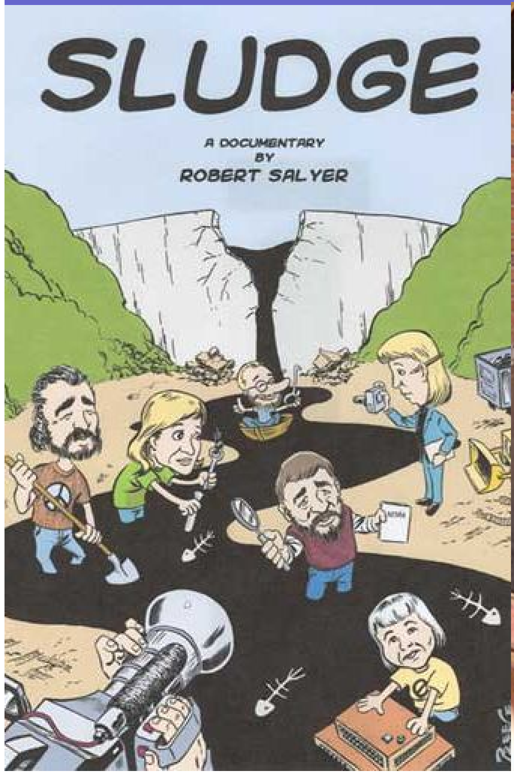
Chapter 8-Sludge stabilization



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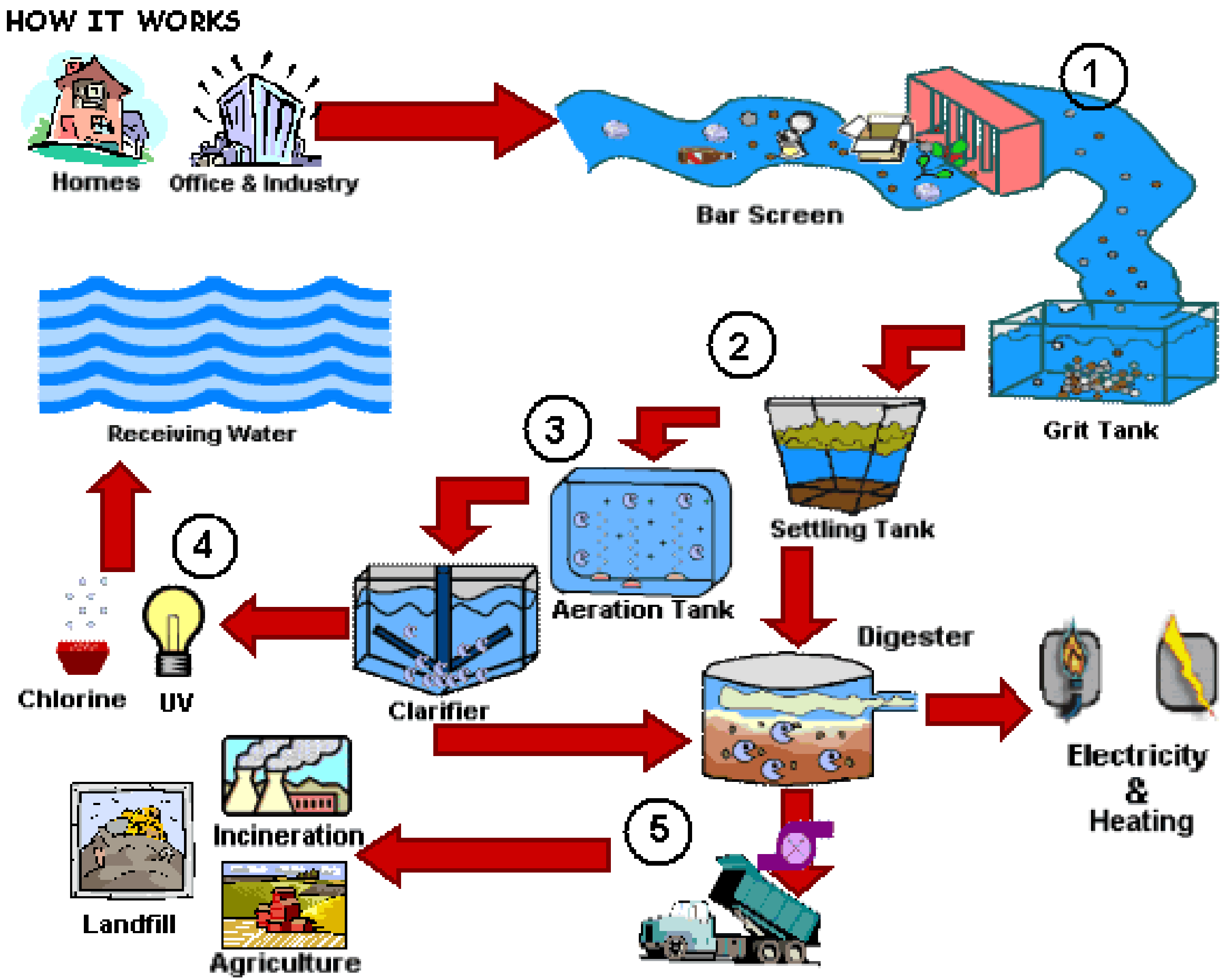
Purpose

Sludge is composed of the pollutants that have been removed by sedimentation and potential pollutants produced when organic matter degrades.

