Wastewater Treatment

Sludge treatment

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Wastewater Treatment

Sludge treatment

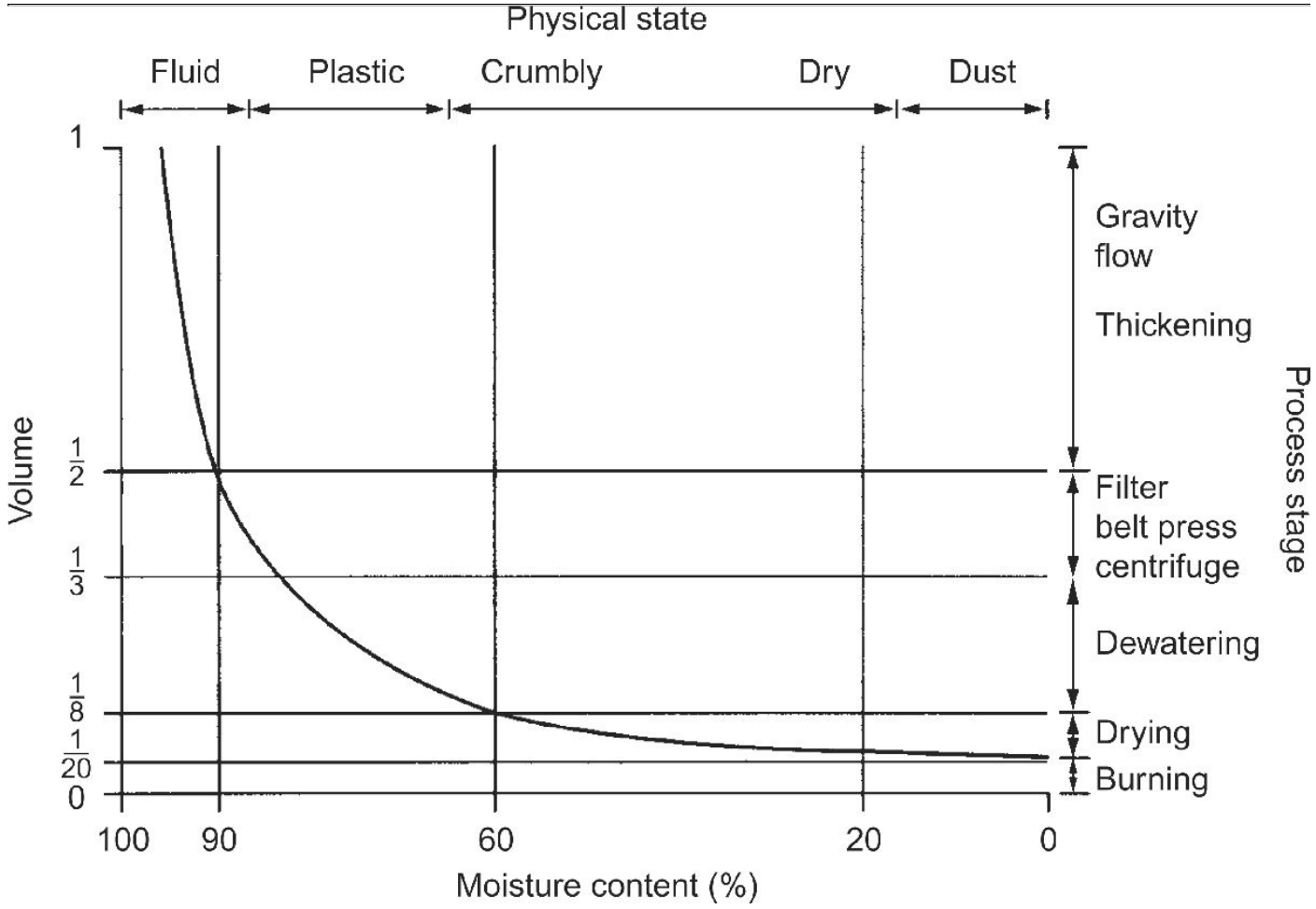
Learning Objectives:

- To understand the key unit treatment processes
- To explore disposal options
- Understand the nature, risk and limitations of sludge

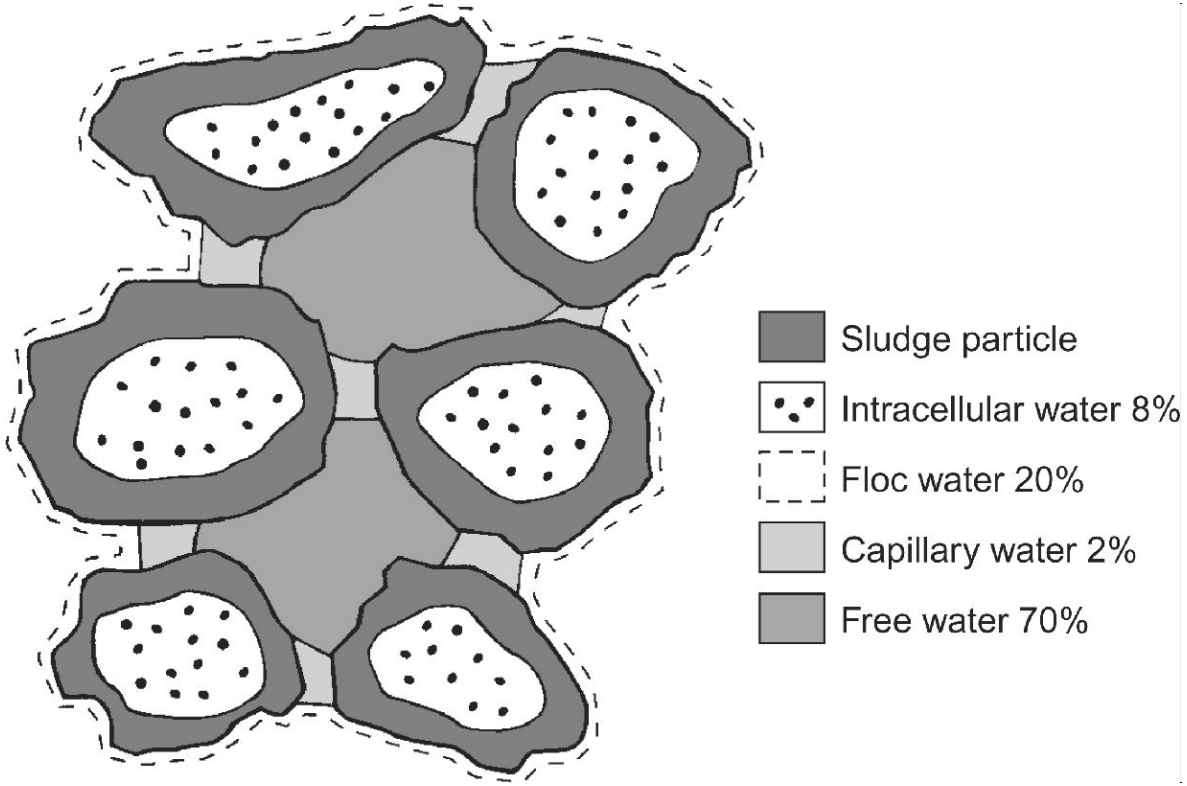
What you should know after this lecture:

