**B.Sc. Course(First Semester)**

**University of Babylon-College of Engineering**

**Environmental Engineering Department**

# ***Chapter Seven (Solid Waste Management)***

## ***Disposal Of Solid Wastes and Residual Matter:***

### ***7.1 Ultimate Disposal***

Disposal on or in the earth's mantle is, at present, the only viable method for long-term handling. Landfilling is the method of disposal used most commonly for municipal wastes; land farming and deep well injection have been used for industrial wastes. 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. Although disposal in the atmosphere has been suggested as a third alternative, it is not a viable method because material discharged into the atmosphere is ultimately deposited either on the earth or in the sea by a variety of natural phenomena, the most important of which is rainfall.

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

***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 days operation. When the disposal site has reached its ultimate capacity a final layer of 2 ft or more of cover material is applied.

***Or, Sanitary landfill:***

Is an engineered facility for the disposal of municipal solid waste MSW designed and operated to minimize public health and environmental impacts. Landfilling includes monitoring of the incoming waste stream, placement and compaction of waste and installation of landfill environmental monitoring and control facilities.

***Landfill management:***

Incorporates the planning, design, operation, closure, and post closure control of landfills.

***A Cell:***

Is the term used to describe the volume of material placed in a landfill during one operating period, usually 1 day. A cell includes the solid waste deposited and the daily cover material.

***A lift:***

Is a complete layer of cells over the active area of a landfill for the placement of surface water drainage channels, and for the location of landfill gas recovery piping.

**ADVANTAGES AND DISADVANTAGES OF SANITARY LANDFILL**

| | Advantages | Disadvantages |
|---|---|---|
| 1 | Where land is available, a sanitary landfill is usually the most economical method of solid waste disposal. | In highly populated areas, suitable land may not be available within economical hauling distance. |
| 2 | The Initial Investment is low compared with other disposal methods. | A completed landfill will settle and require periodic maintenance |
| 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. | Sanitary landfills located in residential areas can provoke extreme public opposition |
| 4 | . A sanitary landfill can receive all types of solid wastes, eliminating the necessity of separate collections. | Proper sanitary landfill standards must be adhered to daily or the operation may result in an open dump |
| 5 | A sanitary landfill is flexible; increased quantities of solid wastes can be disposed of with little additional personnel and equipment. | Special design and construction must be utilized for buildings constructed on completed landfill because of the settlement factor |
| 6 | Sub marginal land may be reclaimed for use as parking lots, playgrounds, golf courses, airports, etc. | 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 |

***<u>7.2 Important Aspects in The Implementation Of Sanitary Landfills:</u>***

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

***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 hydro geologic conditions,
8. Local environmental conditions, and
9. Potential ultimate uses for the completed site.

***1.Available land area:***

In selecting potential land disposal sites, it is important to ensure that sufficient land area is available. Although there are no fixed rules concerning the area required, it is desirable to have sufficient area, including an adequate buffer zone to operate for at least five years at a given site. For shorter periods, the disposal operation becomes considerably more expensive.

***2. Location restrictions:***

Location restrictions refer to where landfills can be located. Restrictions now apply with respect to siting landfills near airports, in floodplains, in wetlands, in areas with known faults, in seismic impact zones, and in unstable areas. All current restrictions must be reviewed carefully during the preliminary siting process to avoid expending time and money evaluating a site that will not conform with the regulatory requirements.

***3.Haul distance:***

Although minimum haul distances are desirable, but it is not the only factor that must be considered.

Other factors should be considered in sire 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 days landfill and a film layer of cover after the filling is completed, data must be obtained 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 hydro geologic conditions:***

Geologic and hydro geologic conditions are perhaps the most important factors in establishing the environmental suitability of the area for a landfill site. Data are required to accesses the pollution potential of the proposed site and to establish what must be done to the site to ensure that the movement of leachate and gases will not impair the quality of ground water or other subsurface or bedrock aquifers.

***8.Local environmental conditions, and:***

While it was possible to build and operate landfill sites in close proximately to both residential and industrial developments. They must be operated carefully if they are to be environmentally acceptable with respect to noise, odor, dust, vector control, hazards to health and property values. To minimize the impact of landfilling operations, landfills should be located in remote areas where adequate butter zones surrounding the landfill can be maintained.

