SOLID WASTE MANAGEMENT

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What is Solid Waste?

- **Solid or semi solid materials, which possess no more value and is the waste for the primary user.**
  - **Agricultural Wastes**
  - **Mining Wastes**
  - **Industrial Wastes**

Municipal Solid Waste (MSW)

- **Urban waste (Municipal Solid Waste) as opposed to agricultural, mining and industrial wastes.**

- **Biomedical Waste and Electronic Waste are also produced in urban areas but are dealt separately in Indian rules.**

Municipal Solid Waste (MSW)

SOLID WASTE MANAGEMENT--

WHY ?

- Solid wastes discarded in the streets and roads could lead to the breeding of rodents and fleas which could lead to spread of several diseases.
  - E.g. **Bubonic Plague** killed half of 14th century Europe.

- Solid wastes could lead to **air and water pollution**.

Deonar Dumping Ground, Mumbai

Source: http://timesofindia.indiatimes.com/city/mumbai/Massive-fire-at-Deonar-dumping-ground-again/articleshow/50985954.cms

Deonar Dumping Ground, Mumbai

NASA image

Is Municipal Solid Waste Management Difficult?

- Treatment of MSW becomes difficult once we mix different types of wastes together.

- Each categories of waste generated, take their own time to degenerate

  – Organic waste(food waste) can degrade biologically within 1-2 weeks.

  – Glass bottles will not degrade biologically --never

Problem of Solid Waste

There are different categories of waste generated, each take their own time to degenerate

The type of litter we generate and the approximate time it takes to degenerate	
Type of litter	Approximate time it takes to degenerate the litter
Organic waste such as vegetable and fruit peels, leftover foodstuff, etc.	A week or two.
Paper	10–30 days
Cotton cloth	2–5 months
Wood	10–15 years
Woolen items	1 year
Tin, aluminium, and other metal items such as cans	100–500 years
Plastic bags	One million years?
Glass bottles	undetermined

SOLID WASTE GENERATION

- **How much MSW you generate everyday?**
- **Calculate…**
- **What is the composition?**

SOLID WASTE GENERATION

- Small towns - 100 g/p/day
- Medium towns - 300-400 g/p/day
- Large towns - 500 g/p/day or more

In general varies between 0.3-0.6 kg/person/day

QUANTITY OF WASTE GENERATION

- ~62 million tonnes of MSW generated annually by 377 million people in urban areas

- More than 80% is disposed at dump (uncontrolled)

(Source: Report of the Task Force on Waste to Energy (Volume I) , 2014

http://planningcommission.nic.in/reports/genrep/rep_wte1205.pdf)

QUANTITY OF WASTE GENERATION

GARBAGE	% OF TOTAL
Waste Generated in 6 Mega Cities	18.4%
Waste Generated in Metro Cities (1 Million Plus Towns)	17.1%
Waste Generated in Other Class-I Towns (0.1 Million Plus Towns)	37.1%
	72.5%

TOTAL QUANTITY OF SOLID WASTE GENERATED IN URBAN AREAS OF THE COUNTRY — **1.15 LAKH TONNE PER DAY (TPD)**

Source: Guidelines for Preparation of Detailed Project Reports and Selection of Technologies for Processing and Final Disposal of Municipal Solid Waste Using 12th Finance Commission Grants.

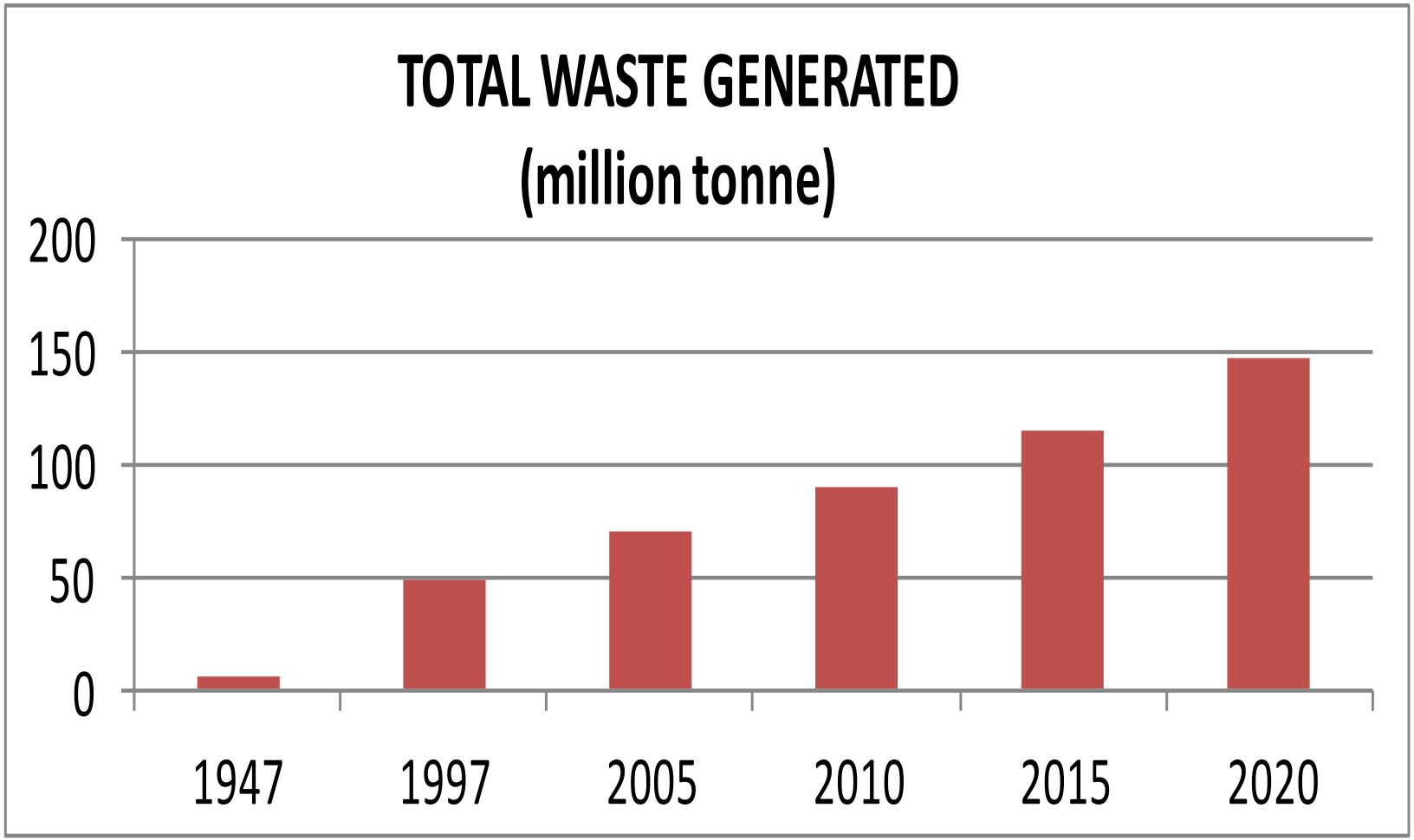
http://www.cmao.nic.in/Resources/12th%20Finnace%20Commission%20Guidelines%20on%20SWM.pdf

How much it cost to manage MSW?

- **Urban Local Bodies spend ~Rs. 500-1500/- per tonne on MSW management**
  - **60-70% of it is spent on collection alone**
  - **20% - 30% is spent on transportation**
  - **Hardly any fund is spent on treatment and disposal of waste**

- **Collection efficiency:**
  - **Major metro cities: 70-90%**
  - **Smaller cities: < 50%**

Source: Position Paper on PPP in Solid Waste Management. November 2009, http://www.pppinindia.com/pdf/ppp_position_paper_solid_waste_mgmt_112k9.pdf


TOTAL WASTE GENERATED
(million tonne)
200
150
100
50
0
1947
1997
2005
2010
2015
2020

How much land is required to manage MSW?

- 3 -3.5% of annual growth of urban population would lead to ~5% annual increase in MSW generation.

- By this trend and if waste not disposed properly, >1400 sq. km of land would be required by 2047 for its disposal.

Source: Position Paper on PPP in Solid Waste Management. November 2009, http://www.pppinindia.com/pdf/ppp_position_paper_solid_waste_mgmt_112k9.pdf

CHARACTERSTICS OF MUNICIPAL SOLID WASTE GENERATED BY MERTO CITIES

Characteristics (Percent by wt.)

Sl. No.	Metro city	Paper	Textile	Leather	Plastic	Metal	Glass	Ash, Fine earth & others	Compostable matter
1	Mumbai	10.0	3.6	0.2	2.0	-	0.2	44.0	**40.0**
2	Delhi	6.6	4.0	0.6	1.5	2.5	1.2	51.5	**31.78**
3	Hyderabad	7.0	1.7	-	1.3	-	-	50.0	**40.0**
4	Jaipur	6.0	2.0	-	1.0	-	2.0	47.0	**42.0**
5	Kanpur	5.0	1.0	5.0	1.5	-	-	52.5	**40.0**
6	Chennai	10.0	5.0	5.0	3.0	-	-	33.0	**44.0**
7	Visakhapatnam	3.0	2.0	-	5.0	-	5.0	50.0	**35.0**

Sharholy et al. / Waste Management 28 (2008) 459–467

SOLID WASTE MANAGEMENT

- Solid waste management may be defined as the management of waste from its generation to the final disposal that uses the best principles of public health, economics, engineering and conservation.

(Source: Environmental Audit of Municipal Solid Waste Management TECHNICAL REPORT: 118 June 2006)

http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR118_SPoonancha/Index.htm.

FUNCTIONAL ELEMENTS OF SOLID WASTE MANAGEMENT SYSTEM

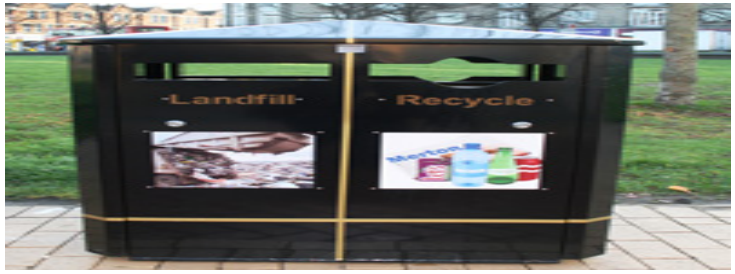
- **Waste generation and primary storage**
- **Collection**
- **Separation, storage and processing at the source**
- **Transfer and transport**
- **Processing & recovery**
- **Disposal**

Bin for Source Segregation and Storage

Bin for Source Segregation and Storage


FOOD WASTE
KEEP YOUR AIRPORT CLEAN
RECYCLABLE WASTE
KEEP YOUR AIRPORT CLEAN

Litter Bins



Street Sweepings

- **Manual sweeping**
- **Mechanical sweepers**

Street Sweepings

Manual Sweeping

Mechanical Sweeper

Collection

- Door to Door Collection
- Community Bins

Community Bins: Commercial Complexes, Multistoried Apartments

Community Bins: Commercial Complexes, Multistoried Apartments

Packers/Compactors Trucks

- Municipal solid waste at the curbside has a density of ~100-200 kg/m^3 in developed countries and 300-400 kg/m^3 in India.
- At those low densities, collection vehicles fill too fast, which means multiple, time- wasting trips to the disposal site would be needed.
- Modern trucks, called *packers,* have hydraulic, compactors that can compress that waste to as much as 750 kg/m^3 density.
- Compaction Ratio: 2-3

Compactors

Compactors

Transportation System

- Selection of proper number and size of trucks.
- Choosing the most efficient collection routes and schedules.
- Locating transfer stations if they were to be used.

COMPLEX SOLID WASTE TRANSPORTATION SYSTEM

- With the growing importance of recycling and composting, those basic operations have become more complicated.
- Now, a municipality may have separate trucks, routes, schedules, and destinations for recyclables and compostable materials—all of which need to be coordinated with already existing refuse collection system.

