# *SOLID WASTE MANAGEMENT*

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# Solid Waste Engineering

Dealing with Solid Waste: It is “More Management than Engineering”

This may be true……..but management alone cannot solve the problem, for sure.

# *Municipal Solid Waste (MSW)*

- MSW = Trash+Rubbish+Refuse+Garbage
- MSW is the waste that is collected in the municipal bins / containers
- Sources of MSW: Domestics, hotels, markets, offices, commercial establishments,etc.
- It does not contain Wastes from: Hospitals, Industries, nuclear installations, etc.

# *Municipal Solid Waste (MSW)*

- It is consistently *INCONSISTENT*
- Design of the treatment facilities is difficult
- It is not hazardous; but the problem is its very large Quantity/Volume
- It is a problem in Cities / Towns / Municipalities; but not a big issue in Villages / Rural areas
- The problem is MSW can be seen and smelled

# *MSW Generation Rate*

- Generation rate varies from season to season, place to place
- It depends upon the affluence, season, education, living habits, traditions, etc.
- In India: 0.15 kg/person/day in rural areas
  0.40 kg/person/day in urban areas
- Possible to estimate the total quantity generated

# *SOLID WASTE MANAGEMENT*

- Waste Collection and Storage
- Waste Transportation
- Recovery through Sorting & Recycling
- Recovery through Processing (Biological or Thermal Route)
- Waste Transformation (Volume reduction, Toxicity reduction, etc.)
- Final Disposal

# *HIERARCHY OF SOLID WASTE MANAGEMENT OPTIONS*

1. Waste minimization at source
2. Material Recycling
3. Waste Processing (Energy / Material recovery)
4. Waste Transformation (no recovery)
5. Land-filling

# *Sorting and Materials Recovery*

- Sorting: separating/segregation of various components
- Sorting can be done at any stage
- Primary Sorting: at any stage (rag pickers)
- Secondary Sorting: sorting on the primary sorted materials (kabaris, middlemen)
- Tertiary Sorting: sorting on the secondary sorted materials (for recycling)

# *Storage of MSW at Source*

- Use containers (buckets, plastic bins, metal bins, plastic bags) with or without lids
- Containers without lids can store the waste only for a day; not beyond
- Capacity 15 lit for a family of 5 members
- Have two containers: one for biodegradable wastes and the other for recyclables
- Domestic haz. wastes should be dealt separately

# *Primary Collection of MSW*

- Removing waste from the storage at sources/street sweeping
- In India, door-to-door collection exists only at a few places
- In Indian condition, the biodegradable wastes are to be collected everyday
- Handcarts or tricycles may be used
- Instead of the traditional ones, a handcart having 4-6 detachable containers (30-40 lit capacity each) can be used

# *MSW Storage Depots*

- Wastes collected (primary collection) go to the large municipal depots
- the collection vehicles carry the  waste from these depots for treatment/transformation
- The depots must be suiting the primary collection system and the transportation vehicles.
- Depots should be properly positioned along the road side

- For container size 3-10 $m^3$ capacity, distance between 2 depots should not be more than 500m
- Shorter distance for smaller depots: 1 $m^3$
- Container size depends upon the density of the waste and the quantity of waste produced
- In India: density is about 500 kg/ $m^3$
- 1 tonne MSW requires about 2 $m^3$ volume
- Provide double the capacity calculated

- Height of the depot should be less than 1 m

Stationary type and hauling type

- Stationary type depot: shall be emptied to the vehicle
- hauling type depot shall be taken along with the vehicle or emptied to the truck mechanically
- The containers that are pulled along shall have wheels
- Life of large containers: 8 to 10 years
- Life of large handcarts: 4 to 5 years

# *Transportation of MSW*

- Transportation vehicles should be compatible with the storage depots
- vehicles either empty the depot (manually or mechanically) or haul it along with
- Manual loading: unhygienic/inefficient/time consuming
- Loader loading: spoils the floor/walls of the depot
- Ordinary truck capacity: 5 tonnes/trip

- Vehicles can carry the containers or pull along with them
- Vehicles can have compaction arrangement; but may not be useful if the density is very high like 500 kg/$m^3$
- TRANSFER STATIONS are required if the disposal site/treatment facility is far away (>10km)
- From these stations, larger capacity vehicles (15 to 20 $m^3$) carry the waste rather than many small vehicles creating more pollution and traffic problems

# *Routing of MSW collection vehicles*

This is for:

- minimizing the distance of transport
- minimizing the time of transport
- minimizing the pollution during transportation
- minimizing the traffic jams and other inconveniences

# *Minimize the disntance of transport*

Two basic approaches:

- The Chinese Postman Problem (arc routing)

  *Finding the minimum distance of a continuous tour through the network that travels all the arcs (roads)*

- The traveling salesman problem (node routing)

  *Finding the minimum distance of a continuous tour through the network visiting all the nodes (container locations)*

# *For MSW collection & transportation: the 2nd method*

- Node routing: to construct a tour through ***n*** points keeping the total distance minimum

  It is difficult to solve.