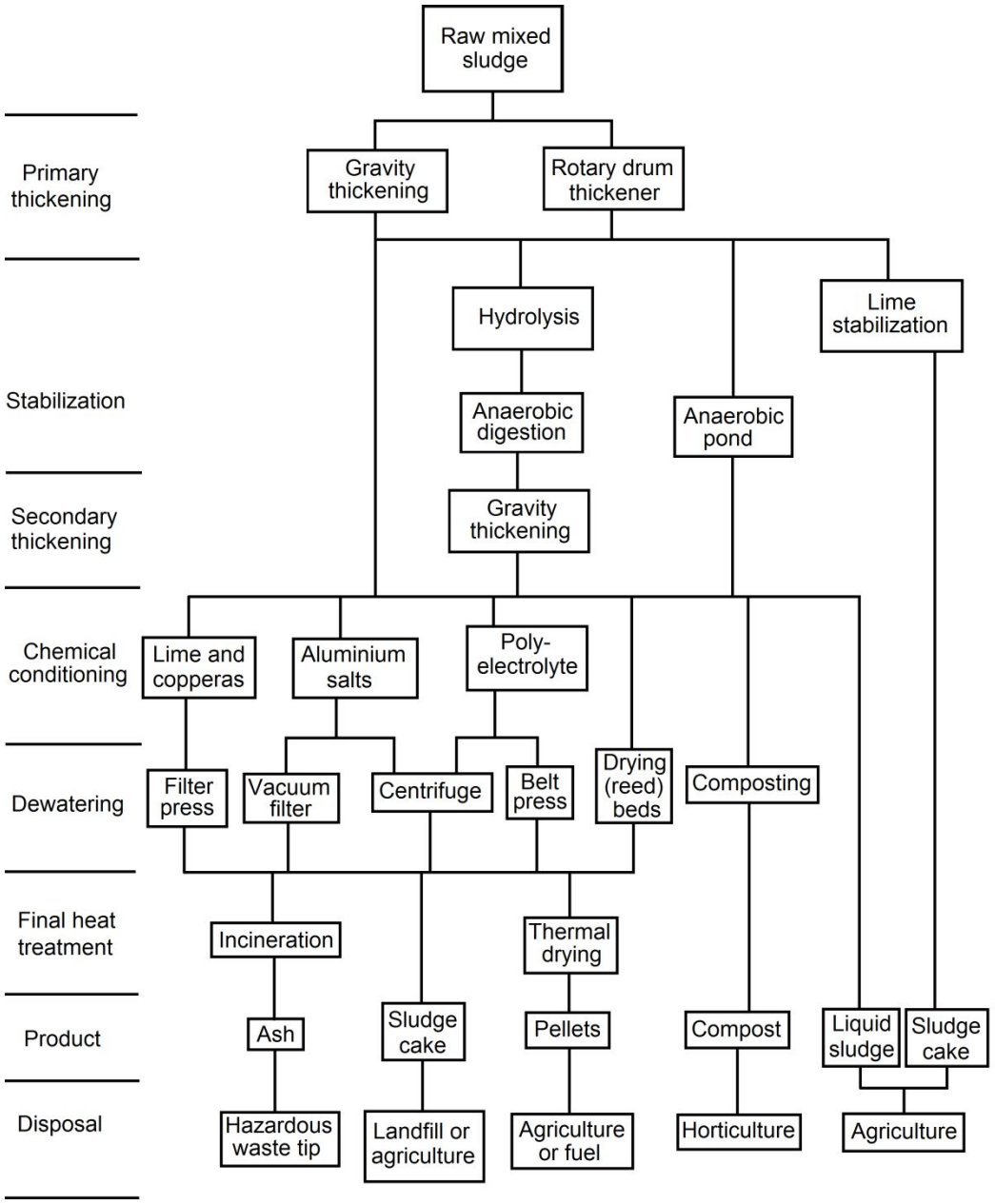
- How sludge is treated
- Limitations on disposal
- How sludge is used on land

Wastewater Treatment: sludge treatment



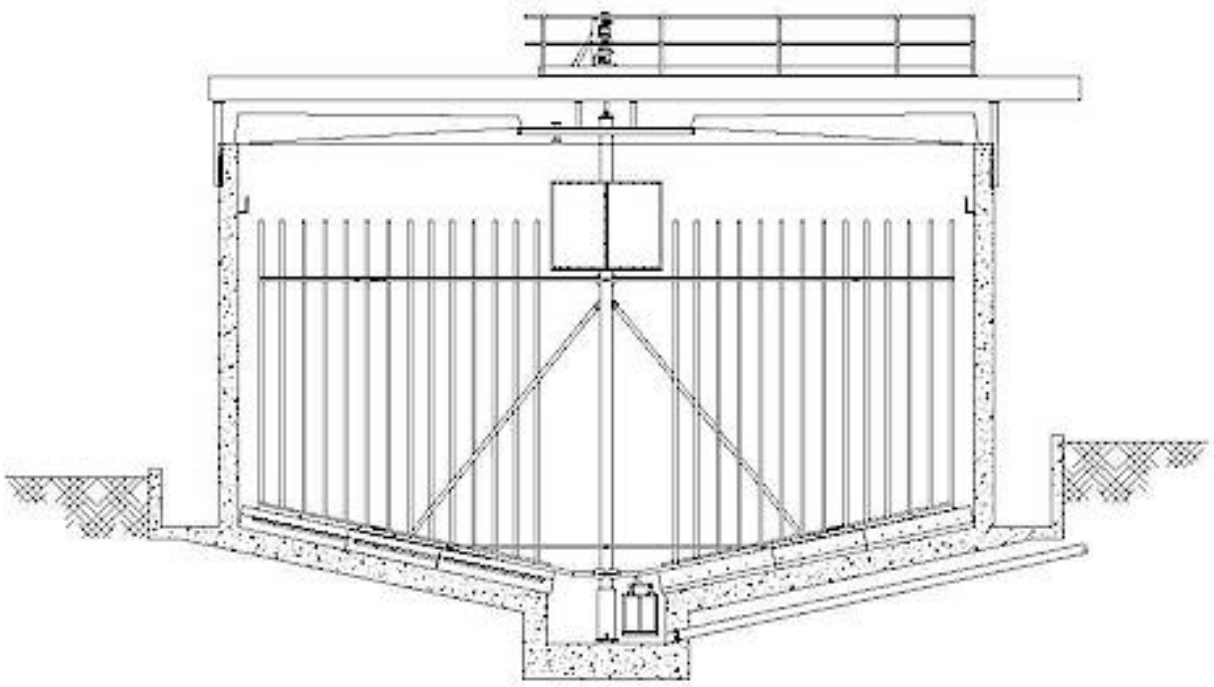
Wastewater Treatment: sludge treatment




Raw mixed sludge
Primary thickening
Gravity thickening
Rotary drum thickener
Stabilization
Hydrolysis
Lime stabilization
Anaerobic digestion
Anaerobic pond
Secondary thickening
Gravity thickening
Chemical conditioning
Lime and copperas
Aluminium salts
Poly-electrolyte
Dewatering
Filter press
Vacuum filter
Centrifuge
Belt press
Drying (reed) beds
Composting
Final heat treatment
Incineration
Thermal drying
Product
Ash
Sludge cake
Pellets
Compost
Liquid sludge
Sludge cake
Disposal
Hazardous waste tip
Landfill or agriculture
Agriculture or fuel
Horticulture
Agriculture

Sludge treatment involves:

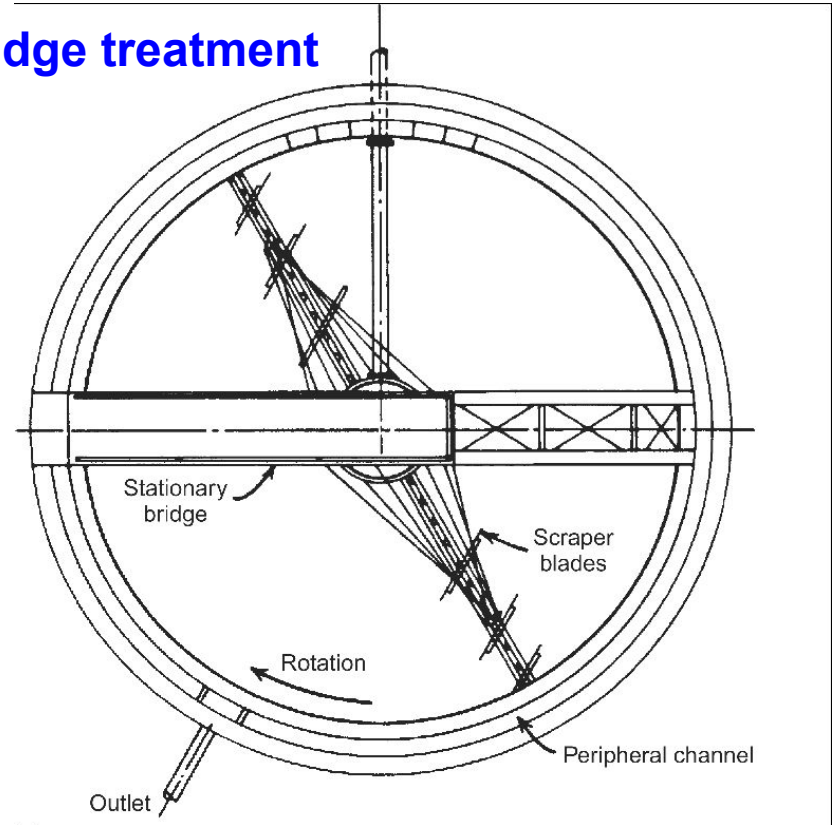
Thickening

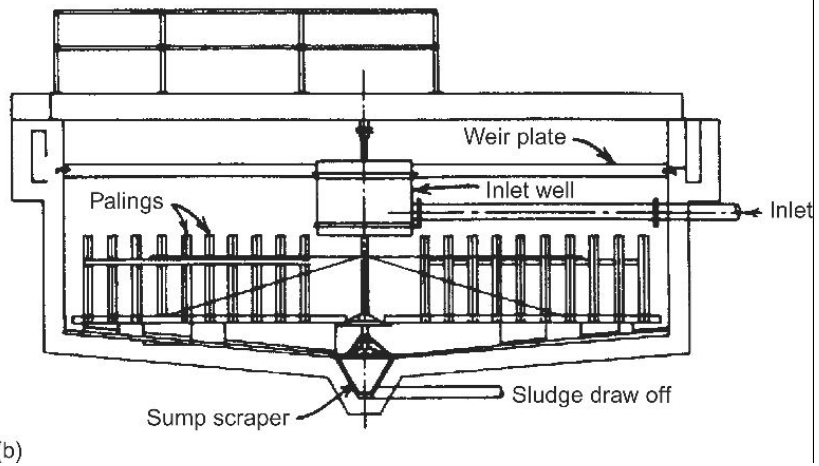


Picket fence thickener

Wastewater Treatment: sludge treatment

- Dilute sludge fed to thickener
- Blades 100mm apart
- Rotate at 0.5 – 3.0 m min^{-1}
- Thickened sludge withdrawn from base
- Primary sludge 2.5 to 8%
- A/S 0.8 – 4.0%
- Reduce sludge volume by 50% overall



