IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | NPTEL

INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

Welcome to Week-7

BRAJESH KUMAR DUBEY
DEPARTMENT OF CIVIL ENGINEERING

During this week (Week-7)

- Biological treatment of waste
- Role of Thermal Treatment as part of ISWM
- Thermal Treatment Basics

Other Environmental Factors

- oxygen requirements – can be calculated from the following stoichiometric equation:

$$C_aH_bO_cN_d + \left(\frac{4a + b - 2c - 3d}{4}\right)O_2 \rightarrow aCO_2 + \left(\frac{b - 3d}{2}\right)H_2O + dNH_3$$

- in processes with forced aeration (static piles and in-vessel systems), total air requirement and air flow rate are essential design parameters
- in windrow composting, air is entrained in the waste from the mixing/turning of the windrows
- odours become a problem when sections of the compost become anaerobic – needs good mixing/turning to entrain air

Other Environmental Factors

- destruction of pathogens is an important element in composting

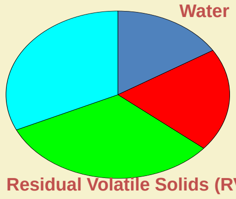
Table 14-8

Organism	Observations
Salmonella typhosa	No growth beyond 46°C; death within 30 minutes at 55–60°C and within 20 minutes at 60°C; destroyed in a short time in compost environment.
Salmonella sp.	Death within 1 hour at 55°C and within 15–20 minutes at 60°C.
Shigella sp.	Death within 1 hour at 55°C.
Escherichia coli	Most die within 1 hour at 55°C and within 15–20 minutes at 60°C.
Entamoeba histolytica cysts	Death within a few minutes at 45°C and within a few seconds at 55°C.
Taenia saginata	Death within a few minutes at 55°C.
Trichinella spiralis larvae	Quickly killed at 55°C; instantly killed at 60°C.
Brucella abortus or *Br. suis*	Death within 3 minutes at 62–63°C and within 1 hour at 55°C.
Micrococcus pyogenes var. *aureus*	Death within 10 minutes at 50°C.
Streptococcus pyogenes	Death within 10 minutes at 54°C.
Mycobacterium tuberculosis var. *hominis*	Death within 15–20 minutes at 66°C or after momentary heating at 67°C.
Corynebacterium diphtheriae	Death within 45 minutes at 55°C.
Necator americanus	Death within 50 minutes at 45°C.
Ascaris lumbricoides eggs	Death in less than 1 hour at temperatures over 50°C.

Air Requirements

- determine the amount of air required to compost 1 tonne of solid waste using an in-vessel composting system with forced aeration
- assume:
  - composition of the waste = $C_{60}H_{94}O_{38}N$
  - moisture content of the organic fraction = 25%
  - volatile solids (VS) = 0.93 x TS (total solids)
  - biodegradable volatile solids (BVS) = 60% of VS
  - expected BVS conversion efficiency = 95%
  - composting time = 5 days
  - oxygen demand is 20%, 35%, 25%, 15% and 5% for the 5 successive days
  - ammonia produced during aerobic decomposition is lost to the atmosphere
  - air contains 23% O_2 and the density of air is 1.2928 kg/m^3
  - a factor of safety of 2 will be used (to assure oxygen content does not drop below 50% of its original value)

Composition of Waste



Air Requirements

- dry mass (total solids) of the 1000 kg of waste:
  $M_{TS} = (1000\ kg \times 0.75\ (dry\ matter)) = 750\ kg$
- mass of volatile solids:
  $M_{VS} = (750\ kg \times 0.93) = 697.5\ kg$
- mass of biodegradable volatile solids:
  $M_{BVS} = (697.5\ kg \times 0.60) = 418.5\ kg$
- mass conversion of the BVS:
  $M_{BVS} = (418.5\ kg \times 0.95) = 397.6\ kg$
- molar mass of BVS compound ($C_{60}H_{94}O_{38}N$):
  $M(BVS) = (60\ (12\ g/mol) + 94\ (1\ g/mol) + 38\ (16\ g/mol) + 1(14\ g/mol)) = 1436\ g/mol$