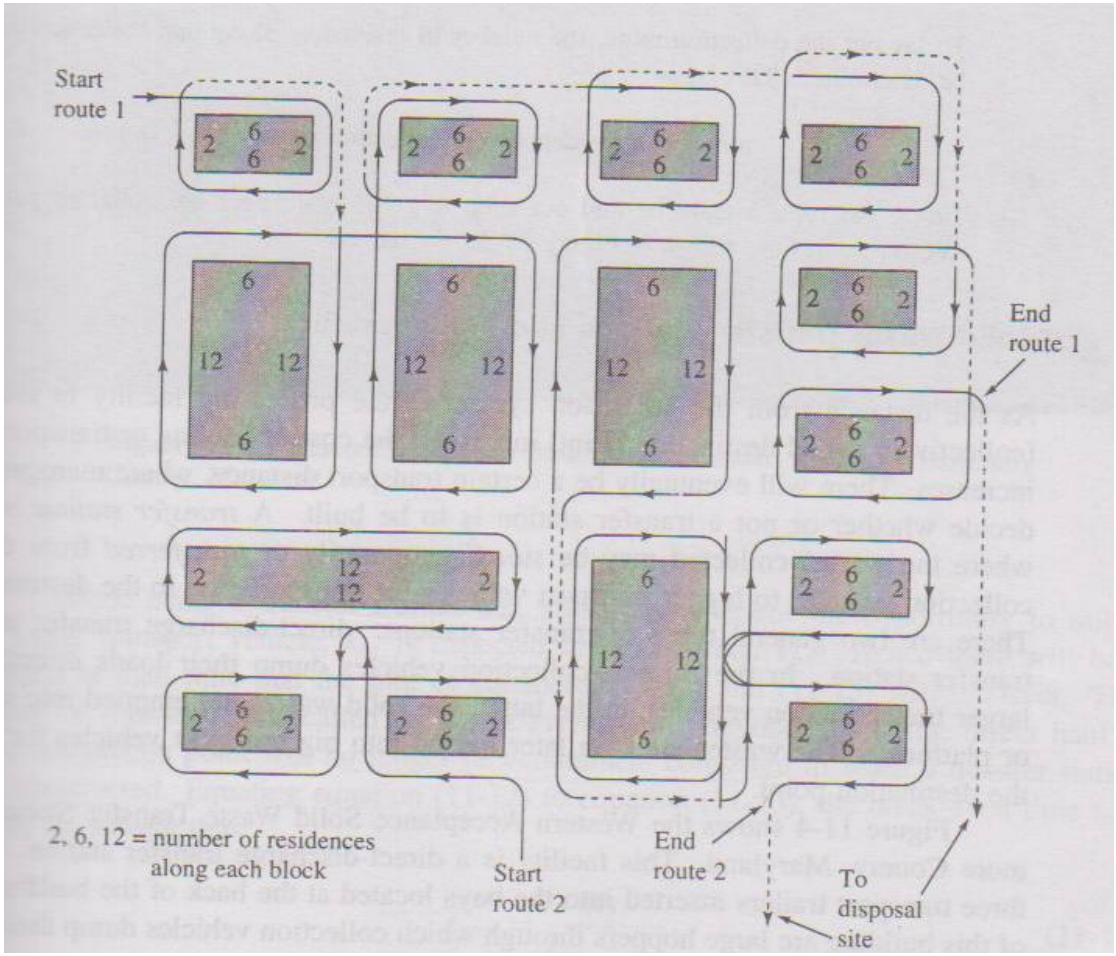
Transportation System

- **Large vs Small Trucks**

- Larger trucks cost more, but they do not- have to make as many trips back and forth to the disposal site, which can more than offset the higher capital costs.

- Larger trucks, however, are also less manoeuvrable in crowded urban areas, and their weight may exceed allowable limits for residential streets.

Routing



Route emphasizing ~~right~~ turns and a minimum amount of deadheading

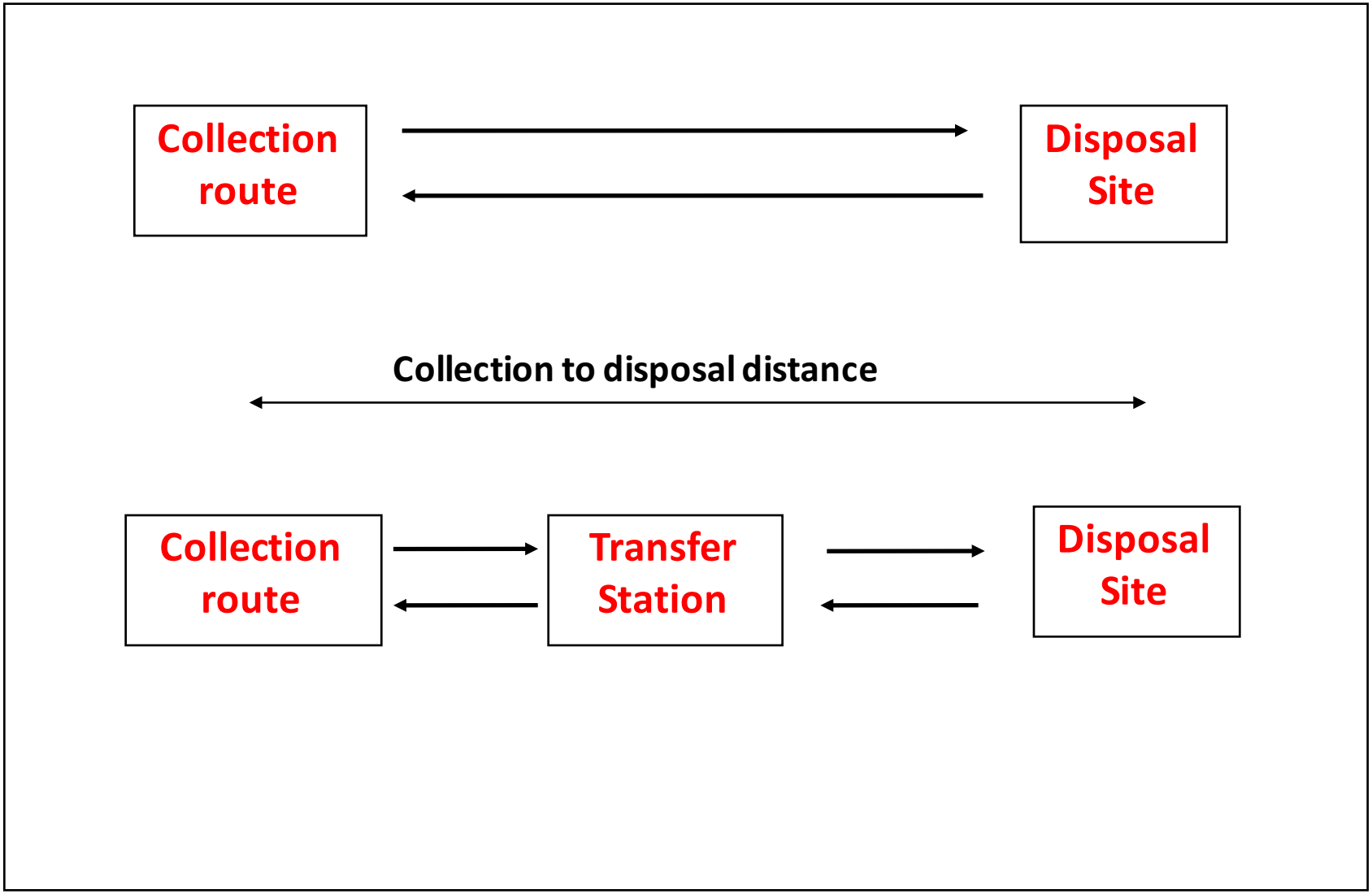
Transfer Station

- A ***transfer station*** is a facility where the wastes collected may be stored temporarily or *transferred* from the smaller collection vehicles to bigger transport vehicles for transportations to the destination point.

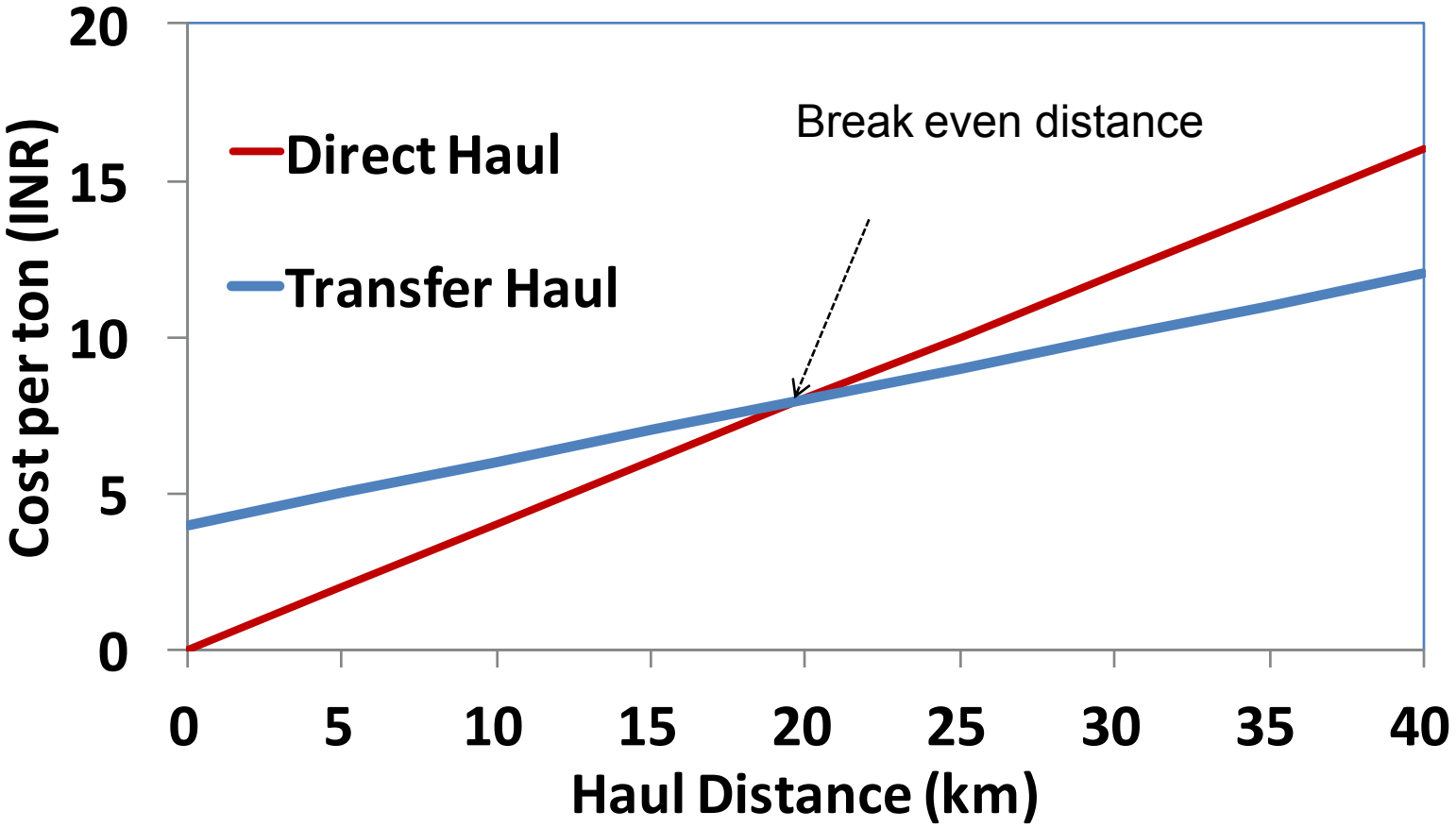
- As the distance from the collection system to the processing facility or disposal site (collectively called destination point) increases, the cost of hauling or transportation also increases.

- There will eventually be a certain transport distance, where management must decide whether or not a transfer station is to be built.

Transfer Station



Transfer Station



TRANSFORMATION OF SOLID WASTE

TRANSFORMATION OF SOLID WASTE

Why transform solid waste?

- Efficient storage, handling and transport
- Reduce disposal cost
- Stabilize waste
- Destroy toxic element (chemical or biological entities)
- Generate useful energy
- Re-use

TRANSFORMATION OF SOLID WASTE

- Physical method
- Chemical method
- Biological method

Physical Transformation

Transformation Process	Transformation Method	Transformation Products
1.Component Separation	Manual and/or Mechanical separation	Individual components of MSW
2. Volume Reduction	Application of energy in the form of force or pressure	Original waste component altered in form and reduced in size
3. Size Reduction	Application of energy in the form of shredding, grinding, or milling	The original waste components altered in the form of and reduced in size.

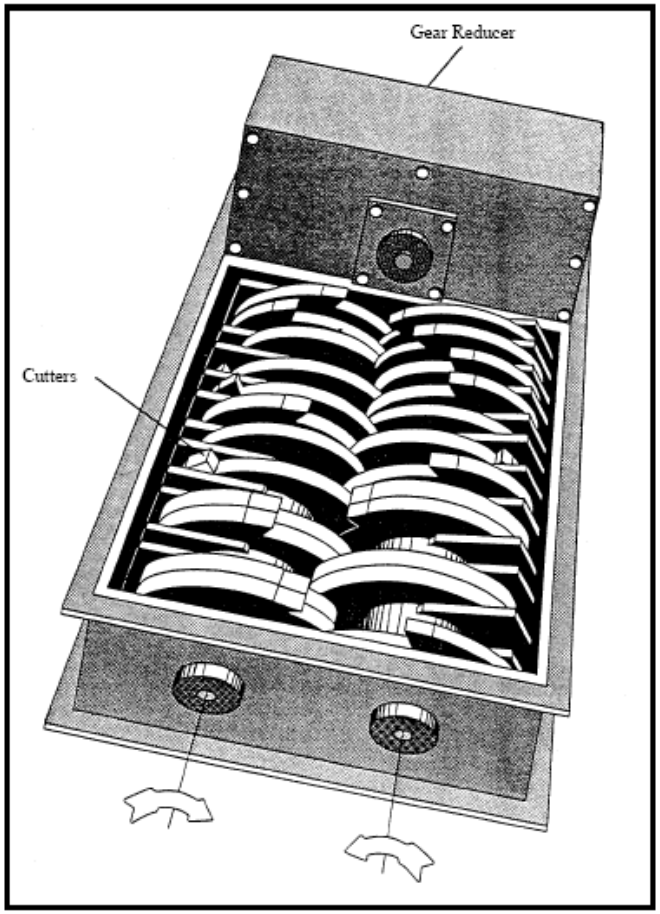
Chemical Transformation

Transformation Process	Transformation Method	Transformation Products
1.Combustion	Thermal Oxidation	Carbon dioxide (CO_2), Sulfur dioxide(SO_2), other oxidation products, and Ash
2.Pyrolysis Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. I	Destructive distillation	A gas stream containing a variety of gases, tar and/or pyrolytic oil, and char
3.Gassification	Starved air combustion	A low calorific value synthetic gas, charcoal containing carbon and the inerts originally in the fuel, and oil.