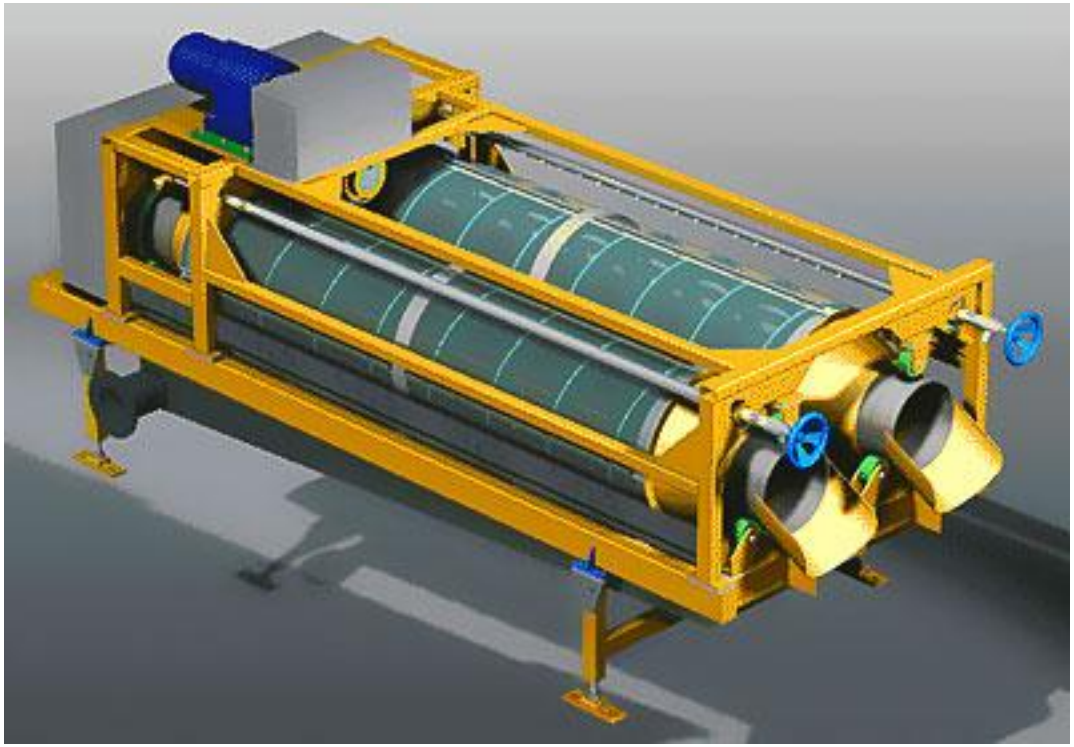


Wastewater Treatment: sludge treatment

All sludges benefit from thickening

Type of sludge	Sludge concentration (%)		Solids loading for gravity thickeners ($kg\ m^{-2}\ day^{-1}$)
	Unthickened	Thickened	
Separate			
Primary sludge	2.5–5.5	8–10	**100–150**
Percolating filter sludge	4–7	7–9	**40–50**
Activated sludge	0.5–1.2	2.5–3.3	**20–40**
Pure oxygen sludge	0.8–3.0	2.5–9.0	**25–50**
Combined			
Primary and percolating filter sludge	3–6	7–9	**60–100**
Primary and modified aeration sludge	3–4	8.3–11.6	**60–100**
Primary and air-activated sludge	**2.6–4.8**	**4.6–9.0**	**40–80**

Rotary drum thickener



Wastewater Treatment: sludge treatment

Once sludge is thickened:

- Dewatered further
- Stabilized

Stabilization Options:

Biological

- Heated anaerobic digestion
- Cold anaerobic tanks/lagoons
- Composting (aerobic)

Chemical

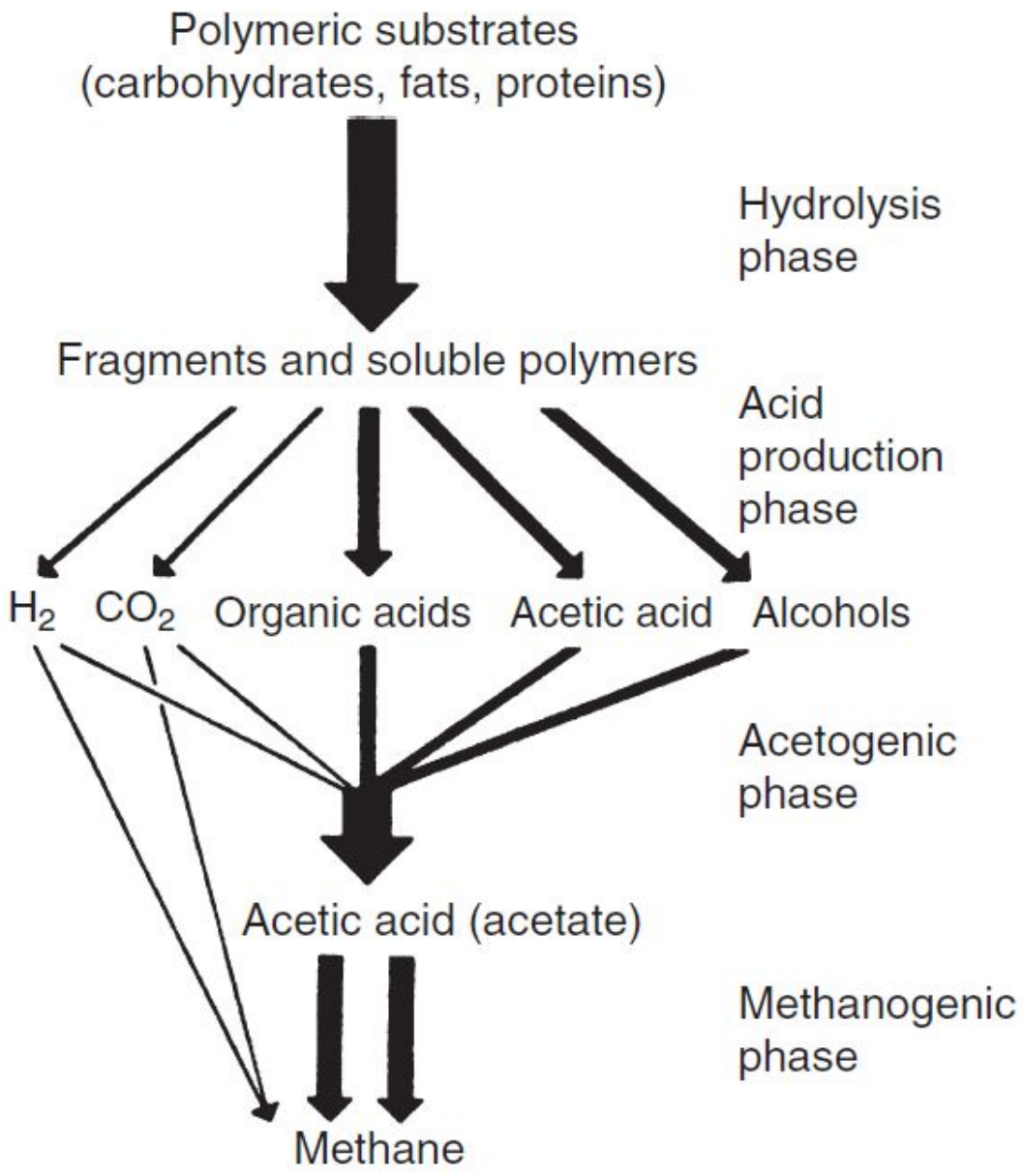
- Lime stabilization pH>11
- Hydrated lime for non-dewatered sludges
- Quicklime for dewatered sludges

