Design and operation of composting plants

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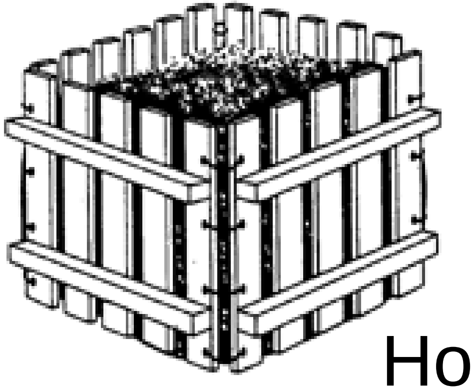
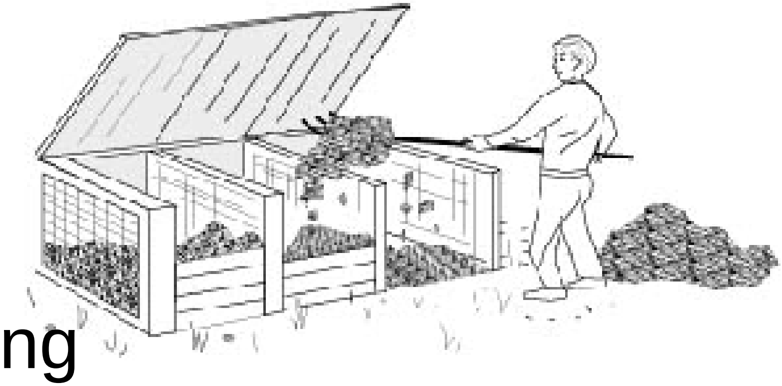
COMPOSTING

Composting is a microbial process of mineralization and partial humification of organic substances under aerobic, controlled conditions.

TECHNOLOGICAL APPROACH

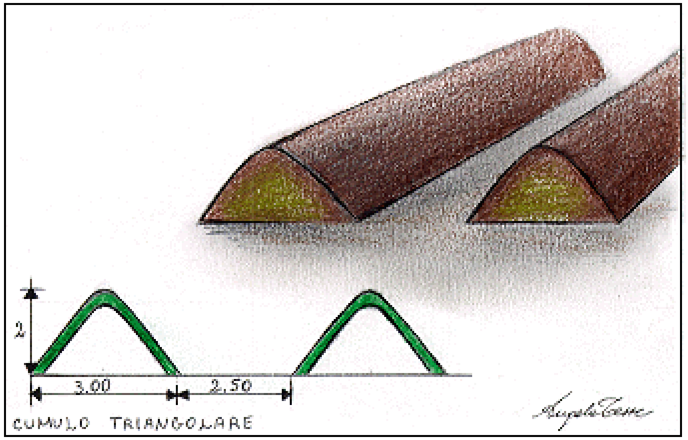




Home composting

TECHNOLOGICAL APPROACH

On-farm composting



TECHNOLOGICAL APPROACH

Industrial composting

Composting systems

OPEN SYSTEMS

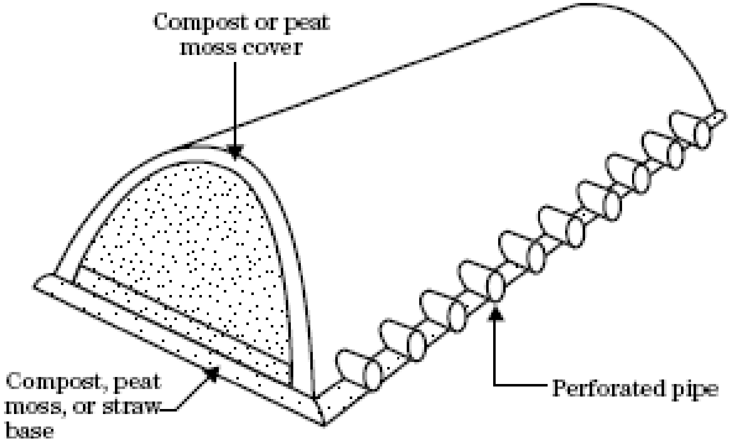
- STATIC: Aereated piles or aereated windrows (in bags/covers)
- DYNAMIC: Windrow or piling and turning (with or without forced aeration)