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Air Requirements

- amount (moles) of O_2 utilized:
  $$O_2 = \left(\frac{4a + b - 2c - 3d}{4}\right) = \left(\frac{4(60) + 94 - 2(38) - 3(1)}{4}\right) = 63.5\ moles\ O_2$$
  $$M(O_2) = (2(16\ g/mol)) = 32\ g/mol$$
- molar mass of O_2: $\left(\frac{mass\ BVS}{moles\ BVS}\right) = \left(\frac{mass\ O_2}{moles\ O_2}\right)$
- mass of O_2: $\left(\frac{397.6\ kg}{1(1436)}\right) = \left(\frac{X\ kg}{63.5\ (32)}\right)$
  $$X = 564.8\ kg\ O_2$$

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Air Requirements

- the volume of air (using a S.F. = 2):
  $$V_{air} = \left(\frac{(564.8\ kg\ O_2) \times 2}{0.23\ kg\ O_2/kg\ air \times 1.2928\ kg\ air/m^3}\right) = 3799\ m^3\ air/tonne\ SW$$
- the largest flowrate is day 2 (35%), so the system needs to be designed to provide: $V_{air} = 3799\ m^3/d \times 0.35 = 1330\ m^3/d$
  $$moles\ H_2O = \left(\frac{b - 3d}{2}\right) = \left(\frac{94 - 3(1)}{2}\right) = 45.5\ moles$$
- the mass of water needed: $\left(\frac{397.6\ kg}{1(1436)}\right) = \left(\frac{X}{45.5\ (2 + 16)}\right)$
  $$X = 226.8\ kg\ H_2O$$

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Water Requirements

- the water content of the waste is initially 25%, so the mass of water
  $M_{water} = 1000\ kg \times 0.25 = 250\ kg$
- over 5 days, assume there is 20% loss of moisture
  $moisture\ loss = 250\ kg \times 0.2 = 50\ kg$
- so, we will have 200 kg of water left at day 5
- however, the composting process needs 226.8 kg, so somewhere in the 5-day process we dropped below the water needs of the system
- so, the water deficit is: $Deficit = (226.8 - 200) = 26.8\ kg$
- let's be conservative and apply a S.F. = 2, so we need 53.6 kg

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Water Requirements

- for day 1, mass of water is 250 kg > 226.8 kg
- so, lets add the 53.6 kg over the next 4 days
  $$M_{added} = \frac{53.6\ kg}{4} = 13.4\ kg/d$$
- this should provide adequate water for the process to complete itself with no moisture problems

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Process and Compost Time

- the time needed to complete the process depends on the system
  - mechanical system — 7 days
  - piles/windrows – turned — 9 – 21 days
  - static piles/some mixing — 30 – 40 days
- when is the process finished?
  - when upon turning the compost, the temperature does not rapidly rise in the pile, which means the organic fuel is gone
  - the material left over is humus-like, dark brown and smells "earthy"
  - the remaining compost is half the original volume

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Process and Compost Time

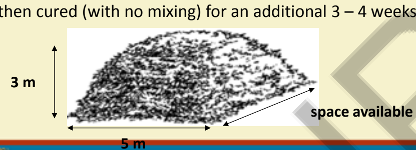
- the compost is then usually cured for an additional 2 – 8 weeks
  - the compost is stored outside in dry conditions and turned occasionally
  - it produces a larger, more diverse microbial population
  - provides a stable source of nitrogen for application to farm land (C:N < 25:1)
  - reduces the temperature so that seeds can survive (germination test)

Composting Techniques

- there are two principle methods of aerobic composting:
  - agitated – the material is agitated periodically to introduce air
  - static – the material remains static and air is blown through the compost

Composting Techniques

- windrow composting
  - organic material is formed into windrows (3 m high, 5 m wide)
  - the compost is turned regularly (up to 2 times per week)
    - front end loader or mixing apparatus
  - complete composting can be accomplished in 1 – 3 weeks
  - the compost is then cured (with no mixing) for an additional 3 – 4 weeks



INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

BRAJESH KUMAR DUBEY
DEPARTMENT OF CIVIL ENGINEERING

Composting Techniques

- aerated static pile composting
  - compost is piled on top of a system of blowers
    - like corrugated steel pipe drainage
  - blower operation is typically controlled by a timer, based on temperature
  - either positive or negative pressure (negative is better)
  - material is composted for 3 – 5 weeks
  - then the compost is cured for another 4 weeks

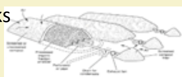
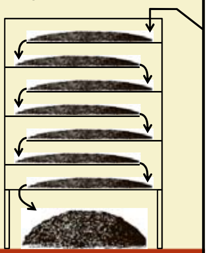


Figure 9-40

Horizontal Reactor

Mechanical or In-vessel Systems

- an industrial form of composting in a closed reactor vessel
- these systems are generally plug flow in an engineered vessel
- the have a rapid process time → 4 – 7 days
- better control of:
  - water content
  - oxygen
  - temperature
  - odour
- needs longer curing → 4 – 12 weeks
- more expensive due to the mechanical configuration
  - essentially, " you pay for the speed"



IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Agitated Bin System

Backyard Composting

- usually pre-built containers or a series of wood bins (fenced in)
- need to be operated well to minimize odours and pests
  - no meat scraps (attract pests, take a long time to decompose)
  - a backyard shredder for fibrous material (wood plants, brush, …)
  - moisture and aeration are the most important control parameters
    - if the initial material added is too dry (sawdust, wood chips), add some water
    - turn the compost pile every 2 – 3 days for good aeration, and to allow for temperature rise (to 60°C) to kill of pathogens
  - climatic conditions
    - composting will occur in summer, and can occur in winter
    - for rainy weather, keep a rounded compost pile to allow good drainage
  - maintain a good "bug" population
    - in addition to the microbes, you will also find a wide range of other organisms
    - fungi, nematodes, roundworms, mites, springtails, centipedes, sow bugs, ground beetles, …

Major Points to Consider – Compost Plant Design

1. provisions should be in-place to handle collection vehicles, surge amounts and downtime of plant
   - at least 2 days +
2. materials should be processed at a uniform rate
   - hence the need for storage capacity in the MRF
3. has the inorganic materials been separated previously, or is it to be separated by processing at the facility
   - stored and sold for money
   - placed/handled by another process
4. how specific must the refuse be
   - is flexibility allowed?
   - just MSW from the local urban areas?
   - if other waste is being allowed, are there provisions for bulking?

Major Points to Consider – Compost Plant Design

5. can other organic wastes be added to the system
   - is it accepting just municipal wet waste, or are there other sources that need to be considered (agricultural waste, WWTP sludge, …)
6. is the end produce free from pathogens/weed seeds
   - QA/QC controls on the produced compost
7. are control measures in-place for fly and odor control
   - positive pressure, HVAC control, …
8. can the facility store/handle finished compost
   - is it equipped to distribute compost to the end market
9. is a market established for the finished compost
   - homeowners – free compost days?
   - commercial landscaping firms – pay for compost?
10. are there zoning by-laws that need to be satisfied

Major Points to Consider – Compost Plant Design

11.specific design requirements
- process design – C:N ratio, moisture content
- composting area sizing – mass, densities, windrow length, shrinkage
- finished compost storage area – 3 months +
- runoff collection pond sizing – design storm events
- land treatment design for runoff – hydraulic budget of the soil
- costing – unit operations, equipment, personnel, …

Anaerobic Digestion

- to maintain an anaerobic treatment system, the non-methanogenic and methanogenic bacteria must be in a state of dynamic equilibrium
- ideal conditions for digestion include:
  - pH = 6.5 – 7.5
  - need lots of alkalinity → 1,000 – 5,000 mg/L as $CaCO_3$
    - so that the pH does not drop below 6.2
    - methane bacteria can not function below this point
  - zero O_2
  - a sufficient amount of nutrients (N and P) need to be present
  - optimal temperatures are:
    - mesophilic → 30 – 38°C, and
    - thermophilic → 55 – 60°C