Thermal/heat treatment

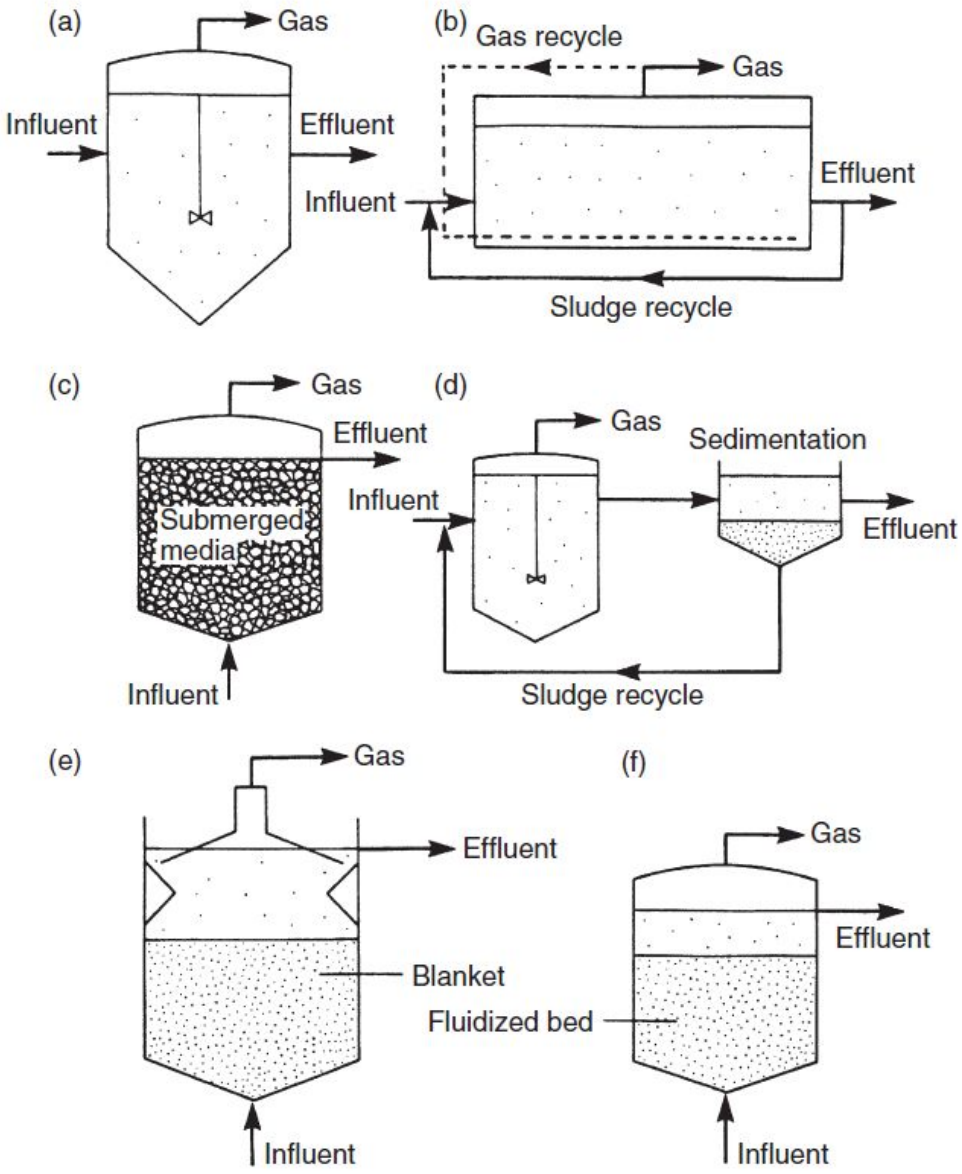
- Sludge heated under pressure to destroy cellular protein

Anaerobic Treatment and Digestion

- Biological breakdown of organic material in the absence of oxygen
- Produces biogas (CH_4+CO_2) which can be used as energy
- Four step biological reaction utilizing four consortium of bacteria
- Food waste and agricultural waste



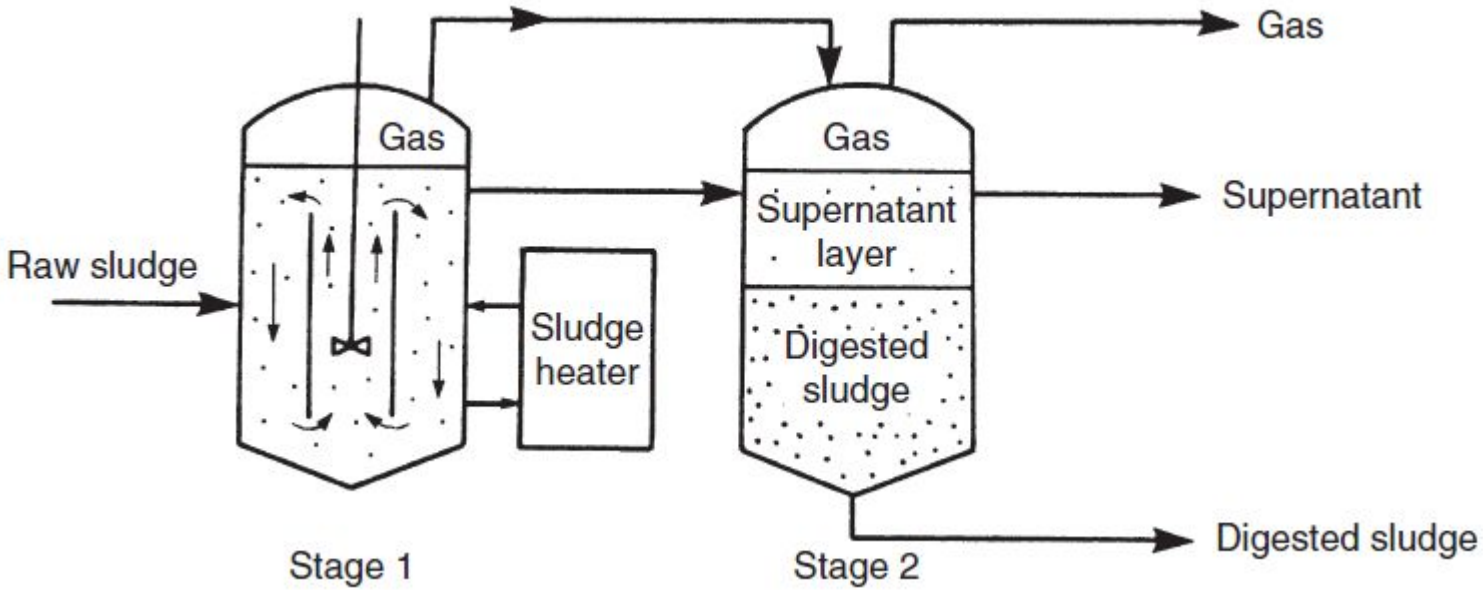
Wastewater Treatment: sludge treatment



Anaerobic Reactor Design

- Completely mixed (flow through) systems (a,b)
- Contact systems (c-f)