***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 land filing.

## ***7.3 Landfilling methods and operations***

To use the available area at a landfill site effectively, a plan of operation for the placement of solid wastes must be prepared. Various operational methods have been developed, primarily based on field experience. The methods used to fill dry areas are substantially different from those used to fill wet areas.

The principal methods used for dry landfilling areas may be classified as:

1. Area method
2. Trench method
3. Depression method

### ***1.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 (1.8 to 3) m at that time or at the end of each day operation a 6 to 12 in (15 to 30) cm layer of cover material is placed over the completed fill. The cover material must be hauled in by truck from adjacent land. 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.

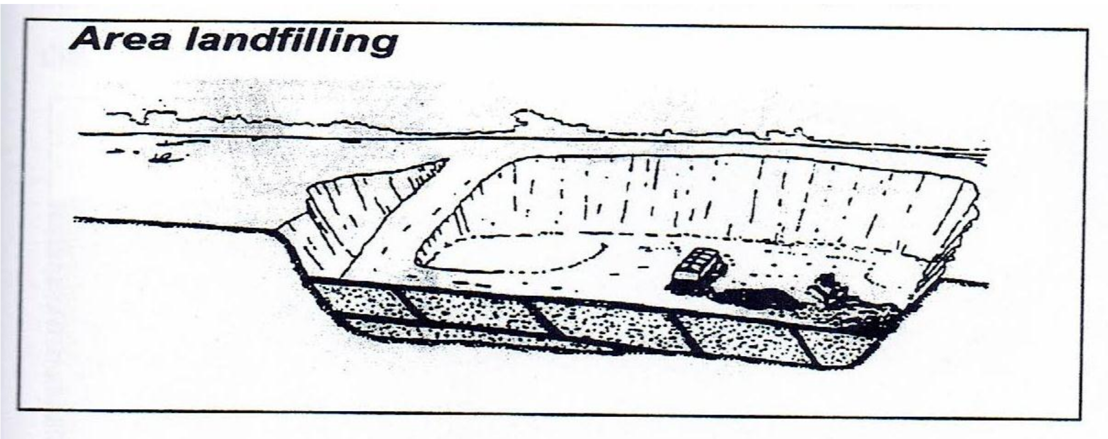


**Fig 7.1: Area landfill**

### ***2.Trench method:***

Is ideally suited to areas where an adequate depth of cover material is available and 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. 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.

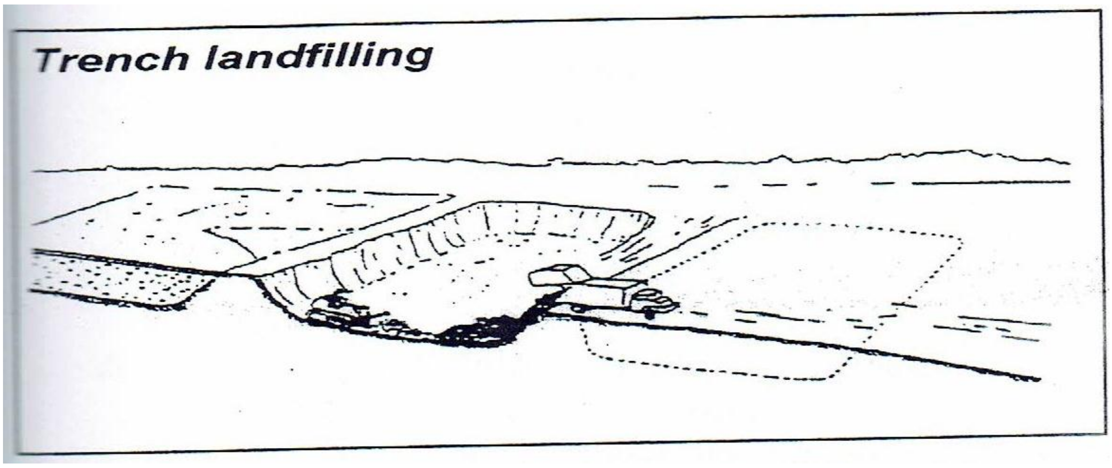


**Fig 7.2: Trench method**

***3.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. Borrow pits and abandoned quarries may not contain sufficient soil for intermediate cover, so that it may have to be imported.

