Processing of Municipal Solid Waste

I. MSW Physical Characteristics

Particle Size

- Difficult to define.
- Sieves only define size based on two dimensions. A wire could pass a sieve and still cause problems with later processing.

Bulk Density

- Following shredding, MSW bulk density can be as high as 250 lb/ft^3 (400 kg/m^3).
- Variation in bulk density can be significant and is important to understand when designing storage facilities.

Angle of Repose

- The angle, to the horizontal, that material can be stacked without sliding.

Material Abrasiveness

- Abrasive material must often be removed prior to some operations, such as pneumatic conveying.

Moisture Content

- All of the previously mentioned characteristics are influenced by moisture content.
- If the MSW moisture content is greater than 50%, the organic fraction can undergo spontaneous combustion if allowed to sit undisturbed.

II. Storing MSW

- MSW storage is required to even out fluctuations in supply.
- Concerns when designing MSW storage facilities are:
    - Public health – rats, odor, etc.
    - Fire – spontaneous combustion of MSW. The maximum length of time to safely store MSW is 2 days. Storage pit fires are difficult to extinguish and resulting waste is difficult to dispose of. “First in-first out” (FIFO) systems are used to make sure waste is processed in the order it is received. However, this may be difficult to achieve.
- Common storage systems:
    - Pit with an overhead bridge crane – the crane takes waste from the transfer trucks and drops it into the storage facility pit. Later, the crane picks up the waste and drops it into a feed chute, conveyor belt, or directly into another transfer vehicle.
    - Tipping floor system – MSW is stacked up to 20 ft (7 m) high using a front end loader. A concrete or steel push wall may be incorporated into the design.

III. Conveying MSW

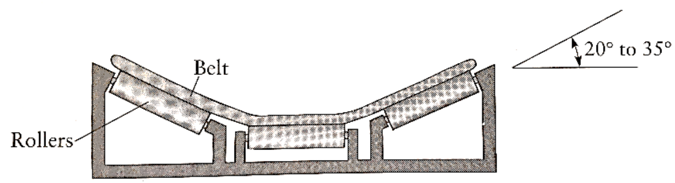
Six Basic Types of Conveyors:

1. Rubber-belted conveyors

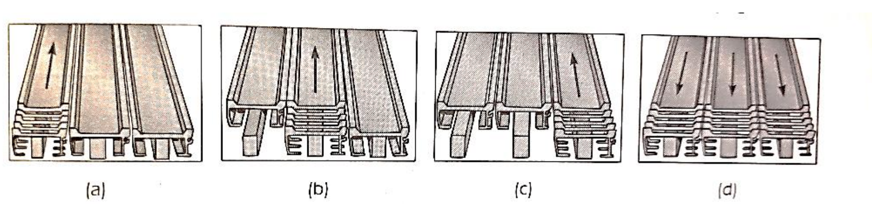
- Power requirements can be estimated with the empirical equation:

$Horsepower = \frac{LSF}{1000} + \frac{LTC}{990} + \frac{TH}{990} + P$ where:

L = length of conveyor belt (ft)
S = speed of belt (ft/min)
F = speed factor (dimensionless)
T = capacity (tons/h)
C = idle resistance factor (dimensionless)
H = lift (ft)
P = pulley friction (hp)



2. Live bottom feeders
   - Used to move MSW out of holding bins or transfer trailers
   - The bottom of the hopper has sliding interlocking beams that move at specific speeds



(a) The first slat group slips under the load at the rear of the load; (b) the second slat group slips under the load; (c) the third slat group slips under the load; (d) all slat groups and the load advance forward together.

3. Pneumatic conveyors
   - Used mainly for raw, bagged MSW and feeding shredded organic fractions to boilers
   - Air pushes MSW through tubes
   - Required air velocity for pneumatic tubes:

$v_m = v_a - v_f$ where:

v_m = material velocity (ft/min)
v_a = velocity of the air (ft/min)
v_f = floating velocity, or terminal velocity when falling in still air (ft/min)

- Floating velocity:

$v_f = 3250\sqrt{SG * d}$ where:

SG = MSW specific gravity, relative to water = 0.1*(W $^{(2/3)}$)
W = the bulk density of the MSW (lb/ft^3)
d = aerodynamic diameter of a representative particle (in)

- Material velocity must be able to dislodge stuck particles and even out the flow:

$v_m = 585\sqrt{W}$

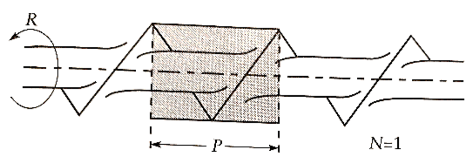
- Recommended air velocity:

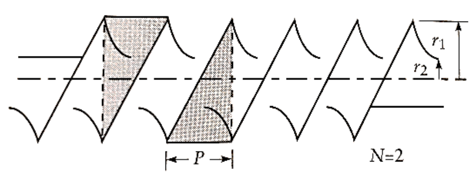
  $v_a = 1030\ \sqrt[3]{W}\ \sqrt{d} + (585\ \sqrt{W}\ )$

4. Vibratory feeders
   - Convey and even out materials flow
5. Screw feeders
   - Used to meter shredded MSW into a furnace
   - Screw serves as an air lock and rotational speed controls feed rate of fuel
   - When the screw conveyor is "flooded", or all space is full between the blades:

     $Q = C * N * R * V$ where:

     Q = delivery rate of MSW (m^3/min)
     C = efficiency factor
     N = number of conveyor leads = number of blades that are wrapped around the conveyor hub
     R = rotational speed of the screw (rpm)
     V = volume of refuse between each pitch (m^3) = $P * \pi * (r_1^2 – r_2^2)$ where:
     P = pitch, distance between conveyors' blades if the number of leads, N = 1 (m)
     r_1 = radius to the conveyor tip (m)
     r_2 = radius to conveyor hub (m)





6. Drag chains
   - Used to convey MSW in waste-to-energy plants.
   - Consists of an open or closed-top metal rectangular pan.
   - A chain runs along the length of the pan on each side and is connected to metal or wood flights at 5- to 10-foot intervals, which move the MSW.
   - Slide door openings to chutes can be on the bottom of the pan.

IV. Compacting

- MSW has a relatively low density, which means large volumes must be handled.
- Compacting can lead to significant cost savings.
- Volume and mass balance:

$V_m = V_s + V_v$ where:

V_m = volume of material

V_s = volume of solids (including moisture)
V_v = volume of voids

$$W_m = W_s + W_w$$ where:

W_m = weight of material (including moisture)
W_s = weight of solids
W_w = weight of moisture

- Void ratio:

$$e = \frac{V_v}{V_s}$$

- Porosity:

$$n = \frac{V_v}{V_m}$$

- Bulk density:

$$\rho_B = \frac{W_m}{V_m}$$

- Cans collapse at pressures of 10-30 psi.
- Glass bottles collapse at pressures of 5-35 psi.
- Compaction is irreversible. However, some items in MSW contribute to reversible compaction.
- At normal compactions pressures, 20% expansion can occur within a few seconds after pressure release; after a few minutes, 50% expansion can occur.

V. Shredding

- A form of size reduction.
- Following shredding, MSW looks like confetti, with a light, bulky nature.
- Overall density is decreased by over 50%.
- Reduces required landfill volume.
- Landfilling of shredded waste does not require a conventional earth cover because:
    - Odor is not a problem due to the well-mixed waste that retains aerobic character.
    - Rats are not attracted to large food particles.
    - Insect are suppressed due to dry character and maggots are killed during shredding.
    - Smaller pieces of paper are not caught by the wind and do not blow away.
- Leachate is produced more quickly due to lack of cover and leachate has a higher pollution concentration than normal leachate.
- However, leachate quantity is lower because shredded MSW open to the air undergoes more drying.
- Refuse-derived fuel (RDF) that is shredded has a more uniform heating value, which requires less excess air.
- Shredding can be used to prepare yard waste, demolition debris, branches and organic material to produce a mulch for composting.