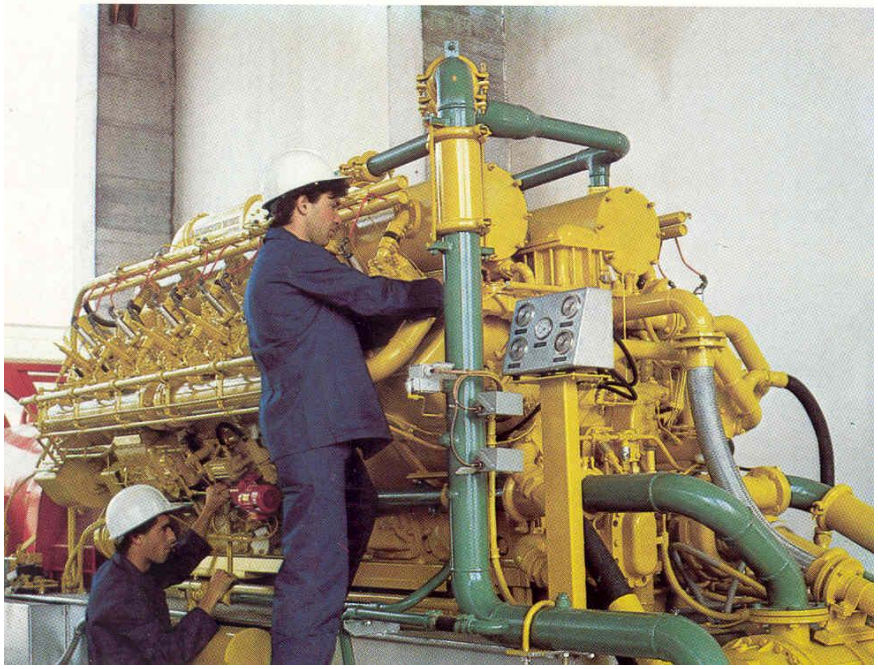
Wastewater Treatment: sludge treatment



Commonly employed two-stage anaerobic digester design

Wastewater Treatment: sludge treatment

Digester



CHP - Gas engine

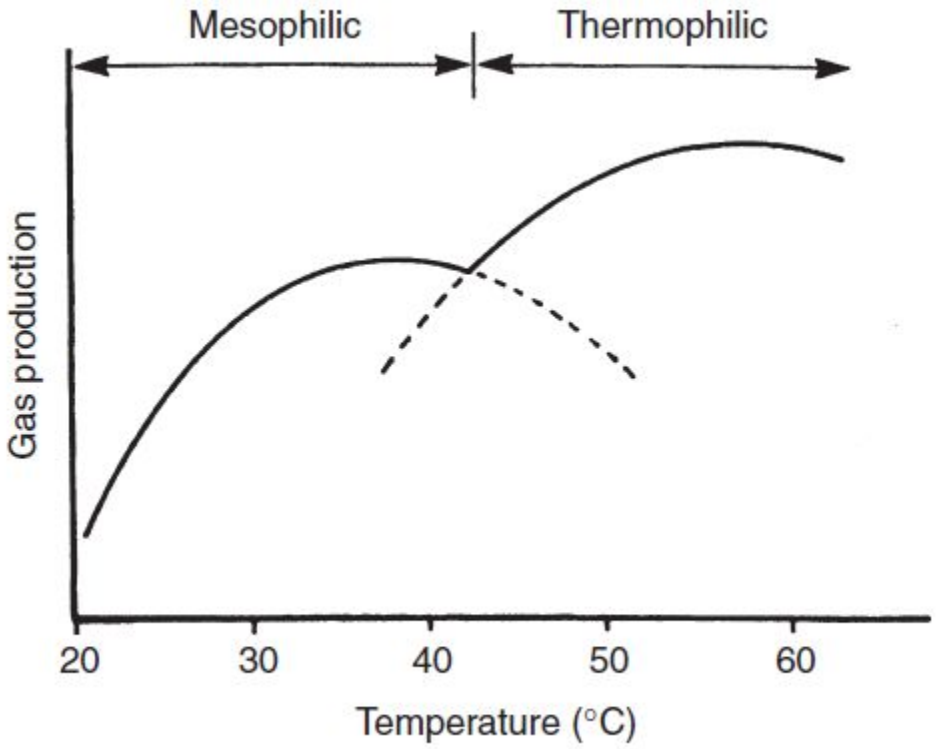
Wastewater Treatment: sludge treatment

Effect of reactor operating temperature

- Rate of biodegradation and biogas production increases with temperature

- High temperature operation
  - Increases gas production rate
  - Increases pathogen destruction
  - Require more heat input (biogas)
  - Increases heat loss

- Doubles for every 10°C rise (approx)
  - Cryophilic <20°C
  - Mesophilic 20-45°C
  - Thermophilic >45°C



Typical expected gas yields and methane content from the anaerobic digestion of various wastes

Material	*Gas yield ($m^3 kg^{-1}$ DS)*	*Methane (% volume)*
Sewage sludge (municipal)	0.43	78
Dairy waste	0.98	75
Abattoir: paunch manure	0.47	74
blood	0.16	51
Brewery waste sludge	0.43	76
Potato tops	0.53	75
Beet leaves	0.46	85
Cattle manure	0.24	80
Pig manure	0.26	81

Gas yield and composition of biogas produced by the digestion of carbohydrates, proteins and lipids

Substrate	*Gas yield ($m^3 kg^{-1}$)*	*Composition*	
		% CH_4	*% CO_2*
Carbohydrates	0.8	50	50
Proteins	0.7	70	30
Lipids	1.2	65	33

Wastewater Treatment: sludge treatment

Excess gas flare (landfill)

Advanced sludge treatment

- First stage of digestion carried out as pre-step to digestion
- Breakdown of long chain molecules into water soluble readily degradable short chain molecules

180^{o}C at 12 bar for 40 minutes

Wastewater Treatment: Sludge treatment

- Cells rupture releasing enzymes that reduce sludge volume (>20%) and increase energy yields (>30%) over normal digestion.
- Hydrolysis replaces thermophilic digestion
- Main enhancement methods are
    - Enzymatic hydrolysis (42-55^{o}C)
    - Pasteurization (70^{o}C)
    - Thermal hydrolysis (high temperature and pressure)

Dublin Cambi system

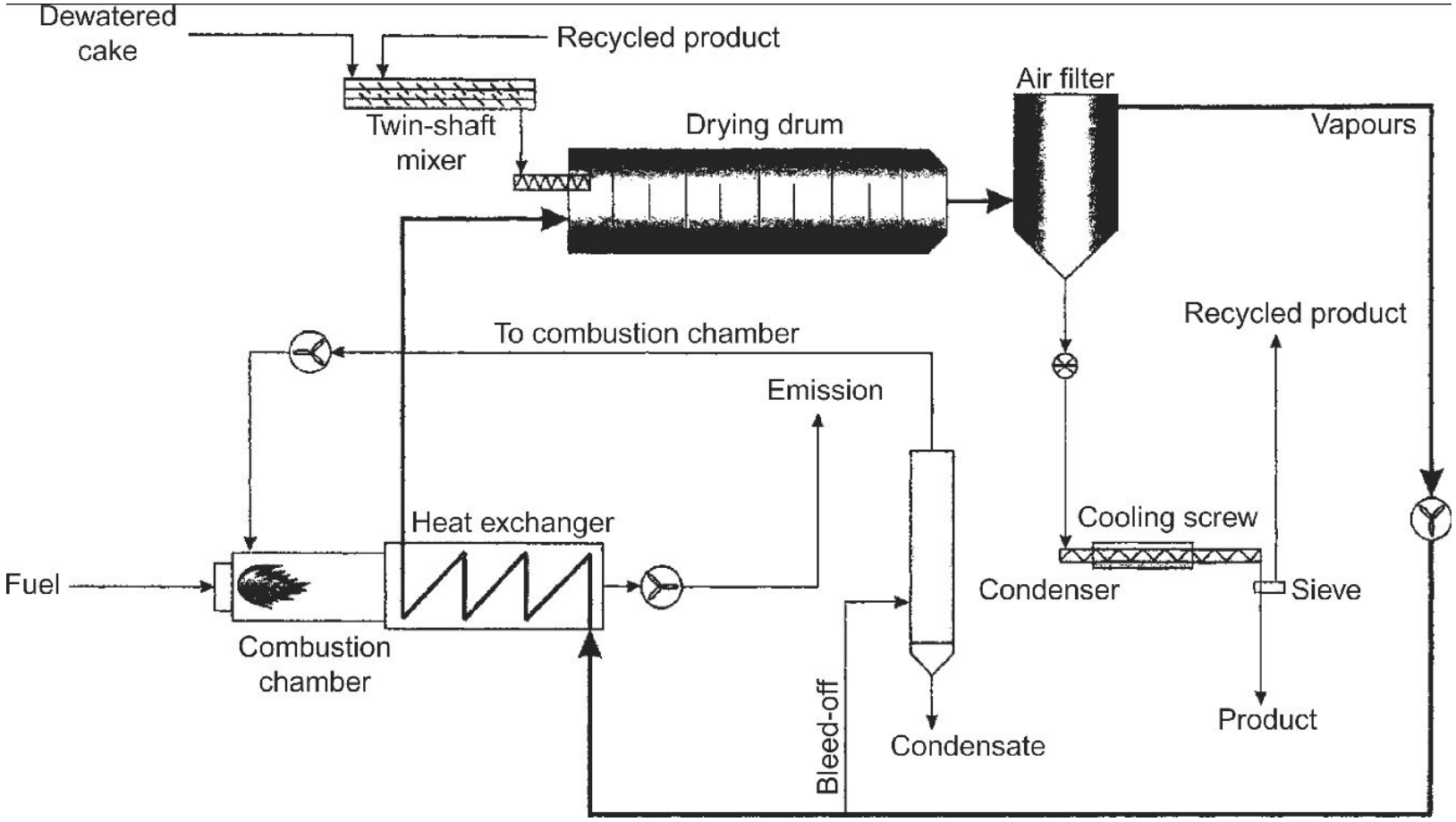
Thermal hydrolysis (Ringsend)

Dublin 1.6 x 10^6 pe

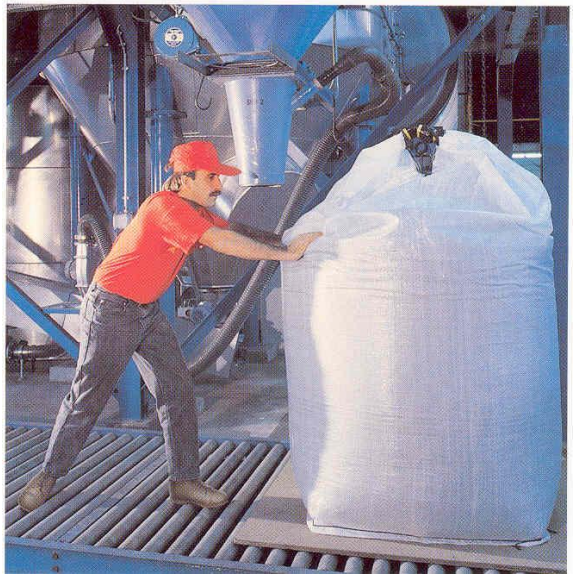
Process steps:

- Feed sludge 18% DS
- Diluted with hot water to 12-14%
- Heated to 100^{o}C using process steam
- Then fed into batch reactor and heated to 165^{o}C at 6 Bar for 90-110 minutes
- Digestion followed by dewatering and fed into drier

Wastewater Treatment: sludge treatment



Wastewater Treatment: sludge treatment



Sludge Drying: Pellets

Typical characteristics of granules/pellets:

- Dry solids 95.3%
- Volatile solids 50.0%
- N 3.3%
- P 4.4%
- K 0.22%

Typical trace elements:

- Zn 884 mg kg^{-1}
- Cu 330 mg kg-1
- Ni 48 mg kg-1
- Cr 25 mg kg-1
- Cd 5 mg kg-1

Wastewater Treatment: sludge treatment

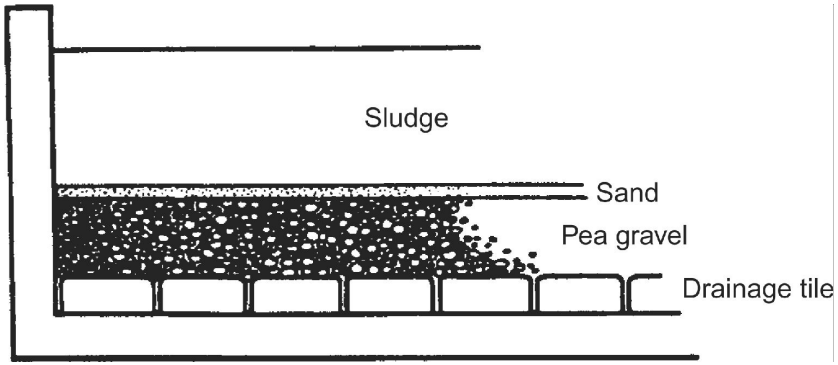
Solar Sludge drying

- The mechanically dewatered sludge will be dried from 15-18 % to up to 90 % DS.
- Uses passive solar energy.
- Material constantly turned to created friable material
- Glass houses allow energy in, while area is vented to control dust and temperature
- 150 systems now in operation mainly in warmer climates

http://www.waterworld.com/articles/print/volume-18/issue-8/case-studies/sludge-drying-system-features-solar-greenhouse.html

Sludge Drying beds

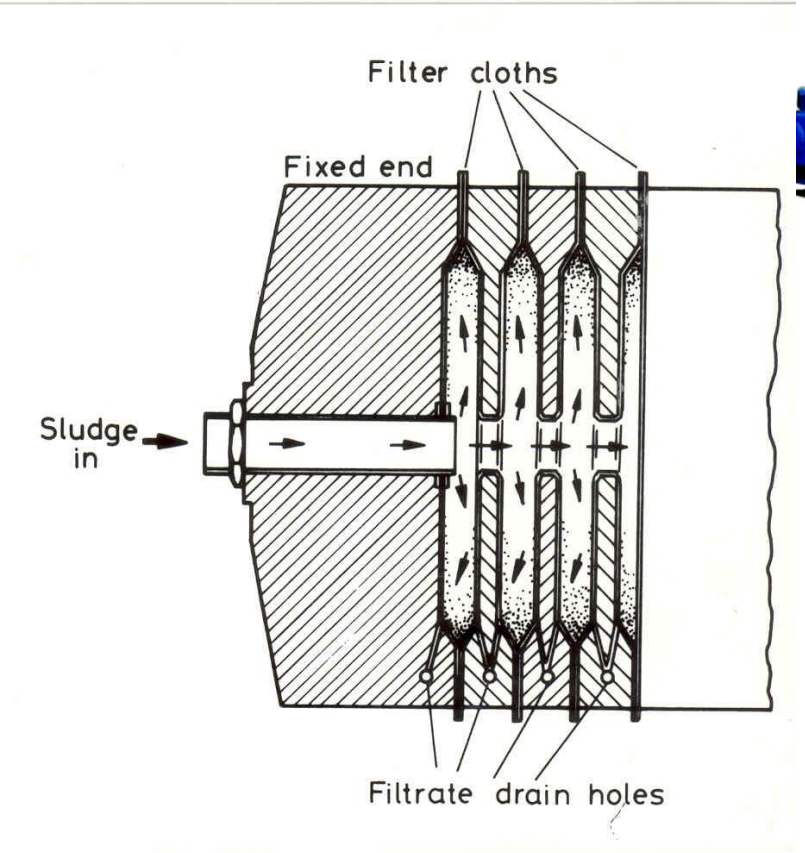
- Shallow tanks with under drains
- 100mm pea gravel plus 25 mm sand
- Ireland 40% DS after 10-15 d hot summer 30-40 d usual
- Work 6-7m year
- 0.12-0.37 m^2 ca^{-1}

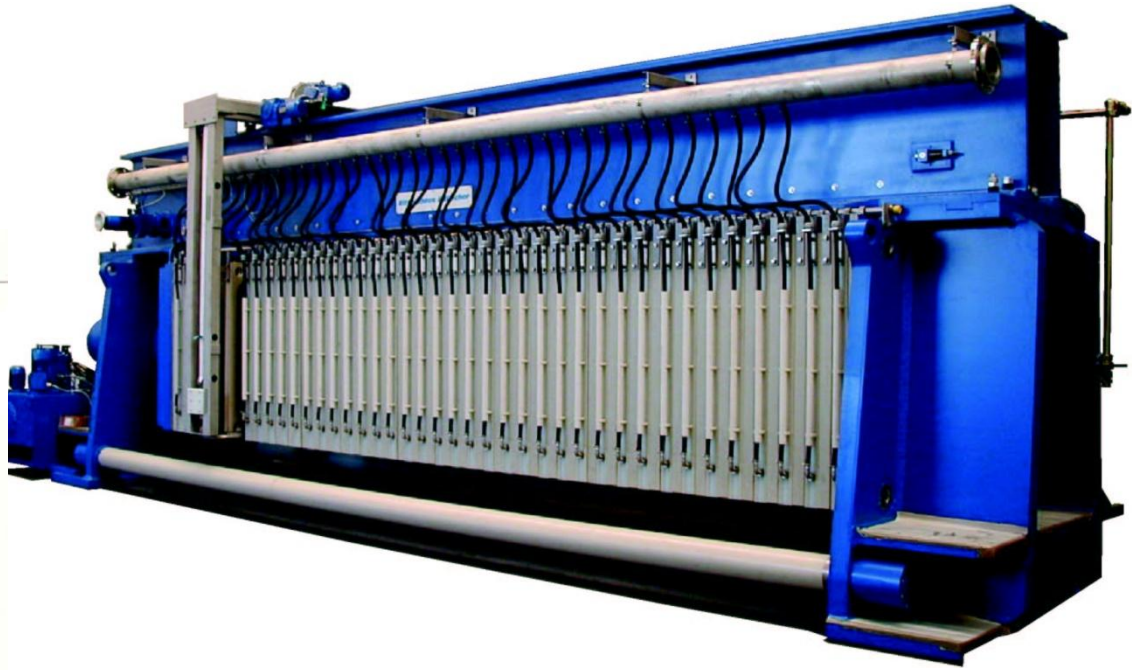


Sludge Press

Series of 50-100 metal plates covered with porous cloth

Compressed at 700 kN m^{-2}





Lime and ferrous sulphate used (copperas)