**Fig 7.3:Depression landfilling**

***<u>Landfilling with milled solid waste:</u>***

Milling of solid waste before placing in a landfill may have advantages and disadvantages

***Advantages:***

1. Daily cover of earth is not necessary (where available cover material is in short supply)
2. The lower layer can be left exposed until the next layer is placed
3. Odors and blowing litter have not been a problem (rate cannot survive on milled solid wastes containing up to 20% food wastes.

***Disadvantages:***

1. There are additional costs associated with the milling and related ancillary facilities.
2. Even if this method of operation is adopted, some type of landfill will be required for the wastes that cannot be milled effectively.
3. By leaving the landfill uncovered, the movement leachate may be accelerated and thus may become a limiting factor.

***Dumping in wet areas:***

Swamps and marshes, tidal areas and ponds, pits, or quarries are typical wet areas that have been used as landfill-sites. Because of problem associated with contamination of local groundwater, the development of odors and structural stability, the design of landfills in wet areas requires special attention. Yet direct filling of wet areas is no longer considered acceptable, because of concern over the possibility of groundwater contamination by both leachate and gases from landfills and the development of odors.

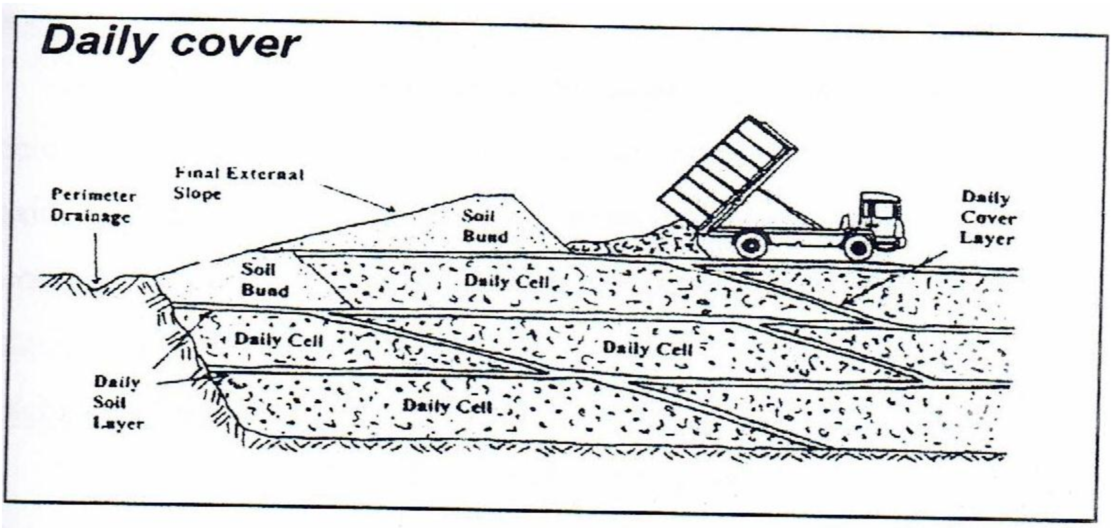


**Fig 7.4: Daily cover**

## ***7.4 Reaction 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 evaluation 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. Uneven settlement caused by consolidation of material into voids.

### ***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.

### ***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, while volatile organic compounds (VOCs) are trace gases.

### ***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 surface drainage, rainfall, ground water and water from underground springs and the liquids already exist the waste. 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.

***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 5yr. the placement of concentrated loads on completed landfills is not recommended.