Biological Transformation

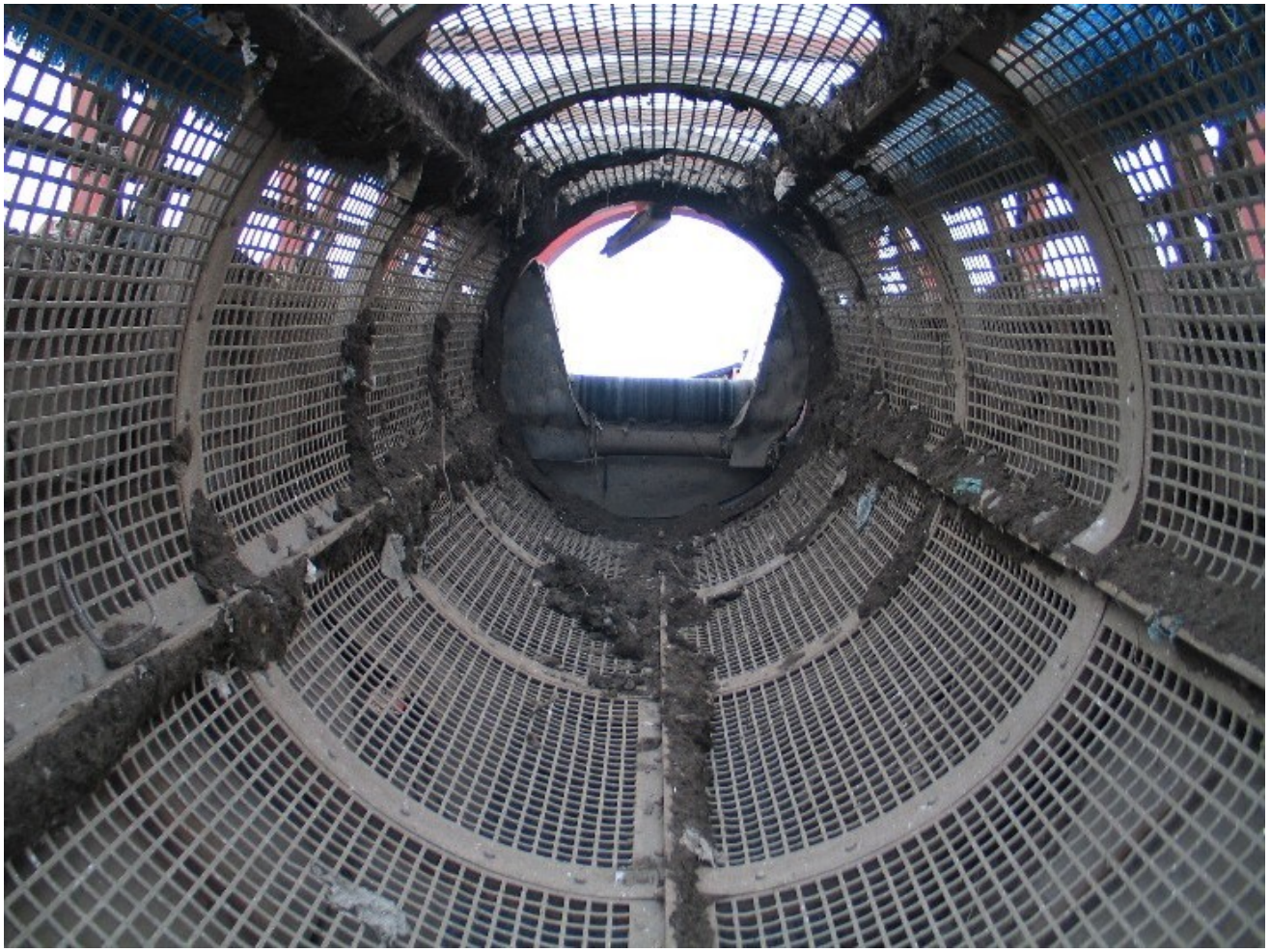
Transformation Process	Transformation Method	Transformation Products
1. Composting	Aerobic biological conversion	Compost (Humus like material used as a soil conditioner or organic fertilizer
2. Anaerobic digestion (Low or high-solids)	Anaerobic biological conversion	Methane (CH_4), Carbon dioxide (CO_2), trace gases, digested humus or sludge

Shear Shredders



Trommel Screen

Trommel Screen



Source: http://www.graepel.ie/index.cfm/page/casestudy/applicationID/24/casestudyID/20

Air Classifiers

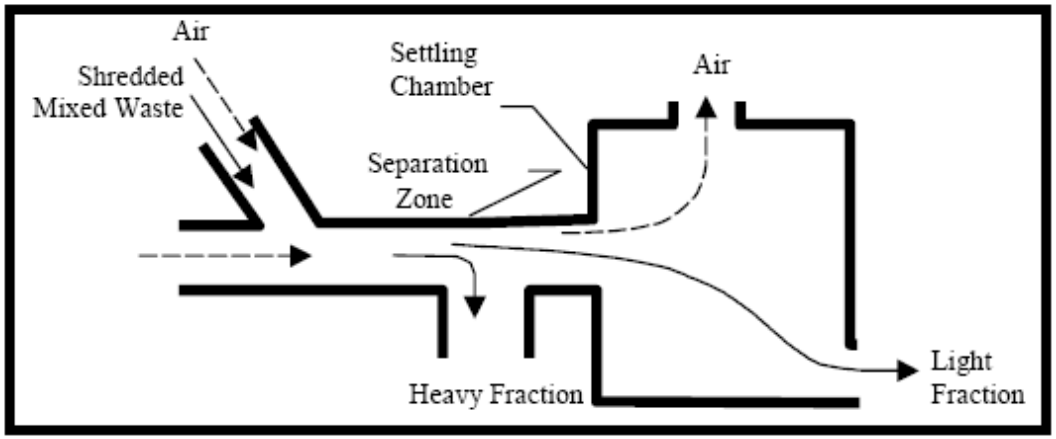
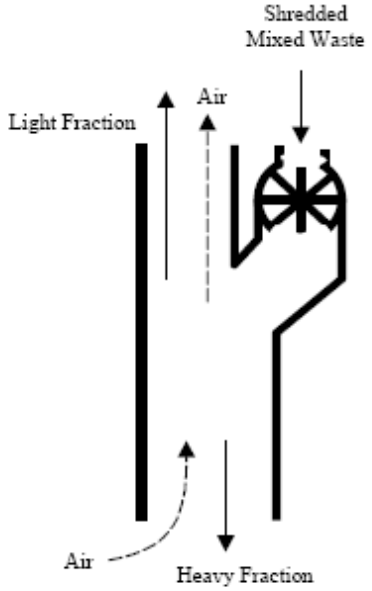
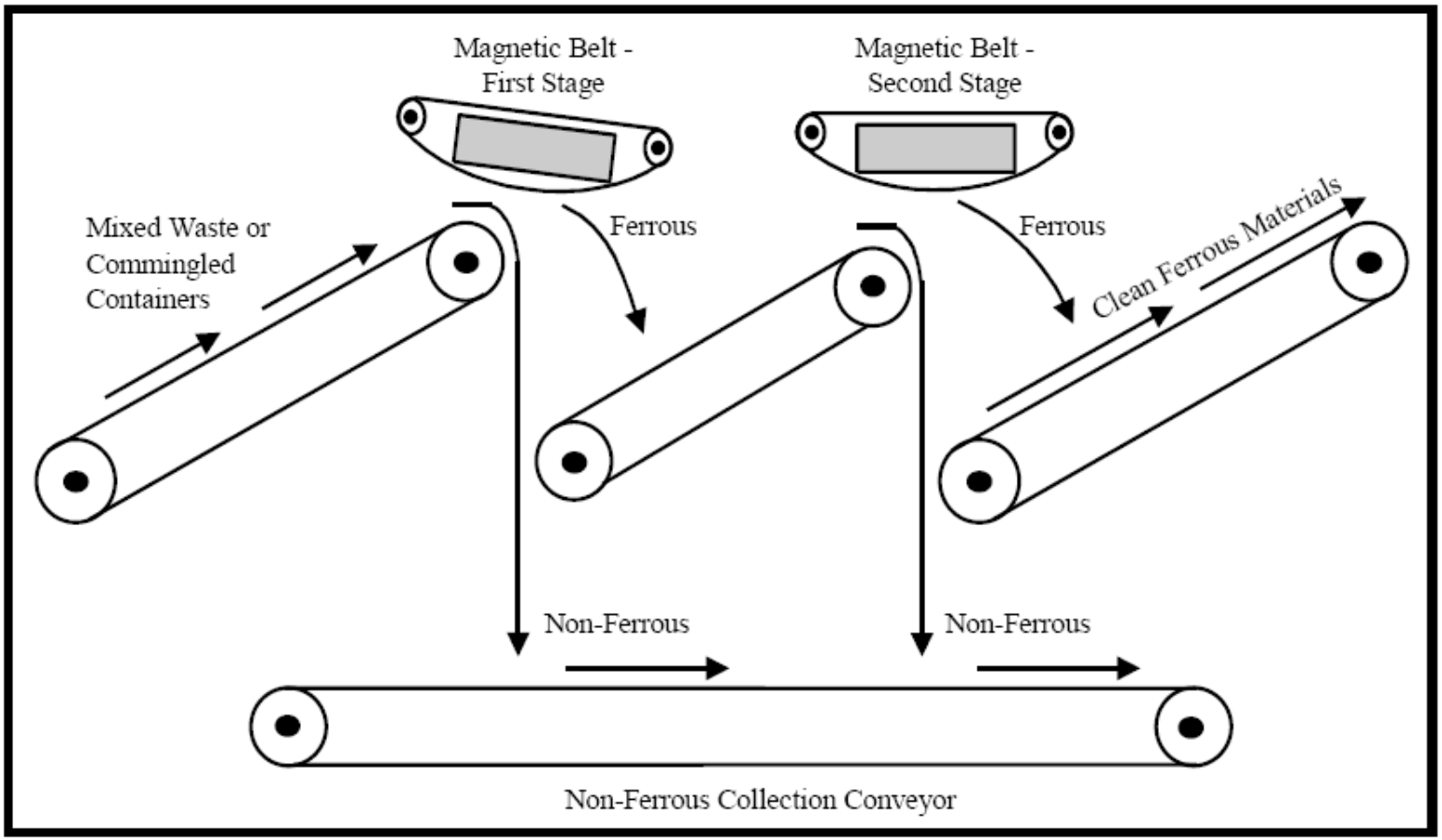


Figure VI-10. Horizontal air classifier



Magnetic Separation



Biological Process

AEROBIC STABILIZATION: COMPOSTING

COMPOSTING: ADVANTAGES

- Transformation of biodegradable waste into biologically stable matter using micro organisms.
- Reduces the volume of waste.
- Destroy pathogens/insects.
- End product is a humus like material called compost that is rich in nutrients. Compost can be used to support plant growth and as a soil amendment.

