Solid Waste Management
Waste Collection and Disposal

Solid Waste Management - is it Effective?

- Is it a struggle to keep the designated areas clean?
- Are some of the areas are not attended adequately?
- Is there accumulation of Waste?
- Is the rate of waste generation much higher that rate of collection?
- Do your contractors resort to indiscriminate dumping of waste?
- Are there complaints with regard to waste disposal?

Solid Waste Management

- Refuse
- Reduce
- Reuse
- Recycle

Collection

Composition of Waste

- Wet Waste (Bio Degradable)
- Recyclable
- Other
- Composition determines collection/disposal frequency

Why Composition?

- Proportion of Recyclable to Compostable – reduction strategy
- Know constituents and Density – energy recovery and recycling

Waste Composition

Type of Waste	Quantity Estimated Per Day at NDLS (2014)
Fruits/Vegetables	22%
Paper	24%
Glass	4%
Plastic (usable)	7%
Clothes	1%
Plastic (other)	22%
Dust/Stones	19%
Hazardous Waste	<1%

Analysis of 100 kg of SW collected from garbage heap at NDLS Station

SOLID WASTE MANAGEMENT AT NEW DELHI RAILWAYSTATION-A CASE STUDY
Capt. Manju Minhas1, Aparajita Saxena, International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 12, December 2014