- Two methods to solve it

1. *The Exhaustive procedure*
2. *Heuristic algorithm*

# *The Exhaustive Procedure*

- Number the nodes (container locations) with integers 1 to n
- Generate all permutations of the first (n-1) positive integers;  that is (n-1)!
- For each permutation, tour is constructed and it's cost/distance/time is computed
- The tour having the least cost (or distance or time) is chosen

# *Heuristic Algorithm*

- Based on the Hill climbing idea (at each node, find out the next cheapest node to visit)
- Here the problem is: it picks up cheap nodes in the beginning; but towards the end, it may have to go for very expensive nodes.
- To avoid this: repeat the algorithm for the same initial nodes going back taking the cheapest route. Then compare the cheapest route.

# TREATMENT TECHNIQUES FOR MSW

- Biological route: the most acceptable option
  - Composting
  - Biomethanation
- Chemical Route: not popular for MSW
- Physico-chemical Route: not popular for MSW
- Thermal Route: Costliest; but rapid
  - Incineration
  - Gasification
  - Pyrolysis

# *Composting of MSW*

- Composting: organized method of producing compost by adopting and accelerating the natural decomposition phenomenon
- Compost : an organic manure containing N,P,K and other micro-nutrients
- Compost should be used with other chemical fertilizers for optimum results

# *Composting Techniques*

- Anaerobic Composting
- Aerobic Composting
  - Conventional windrow Composting
  - Rapid Composting
    - Vermi-composting
    - Mechanical Composting

- Composting: aerobic or anaerobic
- Aerobic composting:

  *using aerobic microorganisms,*

  *end products are $CO_2$, $NH_3$, nitrates, etc*

  *Carbon is the source of energy*

  *exothermic reaction and temp. rises*

  *all pathogens are killed*

  *overall, it takes 2-4 months*

  *no foul smell*

- Anaerobic composting:
  - *using anaerobic microorganisms*
  - *reduction reaction*
  - *end products are $CH_4$, $CO_2$, $H_2S$, etc*
  - *temperature does not increases*
  - *pathogens are not killed*
  - *it takes 4 to 6 months*
  - *odour problem*
  - *large space requirements*

*For MSW, on municipal scale, Aerobic Composting is preferred*

# *Factors affecting Aerobic Composting*

- Microorganisms
- Shredding of refuse
- C/N ratio
- Temperature
- Moisture content
- Windrow details
- Aeration/turning

# *Micro-organisms*

- In the aerobic systems, there are many organisms actively participating !

  *bacteria, actnomycetes, fungi, others*

- In the initial stages: mostly mesophilic form (temp 30 to 40 $^{o}$C)
- then: mostly thermophilic bacteria and fungi (60 to 70 $^{o}$C)
- In final stage: mesophilic bacteria and fungi

- Bacteria: breaks down mostly protein and other organic matter
- Fungi and Actinomycetes decomposes lignin and cellulose
- Most of the organisms for composting are readily available in the MSW itself.
- But there are inoculums and enzymes claiming to hasten composting. This is required for sure for agricultural and industrial wastes

# *Shredding of the MSW*

- For better bacterial invasion
- Shredding destroy the natural resistance of the vegetation to microbial invasion
- Provides larger surface area
- Better availability of oxygen
- Uniform and rapid decomposition
- Materials become more homogeneous
- Better fly control/moisture control

- Desirable size for composting: less than 2 inch
- Material size governs (to certain extent) the size of the finished product
- Compost for flower gardens/lawn: < 1 cm

# *C/N ratio*

- C/N ratio available is important as all C present may not be available for degradation
- For rapid composting, initial C/N ratio of the waste = 30 is ideal. (range 26 to 32)
- If C/N ratio is >>30, add N sources like blood, sewage sludge, slaughter house wastes, etc.
- If C/N ratio is <<30, add C sources like straw, saw dust, paper, etc.
- For the finished compost product: C/N ratio = 16-20 is the best

- If C/N ratio is >>20, robbing of nitrogen takes place. There shall be a delay for the availability of N to the plants. This is because the excess C tend to use N in the soil to build cell protoplasm.
- If C/N ratio is <<20, that compost cannot improve the soil structure considerably.

