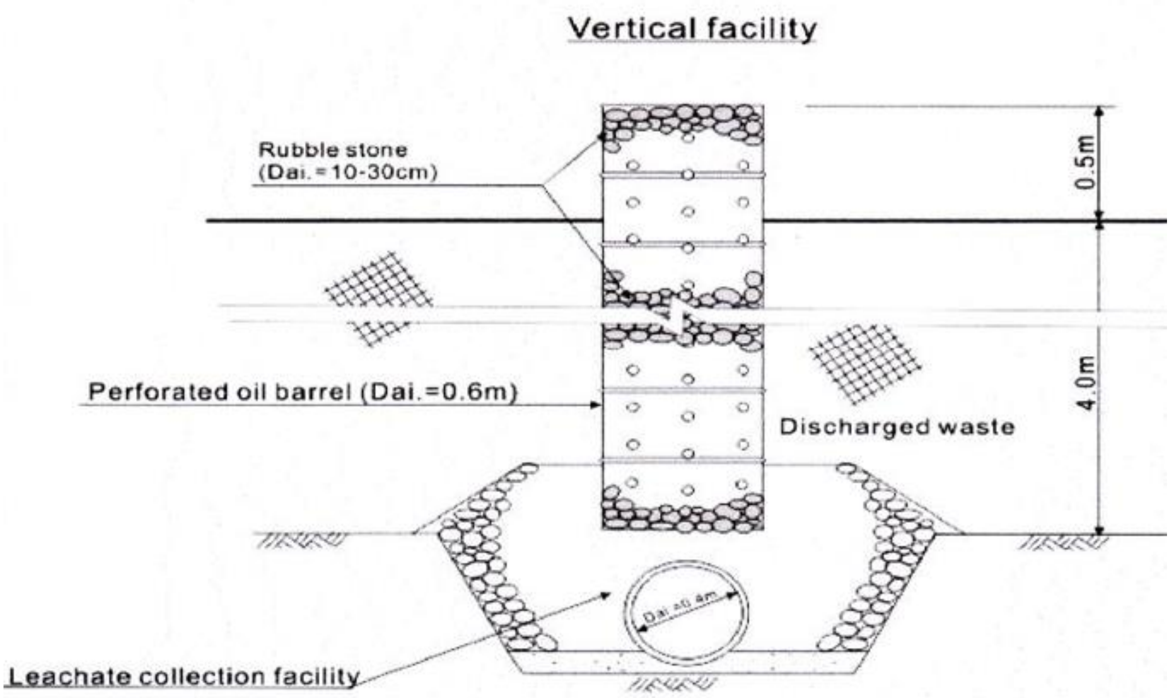
Construction of gas collection wells:

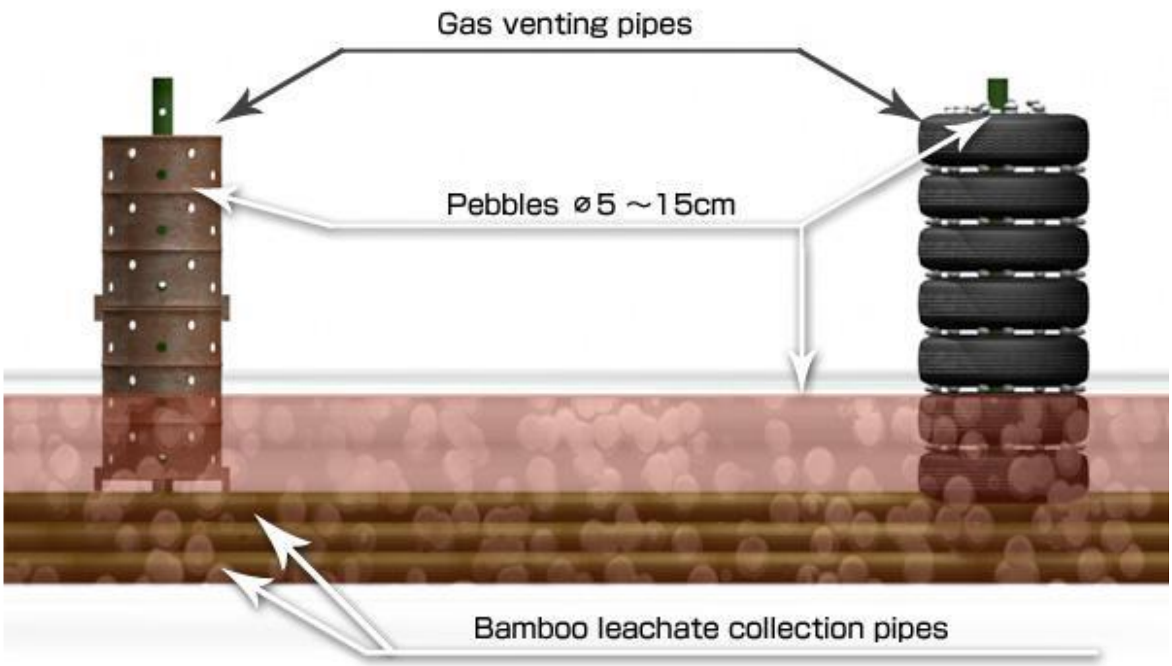
At the beginning of the design of the SLF, a plan is drawn for the gas wells so that the wells serve circles of diameter from 40 to 50 meters and distributes the wells in a cross-section so that the coverage circles intersect the wells to cover the wells all the area of the mold.