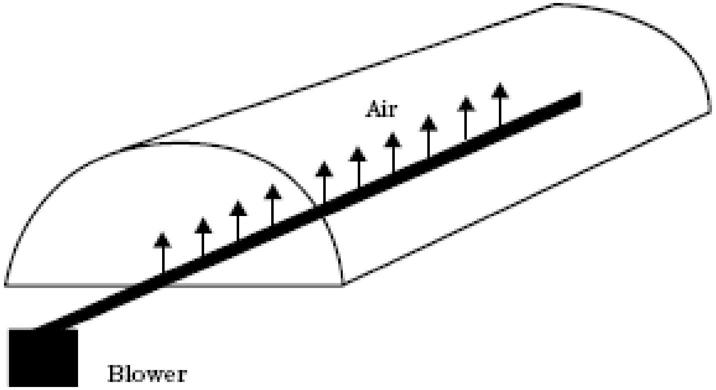
CLOSED “IN VESSEL”SYSTEMS

- STATIC REACTORS: Silos, tunnels, containers or biocells
- VERTICAL DYNAMIC REACTORS: Silos with agitation
- HORIZONTAL DYNAMIC REACTORS: Rotating drum, Agitated bed (in channels or basins) or tunnels and biocells with continuous flow (mobile ground, piston, etc.)

Open systems - static

Aereated piles or aereated windrows (in bags/covers)





from National Engineering Handbook – USDA 2000

Open systems - dynamic

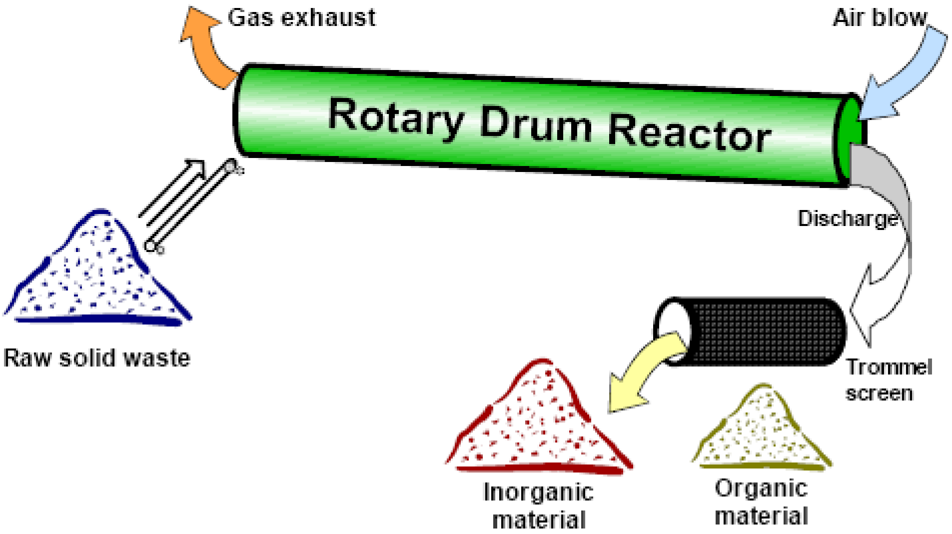
Windrow or piling and turning (with or without forced aeration)

In vessel systems – static reactors

Silos, tunnels, containers or biocells

In vessel systems – dynamic

Rotary drums - areated



From: California Department of Resources Recycling and Recovery - 2010

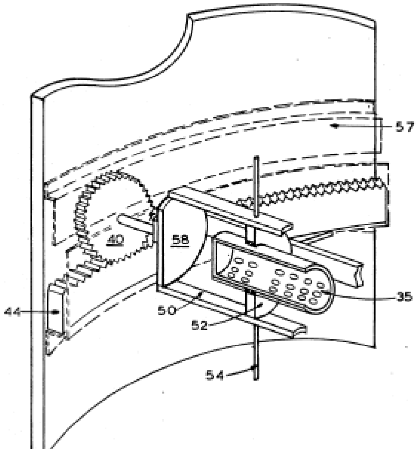
In vessel systems – dynamic

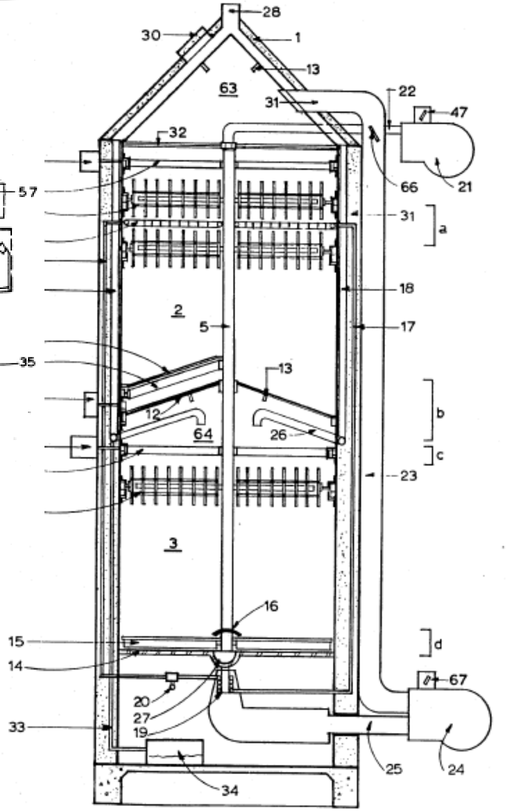
Agitated bed in channels (corridos) - areated