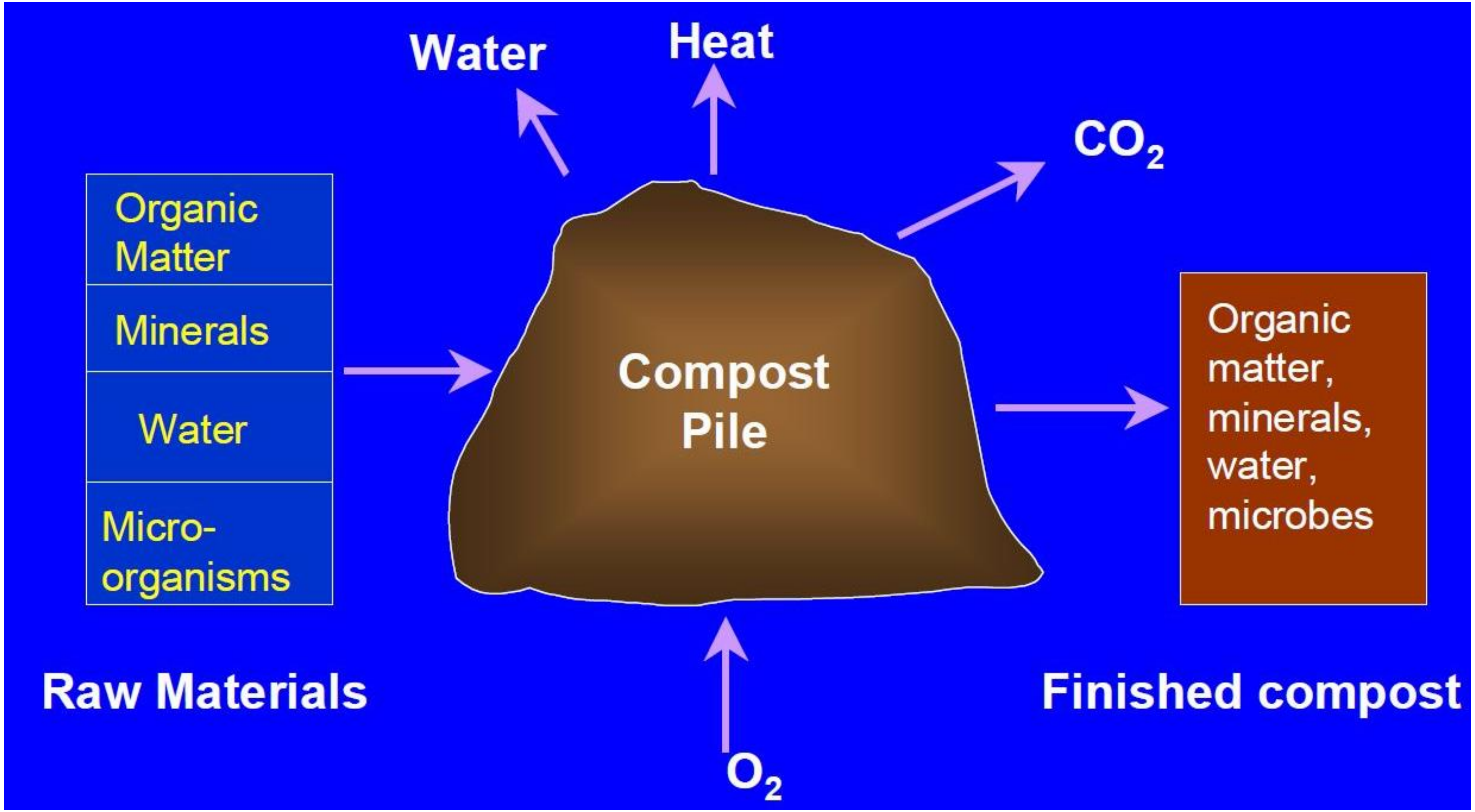
Recycling Bio-Waste : Aerobic Digestion

- Also known as composting
- Use of bacteria to decompose bio-waste in the presence of oxygen
- Requires oxygen, moisture and bacteria

Composting-characteristics and benefits

- Controlled decomposition. Natural breakdown of organic residues
- Biologically stable, humic substance - excellent soil supplement
- Easier to handle than manure and other raw organic materials
- Easy to store and odor-free
- Improves the chemical, physical, and biological characteristics of soils
- Sandy Soils-Improves water retention
- Clayey Soils-promotes soil structure
- Increases the stability of soil aggregates
- Increases soil fertility and can reduce fertilizer requirements up to 50%

The Composting Process



Basics of Composting

- Three basic ingredients:
- **Browns** - dead leaves, branches, and twigs
- **Greens** - grass clippings, vegetable waste, fruit scraps, and coffee grounds
- **Water** - the right amount of water is important for compost development
- The compost pile should have browns to greens ratio of about 2.5:1
- Alternate layers of organic materials of different-sized particles
- Browns provide carbon for your compost, the greens provide nitrogen
- Water provides moisture to help break down the organic matter

What is suitable for composting?

Suitable for Composting	Unsuitable for Composting (and why)
Fruits and vegetables Eggshells Coffee grounds and filters Tea bags Nut shells Shredded newspaper Cardboard, Paper Grass clippings, Houseplants, Leaves Sawdust, Wood chips Cotton and Wool Rags	• Dairy products (e.g., butter, milk, yogurt) and eggs • Fats, grease, lard, or oils • Meat or fish bones and scraps - Creates odor, attract pests such as rodents and flies • Diseased or insect-ridden plants - Diseases or insects might survive and be transferred back to other plants • Pet wastes (e.g., dog or cat feces, soiled cat litter) - Might contain parasites, bacteria, germs, pathogens, and viruses harmful to humans

What happens during composting? (1/2)

- Mesophilic organisms (optimum growth temperature range = 20-45 °C) multiply rapidly on the readily available sugars and amino acids
- They generate heat by their own metabolism and raise the temperature to a point where their own activities become suppressed
- Then a few thermophilic fungi and several thermophilic bacteria (optimum growth temperature range = 50-70 °C or more) continue the process, raising the temperature of the material to 65 °C or higher
- This peak heating phase is important for the quality of the compost as the heat kills pathogens and weed seeds
- The active composting stage is followed by a curing stage, and the pile temperature decreases gradually

What happens during composting? (2/2)

- The start of this phase is identified when turning no longer reheats the pile
- At this stage, another group of thermophilic fungi starts to grow
- These fungi bring about a major phase of decomposition of plant cell-wall materials such as cellulose and hemi-cellulose
- Eventually, the temperature declines to ambient temperature
- By the time composting is completed, the pile becomes more uniform and less active biologically although mesophilic organisms recolonize the compost
- The material becomes dark brown to black in color. The particles reduce in size and become consistent and soil-like in texture
- In the process, the amount of humus increases, the ratio of carbon to nitrogen (C:N) decreases, pH neutralizes, and the exchange capacity of the material increases

Factors affecting aerobic composting (1/5)

- ***Aeration***
- Aerobic composting requires large amounts of Oxygen, particularly at the initial stage
- If supply of Oxygen is not sufficient, the growth of aerobic micro-organisms is limited, resulting in slower decomposition
- Moreover, aeration removes excessive heat, water vapor and other gases trapped in the pile
- Heat removal is particularly important in warm climates as the risk of overheating and fire is higher
- ***Moisture***
- Moisture is necessary to support the metabolic activity of the micro-organisms
- Composting materials should maintain a moisture content of 40-65 percent
- Where the pile is too dry, composting occurs more slowly, while a moisture content in excess of 65 percent develops anaerobic conditions
- In practice, it is advisable to start the pile with a moisture content of 50-60 percent, finishing at about 30 percent