COMPOSTING

- Conventional
- Vermicomposting
- High Rate: Rotary Drum Composting

Windrow Composting

Source http://www.grand-island.com/index.aspx?page=173

Rotary Drum Composting

Source: https://www.americanbiogascouncil.org/images/genericDigestionProcess.gif

VERMICOMPOSTING

Worms

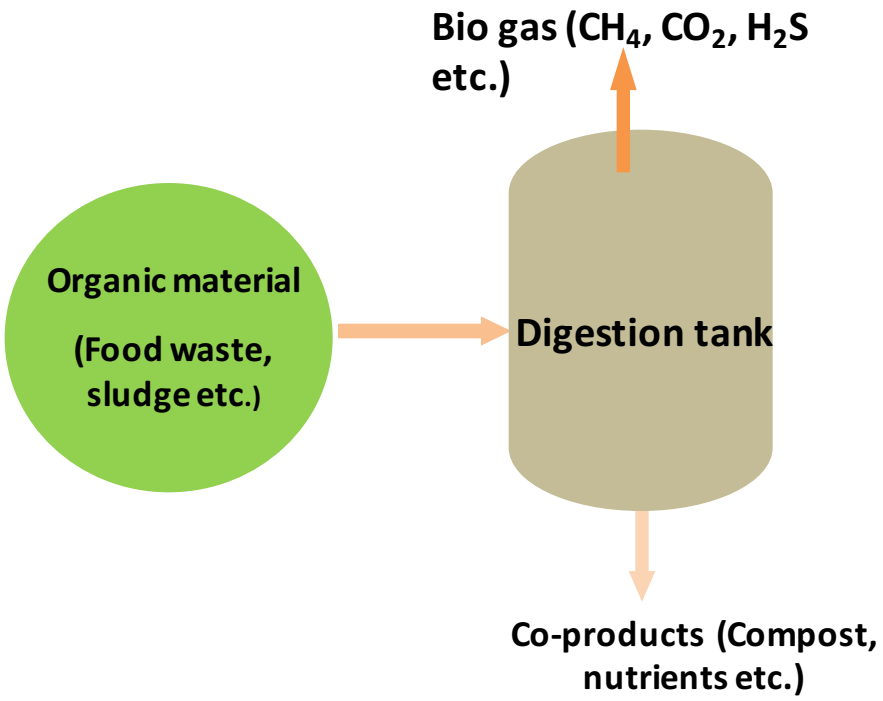
Eudrilus eugeniae

Use of earthworms for composting of organic matter

1kg of worms can consume 1kg of residue every day

Eisenia fetida

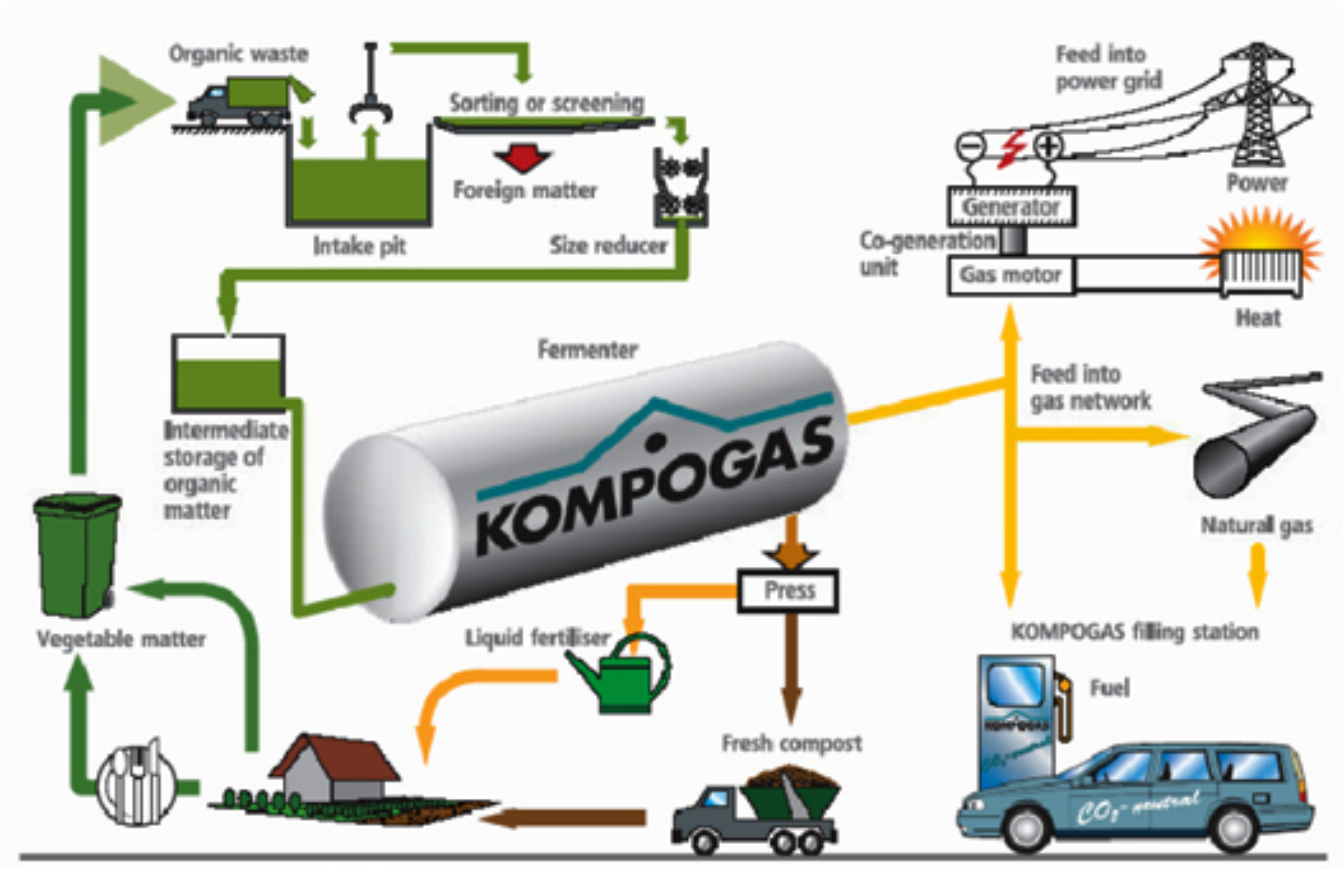
Anaerobic Digestion of Solid Waste



- **The gas stream is composed of mainly methane and carbon dioxide.**

- **The slurry stream consist of an aqueous suspension of undigested organic matter**.

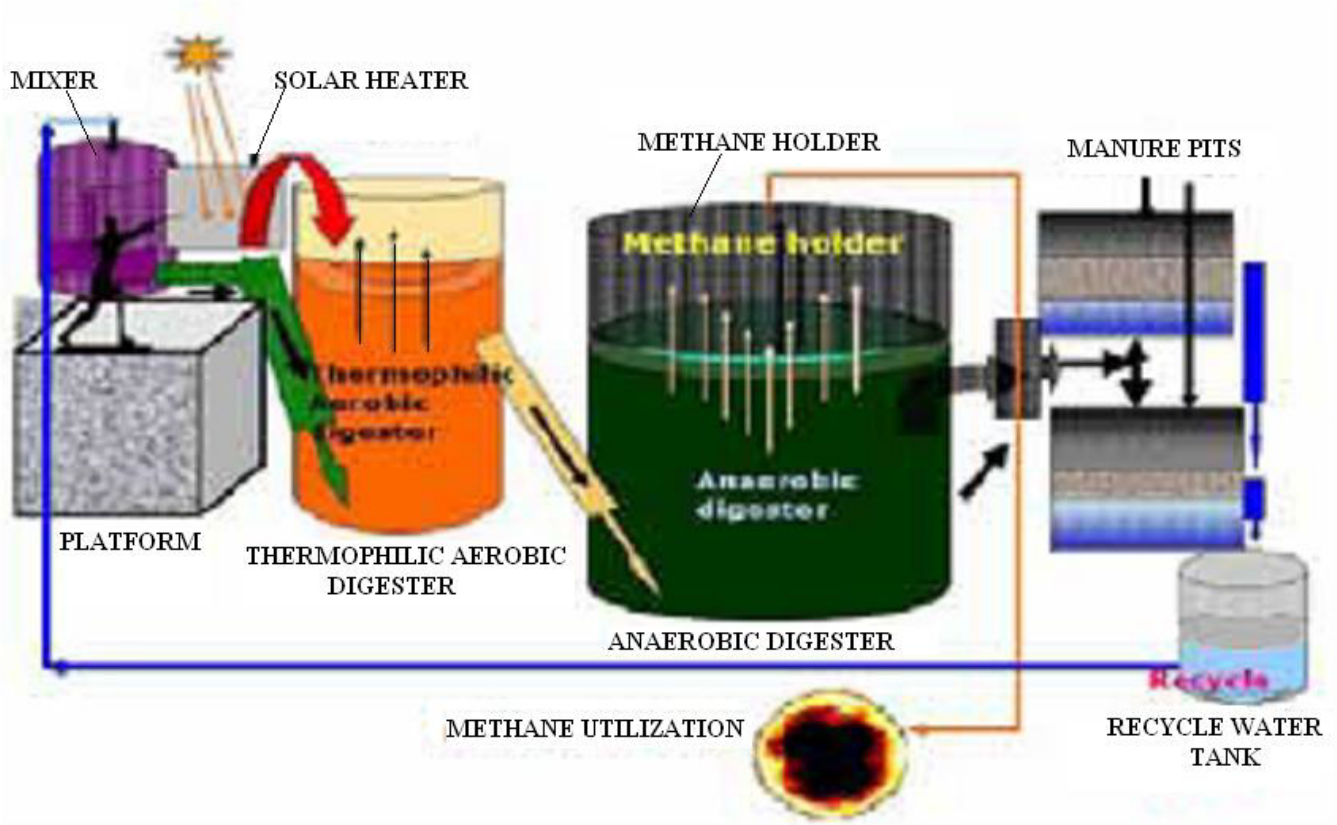
Anaerobic Digestion of Solid Waste



Schematic diagram of Kompogas AD facility

Source: http://sternerconsulting.com/blog/new-efficient-anaerobic-digestion-facilities-recycle-organic-wastes-into-renewable-energy-and-rich-compost/

Bhabha Atomic Research Centre (BARC) Mumbai's Biogas Plant



Status India

- The results of the pilot plant, by Western Paques, show that 150 t/day of MSW produce 14,000 m^3 of biogas with a methane content of 55–65%, which can generate 1.2 MW of power.

- Which means 56 MWe from Mumbai MSW with 7000 tonne/day

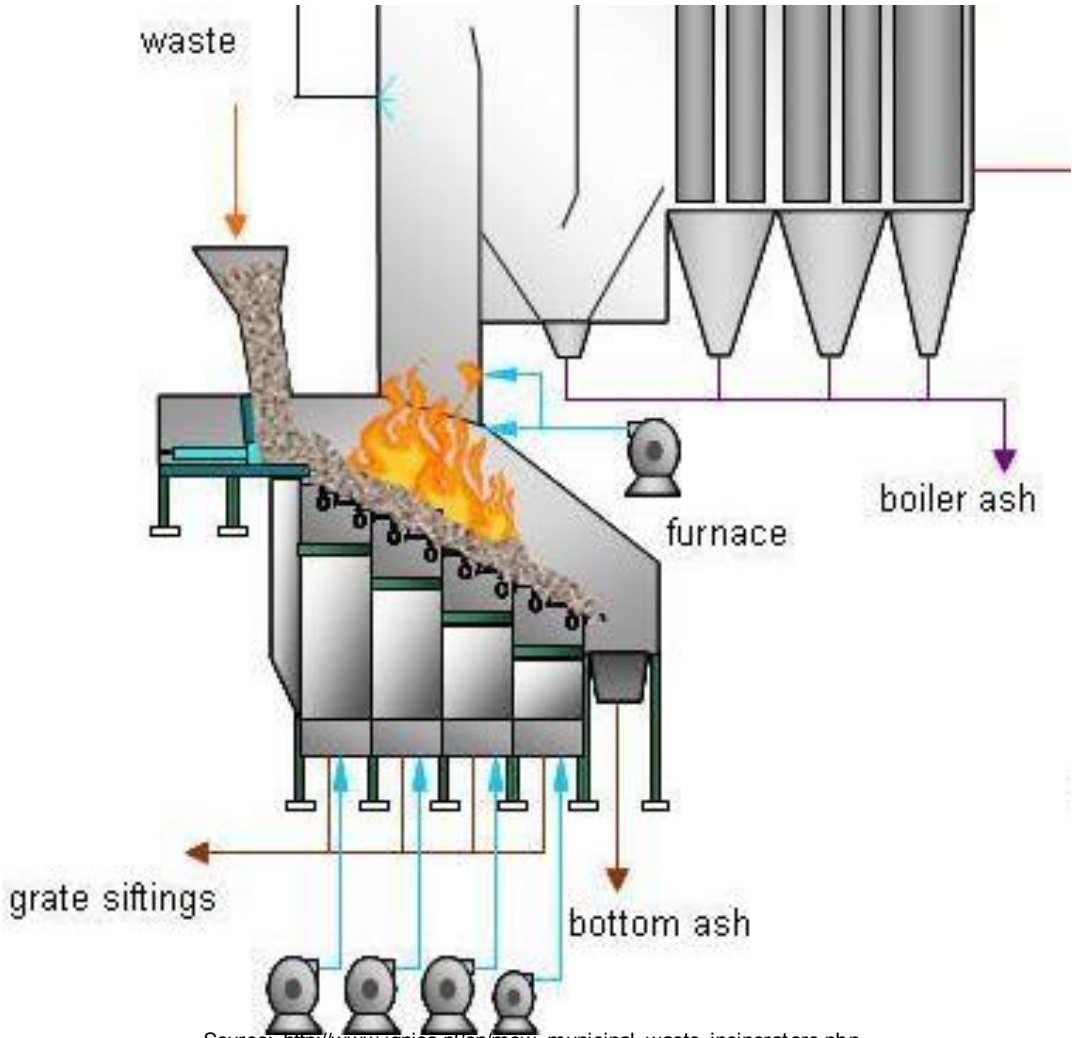
- **How much electricity can be produced from anaerobic digestion in your city?**