Anaerobic Digestion

- batch systems – need a large footprint, but low CH_4 production
  - low tech systems
  - ideal for developing countries
- two-stage system the best
  - stage 1 – provides a home for the acidogens; allows for good buffering
  - constant feed stock for stage 2 where the methanogens live
  - removal of solids from stage 2 reduces gas formation
  - but, high costs
  - can be run as a slurried system to speed things up
- in the United Kingdom
  - the first step is shredding of the organic matter
  - stage 1 operated at 37°C to break down large MWT organic material
  - stage 2 operated at 70°C to pasteurize – which is important for animal waste
  - 5000 tonnes/year @ $100/tonne → produces 880 tonnes CH_4/year
  - residue applied to land as fertilizer

Anaerobic Digestion

- Europe has done a lot of work on this over the past 25 years to stabilize the waste before land application
  - 4 million tonnes capacity
  - operating costs are high
  - lower environmental impacts than straight landfilling
  - generates a useable fuel (CH_4)
    - used to run busses
    - generate electricity
- India and Thailand have thousands of small scale facilities for low cost energy
  - reduces costs associated with transport of MSW and compost
- also think about other applications
  - agriculture – manure and crop residue
  - restaurants – food waste
  - bioremediation – composting of contaminated soil

Anaerobic Digestion (simplified)

Hydrolyzing Bacteria

↓

Acidogenic Bacteria

↓

Acetogenic Bacteria

↓

Methanogenic Bacteria

Example: Methane Production

- let's determine the percentage of CH_4 and CO_2 that are produced for 100 kg of MSW which is:
  - 78% organic matter including water content
  - with water content at 25%
  - waste represented by $C_{60}H_{94.3}O_{37.8}N$

$$\text{moles } CH_4 = \left(\frac{4a + b - 2c - 3d}{8}\right) = \left(\frac{4(60) + 94.3 - 2(37.8) - 3}{8}\right) = 32 \text{ moles}$$

$$\text{moles } CO_2 = \left(\frac{4(60) - 94.3 + 2(37.8) - 3}{8}\right) = 28 \text{ moles}$$

- waste to be decomposed

$$M_{organic} = 100 \text{ kg} \times 0.78 = 78 \text{ kg}$$

- assume sufficient H_2O

Example: Methane Production

- mass of waste components:

$$\text{mass of dry solids} = 78 \times 0.75 = 58.5 \text{ kg}$$

$$\text{molar mass } CH_4 = (32 \text{ mole})(12 + 4(1)) = 512 \text{ g}$$

$$\text{molar mass } CO_2 = (28 \text{ mole})(12 + 2(16)) = 1232 \text{ g}$$

$$\text{molar mass MSW} = (1 \text{ mole})(12(60) + 94.3(1) + 37.8(16) + 14) = 1433 \text{ g}$$

$$\text{mass of } CH_4 = \left(\frac{58.5 \text{ kg}}{1433}\right)(512) = 20.9 \text{ kg}$$

$$\text{mass of } CO_2 = \left(\frac{58.5 \text{ kg}}{1433}\right)(1232) = 50.4 \text{ kg}$$

$$\text{volume of } CH_4 = \left(\frac{20.9}{0.7167}\right) = 29.2 \text{ m}^3/100 \text{ kg organic}$$

$$\text{volume of } CO_2 = \left(\frac{50.4}{1.9768}\right) = 25.5 \text{ m}^3/100 \text{ kg organic}$$

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Example: Methane Production

- total gas produced:

$$\text{total gas} = (29.2 + 25.5) = 54.7 \text{ m}^3$$

$$\% \, CH_4 = \left(\frac{29.2}{54.7}\right) \div 100 = 53.4 \%$$

$$\% \, CO_2 = 46.4 \%$$

$$\text{methane produced} = \left(\frac{29.2}{100}\right) = 0.29 \text{ m}^3/\text{kg}$$

- methane produced per 100 kg of solid waste:

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

BRAJESH KUMAR DUBEY

DEPARTMENT OF CIVIL ENGINEERING

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Another Biological treatment example

- Go through example problem of biological treatment of solid waste
  - Two Waste Streams
    - Chicken Manure
    - Yard Waste
- Chicken Manure (CM) Characteristics
  - 10 tons per month
  - MC = 40 %
  - VS = 75 %
  - BVS = 68 – 76% (72%)
- Yard Waste (YW) Characteristics
  - 20 tons per month
  - MC = 20 %
  - VS = 85 %
  - LC = 6%

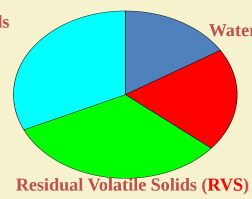
IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Another Biological treatment example

- Calculate BVS
  - BVS = 0.083 – 0.028(LC)
    - BVS = 0.083 – 0.028(6) = 0.662

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Composition of Waste



IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Question 1

- How many tons of dry compost produced per month?