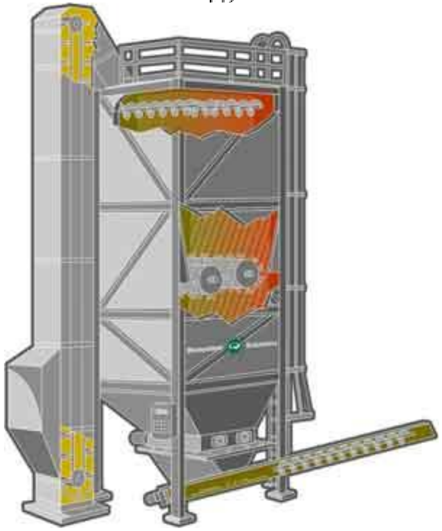
In vessel systems – dynamic

Silos - areated

Source: Parsons, 2002





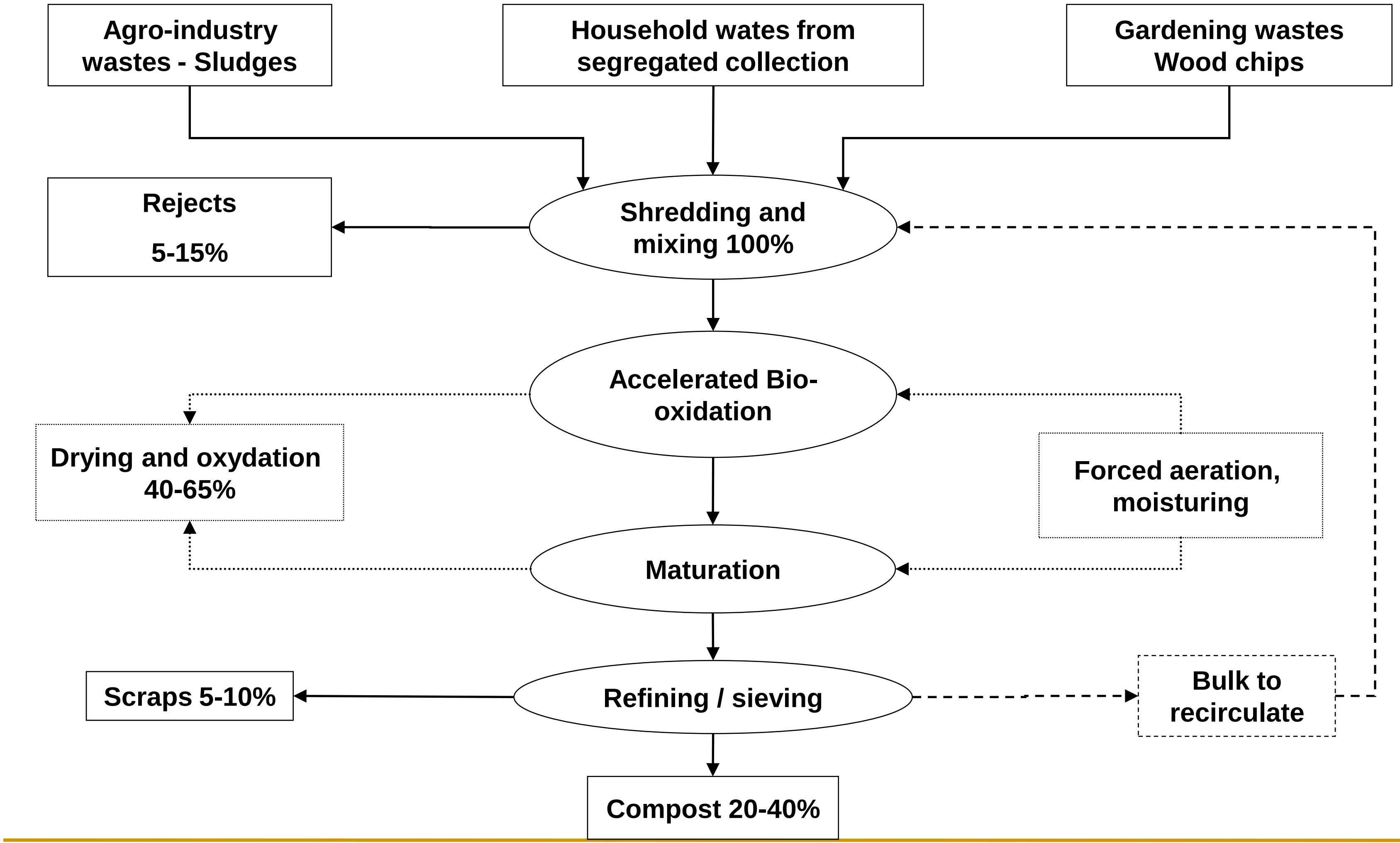


www.biosystemsolutions.com

In vessel systems – dynamic

Agitated bed in basins - areated

Composting of selected feedstocks



Agro-industry wastes - Sludges

Household wates from segregated collection

Gardening wastes Wood chips

Rejects

5-15%

Shredding and mixing 100%

Accelerated Bio-oxidation

Drying and oxydation 40-65%

Forced aeration, moisturing

Maturation

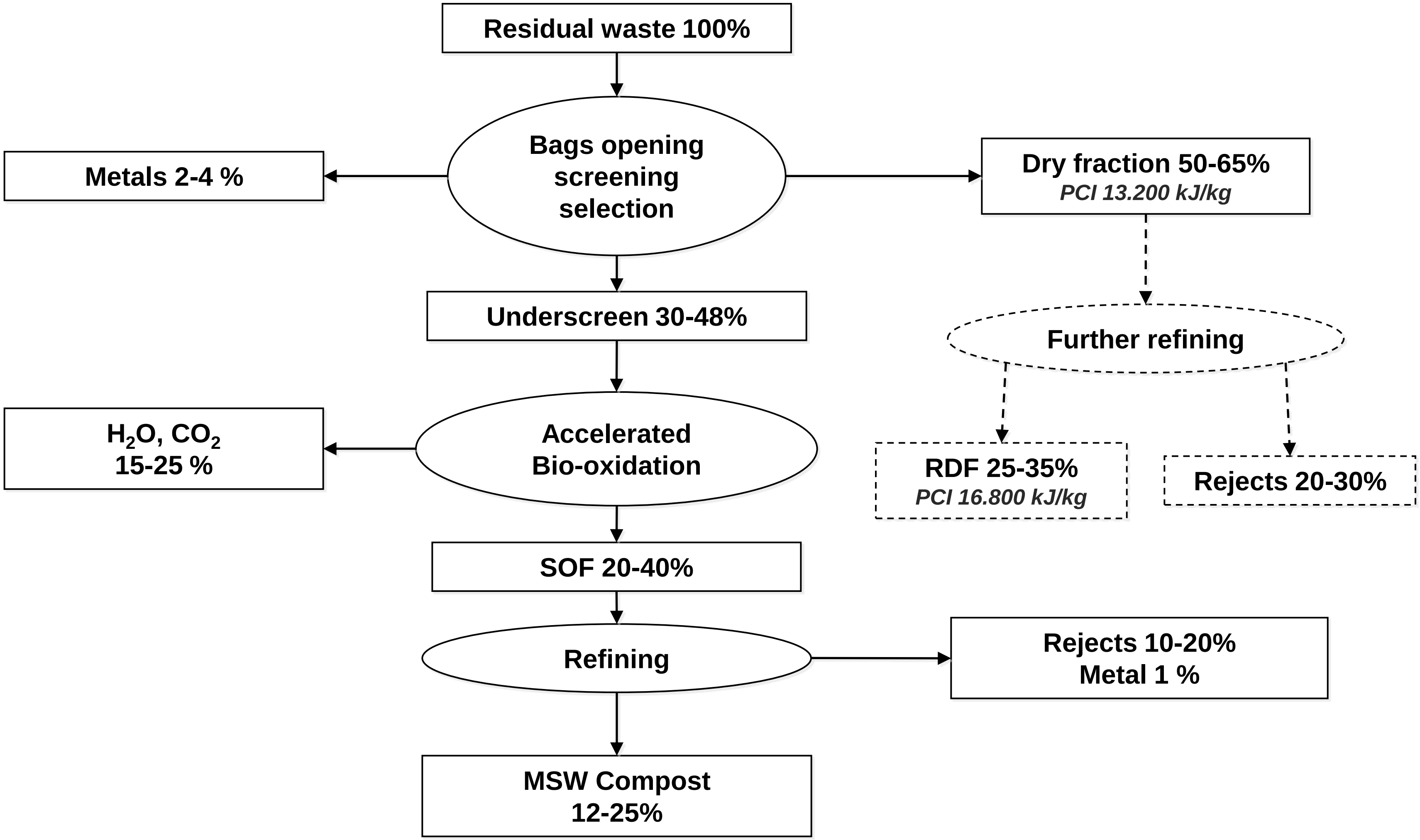
Scraps 5-10%

Refining / sieving

Bulk to recirculate

Compost 20-40%

MBT – biological stabilisation



Residual waste 100%

Bags opening screening selection

Metals 2-4 %

Dry fraction 50-65%
PCI 13.200 kJ/kg

Underscreen 30-48%

Further refining

RDF 25-35%
PCI 16.800 kJ/kg