Factors affecting aerobic composting (2/5)

- ***Nutrients***
- Micro-organisms require C, N, phosphorus (P) and potassium (K) as the primary nutrients
- Of particular importance is the C:N ratio of raw materials. The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable
- Where the ratio is higher than 40:1, the growth of micro-organisms is limited, resulting in a longer composting time
- A C:N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide, and odor can be a problem
- The C:N ratio of the final product should be between about 10:1 and 15:1
- Browns are high in Carbon and Greens are high in Nitrogen

Factors affecting aerobic composting (3/5)

- ***Temperature***
- The ideal temperature for initial composting stage is 20-45 °C, at subsequent stages with thermophilic organisms taking over, a temperature range of 50-70 °C may be ideal
- High temperatures characterize aerobic composting process and serve as signs of vigorous microbial activities
- Pathogens are normally destroyed at 55 °C and above, while critical point for elimination of weed seeds is 62 °C
- Turnings and aeration can be used to regulate temperature

Factors affecting aerobic composting (4/5)

- ***Lignin content***
- Lignin is one of the main constituents of plant cell walls, and is resistant to microbial degradation
- Lignin makes the actual C:N ratio lower than the one normally cited
- Lignin serves as a porosity enhancer, which creates favorable conditions for aerobic composting
- Therefore, while the addition of lignin-decomposing fungi may in some cases increase available C, accelerate composting and reduce N loss, in other cases it may result in a higher actual C:N ratio and poor porosity, both of which prolong composting time

Factors affecting aerobic composting (5/5)

- ***pH value***
- Composting process lends itself to accepting material with a wide range of pH
- However, the pH level should not exceed 8
- At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere

Optimal conditions for rapid aerobic composting

Condition	Acceptable	Ideal
C:N ratios of combined feedstocks	20:1 to 40:1	25-35:1
Moisture content	40-65%	45-60% by weight
Available oxygen concentration	>5%	>10% or more
Feedstock particle size	< 1 inch	Variable
Bulk density	600 g/cum	600 g/cum
pH	5.5-9.0	6.5-8.0
Temperature	43-66^{o}C	43-66^{o}C

Recycling Bio-Waste : Anaerobic Digestion

- Breakdown of bio-waste in absence of oxygen
- Slower as compared to aerobic digestion
- Higher skills required
- 10 kg wet weight of biowaste needed to produce 1 m^3 of biogas
- This contains approximately 6 kWh (or 21.6 MJ) of energy
- This is equal to about 500 g of diesel

Anaerobic digestion- characteristics and benefits

- Anaerobic digestion (AD) - organic matter decomposed in absence of oxygen
- Various microorganisms are involved in the AD process
- It generates two products: energy-rich biogas and nutritious digestate
- AD process requires airproof reactor tanks, aka digesters
- Benefits
  - generation of energy
  - reduction of greenhouse gases
  - reduced dependency on fossil fuels, reducing pollution from use of fossil fuels
  - reducing solid waste volumes and thus waste disposal costs
  - preservation of the natural resources by reducing deforestation

The anaerobic digestion process

- **Hydrolysis** - This the slowest of the four degradation steps
- The bacteria transform proteins, carbohydrates and fats to amino acids, monosaccharides and fatty acids respectively
- This is important as particulate organic materials are too large to be directly absorbed by microorganisms as food source
- **Acidogenesis** - This is the second stage
- Acidogenic bacteria convert the monomers of sugars and amino acids to ethanol and acids, acetate, H_2 and CO_2
- The degradation of amino acids also leads to production of ammonia

The anaerobic digestion process

- **Acetogenesis** – The third stage
- Both long chain fatty acids and volatile fatty acids and alcohols are transformed by acetogenic bacteria into hydrogen, carbon dioxide and acetic acid
- During this reaction the BOD and the COD are both reduced and the pH decreased
- Hydrogen plays an important role in this process. The hydrogen concentration in a digester is an indicator of its “health”