Source: WASTE MANAGEMENT SUMMIT INDIA 2014 TOWARDS GREENER AND CLEANER INDIA, https://www.linkedin.com/pulse/20141205154946-87779745-waste-management-summit-india-2014towards-greener-and-cleaner-india

Waste-to-energy

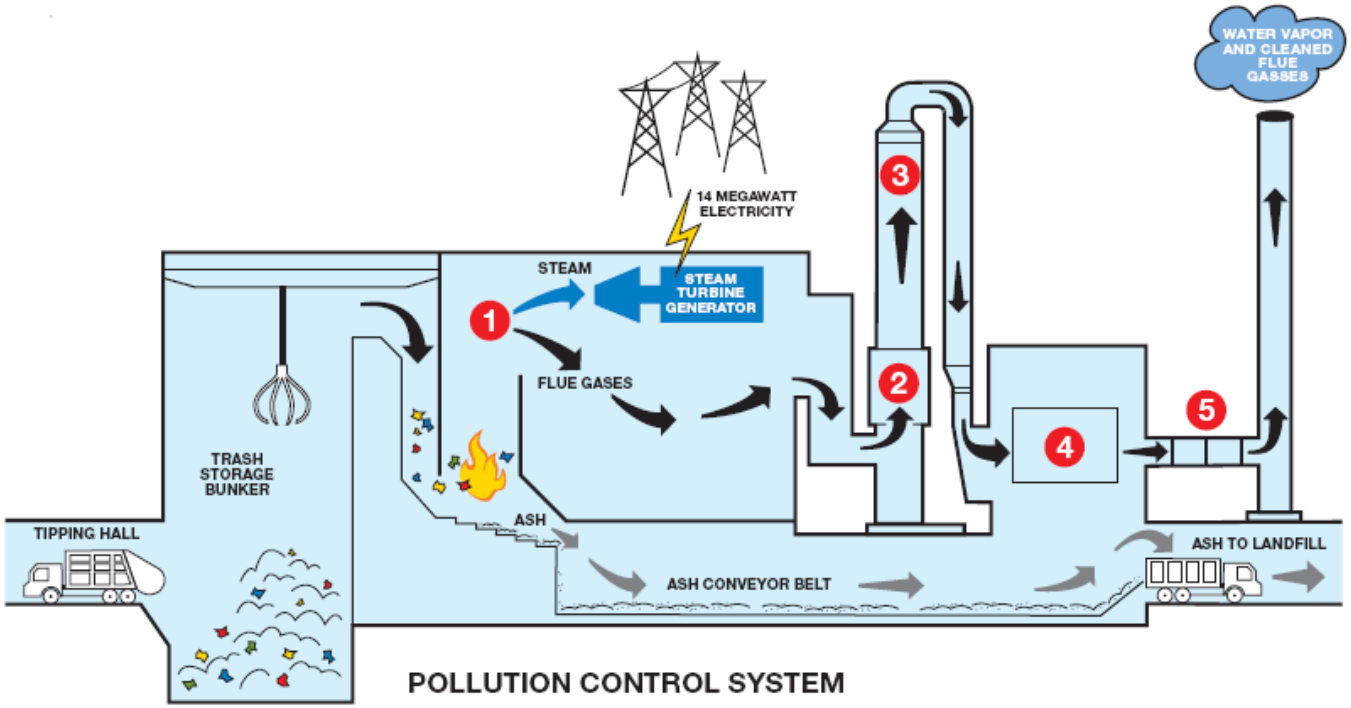
- Thermal Route (Incineration)

Grate incinerator for MSW burning



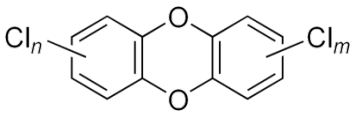
Source: http://www.igniss.pl/en/msw_municipal_waste_incinerators.php

Waste-to-energy



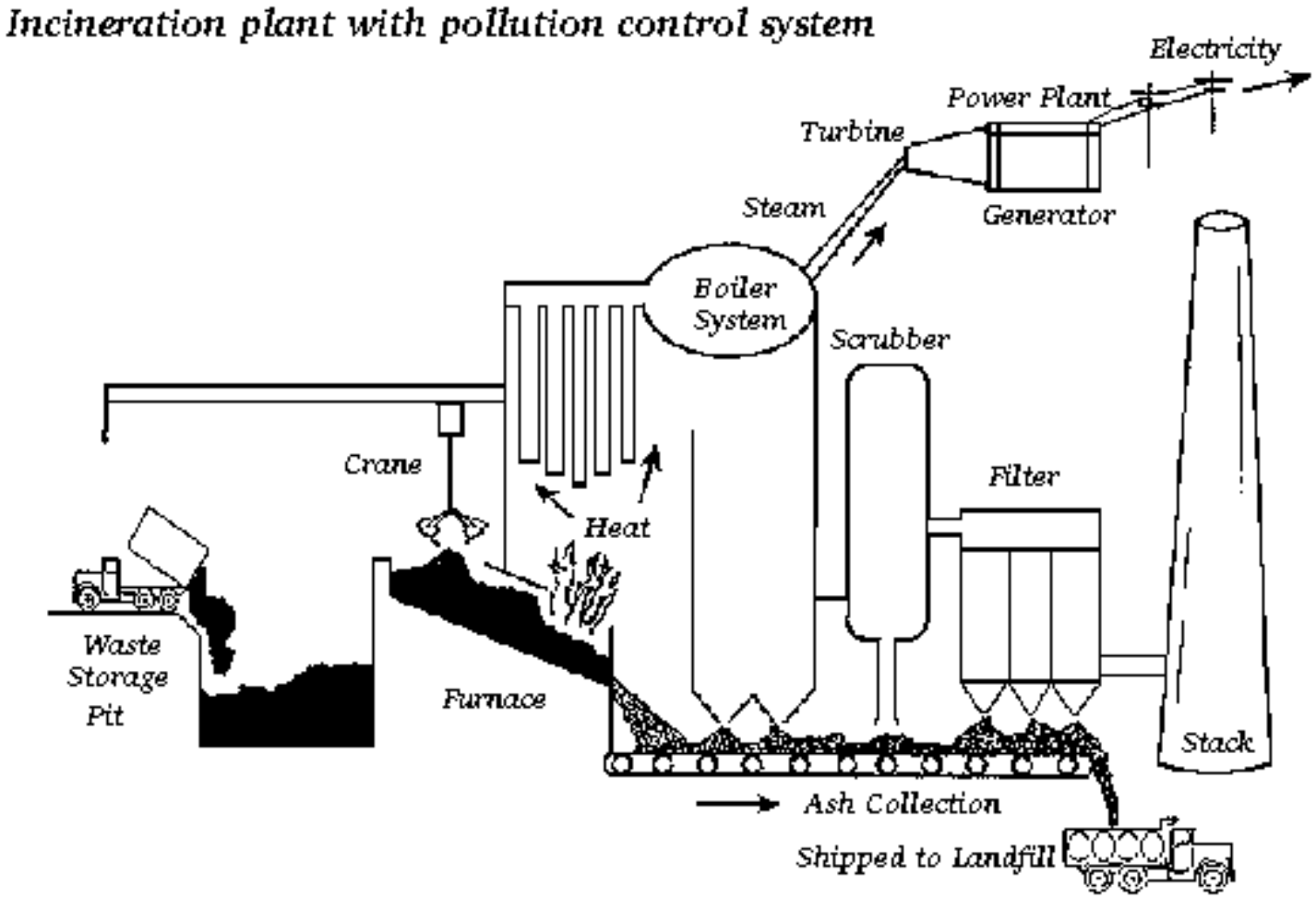
Waste-to-Energy

- 90% reduction of trash volume
- Power generation
- Pollution control



ecomaine
the future of regional waste systems
www.ecomaine.org

Polychlorinated dibenzo-p-dioxins



Source: http://earthsci.org/education/teacher/basicgeol/solid_waste/solid_waste.html

- Many developed countries do not want to use incinerators/waste to energy for the MSW management…
- Why?

EMISSIONS FROM INCINERATORS

Emissions:

- **Organic Compounds: Dioxins, Furans, Polychlorinated biphenyls (PCBs), Volatile organic compounds (VOCs), Polycyclic aromatic hydrocarbons (PAHs), Chlorinated Benzenes etc.**
- **Heavy Metals: As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, etc.**
- **Gases: HCl, HF, HBr, SOx, NOx, CO, CO_2 etc.**

EMISSIONS FROM INCINERATORS

Solid Outputs:

- **Fly ash: contains soot, PAHs, PCBs, Dioxins, Furans and Heavy Metals like Pb, Cd, Cu, Zn etc.**
  - **Particulate Matter: PM 2.5, PM 10**

Incinerator Effluent:

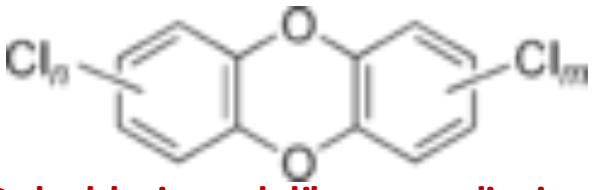
- **Wastewater from wet exhaust gas cleaning contains heavy metals (Pb, Cd, Sb, Cu, Hg, Zn etc.), neutral salts and unburned organic material.**

Dioxins and Furans:

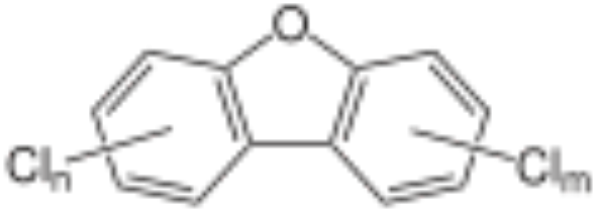
- **The most publicized concerns from environmentalists about the incineration of municipal solid wastes (MSW) involve the fear that it produces significant amounts of dioxin and furan emissions**
- **Class of compounds that are highly toxic**
- **Formed as a by-product of combustion involving chlorine related compounds and hydrocarbons.**
- **Persistent organic pollutants (POPs).**

Dioxins and Furans:

- **Polychlorinated dibenzo-p-dioxins (PCDDs)**
  - Technically PCDDs are derivatives of dibenzo-p-dioxin.
  - 75 PCDDs, and seven of them are specifically toxic



Polychlorinated dibenzo-p-dioxins (PCDDs)



Polychlorinated dibenzofurans (PCDFs)

- **Polychlorinated dibenzofurans (PCDFs)**
  - Technically PCDFs are derivatives of dibenzofuran.
  - 135 congeners (derivatives differing only in the number and location of chlorine atoms).
  - Strictly speaking are not dioxins, ten of them have "dioxin-like" properties.

- TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) - most toxic compound known to science.

Dioxins and Furans:

- Do we have control technologies now?
  - YES. e.g. activated carbon beds, others
  - Also can be controlled by process control

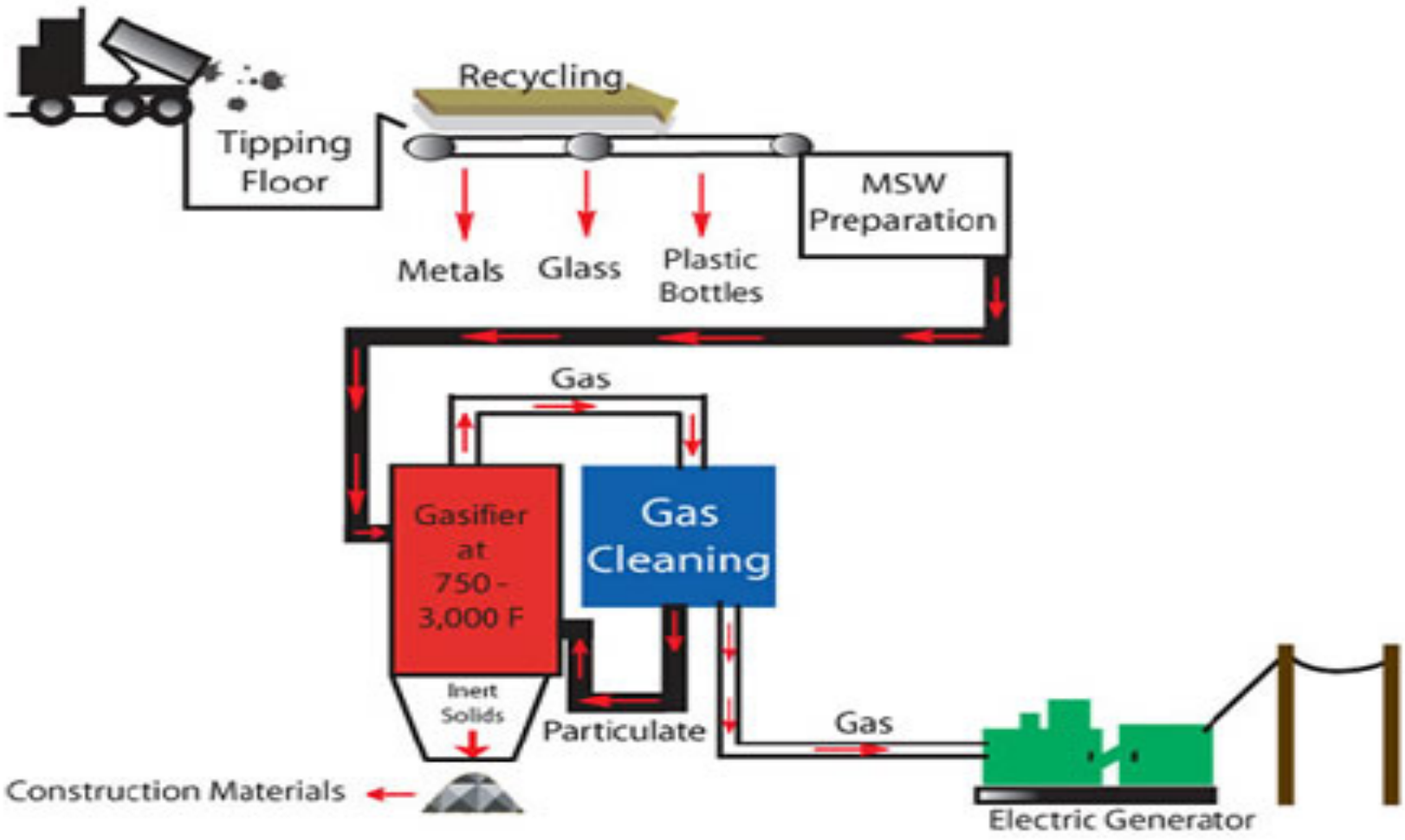
Gasification

- Partial oxidation of the organic and fossil fuel based materials into gaseous fuel (CO and H2) at elevated temperature.