Dry tons of CM compost per month

$$10\,wet\,tons\left((1-0.40)\frac{dry\,ton}{wet\,ton}\right)\left(0.75\frac{ton\,VS}{dry\,ton}\right)\left(0.72\frac{ton\,\,BVS}{ton\,VS}\right)$$

Dry tons of CM compost per month

$$10\,\cancel{wet\,tons}\left((1-0.40)\frac{\cancel{dry\,ton}}{\cancel{wet\,ton}}\right)\left(0.75\frac{ton\,VS}{\cancel{dry\,ton}}\right)\left(0.72\frac{ton\,\,BVS}{ton\,VS}\right)$$

3.24 tons of CM destroyed!

Note: This is not compost produced but rather what is "biodegraded" in process

Dry tons of CM compost per month

$$10\,\cancel{wet\,tons}\left((1-0.40)\frac{dry\,ton}{\cancel{wet\,ton}}\right)-3.24\,dry\,tons$$

2.76 tons of dry CM compost

Dry tons of YW compost per month

$$20\,tons\,(1-0.20)\,(1-0.85(0.662))$$

7.00 tons of dry YW compost

Total Tons of Dry Compost

2.76 tons of dry CM compost
\+ 7.00 tons of dry YW compost

9.76 tons of dry compost

Question 2

- How many standard cubic meter of air are needed to stabilize a year's worth of compost?

Basic Question

- What does stabilize mean?
- In this problem:

100% BVS → $CO_2 + H_2O$

Air Requirement

- Need to know the amount of air required.
- Air = 79% N_2 and 21% O_2
- It is only the oxygen that is participating
- How do we determine?
- Measure.
- Remember the reaction from the previous slide?

Aerobic Decomposition

$$C_aH_bO_cN_d + \left(\frac{4a+b-2c}{4}\right)O_2 \rightarrow$$

$$(a)CO_2 + \left(\frac{b}{2}\right)H_2O$$

We should be able to figure out air requirements from this equation.

Aerobic Decomposition

Example for Cellulose

$$C_6H_{10}O_5 + 6\,O_2 \rightarrow 6\,CO_2 + 5\,H_2O$$

Info Needed

- We need to get some information regarding the composition of the waste.
- Which part of the waste?
- Really need it for the BVS.

How Do We Get this Composition Info?

- Measure it ($$)
- Find a reference in the literature
  - Two ways data encountered:

    %C, %H, %O

    $C_aH_bO_c$

Air Requirement for Yard Waste

- Reference in Compost Book

  Yard Wastes: $C_{27}H_{38}O_{16}N$

- Assumptions
  - Don't worry about nitrogen contributing to air demand. But let's assume it does contribute to mass of BVS.
  - This formula is representative of the BVS

Solve

$$C_{27}H_{38}O_{16}N + \left(\frac{4(27)+38-2(16)}{4}\right)O_2 \rightarrow$$

$$(27)CO_2 + \left(\frac{38}{2}\right)H_2O$$

Solve

$$C_{27}H_{38}O_{16}N + \left(\frac{4(27)+38-2(16)}{4}\right)O_2 \rightarrow$$

$$\boxed{28.5\ \frac{kg-mole\ O_2}{kg-mole\ C_{27}H_{38}O_{16}N}}$$

So How Do We Get Air Requirement?