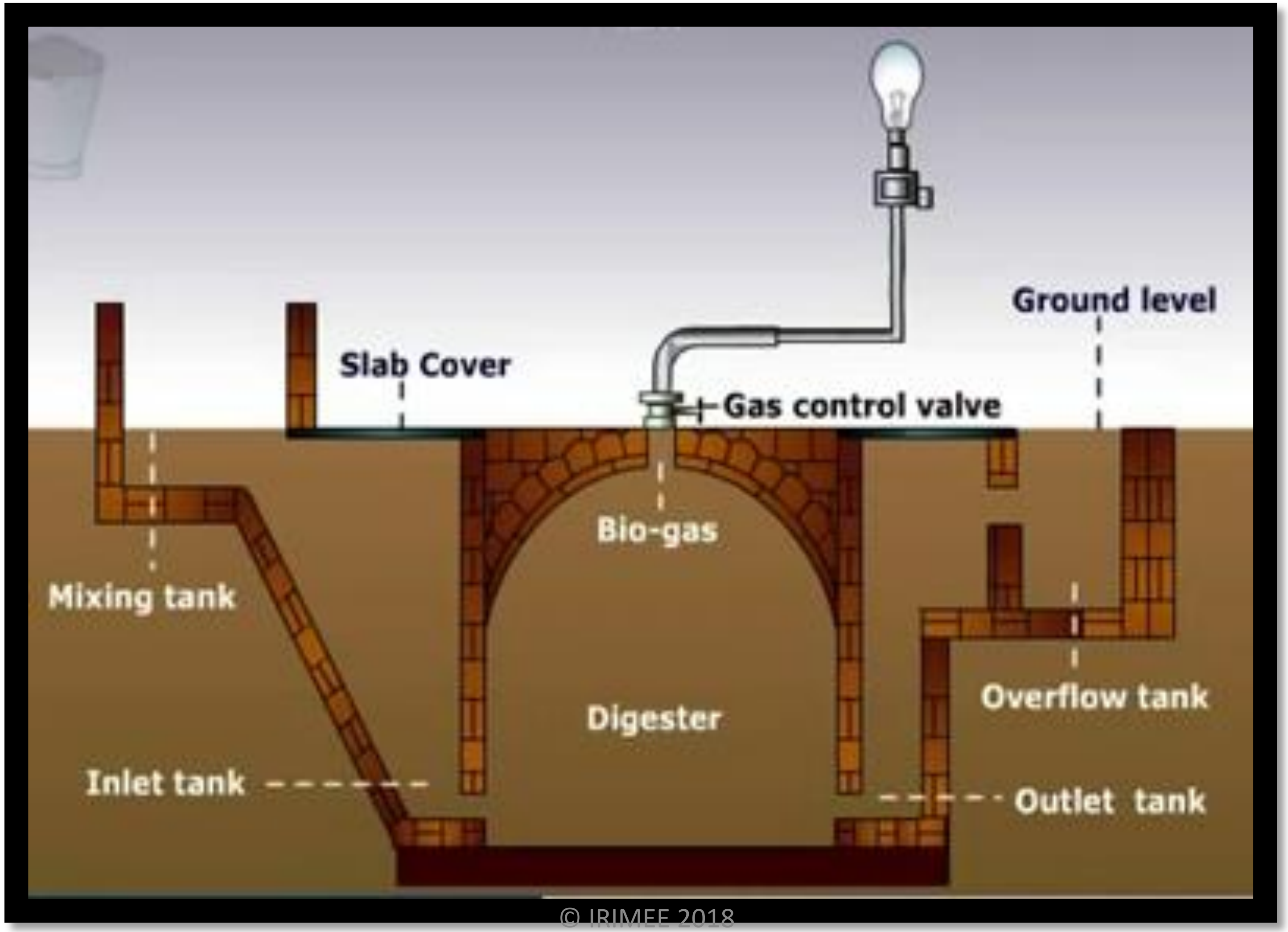
The anaerobic digestion process

- **Methanogenesis** – The final stage
- Methanogenic bacteria convert the hydrogen and acetic acid to CH_4 and CO_2
- Methanogenesis is affected by conditions in the reactor such as temperature, feed composition and organic loading rate
- The gaseous product, biogas, consists mainly of CH_4 and CO_2 but also contains several other gaseous “impurities” such as H_2S, nitrogen, oxygen and hydrogen
- Biogas with a CH_4 content higher than 45 % is flammable; the higher the CH_4 content the higher the energy value of the gas