- The gaseous fuel (Synthetic fuel) can be further used either to generate energy or to form other products.

- Comparatively new technology for MSW

Gasification



DISPOSAL

DISPOSAL

- **Open dumping**
- **Barging in to sea**
- **Land filling: Disposal of residual solid wastes in the surface soils of the earth.**

Why Landfill

Unmanaged and uncontrolled, solid wastes openly dumped on the land:

- Generate liquid and gaseous emissions (leachate and landfill gas) that can pollute the environment
- Represent a breeding ground for disease-bearing animals and microorganisms
- Other risks to the public health and safety and to the environment

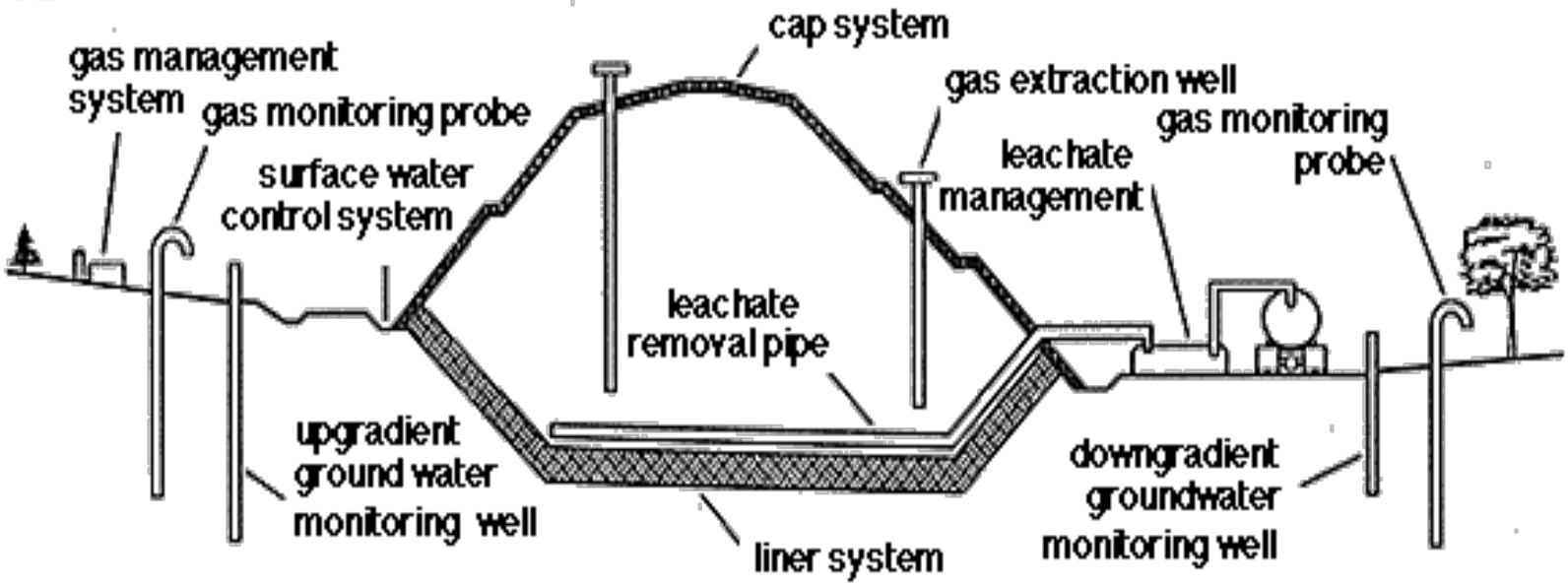
Sanitary Landfill

- Controlled disposal of waste on the land.
- Controls the exposure of the environment and humans to the detrimental effects of solid wastes placed on the land.
- Disposal is accomplished in a way such that contact between wastes and the environment is significantly reduced, and wastes are concentrated in a well defined area.
- Good control of landfill gas and leachate, and limited access of vectors (e.g., rodents, flies, etc.) to the wastes

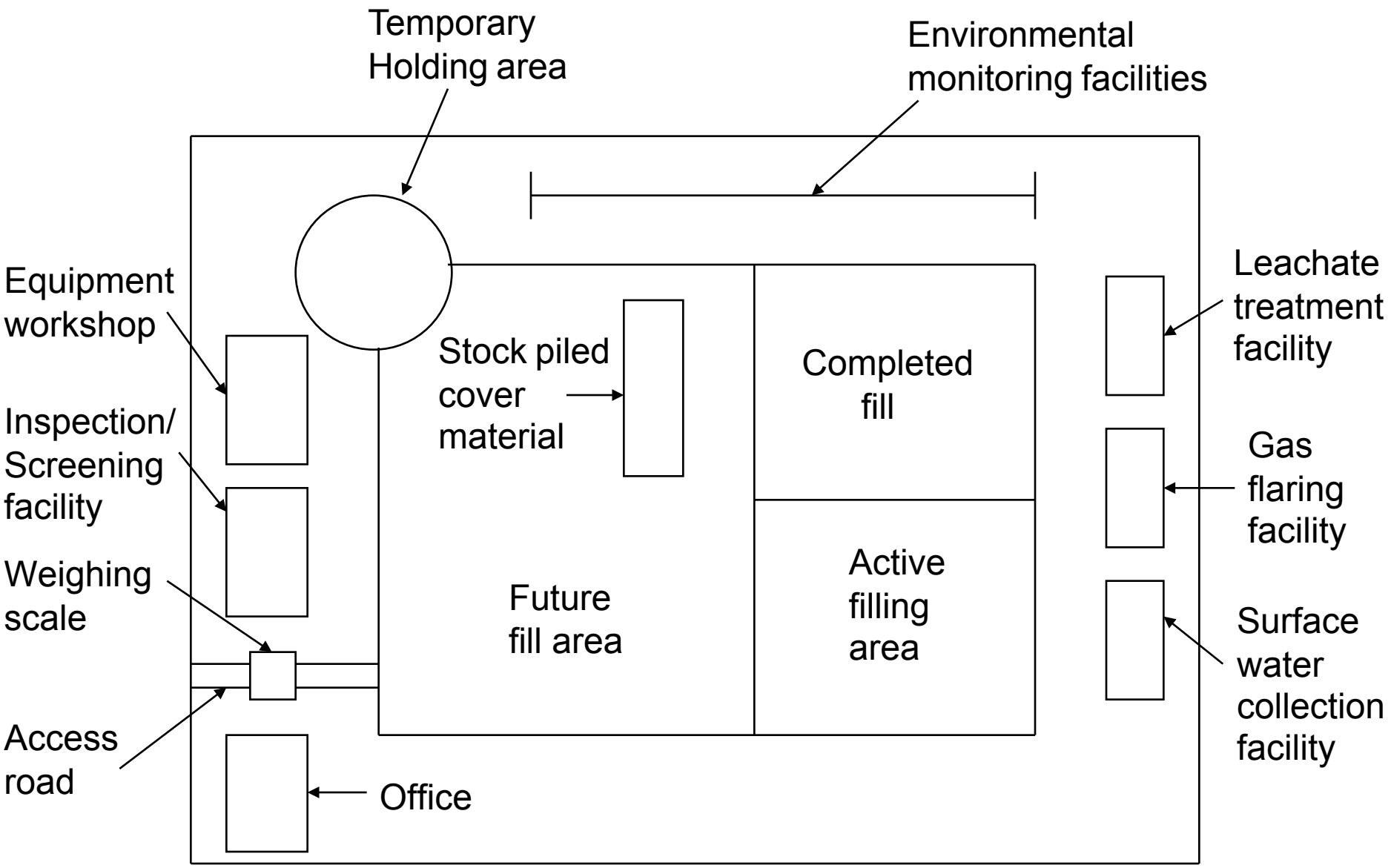
Sanitary Landfill

- LINER SYSTEM
- CAP SYSTEM
- GAS MANAGEMENT SYSTEM
  - Gas collection, treatment, flaring etc.
- LEACHATE MANAGEMENT SYSTEM
  - Leachate collection and treatment system
- MONITORING SYSTEMS:
  - Water: Ground water monitoring system
  - Air: Air monitoring system

Typical schematic of a state-of-the-art landfill



(credit: Paul C. Rizzo Associates)