- One good thing to remember:
  - 22.4 standard m³ of perfect gas per kg-mole
  - 22.4 liters of perfect gas per g-mole

Air Requirement

$$28.5\ \frac{kg-mole\ O_2}{kg-mole\ C_{27}H_{38}O_{16}N}\left(\frac{22.4\ m^3\ O_2}{kg-mole\ O_2}\right)$$

$$\frac{638.\ m^3\ O_2}{kg-mole\ C_{27}H_{38}O_{16}N}\left(\frac{100\ m^3\ air}{21\ m^3\ O_2}\right)$$

Next Step: Convert to tons of BVS

$$\frac{3040 m^3\ air}{kg-mole\ C_{27}H_{38}O_{16}N}\left(\frac{1\ kg-mole\ C_{27}H_{38}O_{16}N}{MW\ kg\ C_{27}H_{38}O_{16}N}\right)$$

Where MW is the molecular weight of $C_{27}H_{38}O_{16}N$

Find Molecular Weight

Carbon 27(12)
Hydrogen + 38(1)
Oxygen + 16(16)
Nitrogen + 1(14)
632

$$MW = \frac{632\ kg\ C_{27}H_{38}O_{16}N}{kg-mole\ C_{27}H_{38}O_{16}N}$$

Next Step: Convert to tons of BVS

$$\frac{3040 m^3\ air}{kg-mole\ C_{27}H_{38}O_{16}N}\left(\frac{1\ kg-mole\ C_{27}H_{38}O_{16}N}{632\ kg\ C_{27}H_{38}O_{16}N}\right)$$

$$4.81\frac{m^3\ air}{kg\ C_{27}H_{38}O_{16}N}\left(\frac{1{,}000\ kg\ C_{27}H_{38}O_{16}N}{ton\ C_{27}H_{38}O_{16}N}\right)$$

$$4{,}810\frac{m^3\ air}{ton\ YW\ BVS}$$

We Are Half-Way Through Question 2

- Let's tackle Chicken Manure

%C = 48.0 %
%H = 6.4%
%O = 37.6%
%N = 2.6%
%S = 0.2%
%others = 5.0%

- Chicken Manure (CM)
  - 10 tons per month
  - MC = 40 %
  - VS = 75 %
  - BVS = 68 – 76% (72%)

Let's Get Air Requirement a Different Way

- Assume that components minus "others" represent BVS composition.
- So actual composition of BVS is:

%C = 48.0/95.0 = 50.5%
%H = 6.4/95.0 = 6.7%
%O = 37.6/95.0 = 39.6%
%N = 2.6/95.0 = 2.7%
%S = 0.2/95.0 = .21%

For 1 ton of BVS

Carbon = 0.505 tons = 505 kg
Hydrogen = 0.067 tons = 67 kg
Oxygen = 0.396 tons = 396 kg
Nitrogen = 0.027 tons = 27 kg
Sulfur = 0.0021 tons = 2.1 kg

For 1 ton of BVS, Find $C_aH_bO_c$

Remember we assumed that only CHO contribute to air demand

$$Carbon: \ a = 505 kg\ C\left(\frac{kg-mole\ C}{12\ kg\ C}\right) = 42.1\ kg-mole\ C$$

$$Hydrogen: \ b = 67\ kg\ \ H\left(\frac{kg-mole\ H}{1\ kg\ H}\right) = 67\ \ kg-mole\ H$$

$$Oxygen: \ c = 396\ kg\ O\left(\frac{kg-mole\ O}{16\ kg\ O}\right) = 24.8\ kg-mole\ H$$

For 1 ton of BVS ⟶ $C_{42.1}H_{67}O_{24.8}$

Find Air Required for 1 ton of CM BVS

- Use similar approach as for Yard Waste.

$C_{42.1}H_{67}O_{24.8}$

Solve

$$C_{42.1}H_{67}\ O_{24.8} + \left(\frac{4(42.1)+67\ \ -2(24.8)}{4}\right)O_2$$

$$\boxed{46.5\ \frac{kg-mole\ O_2}{ton\ \ \ CM\ \ BVS}}$$

Air Requirement

$$46.5\ \frac{kg-mole\ O_2}{ton\ CM\ \ BVS}\left(\frac{22.4\ m^3\ O_2}{kg-mole\ O_2}\right)$$