***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 as shown in figure7.5.

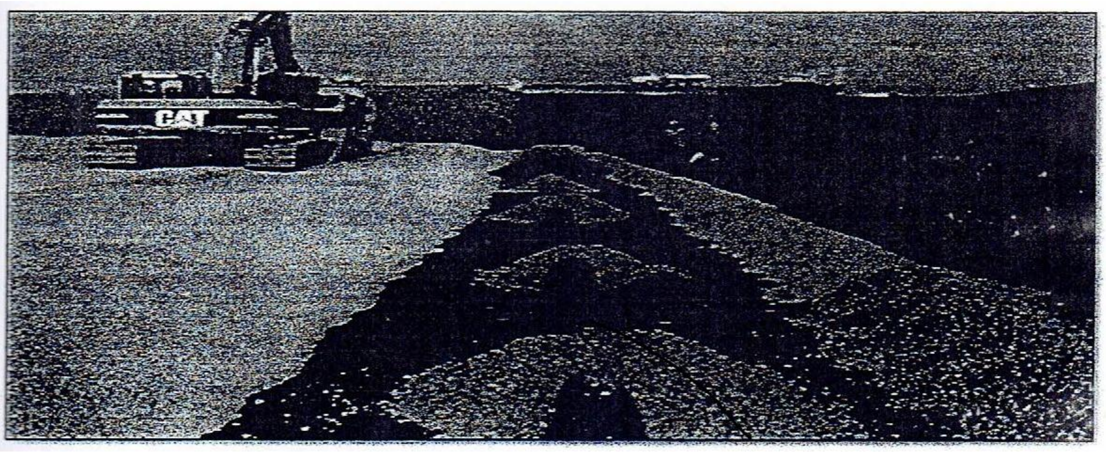


**Fig.7.5:Leachate collection**

***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 percent it is explosive. Because only limited amounts of oxygen are present in a landfill when methane concentration reaches this critical level, there is little danger that the landfill will explode. However, 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 close to a sanitary landfill and may cause explosions.

Both methane and $CO_2$ have been found in concentrations up to 40% at lateral distances of up to 120 m from the edges of the landfills. 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 through the under laying formation until it reaches the ground water. As a result, the concentration of $CO_2$ at the bottom of the landfill may be high for years.

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.

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad \ldots\ldots (7.1)$$

$$H_2CO_3 + CaCO_3 \rightarrow Ca^{+2} + 2H_2CO_3 \quad \ldots\ldots (7.2)$$

***Control of gas movement:***

The movement of gases in landfills can be controlled by construction of vents and barriers and by gas recovery as shown in figure(7.6).

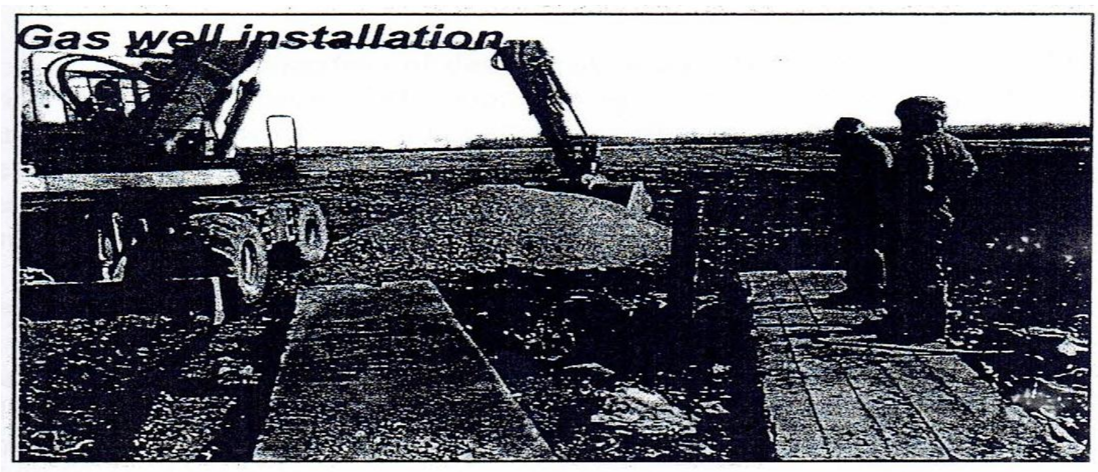


**Fig.7.6: Gas piping**

***Example7.1:***

Find the amount of land required in a sanitary landfill to dispose of urban waste of a city of 40000 in population, knowing that; amount of waste generation=2.5 kg/capita/d, density of landfill waste=500 kg/$m^3$ and waste is filled into a depth of about 3m.

***Solution:***

$$2.5\, kg/capita/d \times 365\, d \times 40000\, capita = 36500000\, kg\ total\ amount\ of\ waste$$

$$36500000\, kg/500\ kg/m^3 = 73000\, m^3$$

$$73000\, m^3/3\, m = 24333.333\, m^2/2500\ m^2/donme = 9.73\, donme$$

***Example7.2:***

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

City population=176119

Waste generation rate=0.875 kg/capita/d,

Density of landfill waste=560 kg/$m^3$

Waste is filled into a depth of about 8.5m

The landfill site is to be used for 13 years and 25% should be added as area necessary for construction facilities.