Rejects 20-30%

Accelerated Bio-oxidation

H_2O, CO_2
15-25 %

SOF 20-40%

Refining

Rejects 10-20%
Metal 1 %

MSW Compost
12-25%

GOALS of COMPOSTING

- ✓ Obtaining a compost of suitable quality for its intended use
- ✓ Minimizing the cost of its production
- ✓ Minimizing pollution (odors, leachate)

also, for Mechanical Biological Treatment:

- ✓ Reducing biodegradability of residual waste before landfilling
- ✓ Increasing calorific value before incineration

COMPOSTING
what it is – what is not

☹ It is not just a chemical reaction

☹ It is not just a phisical process

☺ It is a **biological** trasformation

COMPOSTING

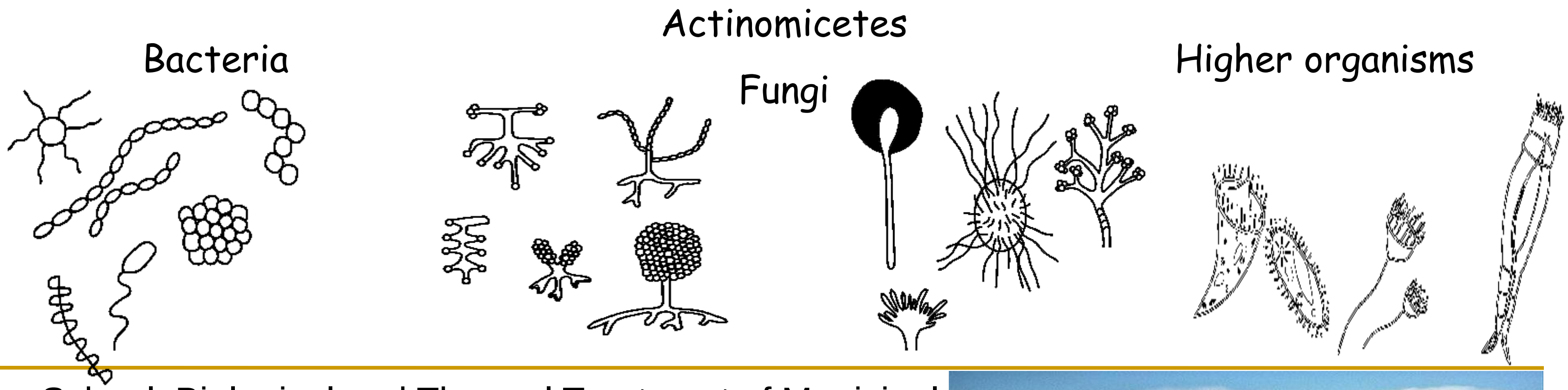
TYPICAL EVOLUTION

Active Composting Time

- ⇒ High temperatures (>55°C)
- ⇒ High O_2 consumption
- ⇒ Water evaporation
- ⇒ phytotoxycity
- ⇒ Odour release
- ⇒ Leachate

Curing

- ⇒ Lower temperatures (<45°C)
- ⇒ Lower respiratory activity
- ⇒ Lower odour release
- ⇒ Stability
- ⇒ Maturity
- ⇒ Humic sustances



Modelling composting

k = Rate of disappearance of dry matter per unit of compostable dry matter per day

$$k = -k_{max} X_{T} X_{wc} X_{O2} X_{FAS} X_{C/N}$$

T = temperature

wc = moisture content

O2 = oxygen concentration in interstitial atmosphere

FAS = free air spaces

C/N = Carbon / Nitrogen ratio

Haug (1993); Ekinci et al. (2002); Keener et al. (2002)

KEY POINTS IN PROCESS OPTIMISATION

1. A good mix of starting ingredients
2. An efficient monitoring
3. An effective process control
4. Time

KEY POINTS IN PROCESS OPTIMISATION

1. A good mix of starting ingredients:
    - Equilibrate ratio of nutrients
    - Adequate water content
    - Proper particle size, porosity and structure