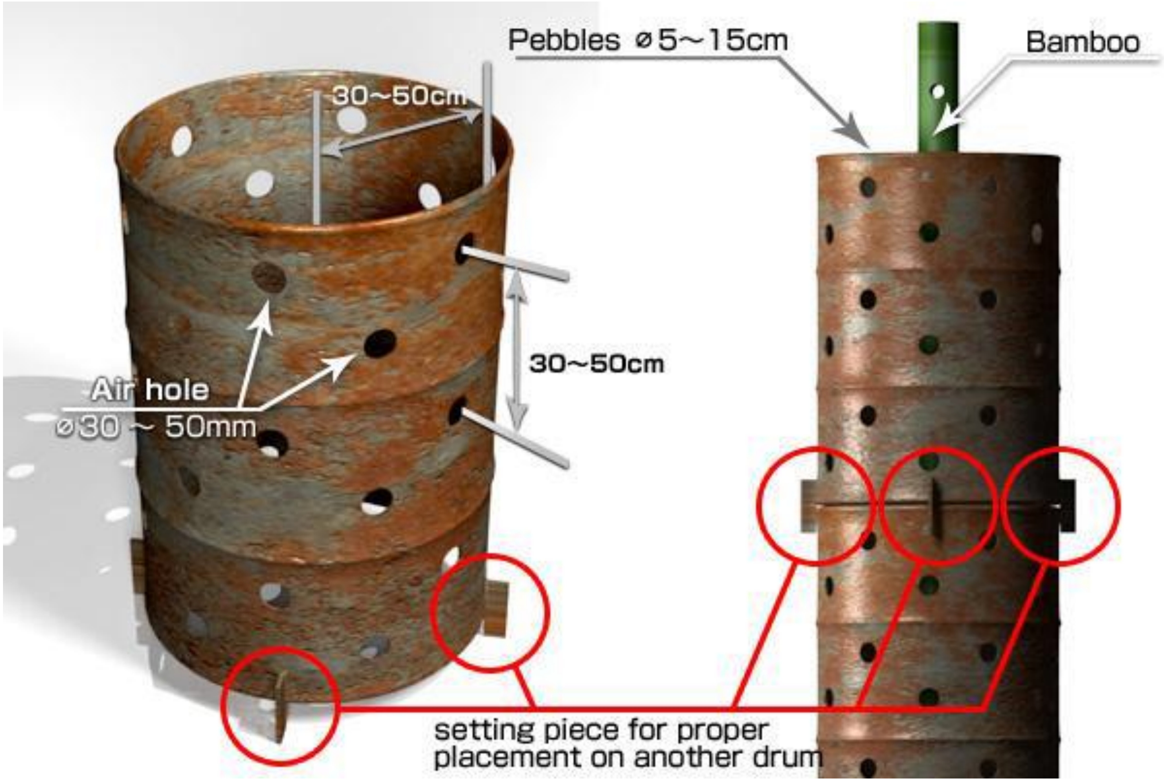
The gas wells start from the base of the SLF and continue with the successive layers until the final layer of the SLF and the wells are installed by placing plastic pipes of PVC for the drainage of the gas (3 - 4 inch) surrounded by a cylinder of gravel radius (0.5 m) and surrounded by a network to work on the cohesion of gravel with in order to ensure the passage of the gas, the well nozzle ends with a cement cover or a similar material to prevent the leakage of the cover soil into the well. Before starting the landfill, a cement layer is placed at the base of the pipe to hold it under the base of the cell.