Sludge treatment is needed to reduce the water and organic content of the sludge and render the solids suitable for reuse or final disposal

More specifically, the purpose of sludge stabilization is to 1) reduce pathogens, 2) eliminate offensive odors; and 3) inhibit, reduce or eliminate the potential for putrefaction (which is done by biological reduction of the volatile organic fraction or addition of chemicals).

City of Toronto



Sources of Sludge

Screenings	Coarse/large organic and inorganic materials
Grit removal	Grit (heavy inorganic solids) and scum (Floatable material containing grease, oils, fats, waxes… of specific gravity lower than 1)
Primary sedimentation	Primary solids and scum, “smelly gray and slimy” sludge from primary tanks
Biological treatment	Suspended solids
Secondary sedimentation	Biosolids and scum
Solids processing facilities	Solids, compost, ashes…

Composition

Untreated primary sludge:

Total solids (% of TS)	5-6 % (6 % typical)
VS (% of TS)	60 - 80 (65)
Grease and fats (% of TS)	13 – 65
Protein (% of TS)	20 - 30 (25)
Nitrogen (% of TS)	1.5 – 4 (2.5)
Energy (kJ TS/kg)	23 000 - 29 000 (25 000)

Untreated activated sludge:

Total solids (TS)	0.8 – 1.2 %
VS (% of TS)	59 - 88
Grease and fats (% of TS)	5 - 12
Protein (% of TS)	39 - 41
Nitrogen (% of TS)	2.4 – 5.0
Energy (kJ TS/kg)	19 000 – 23 000

Other contaminants include SiO_2, pathogens, P, heavy metals

Sludge Treatment

Primary operation

- Storage
- Grinding
- Blending
- Degrifting

thickening

- Settling
- Gravity
- Centrifuge
- …

stabilization

- Lime
- Anaerobic
- Aerobíc

conditioning

dewatering

- Centrifuge
- Press
- ….

drying

incineration

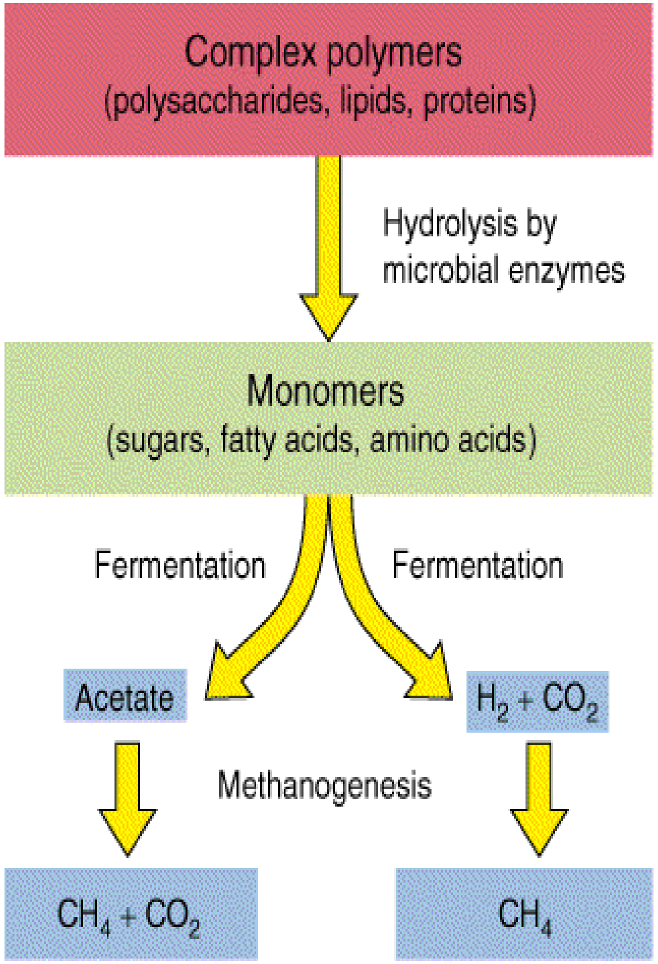
Main methods for sludge reduction

Alkaline stabilization	Addition of lime $Ca(OH)_2$ to maintain high pH: this actually increases the amount of sludge.
Anaerobic digestion	VS are converted into CH_4 and CO_2: energy production
Aerobic digestion	VS are converted to CO_2: simple but energy intensive
Autothermal thermophilic digestion	Similar to aerobic digestion, large amount of O_2 + insulated covered reactor $\Rightarrow$ heat
Composting	VS is biodegraded, requires bulking agent, net solid production, odor formation

Comparison

Process	Pathogen removal	Putrefaction attenuation	Odor control
Alkaline stabilization	Good	Fair	Fair
Anaerobic stabilization	Fair	Good	Good
Aerobic stabilization	Fair	Good	Good
Autothermal termophilic	Excellent	Good	Good
Composting	Fair	Good	Poor to Fair
Thermophilic composting	Excellent	Good	Poor to Fair