Typical Layout of a Landfill

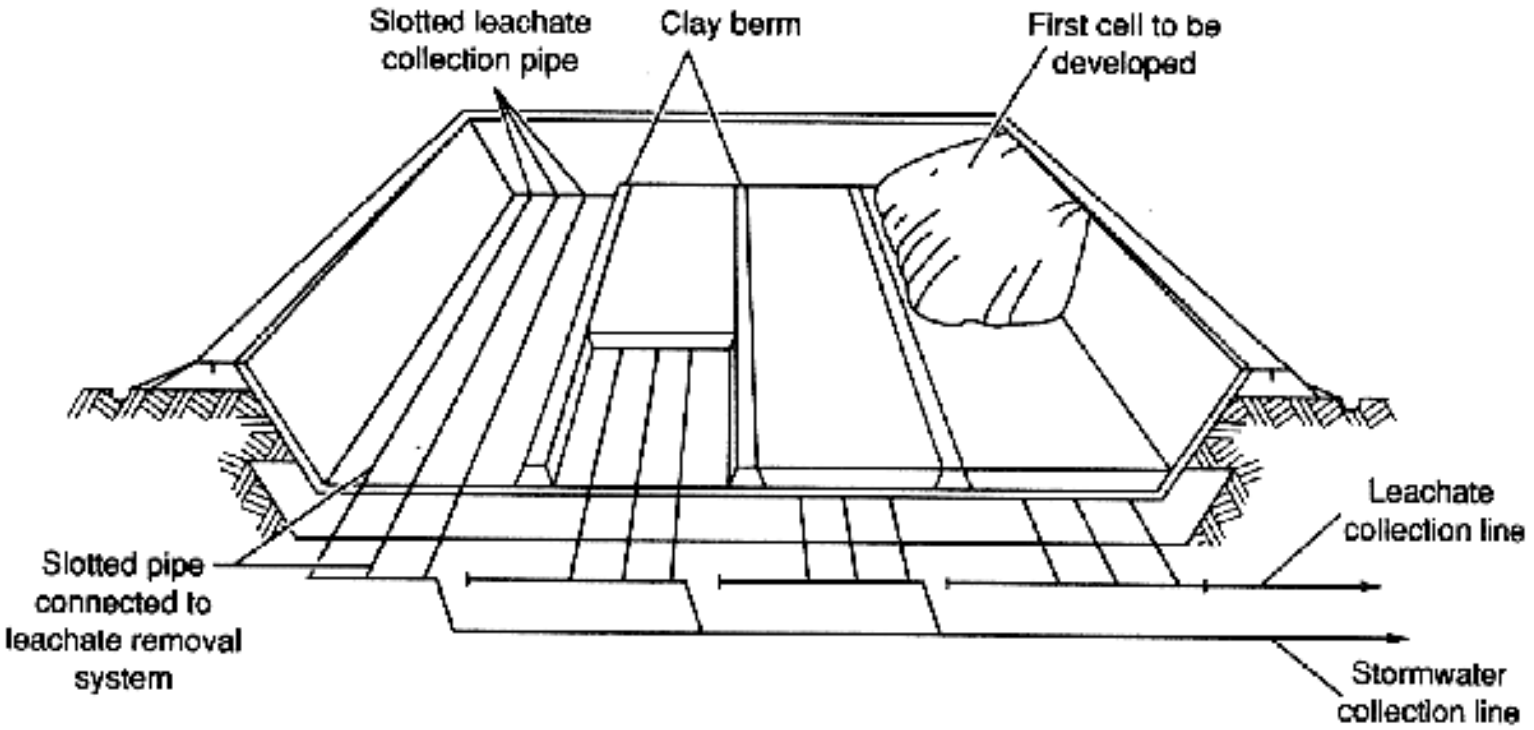
Landfill operation

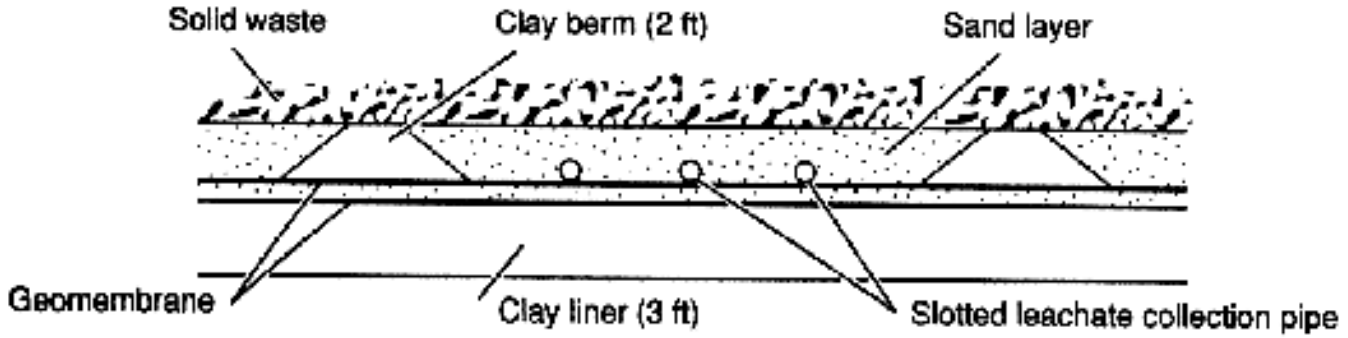
Source:
http://commons.wikimedia.org/wiki/File:Landfill_Hawaii.jpg#

Landfill-Bottom

Cell liner

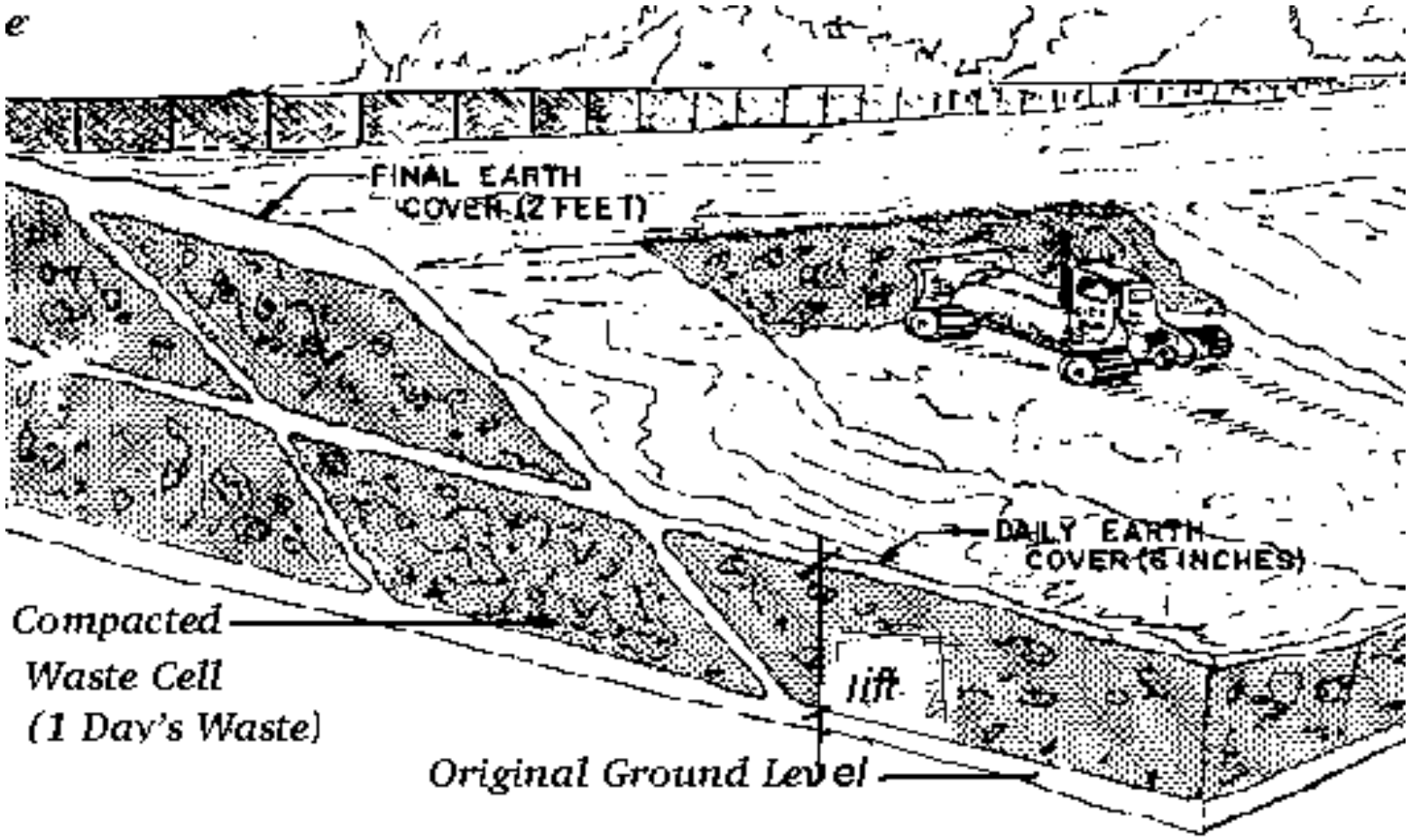
Leachate Collection System





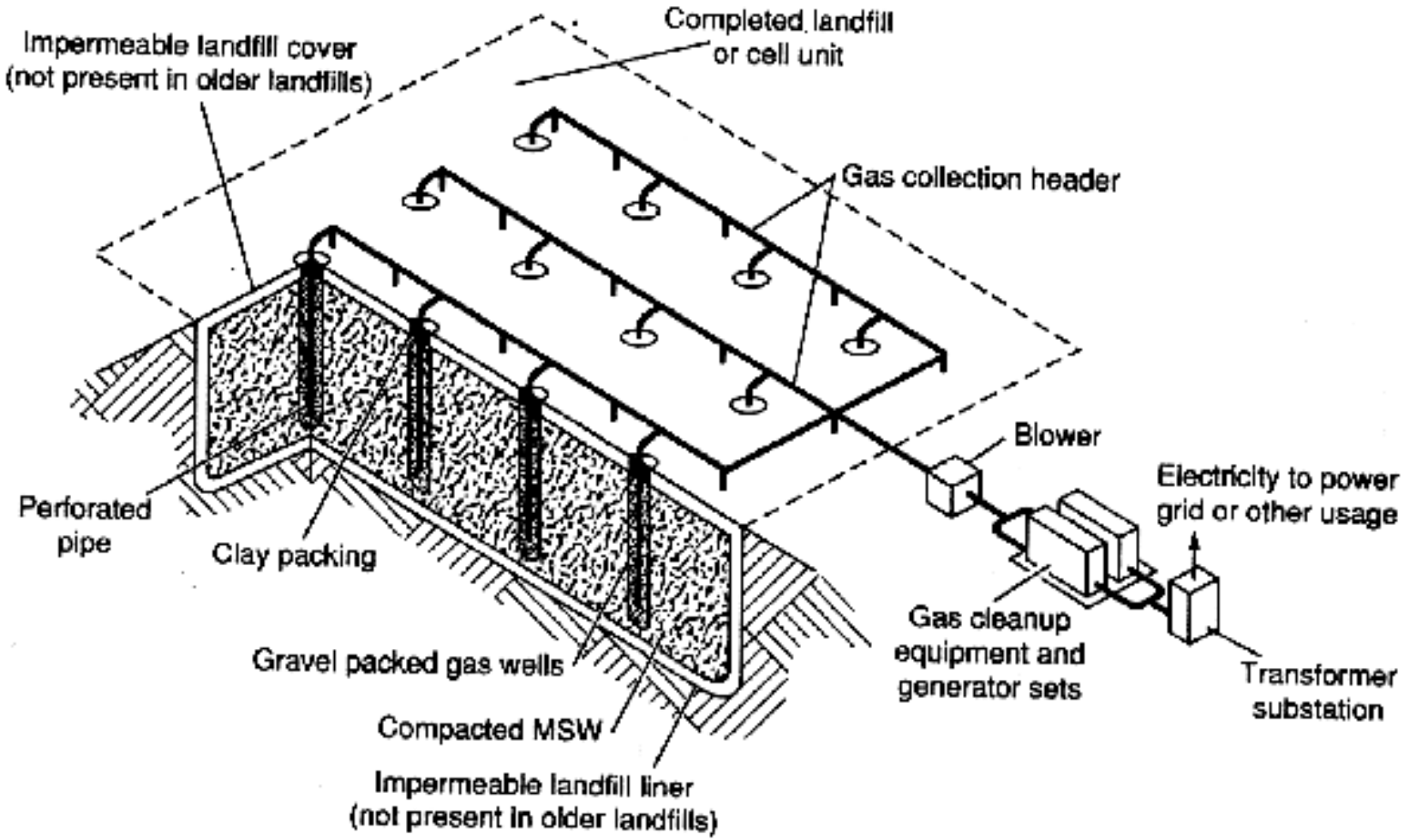
Dump truck

Landfill Cell



Source:
http://earthsci.org/education/teacher/basicgeol/solid_waste/solid_waste.html

Vertical Piping System



Leachate treatment plant

POSTCLOSURE CARE

Activities associated with the long-term monitoring and maintenance of the landfill **(typically 30-50 years).**