$$\frac{1{,}040.5\ m^3\ O_2}{ton\ CM\ \ BVS}\left(\frac{100\ m^3\ air}{21\ m^3\ O_2}\right)$$

$$\boxed{\frac{4{,}955\ m^3\ air}{ton\ CM\ \ BVS}}$$

Let's Compare

Chicken Manure $\frac{4{,}955\ m^3\ air}{ton\ CM\ \ BVS}$

Yard Waste $4{,}810\frac{m^3\ air}{ton\ YW\ \ BVS}$

Total Air Demand

Chicken Manure

$$4,955\ \frac{m^3\ \ air}{ton\ \ CM\ \ \ BVS}\left(3.24\ \frac{tons\ \ \ CM\ \ \ \ BVS}{Month}\right)\left(\frac{12\ \ \ month}{year}\right)1\ \ year$$

$$192{,}650\ \frac{m^3\ air}{year}$$

Yard Waste

$$4{,}810\ \frac{m^3\ air}{ton\ CM\ \ BVS}\left(20(0.8)(0.85)(0.662)\frac{tons\ CM\ \ BVS}{Month}\right)\left(\frac{12\ month}{year}\right)1\ year$$

$$519{,}665\ \frac{m^3\ \ air}{year}$$

Total Air Demand

$$0.7\,million\ \frac{m^3\ air}{year}$$

How Do We Use this Number for Design?

- We want to determine what blower capacity is needed? Typical units: SCMM.

Total Air Demand

$$0.7\,million\ \frac{m^3\ air}{year}\left(\frac{year}{365\ days}\right)\left(\frac{day}{24\ hours}\right)\left(\frac{hour}{60\ min}\right)$$

$$1.33\ scm/m$$

What Other Questions Could You Answer for This Waste Stream?

- How much water is produced?
- What is the moisture content of the final compost?
- How much methane would be generated in an anaerobic treatment system for the same waste?

Anaerobic Decomposition

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c+3d}{4}\right)H_2O \rightarrow$$

$$\left(\frac{4a+b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b+2c+3d}{8}\right)CO_2 + dNH_3$$

Other Questions

- If wastes were mixed to achieve optimum Carbon to Nitrogen ratios…
- Chicken manure is high in arsenic, what would be concentration of dry compost?

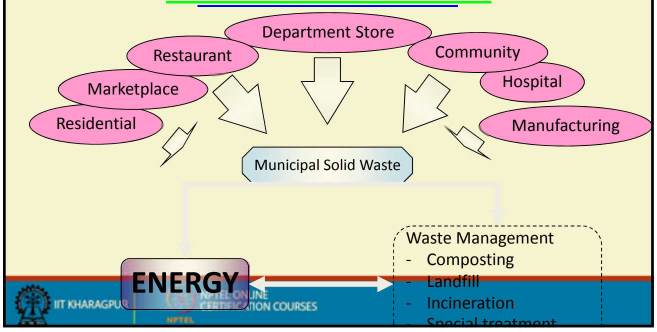
INTEGRATED WASTE MANAGEMENT FOR A SMART CITY

FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT

Thermal Treatment

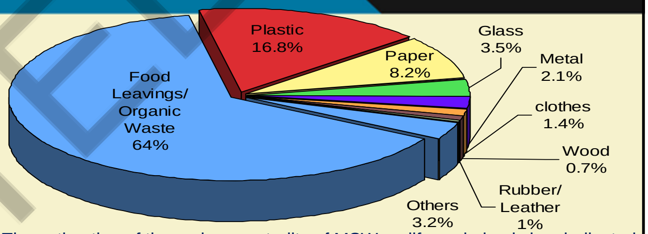
BRAJESH KUMAR DUBEY
DEPARTMENT OF CIVIL ENGINEERING

Introduction



Why waste to energy?