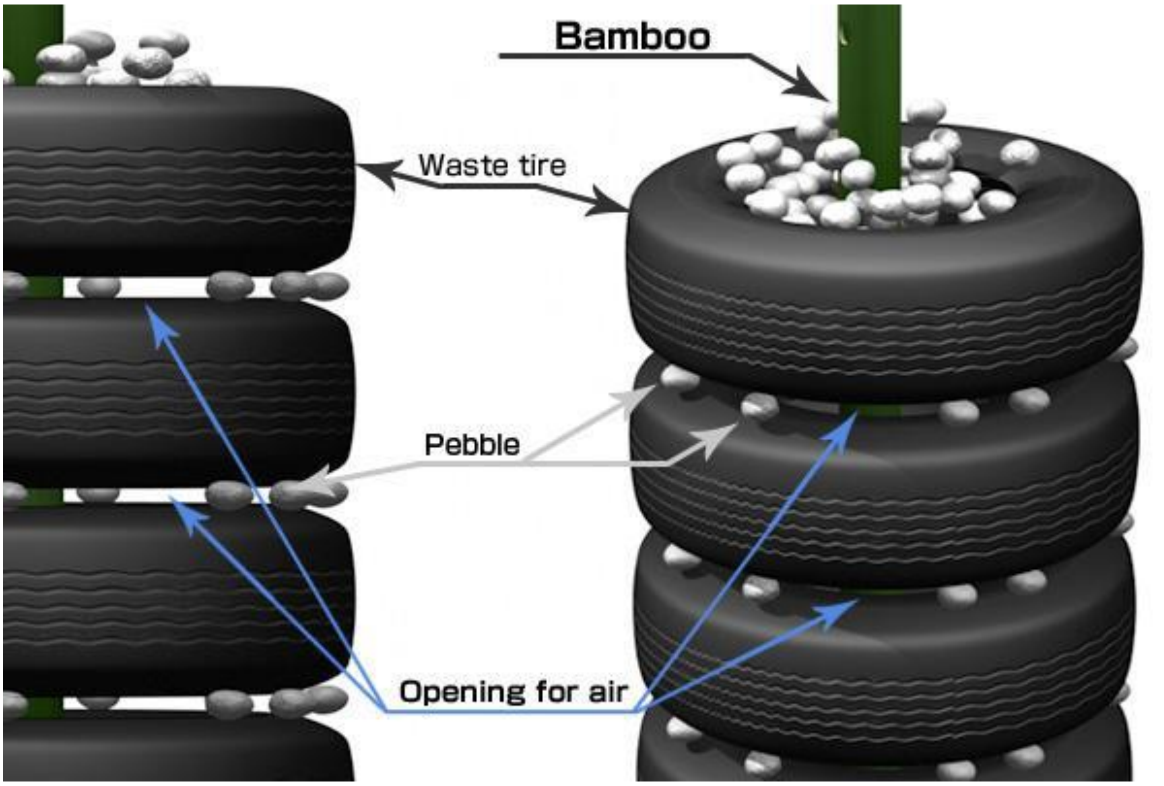
After completion of the gas wells, they are connected to a horizontal network of plastic or iron pipes lined with 3-inch pipelines and connected to a 6-inch main line with a gas-withdrawal pump attached to a gas burner. The pipe network is preferred with a layer of sand to protect against shocks and weather conditions.