MSW rules 2016 recommends at least **fifteen years**

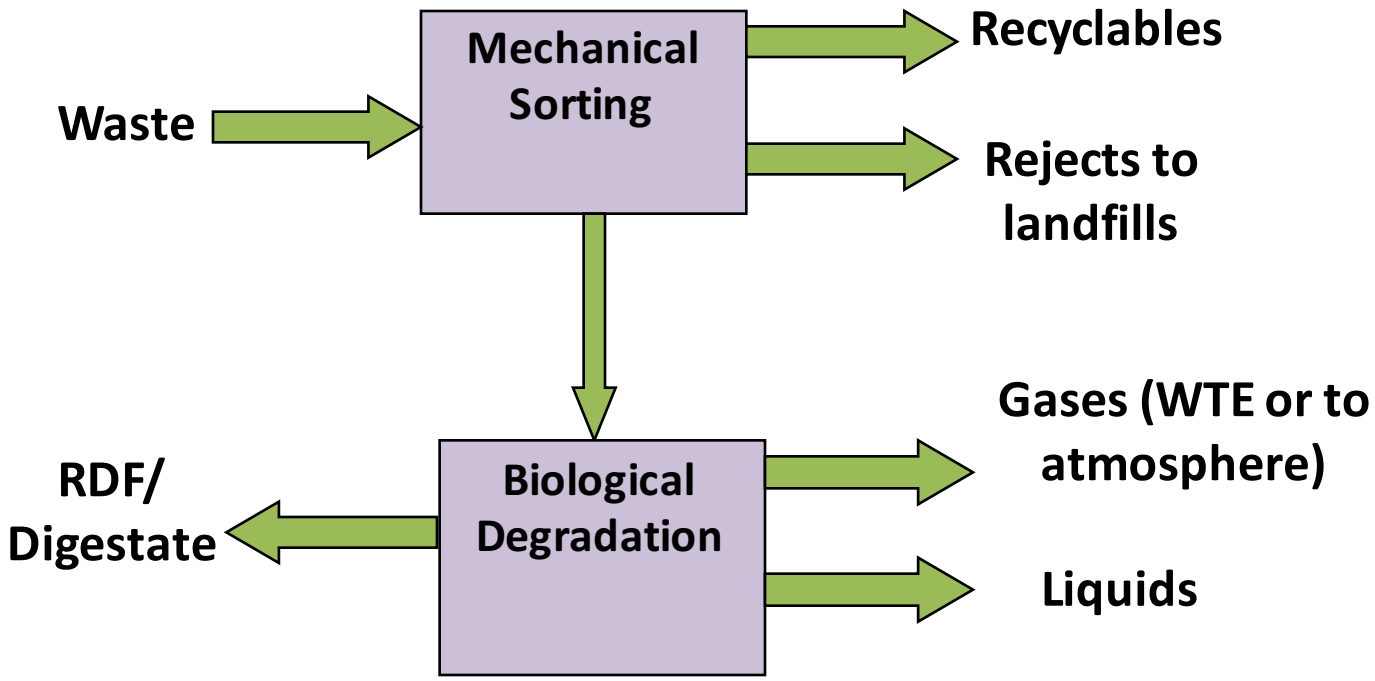
Restored landfill

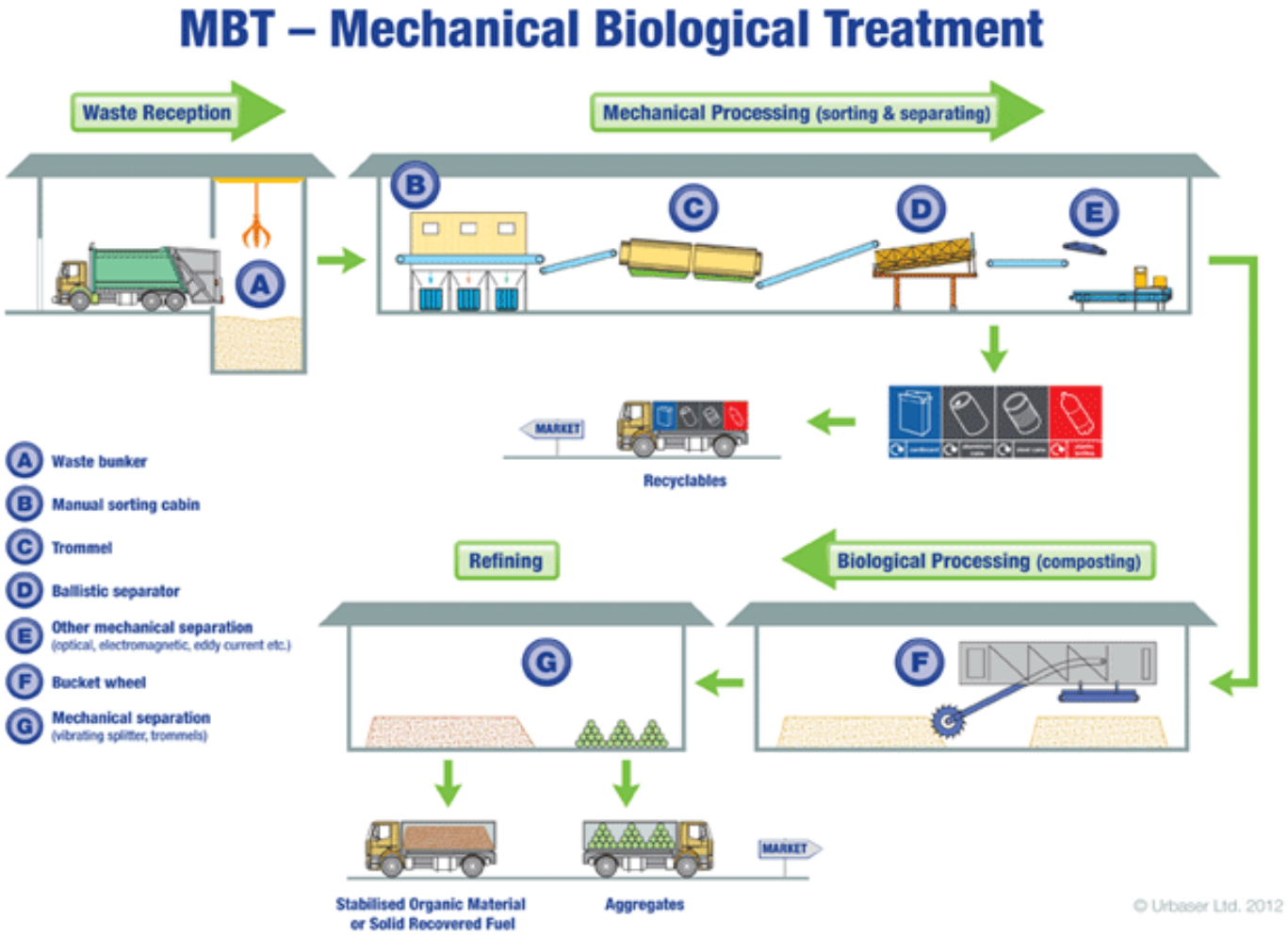
Can be converted to recreational parks, gardens etc..

Example: Estimating Landfill Requirements

Estimate the landfill area needed to handle one year's **MSW** for Mumbai. Assume national average discards, no combustion, a landfill density of 600 kg/m^3, and a single 3m lift. Assume that 20 percent of the cell volume is soil used for cover.

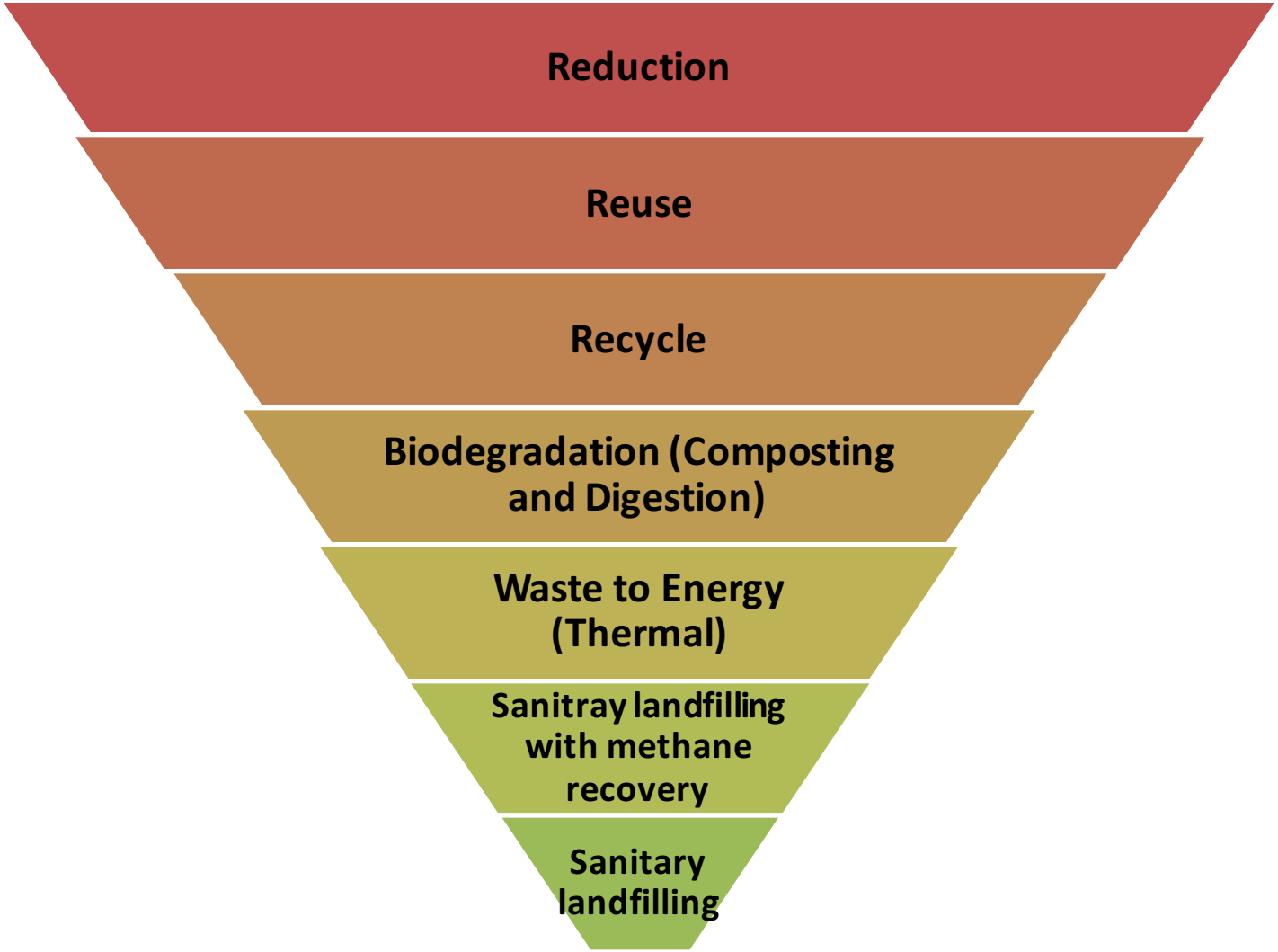
MBT– Mechanical Biological Treatment





http://www.ubbessex.co.uk/technology/

Environmental hierarchy of MSW Management



3R's of better MSW management

Reduce & Reuse

- The most effective way to reduce waste is to not create it in the first place.
- By reducing and reusing, consumers and industry can save natural resources and reduce waste management costs.

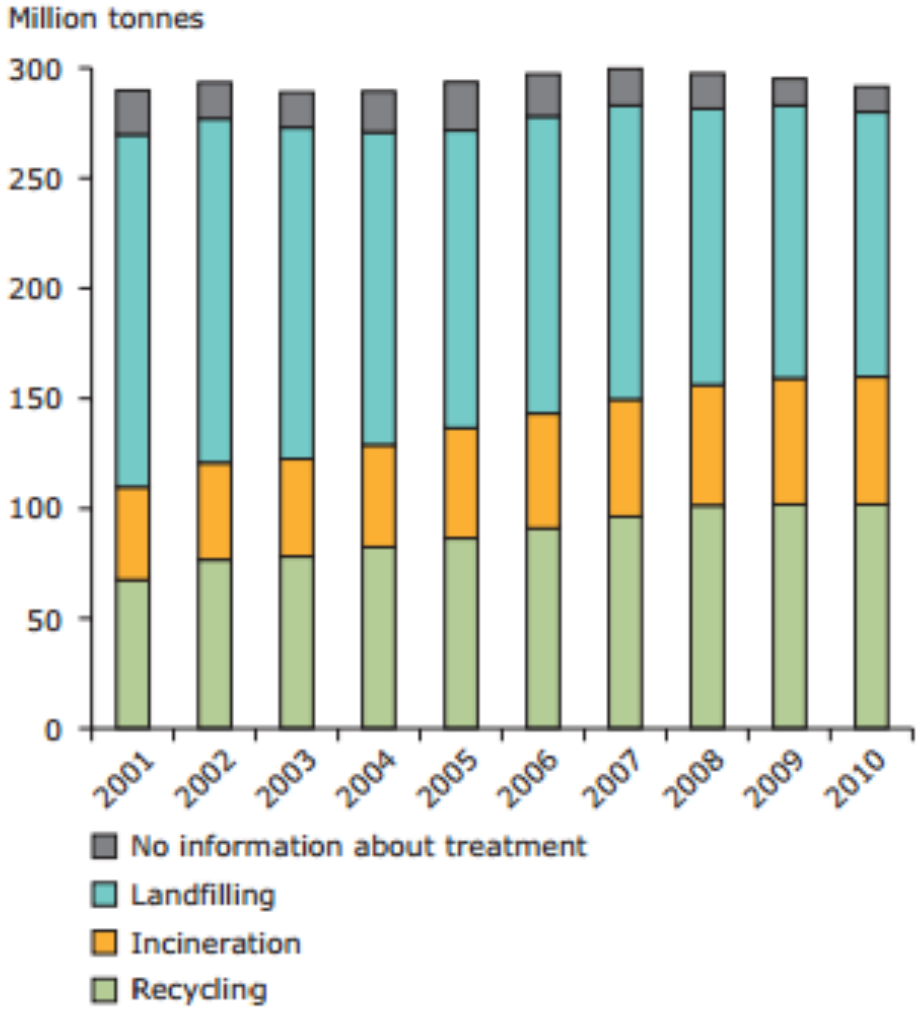
Recycling

Recycling turns materials that would otherwise become waste into valuable resources.

Benefits of Recycling

- Recycling reduces the need for landfilling and incineration.
- Recycling prevents pollution caused by the manufacturing of products from virgin materials.
- Recycling saves energy.
- Recycling decreases emissions of greenhouse gases that contribute to climate change
- Recycling conserves natural resources such as timber, water, and minerals.
- Recycling helps sustain the environment for future generations.

Municipal waste management in 32 European countries, 2001–2010



Source: Managing municipal solid waste — a review of achievements in 32 European countries (EEA Report No 2/2013)

Legal framework

Solid Waste Management Rules, 2016:

- Responsibilities of Generators to **segregate waste in to three streams**: Wet (Biodegradable), Dry (Plastic, Paper, metal, wood, etc.) and domestic hazardous wastes (diapers, napkins, empty containers of cleaning agents, mosquito repellents, etc.) and handover segregated wastes to authorized rag-pickers or waste collectors or local bodies.

- Generator will have to pay 'User Fee' to waste collector and for 'Spot Fine' for Littering and Non-segregation.

Source: http://pib.nic.in/newsite/PrintRelease.aspx?relid=138591

Status of MSW Management

- Only about 75- 80% of the municipal waste gets collected and out of this only 22-28 % is processed and treated and remaining is disposed of indiscriminately at dump yards.

- In 2013-14, municipal authorities have so far only set up 553 compost & vermi-compost plants, 56 bio-methanation plants, 22 RDF plants and 13 Waste to Energy (W to E) plants in the country.

Source: http://pib.nic.in/newsite/PrintRelease.aspx?relid=138591

VIDEO

Recology San Francisco Solid Waste Transfer and Recycling Center

https://www.youtube.com/watch?v=PdBB6s3PDGk