Starting Mix: C/N ratio

$$R = \frac{Q_1(C_1 \times (100 - M_1) + Q_2(C_2 \times (100 - M_2) + Q_3(C_3 \times (100 - M_3) + \ldots}{Q_1(N_1 \times (100 - M_1) + Q_2(N_2 \times (100 - M_2) + Q_3(N_3 \times (100 - M_3) + \ldots}$$

where:
R = C/N of the mix
Qn = mass of the n material (wet weight)
Cn = COT (%) of the n material
Nn = Nitrogen (%) of the n material
Mn = Moisture (%) of the n material

http://compost.css.cornell.edu

SHOULD BE BETWEEN 25 AND 45

Starting Mix : moisture

weighted average

$$G = \frac{(Q_1 \times M_1) + (Q_2 \times M_2) + (Q_3 \times M_3) + \ldots}{Q_1 + Q_2 + Q_3 + \ldots}$$

where:
Qn = mass of the n material (wet weight)
G = moisture of the mix (%)
Mn = moisture (%) of the n material

http://compost.css.cornell.edu

SHOULD BE BETWEEN 50 AND 65%

Starting Mix : particle size, porosity (FAS) and structure

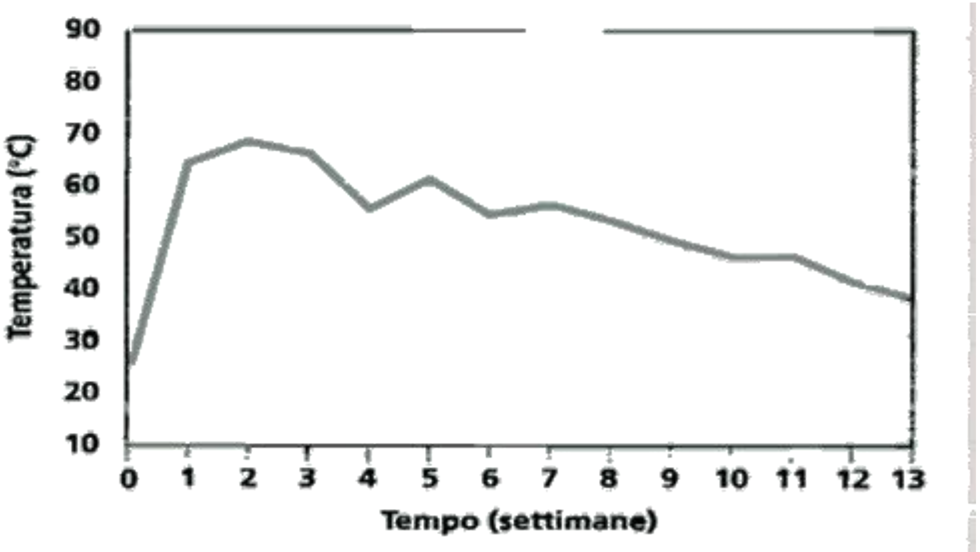
- Affect:
  - micro organisms oxygen availability
  - surface exposed to degradation
- Bulk density: should not be > 0,65
  - Add bulking agents

KEY POINTS IN PROCESS OPTIMISATION

2. An efficient monitoring
    - Temperature
    - Water content
    - Oxygen level
    - Respiratory activity

Monitoring: temperature

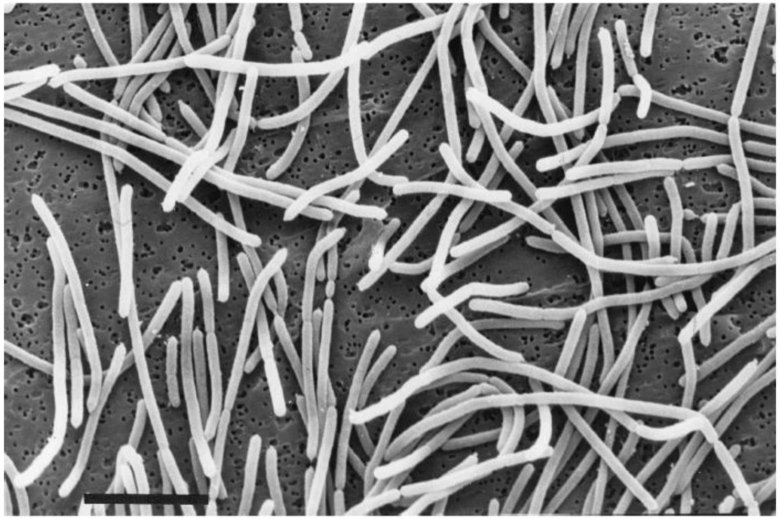
- Range
    1. ACT phase: 45-65°C
    2. Curing phase: <45°C
- High temperature (>55°C) kills pathogens and phytopathogens