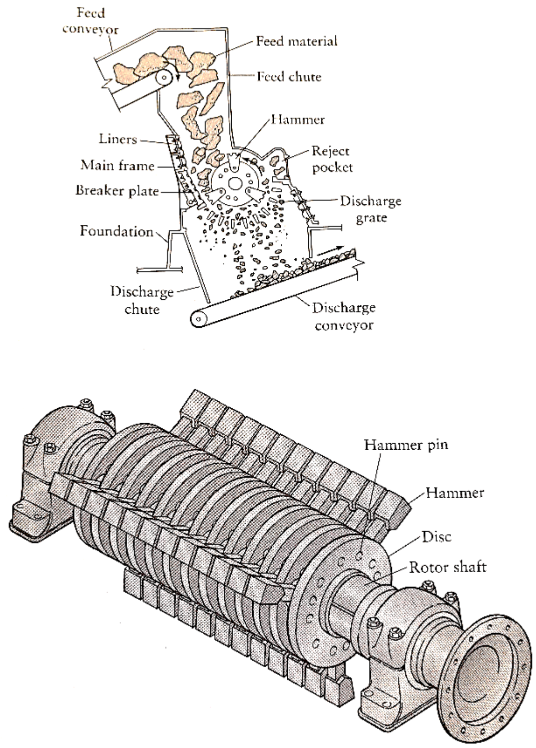


Figure 5-8 Horizontal hammermill shredder. Source: (15)

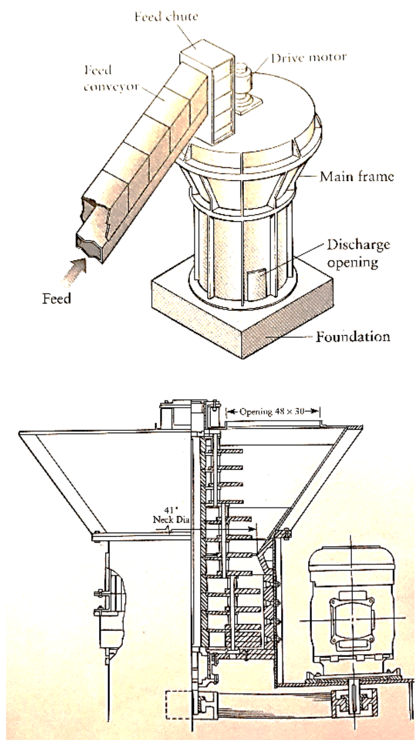


Figure 5-9 Vertical hammermill shredder. Source: (15)

- Shredder performance is described by the change in particle-size distribution.
- A single-valued function cannot be used to express the size distribution of particles, so an equation must be used that describes the distribution of various size fractions.
- Rosin-Rammler model:

  $$Y = 1 - e^{\left(\frac{-x}{x_0}\right)^n}$$

  Y = cumulative fraction of material by weight less than size x

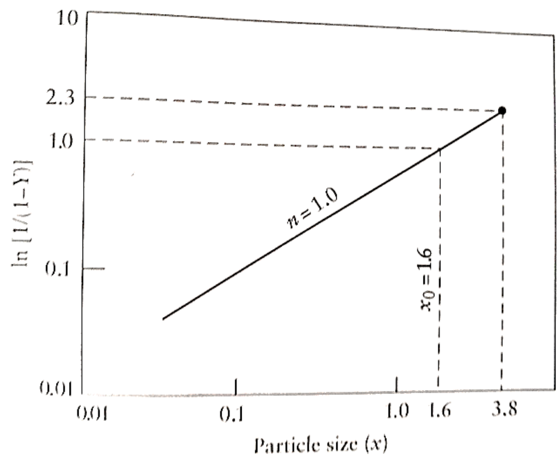
  x_0 = characteristic particle size = the size at which 63.2% ($1 - {}^1/_e = 0.632$) of the particles (by weight) are smaller

  n = a constant = slope of the line ln(1/(1-Y)) versus x on log-log coordinates
- For a specific value of x_0, as the constant n increases due to changes in machine or feed characteristics, the value Y decreases and a coarser product is obtained.
- <u>Example:</u> Suppose that a sample of refuse must be shredded so as to produce a product with 90% passing 3.8 cm. Assume that n = 1. Calculate the characteristic size.

  $$Y = 0.90$$

  $$\ln\left(\frac{1}{1-Y}\right) = \ln\left(\frac{1}{1-0.90}\right) = \ln 10 = 2.3$$

  Plotting x = 3.8 cm versus ln(1/(1-Y)) = 2.3 on log-log paper:



For n = 1, the slope of the line is 45°, which is drawn. The characteristic size, x_0, is then found at ln(1/(1-Y)) = 1.0. Thus, x_0 = 1.6 cm.

Reference

Vesilind, P. A., Worrell, W., & Reinhart, D. (2002). *Solid Waste Engineering*. Pacific Grove, CA: Brooks Cole.