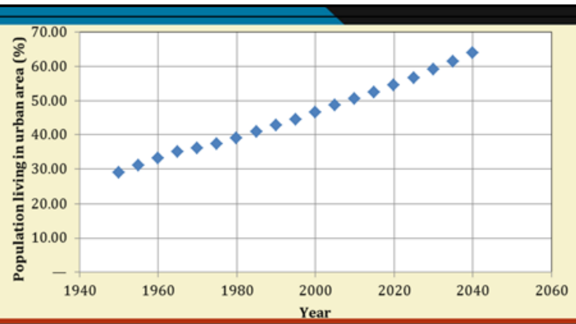
- The importance of finding environmentally benign methods for handling and disposal of MSW is increasing substantially
- Dumping in landfills is not a sustainable solution, and in fact, pressure against land filling is constantly rising in many parts of the world
- In major cities and tourism areas, MSW is produced at a rate of approximately 500 kg or more, per person per year
- This is a substantial amount, which constitutes a “renewable biofuel” energy resource
- These drivers provide an opportunity for the development and deployment of cost-effective energy recovery systems



The estimation of the carbon neutrality of MSW on life cycle basis has indicated that around 36% of the total CO_2 emissions from incineration of unsorted waste are of fossil origin, which implies that MSW is 64% carbon-neutral

Why waste to energy

- The solution to this solid-waste disposal problem is not to simply add more waste-to-energy plants rather it should involve a variety of options that will minimize the effect on the environment while maximizing the conservation and recovery of energy and materials
- The solution to this problem must be able to integrate the four options available for the management of MSW: source reduction, recycling including composting, conversion to energy and land filling



Thermal Conversion

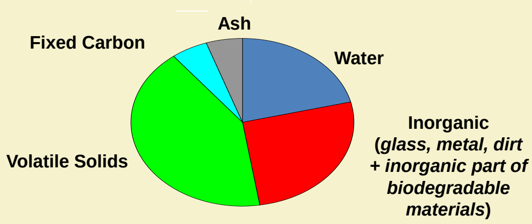
- thermal processing of waste is used for *volume reduction* and for *energy recover*
- it can be an important component of integrated waste management
  - stand alone systems are not always the best
  - in Europe, incineration is becoming a larger and more central component in integrated waste management systems
  - in Ontario, in 1991 the NDP government banned their consideration
  - in 1995, the PC government repealed this ban
- the focus herein will be on the analysis of conversion systems and not on specific design details
- first, we will discuss the principles of thermal processing
- then, we will go over the details of some of the processes

Processes

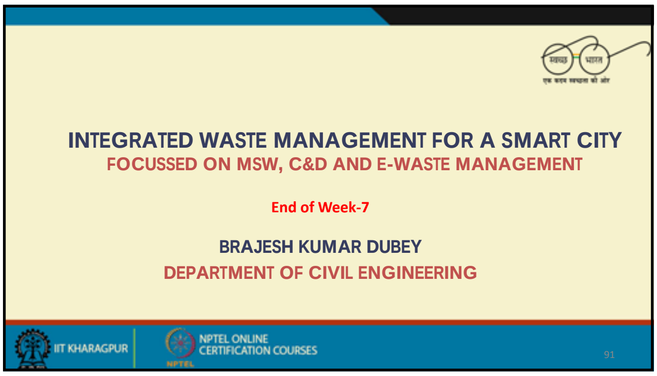
- including discussion of the following thermal processes:

1. combustion – thermal destruction in the present of oxygen
   - incineration
   - co-generation
   - energy from waste
   - co-incineration
2. pyrolysis – thermal processing in the absence of oxygen
3. gasification – partial combustion to generate a combustible gas
4. plasma arc – superheating a gas to an ionized state
   - completely destroying the chemical bonds in all organic matter it encounters

Composition of Waste



- Example:
  - Mixed Food Wastes:
  - Water = 70%, VS = 21.4%, Fixed Carbon = 3.6%, Non combustible = 5%
- Example:
  - Cardboard
  - Water = 5.2%, VS = 77.5%, Fixed Carbon = 12.3%, Noncombustable = 5%
- Example:
  - Yard Waste
  - Water = 60%, VS = 30%, Fixed Carbon = 9.5%, Noncombustable = 0.5%


INTEGRATED WASTE MANAGEMENT FOR A SMART CITY
FOCUSSED ON MSW, C&D AND E-WASTE MANAGEMENT
End of Week-7
BRAJESH KUMAR DUBEY
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR
NPTEL ONLINE
CERTIFICATION COURSES