Typical temperature profile during composting

Monitoring: water content

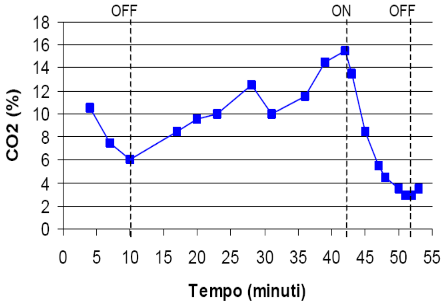
- Water film surrounding particles is where micro organisms live (especially bacteria in the ACT phase)
    - Bacterial activity is inhibited if $a_w<0,95$
    - Water displaces air in the pore spaces: excessive moisture may cause anaerobic condition
    - Empirical optimum values are between 65 and 45%



From Beffa et al. 1996

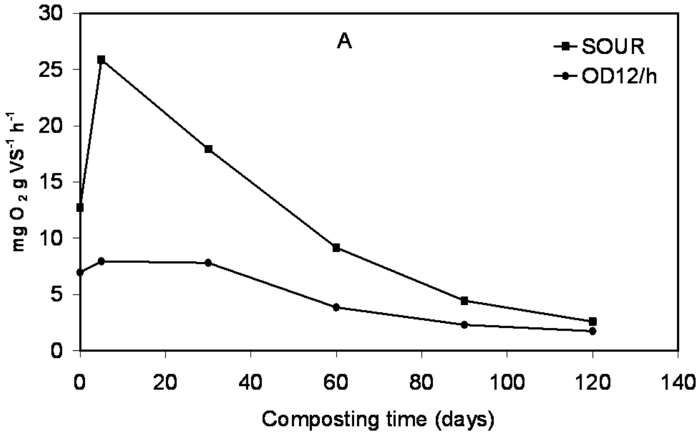
Monitoring: oxygen

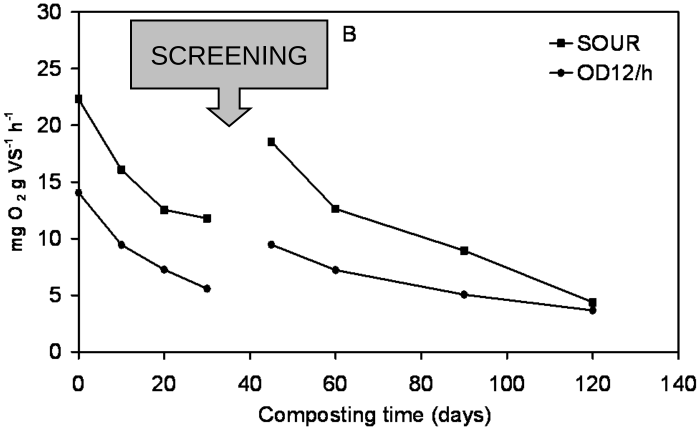
- Optimum O_2 level inside material is > 15% and should always be >8-10%
  - may measure CO_2
- During ACT of putrescible material microbial respiration can deplete oxygen inside free air spaces (FAS) very quickly (few minutes)
- Lack of oxygen will turn the process to anaerobic



Monitoring: stability

- Respiration indexes may be very useful in understanding the process and validating management choices
- Methods should be quick and reliable (e.g. SOUR)
- Best would be continuous measuring





Stability assessment

Several analytical methods were proposed which are in some way related to the concept of “stability”.

These are based of different principles:

- chemical: pH variation, ammoniacal-N concentration, C/N ratio; volatile solids changes; organic carbon fractions extracted in different solvents; etc.;
- physical: self-heating, IR spectroscopy, solid state NMR spectroscopy, optical density, etc.;
- biological: $O2$ uptake, $CO2$ production, enzymatic activity, ATP content, bioassays on plants and seeds, etc.