Batch process

50% of final cake is conditioner

45% DS

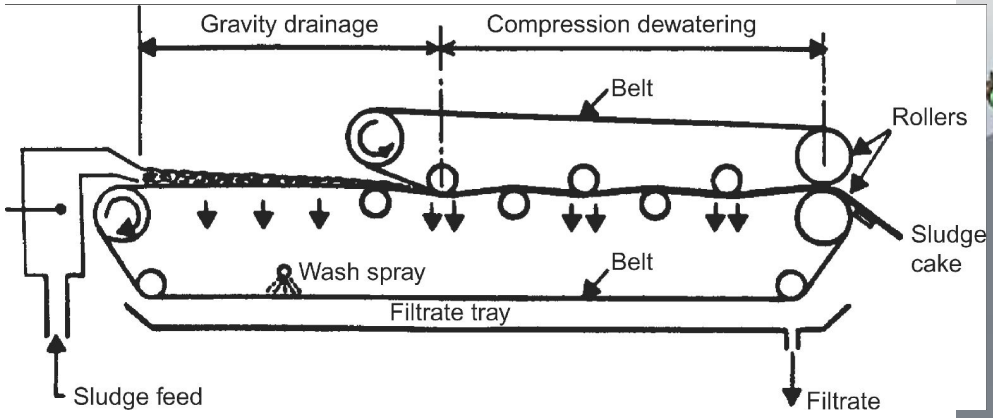
Wastewater Treatment: sludge treatment

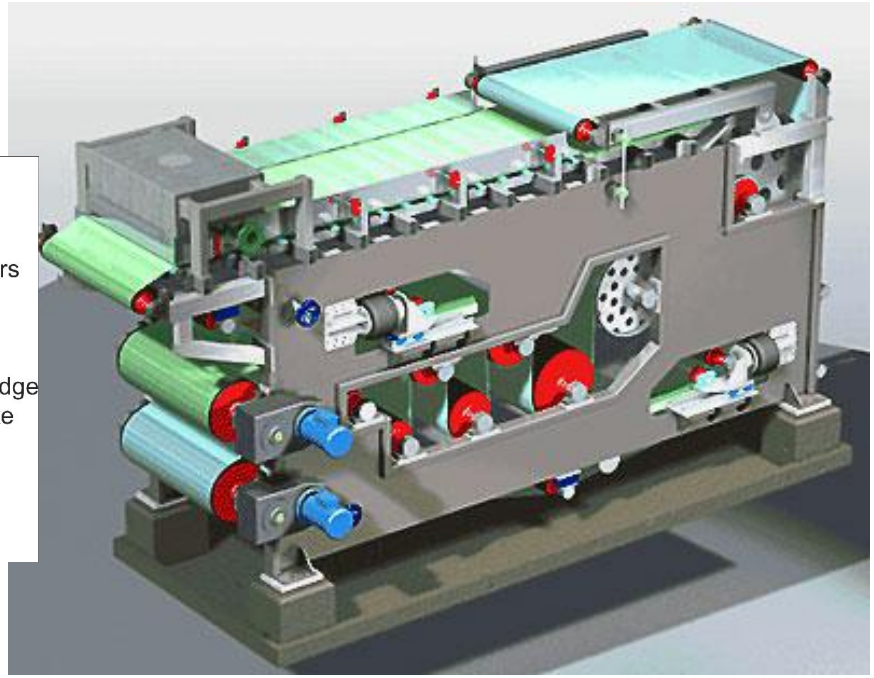
Belt press

Continuous process using two belts one impervious the other porous

Polyelectrolyte used to condition sludge

20-30% DS





Wastewater Treatment: sludge treatment

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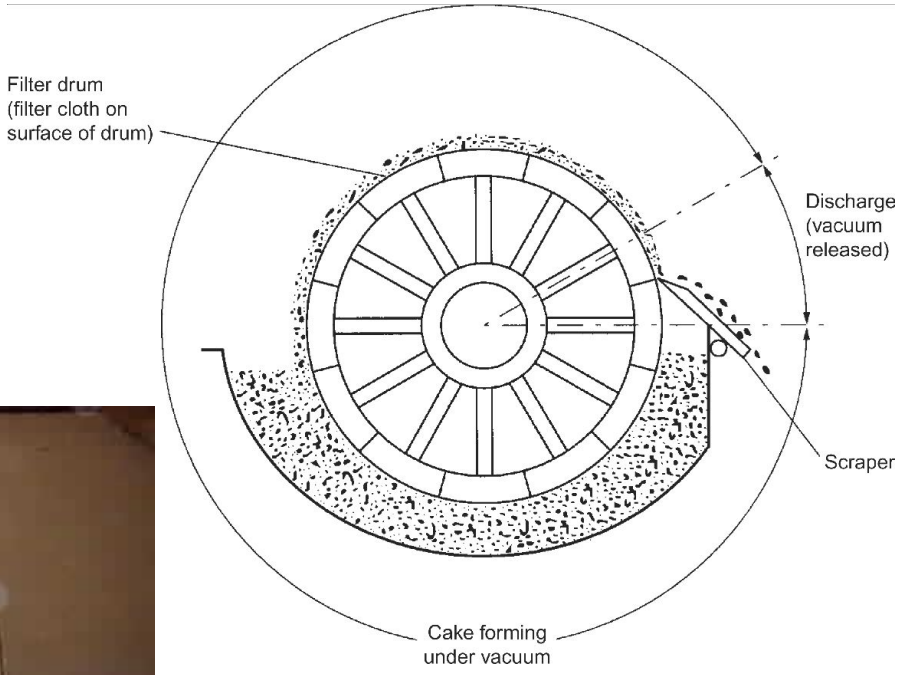
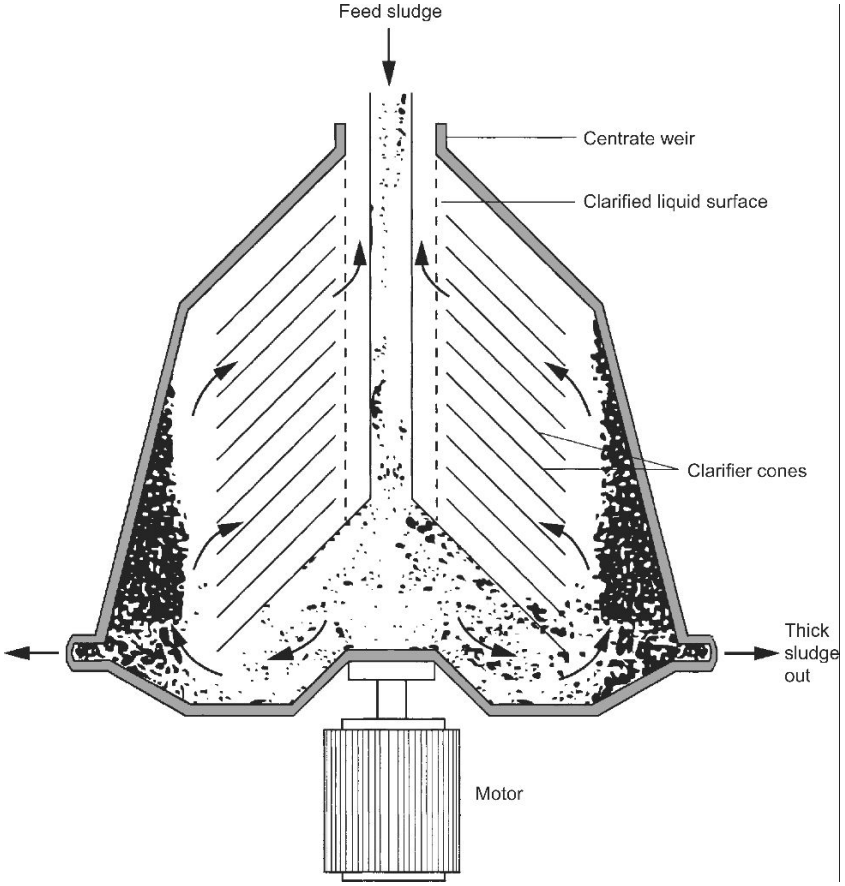
Vacuum filtration

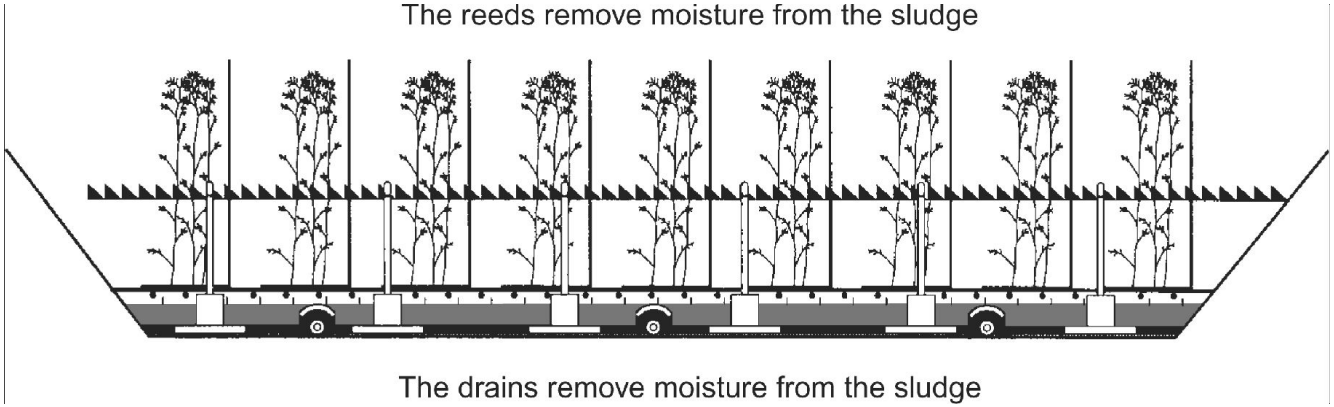


Centrifuge


NX 4850
Alfa Laval

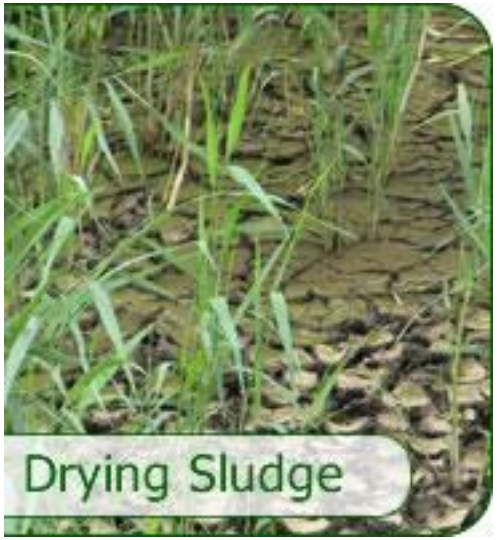

Feed sludge
Centrate weir
Clarified liquid surface
Clarifier cones
Thick sludge out
Motor