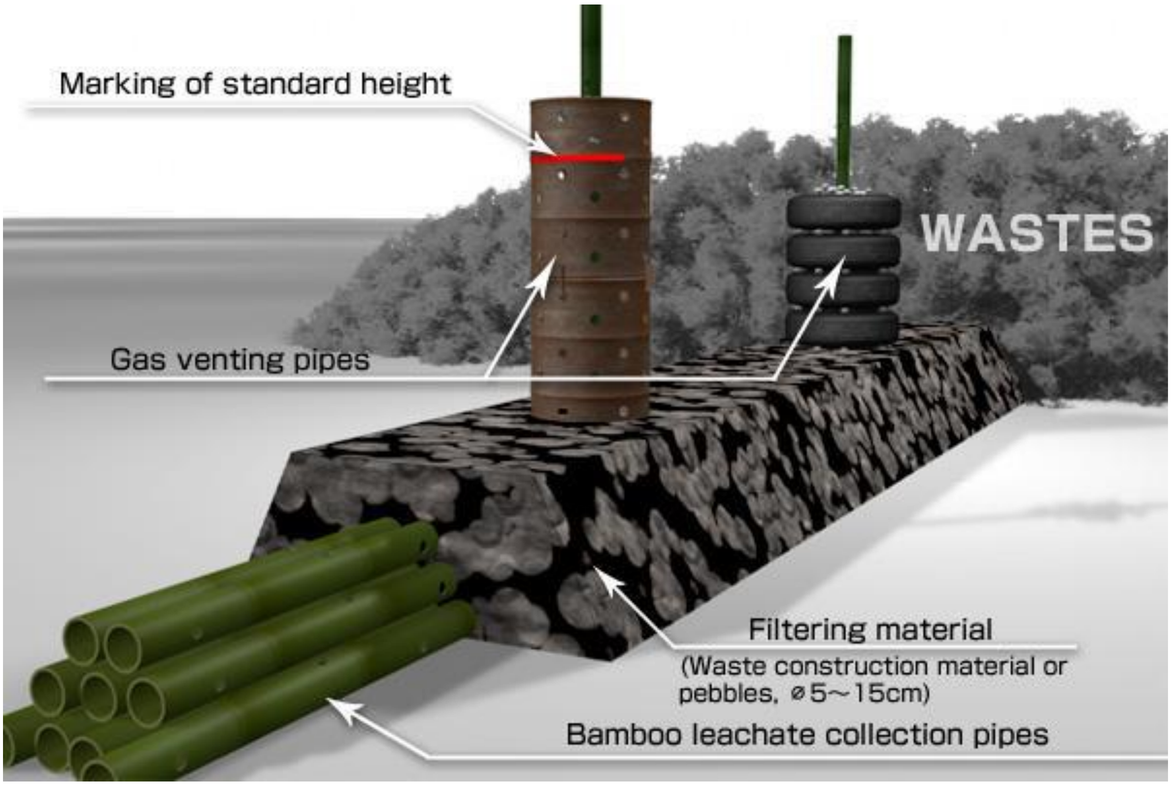



Vertical facility
Rubble stone
(Dai.=10-30cm)
0.5m
4.0m
Perforated oil barrel (Dai.=0.6m)
Discharged waste
Leachate collection facility


Gas venting pipes
Pebbles ⌀5～15cm
Bamboo leachate collection pipes


Pebbles ø5～15cm
Bamboo
30～50cm
30～50cm
Air hole
ø30 ～ 50mm
setting piece for proper
placement on another drum


Bamboo
Waste tire
Pebble
Opening for air


Marking of standard height
WASTES
Gas venting pipes
Filtering material
(Waste construction material or pebbles, ø5～15cm)
Bamboo leachate collection pipes

EXA. 1

Find the amount of land required in a sanitary landfill to dispose of urban waste of city of 40000 in population , knowing that

Amount of waste generation = 2.5 kg/capita/d

density of landfill waste = 500 kg/m^3

refuse is filled into a depth of about 3 m.

Sol

2.5 kg/capita/d X 365d X 40000 capita= 36500000 kg total amount of waste

36500000 kg/500 kg/m^3 = 73000m^3

73000m^3 /3m =24333.333 m^2 /2500 m^2 /donme =9.73 donme

EXA.2

Find the amount of land required in a sanitary landfill to dispose of urban waste knowing that:

City population = 176119

Amount of waste generation = 0.875 kg/capita/d

density of landfill waste = 560 kg/m^3

refuse is filled into a depth of about 8.5 m.

The landfill site is to be used for 13 years

25% should be added as area necessary for construction facilities

Sol

0.875 kg/capita/d X 176119 =154104 kg/d X 365 =56247960 kg /560 kg/m^3

= 100442.78 m^3

100442.78 m^3 X13 =1305756.1 m^3 / 8.5 m =153618.36 m^2 /10 000 = 15.3618 Hectares

15.3618 X 0.25 =3.840 Hectares +15.3618 = 19.202 Hectares

Ex 3

Determine the density in a well –compacted landfill for solid wastes with the characteristics given in the table below, Density = 1000lb / 28.6 ft^3.