***Solution:***

$$0.875\ kg/capita/d \times 365\, d \times 176119\, capita = 56247960\, kg\ total\ amount\ of\ waste$$

$$56247960\, kg/560\ kg/m^3 = 100442.78\ m^3/yr \times 13\, yr = 1305756.1\, m^3$$

$$1305756.1\, m^3/8.5\, m = 153618.36\, m^2/10000\ m^2/hectares$$

$$= 15.3618\, hectares$$

$$15.3618\, hectares \times 0.25 = 3.840\, hectares + 15.3618\, hectares$$

$$= 19.202 hectares$$

***Example7.3:***

Determination of density of compacted solid wastes without and with waste diversion: Determine the specific weight in a well-compacted landfill for solid wastes with the characteristics given in the table below. Also, determine the impact of a resource recovery program on landfill area requirements in which 50 percent of the paper and 80 percent of the glass and tin cans are recovered.

***Solution:***

1. Set up a computation table with separate columns for:

- ❖ The weight of the individual solid waste components,
- ❖ The volume of the wastes as discarded,
- ❖ The compaction factors for well-compacted solid wastes, and
- ❖ The compacted volume in the landfill

The required table, based on a total weight of 1000 Ib, is given below:

**Disposal of Solid Wastes and Residual Matter**

| Component | %Weigh | Weight 1b | Density as discarde d 1b/ft3 | Vol. ft3 | Compac tion factor | Volume in ft3 |
|---|---|---|---|---|---|---|
| Food waste | 9 | 90 | 18.0 | 5.00 | 0.33 | 1.64 |
| Paper | 34 | 340 | 5.1 | 66.60 | 0.15 | 9.9 |
| Cardboard | 6 | 60 | 3.1 | 19.30 | 0.18 | 3.47 |
| Plastics | 7 | 70 | 4 | 17.50 | 0.10 | 1.75 |
| Textile | 2 | 20 | 4 | 5.00 | 0.15 | 0.75 |
| Rubber | 0.5 | 5 | 8 | 0.62 | 0.3 | 0.18 |
| Leather | 0.5 | 5 | 10 | 0.50 | 0.3 | 0.15 |
| Garden trimming | 18.5 | 185 | 6.5 | 28.40 | 0.2 | 5.68 |
| Wood | 2 | 20 | 15.0 | 1.33 | 0.3 | 0.39 |
| Glass | 8 | 80 | 12.1 | 6.61 | 0.4 | 2.64 |
| Tin cans | 6 | 60 | 5.5 | 10.90 | 0.15 | 1.63 |
| Non ferrous materials | 0.5 | 5 | 10 | 0.50 | 0.15 | 0.075 |
| ferrous materials | 3 | 30 | 20 | 1.50 | 0.3 | 0.45 |
| Dirt, ashes,brick | 3 | 30 | 30 | 1.00 | 0.75 | 0.75 |
| Total | 100 | 1000 | | 153.40 | | 28.95 |

2. Compute the compacted specific weight of the solid wastes:

$$Compacted\ specific\ weight = 1000\ Ib/28{,}95\ ft^3 \times 27\ \ ft^3/yd^3$$
$$= 933\ \ Ib/yd^3\ (554\ \ kg/m^3)$$

3.Determine the compacted specific weight in the landfill in which 50% of the paper and 80% of the glass and tin cans are recovered

Determine the weight of waste after resource recovery:

$$Weight\ remaining = 1000\ Ib - (340\ Ib \times 0.5 + 80\ Ib \times 0.8 + 60\ Ib \times 0.80) = 718\ Ib$$

Determine the volume and compacted specific weight of waste after resource recovery:

$$Volume\ remaining = 28.95\ ft^3 - (9.18\ ft^3 \times 0.5 + 2.62\ ft^3 \times 0.8 + 1.62\ ft^3 \times 0.80)$$
$$= 20.97\ ft^3$$

$$Compacted\ specific\ weight = 718\ Ib \times 27\ \ ft^3/yd^3/20.97\ ft^3\ = 924\ \ Ib/yd^3$$