Definitions:

Maturity: absence of phytotoxicity

Evolution of the organic matter: OM transformation i.e. degradation and humification

Stability: slow microbial activity *(Respirometric techniques that measure the O_2 uptake or CO_2 production from the biomass as a consequence of the microbial activity are a direct measure of the degradation activity)*

KEY POINTS IN PROCESS OPTIMISATION

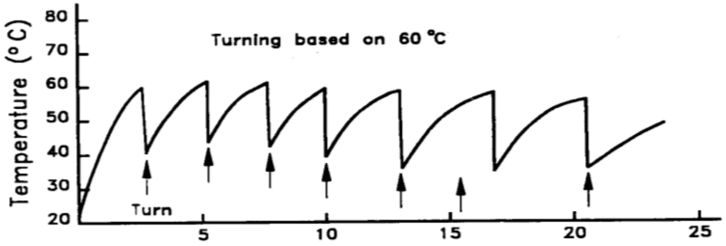
3. An effective process control

Target	Tools
Temperature control	Aeration; Air recirculation; Turning
Oxygen supply	Aeration; turning; (oxygen air enrichment)
Water content control	Watering (+); process air recirculation (+); prevent evaporation (+); Aeration and turning (-)
Homogenisation of material/preventing compaction	Turning

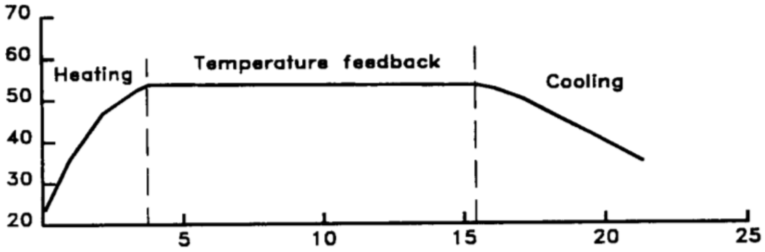
Process control: temperature control strategies

1. Turning

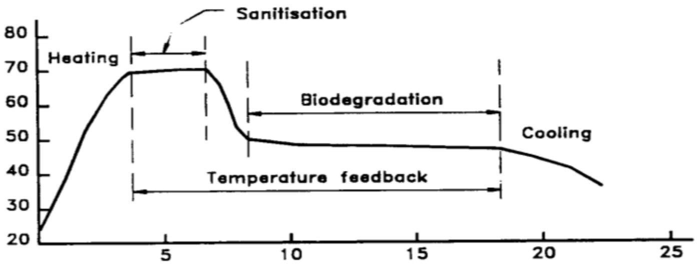
1. Forced aeration
   1. Simple feedback
   1. “Tailored”
      (in vessel systems)



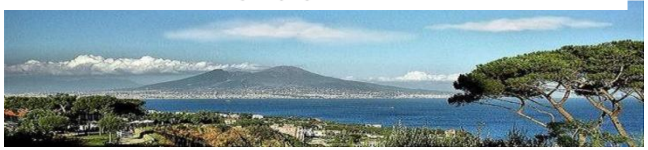
(a) Windrow profile



(b) aerated static pile



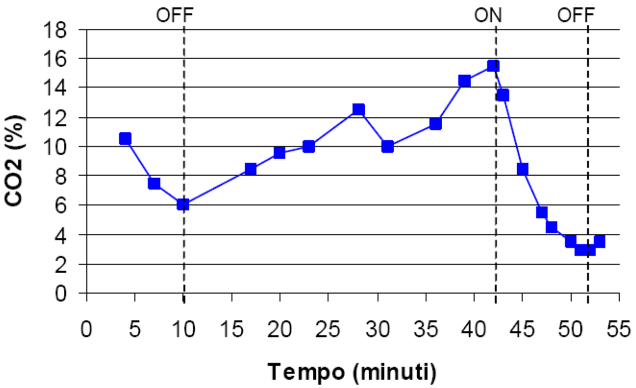
(c) "designer" profile



Process control: oxygen supply

Air contains 21% *[can be enriched to over 30%(=$!)]*

- Usually aeration needed for temperature control exceed (up to 9 times) stoichiometric needs (in ACT)
- In large volumes of highly putrescible material turning **do not** allow steady aerobic conditions
- On – off intervals should be based on monitoring of O_2 (CO_2) inside the mass
- Off periods should not exceed 30 min (in ACT)



Process control: water content

Forced vantilation and turning used for temperature management and oxygen supply may dry out the material

- •Air recirculation in closed systems (tunnels, containers) may help
- •Adding water
  - •Wetting the material may be difficult due to lipophyllic surface of organic matter
  - •Leachate forming in the firsts days of composting may be recirculate
- •Semi-permeable membrane

Process control: homogenise and re-structure

Turning helps in:

- Homogenizing material
- Restoring structure and prevent compaction
- Replenish oxygen (but not enough)
- Remove heat

KEY POINTS IN PROCESS OPTIMISATION

4. Time
   - There is **not** a “3 days composting”
   - ACT/Biostabilization: 2-5 week
   - Curing: 4-10 week or more

Thank you

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