Component	Weight percentages	Weight 1b	Density as discarded 1b/ft^3	Vol. ft^3	Compaction factor	Volume in landfill ft^3
Food waste	15	150	18.o	8.3	0.33	2.7
Paper	40	400	15.1	78.4	0.15	11.8
Cardboard	4	40	3.1	12.9	0.18	2.3
Plastics	3	30	4	7.5	0.10	0.8
Textile	2	20	4	5.0	0.15	0.8
Rubber	0.5	5	8	0.6	0.3	0.2
Leather	0.5	5	10	0.5	0.3	0.2
Garden trimming	12	120	6.5	18.5	0.2	3.7
Wood	2	20	15.0		0.3	0.4
Glass	8	80	12.1		0.4	2.6
Tin cans	6	60	5.5		0.15	1.6
Non ferrous materials	1	10	10		0.15	0.2
ferrous materials	2	20	20		0.3	0.3
Dirt, ashes,brick	4	40	30		0.75	1,0
Total	100	1000		153.4		28.6

Example 4.

A landfill with a gas collection system is in operation and serves a population of 200,000. MSW is generated at a rate of $1.95\ kg \cdot (capita)^{-1} day^{-1}$. Gas is produced at an annual rate of $6.2\ L \cdot kg^{-1}$ of MSW delivered to the landfill. The gas contains 55% methane. Gas recovery is 15% of that generated. The heat content of the landfill gas is approximately $17{,}000\ kJ \cdot m^{-3}$ (a value lower than the theoretical value because of dilution of the methane with air during recovery). The landfill company and a developer have proposed to build a subdivision in the vicinity of the landfill and pipe the methane generated to the homes to be used for heating. The homes are estimated to use an average of 110×10^6 kJ of heat energy each year. Peak usage during winter is 1.5 times the average usage. How many homes can be built in the subdivision?

Solution This is essentially a mass and energy-balance problem, in which solid waste is being disposed of in a landfill. Methane is generated during the decomposition of the waste. The methane is used by the homes for heating. The energy generated in the landfill must equal the energy consumed by the homeowners.

The amount of methane generated is equal to
(Amount of waste disposed in landfill per person on yearly basis)
× (Number of people served by landfill)
× (Rate of gas production per mass of solid waste)
× (Fraction of methane in gas)

But only 15% is recovered.

$(4.85 \times 10^8 \text{ L methane} \cdot \text{year}^{-1})(0.15) = 7.28 \times 10^7 \text{ L methane} \cdot \text{year}^{-1}$

The heat content of the methane recovered is

$(17{,}000 \text{ kJ} \cdot \text{m}^{-3})(7.28 \times 10^7 \text{ L} \cdot \text{year}^{-1})(10^{-3} \text{ m}^3 \cdot \text{L}^{-1}) = 1.24 \times 10^9 \text{ kJ} \cdot \text{year}^{-1}$

Energy to heat the homes during times of peak demand (i.e., winter) must be supplied:

$$\text{Peak demand} = \text{Averaged usage} \times 1.5$$
$$= (110 \times 10^6 \text{ kJ} \cdot \text{year}^1)(1.5) = 1.65 \times 10^8 \text{ kJ} \cdot \text{home}^{-1} \cdot \text{year}^{-1}$$

$$\text{Number of homes that can be heated} = \frac{\text{energy generated}}{\text{energy required per home}}$$
$$= \frac{1.24 \times 10^9 \text{ kJ} \cdot \text{year}^{-1}}{1.65 \times 10^8 \text{ kJ} \cdot \text{home}^{-1} \cdot \text{year}^{-1}} = 7.5 \text{ homes}$$

Because we can't heat a fraction of a home, then we can build seven homes.