Sludge Reed Beds



Wastewater Treatment: sludge treatment

Process steps



Wastewater Treatment: sludge treatment

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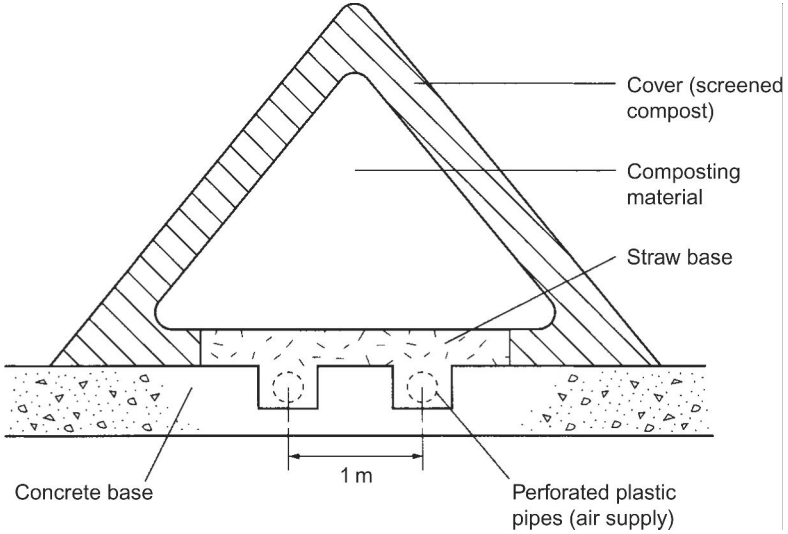
CAT


Cover (screened compost)
Composting material
Straw base
1 m
Concrete base
Perforated plastic pipes (air supply)

In-vessel Composting

- An industrial form of composting which occurs in enclosed reactors. It allows greater control on the environment by enhancing organic matter breakdown.
- Air temperature is continually monitored and re-circulated under pressure to create optimum conditions for biodegradation.
- Odour is physically contained and any aqueous or gas by-products are collected for further treatment.

Windrow Composting

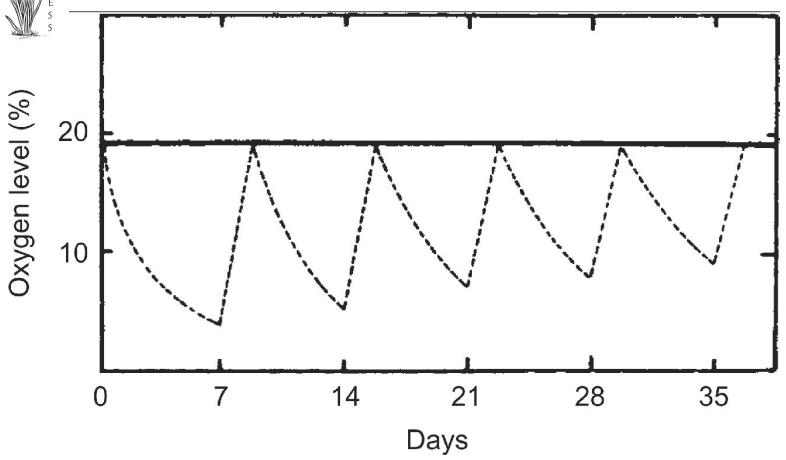
- Compost is produced by piling biodegradable waste into windrows which allows for large scale composting under natural conditions.
- The windrows are regularly turned to improve the oxygen capacity and porosity of the substrate. The temperatures are monitored to ensure it achieves sufficient pathogen kill.

Composting process

- Solids mixed with a bulking agent (straw, woodchip etc.)
- Minimum moisture content >40% for optimum microbial activity.
- The microbes give off heat and CO_2.
- The temperature initially rises to 50-65^{o}C
- Rows are is mechanically mixed every 3-7 days for 8 turns. This turning reduces the particle size to increase the rate of break down, and aerates and mixes the windrow to manage the temperature and oxygen levels.
- Oxygen levels must be maintained at a minimum of 5% to support aerobic microbial activity. When there is adequate oxygen present, the process does not produce objectionable odours.
- During the composting process, the compost windrow is sprayed with water to create an exterior crust to seal in the interior moisture
- Process takes 60-120 days from process start to finish.

https://www.youtube.com/watch?v=MxnqLGRjNOE

https://www.youtube.com/watch?v=N1_p2-MhX2U



Initial C:N ratio 25-40 (inc. bulk agent)

- Sludge 11
- Straw (wheat) 140
- Sawdust 220-500
- Too high process slows
- Too low ammonia often released

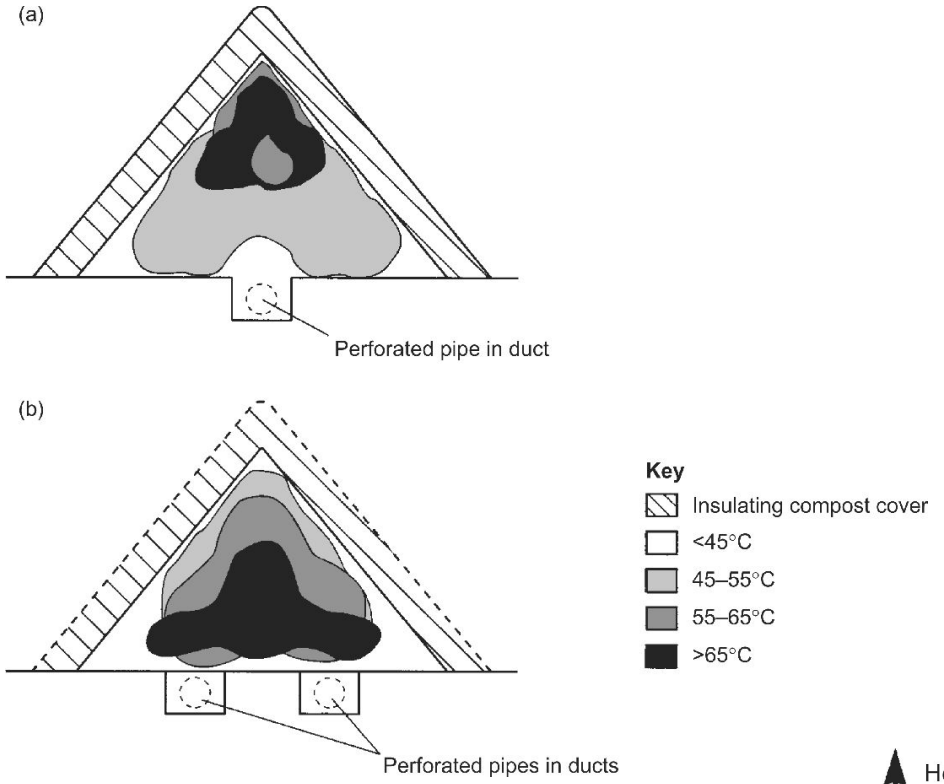
Problems related to moisture loss <40% increasing inhibition. Initial value normally 60-70% depending on material

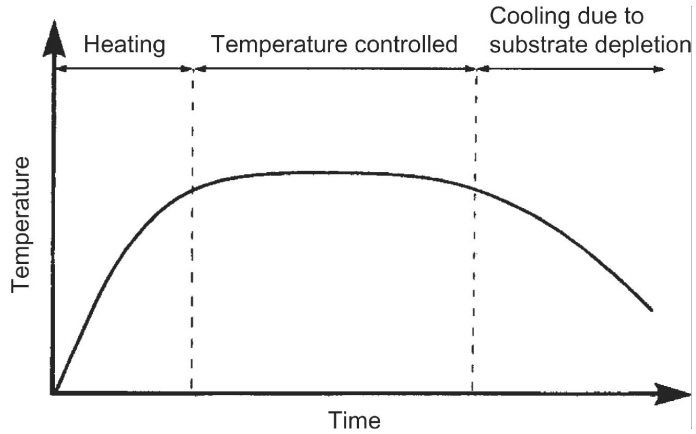
Temperature is critical

35-45°C greatest diversity

45-55°C highest rate of biodegredation

>55°C highest rate of pathogen inactivation





Stability achieved when

- Can be stored without odour production
- No longer self heating
- Good friable consistency
- Organic/earthy smell
- Low pathogen count
- Usually measured using SOUR (i.e. less than 1 mg O_2 g^{-1} h^{-1})

Advantages of product

- Improves soil structure
- Provides nutrients in organic (slow release) form
- Aids the soils microbial activity
- Provides the soil with vital humic acids
- Increases organic content reducing bulk density
- Protects plants, by fending off soil born diseases
- Reduces the amount of waste taken to landfill

Wastewater Treatment: composting

Wastewater Treatment: sludge treatment

References:

Further information in Chapter 15 of the Course text.

Gray, N.F. (2017) *Water Science and Technology: An Introduction*, CRC Press, Oxford.

http://www.leightonasia.com/en/what-we-do/pages/project-showcase.aspx/sludge-treatment-facility?project=3&s=Active&l=Hong+Kong&d=