# *Temperature*

- MSW has good insulation properties; so the temperature shoots up in aerobic composting.
- It may increase to 65 to 70 $^{o}$C. But optimum temp is 50 to 60 $^{o}$C
- If temp is > 70 $^{o}$C, it may inactivate the enzymes/organisms
- All pathogens shall be killed if 50 to 60 $^{o}$C is maintained for 5-7 days
- No temp. rise in anaerobic composting

# *Moisture Content*

- Optimum : 45 to 55 % by weight
- If moisture is considerably less than the optimum, the physiological needs of the organisms are not met.
- If moisture is considerably greater than the optimum, pores may be blocked affecting the oxygen supply. System may turn anaerobic
- If moisture is < 40%, just add water
- No composting if moisture is < 12 %

# *Windrow Dimensions*

- For aerobic composting, materials should be loosely packed.
- If windrow height is too much, self weight causes some compression and the pore space reduces
- If windrow height is too low, heat loss will be high and temperature goes below optimum
- Height can be more in cold season/countries
- For MSW, for simple windrow, height shall not be more than 1.5 to 1.8 m and not less than 1 to 1.2 m , width: 2.4 m to 3.6 m

- Height is in between 1.8 to 2.7 m for the windrows with air circulation arrangement at the center. In this case, width is 3.6 m to 6.1 m
- Turning / mixing equipment also decides the height of the windrows

# *Finished Product – Ripe Compost*

- Colour: black brown or black
- Odour: earthy
- Crumbly in nature
- Weight: about 50 % of the original waste
- It is neither very dry nor watery
- N,P,K content > 1% (each)
- C/N ratio  < 20

# *MSW Compost Plant*

- Major expenditure (capital and operational) is for the SEPERATION of the bio-degradable from the inerts
- An array of separation techniques may be required
- *Separation may be carried after or before Composting*

| | |
|---|---|
| • Air Classification | • To separate light materials |
| • Magnetic Separator | • For ferrous metals |
| • Screens | • Size Separation |
| • Manual Separation | • Materials that can be hand picked |

- Many compost plants are likely to come up in future
- This is a promising technology for MSW management.

…….*However*…..

- There should be a better market for the compost
- Subsidize the price of compost
- Hike the price of chemical fertilizers

# *Vermi-Composting (Rapid Composting)*

- Bio-degradable are degraded by the aerobic bacteria
- Earthworms feed on the organic matter. During the passage through the worm's alimentary canal, it is converted to a simpler humus rich material due to the action of the enzymatic secretions and bacteria.
- Earthworms are effectively used for maximizing the growth of aerobic bacteria
- Time requirement: about 1 to 1.50 months

# *Earthworms*

- They are invertebrates, Phylum: Annelida
- More than 3000 species
- In India, there are about 500 species
- Only surface dwelling earthworms are useful a composters
- Deep burrowing type is not preferred
- Most suitable species: Eudrilus Eugeinae and Eisenia Foetida

# + *and* – *of vermi-composting*

- Simple to construct and operate
- No mechanical/electrical parts
- Minimum cost
- High process stability
- Elimination of pathogens
- Large land requirements
- Uncertainty and lack of understanding
- Slow nature ( about 1 to 1.5 months )

- Vermi-Composting is a viable and eco-friendly technology for MSW management
- But mostly feasible for small community or campus (NOT SUITABLE ON A LARGE~SCALE)
- There should be a good market for vermi-compost for self-sustainability of a vermi-compost project

# COMPOST QUALITY

| | VERMICOMPOST | ORDINARY COMPOST |
|---|---|---|
| **Nitrogen (%)** | 2.5 - 3.5 | 0.5 - 1.5 |
| **Phosphorus (%)** | 0.5 - 2.0 | 0.5 - 0.9 |
| **Potash (%)** | 1.5 - 2.0 | 1.2 - 1.4 |

ò Besides, Vermi-compost contains beneficial Microorganisms, Actinomycetes, Micro-nutrients Enzymes and Hormones in available form

# *Rotary Drum Composting*

- To decrease the composting time to about 7-10 days to get green compost
- Another 10 to 15 days maturation to get ripe compost
- To get very high quality compost (all N, P. K about 3%)
- Rotary drum composting is a sort of High rate Composting !