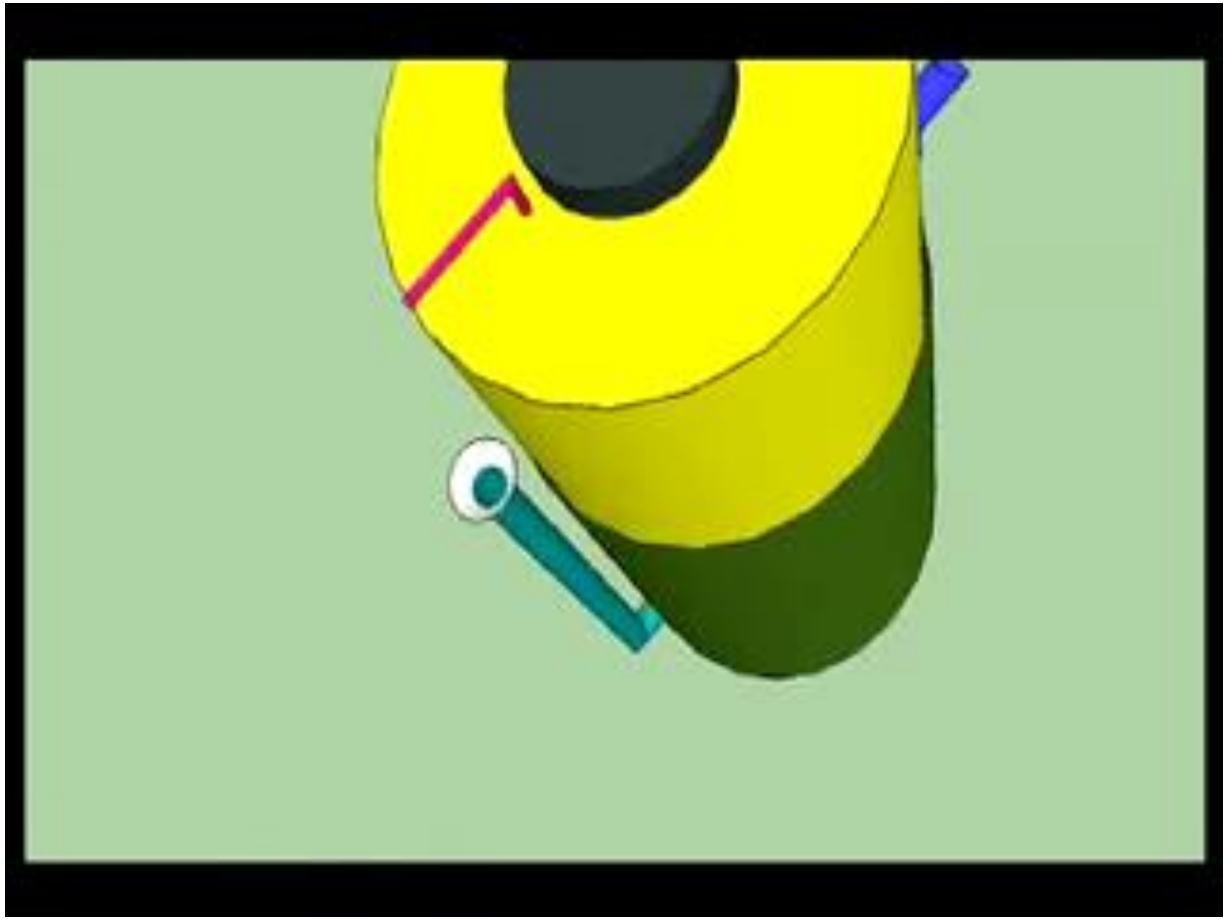
Operational Parameters

- Temperature-30 to 40 ^{o}C
- pH-6.5 to 7.5 add lime if pH drops
- C:N Ratio- 16 to 25. high C:N => less gas produced, low C:N => high pH
- Inoculation and Start Up- dil. cow-dung (1:1) ~ 10% of reactor vol.
- Organic Loading- less than 2 kg VS/m^{3}·day (VS – Volatile solid)
- Hydraulic Retention Time-10 to 40 days (Vol of reactor/Vol of I/P per day)
- Mixing-feeding back digestate outflow into the inlet. Prevents formation of scum

Fixed Dome Bio-Digester



Floating-Drum Type Bio-Digester



Maintenance Issues (1/3)

- The plant must be fed regularly because the bacteria require constant feeding
- Particle size of all feedstock must be reduced to 3 – 5 cm in length and mixed with water or effluent from the biogas plant
- Impurities (e.g. inorganic materials such as glass, metals, plastics etc.) should be removed before pre-treatment
- The amount of daily feedstock should be measured using a scale or using selected containers where the required filling level is indicated