Example 5. Calculation of CH_4

LFG model	Model formula	Symbol index
German EPER model	$Q = (M)\,(DOC)\,(DOC_f)\,(F)\,(D)$	**Q : Methane production (kt/yr)**
		M : Waste generation (Mt/yr)
		DOC : Degradable organic carbon (kg/tonne)
		DOC_f : Fraction assimilated DOC
		F : Fraction of methane in landfill gas
		D : Collection efficiency factor
TNO model	$Q = (DOC_f)(1.87)(M)(DOC)(k)e^{-(kt)}$	**Q : Methane production (kTone/yr)**
		DOC: Fraction of assimilated DOC
		M : Waste generation (Mt/yr)
		DOC : Degradable organic carbon (kg/Tone)
		k: Decay rate (yr^{-1})
		***t:* Time of waste disposal (yr)**

Scholl Canyon	**$Q = (M)(k)(Lo)\exp-(kt)$**	***Q*:= methane production (kt/yr)** ***M* : waste generation (Mt/yr)** ***k* : decay rate (yr^{-1})** **Lo : methane generation potential (kg/tonne)** ***t* : time of waste disposal (yr)**
LandGEM version 3.02	**$Q_{CH4}=\sum^{n}_{i=1}\sum^{1}_{j=0.1} kL_0 (M_i/10)e^{-kt_{ij}}$**	**Q_{CH4} : annual methane generation in the year of the calculation (m^3/year)** **i: 1 year time increment** **n: (year of the calculation)-(initial year of** **j: 0.1 year time increment** **k: methane generation rate($year^{-1}$)** **L_0: potential methane generation capacity(m^3/ton)** **M_i: mass of waste accepted in the i^{th} year (ton)** **t_{ij}: age of the j^{th} section of waste mass M_i accepted in the i^{th} year**

The organic fraction of each type of organic waste is considered as all having different decay rates.

$$DOC = (0.4 \times A) + (0.17 \times B) + (0.15 \times C) + (0.30 \times D)[\text{all units wet weight(w/w)of kg carbon/kg waste}]$$

where DOC is degradable organic carbon, A is fraction of municipal solid waste (MSW) that is paper and textiles waste, B is a fraction of MSW is the garden or park waste, C is a fraction of MSW is food waste, and D is a fraction of MSW is the wood or straw waste.

The value of L0 ranges from 6.2 to 270 m3 / Mg refuse. The EPA default value of L_o is 170 m^3 /Mg refuse.

$$Lo = DOC \times DOCf \times 16/12 \times MCF$$

where Lo is a potential methane generation capacity (kg/tonne), MCF is a Methane correction factor (fraction; default =1.0), DOC is a Degradable organic carbon (kg/tonne), DOCf is a Fraction of assimilated DOC (IPCC,1996 default = 0.77; IPCC, 2006 default = 0.50), F is a Fraction of methane in landfill gas (0.5 default), and 16/12 is a Stoichiometric factor.

Application:

Estimate the quantity of Methane CH_4 resulted from Ramadi city landfill if you have the following:

كميتها او نسبها	البيانات
562372	عدد سكان مدينة الرمادي
0.850	معدل تولد النفايات الصلبة كغم/شخص/يوم
47816.2	كمية النفايات المتولدة في اليوم في مدينة الرمادي (كغم/يوم
174475913	كمية النفايات المتولدة في السنة كغم/سنة
174.48	كمية النفايات المتولدة في السنة (كيكا غرام/مدينة/سنة)
90%	كمية النفايات الواصلة الى منطقة الطمر
0.4[٢]	معامل تصحيح الميثان(MCF)
0.19[١]	الكربون العضوي القابل للتحلل (DOC)
0.77[٤]	الجزء المتباين من الكربون العضوي القابل للتحلل(DOC_F)
0.5[١]	جزء الميثان في غاز مناطق الطمر (F)
0[٧]	استخلاص الميثان(RF)
0[٨]	معامل الاكسدة(OX)

t(Gg/yr)={ $mswt * mswf * lo) - R\} * (1 - OX)$

CH4=(174.48*(90%)*(0.4%)*(0 .19%)*(0.77%)* (0.5) *(16/12)0*(1-0).

= 6.28Gg/yr = 6280 ton/yr = 6280 m^3/yr

Estimation of electricity producing from this quantity of methane:

Electricity power = 1.8 Kw/hr/ for each m^3 of CH_4

Total power = 11304 Kw/hr

Per capita power consumption = 2.1 Kw/hr.cap

This amount of CH_4 sufficient for 5383 person

And if we assume that 1 m^3 of CH_4 is enough for providing 1 truck at speed of 10km/hr, then we have 6280 trucks.