Maintenance Issues (2/3)

- Biogas stoves need to be cleaned regularly
- Gas pipes, joints to be checked for leakage
- Condensed water in the pipes should be removed on a weekly basis to ensure that the biogas can pass through the gas pipe easily
- The appearance and odor of the digested slurry needs to be checked on a regular basis. If well digested, the effluent should not have an acidic odor
- Checking the pH of the digested slurry by means of litmus paper or a pH-meter can help to examine biological activity
- If the pH is below 5.5, feeding has to be stopped and only started again with a gradually increasing feeding rate once the pH has stabilized

Maintenance Issues (3/3)

- Check blockage of inlet pipe
- Check slurry level at overflow tank – should be high before gas is consumed and decrease as gas is consumed
- Remove sludge from bottom
- Painting to prevent corrosion
- Digestate -The effluent from digesters treating only kitchen waste is safe for reuse in the garden and is a good organic fertilizer

Aerobic v Anaerobic digestion

Aerobic digestion	Anaerobic digestion
• In the presence of oxygen • Faster than anaerobic • Temperature rises to about 70^{o}C • Almost all energy is used • Not very sensitive to environmental changes	• In the absence of oxygen • Slower than aerobic • No significant rise in temperature • Energy is left unused in the form of methane gas • Highly sensitive to environmental changes

Lessons Learnt

- Recycling of solid waste has several benefits
- Recycling bio waste is not too complicated, however it is not too simple either
- Segregation of waste is crucial for success of any recycling initiative
- Selection of recycling technology depends on waste composition
- Decisions taken on the basis of solid data will give the desired results
- There are no shortcuts to successful solid waste management

Collection and Transportation

- Key activities in Solid Waste Management (SWM)
- Stages
  - Initial collection
  - Loading , Unloading
  - All stages of Transportation
  - Disposal at final destination
- Includes
  - Collection of Discrete Waste Material
  - Sweeping
  - Cleaning of Drains

Lesson

- Think about the entire process
- From the point of generation
- To the point of final disposal
- This will help establish a workable SWM System
- Minimizing multiple handling of waste is a good way to start

How Can We Estimate the Quantity

- Sampling is one option
- Estimation based on experience expertise is another option
- Availability of resources and confidence determines the choice
- Quantification is required in terms of weight and volume
- Density of Waste determines many future decisions
  - How Many Lorry Trips?
  - Size of Garbage Bin

Waste Collection

- When? Frequency/Timing
- Where? Place
- How? Method
- Frequency of Collection decides the size of collection containers

Stages of Collection

Collection
- From Coach Bays

Storage
- In Polythene Bags/Storage Bins

Unloading
- At Intermediate Stations
- Multi Color Bins?

Stages of Collection

- Transfer
  - From Storage Bins on Platforms
- Transport
  - In suitable Vehicle
  - Multiple Compartments/Trips
- Unloading
  - Disposal Point

Storage Bins

- Height – decided accessibility
- Size of Opening
- Volume
- Location
- Shape – Tapered
- Ground Clearance
- Durable – Suit the composition, frequency and handling method
- Spare (Unit Exchange) help in effective SWM

Sweeping and Drain Cleaning

- Waste on the ground depends on
  - Habits
  - Availability of Waste Storage Bins
- Much of this ends up in open drains
- Drain Cleaning Equipment
  - Able to handle wet dense material
  - Profile to suit the bottom surface of drain
  - Collection of silt and muck collected from cleaning activity

Copying Western Practice

- Blind copying of successful models in other countries not advisable
- Difference in waste composition, density
- Different social and cultural norms
- Difference in Infrastructure Quality
- Quality of Labour
- Developed Countries generally generate more waste per Capita
- The waste generated in Developed Countries is also less dense

It is all about Waste Management!

- Waiting
- Movement
- Transportation
- Rework

Recycling

- Adequate Quantity
- Dependable Supply
- Proximity
- Quality of Material
- Stable Market

Other Factors

- Dignity
- Physical Stress
- Child Labour
- Gender Aspects
- Massive Awareness Campaigns (á lá Pulse Polio)

A Long Term Strategy

- Solid waste is not a transitory phenomenon
- So we must not think of temporary solutions
- We need to invest wisely to tackle solid waste effectively
  - Money
  - Time
  - Effort
  - Thought
  - Energy

Development
which meets the needs
of the present generation
without compromising the needs
of the future generations
to meet their own needs