Anaerobic stabilization



Important parameters:

- **pH**
- **Temperature**
- **Inhibitory substances**

Single stage

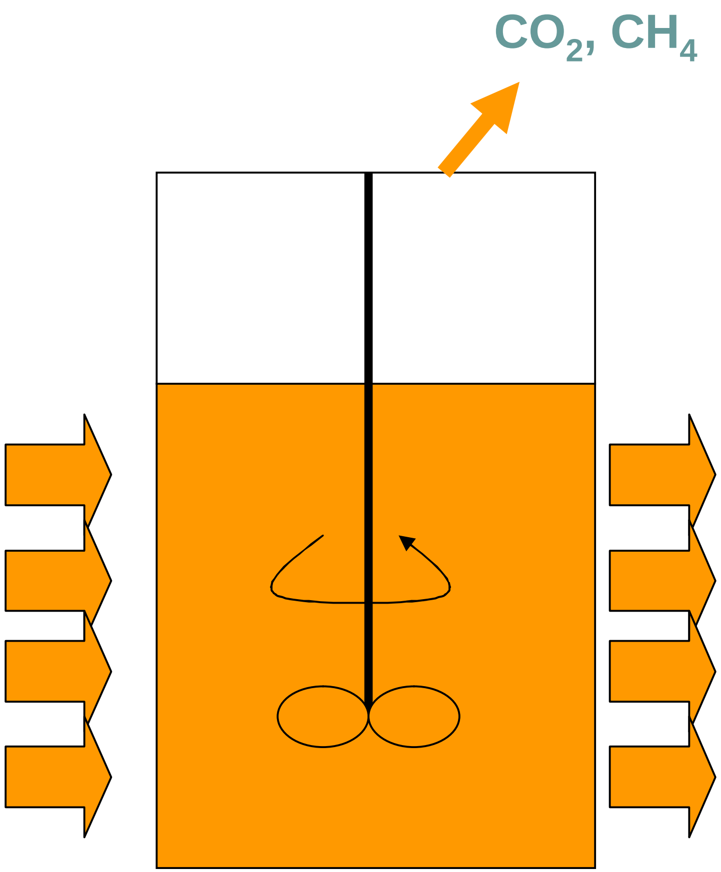
Heating is often necessary

Mechanical mixing

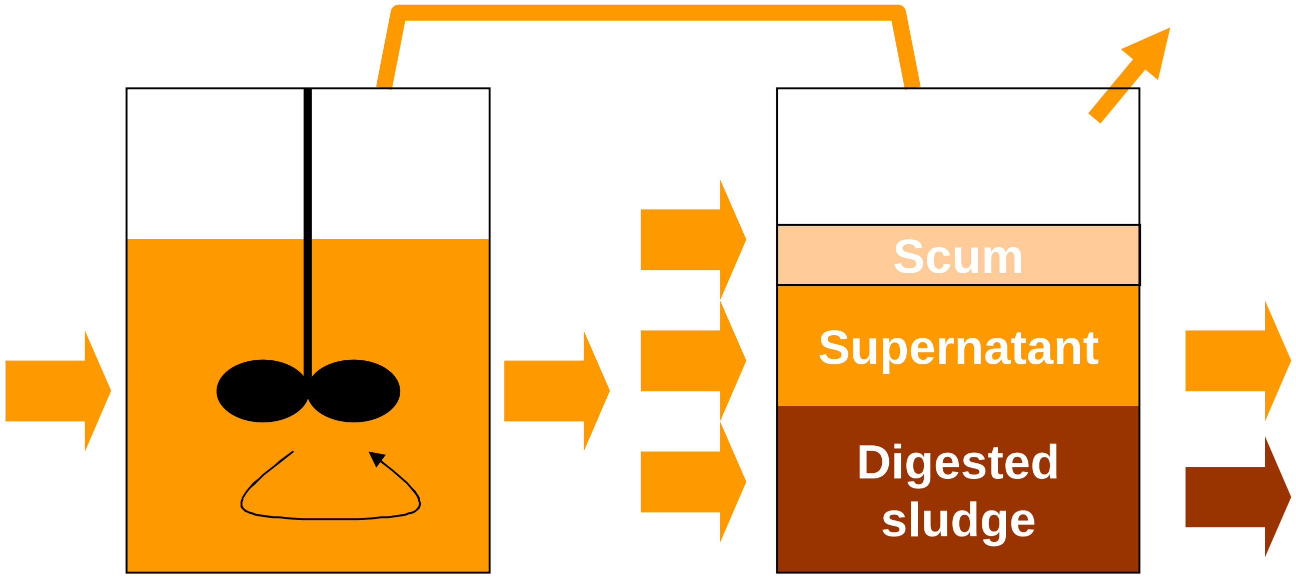
Multiple point feed

Required thickened sludge

Continuous or fed-batch operation



Classical two-stage digestion



First tank for digestion (heated)

Second tank for storage (not heated)

Temperature-staged anaerobic digestion

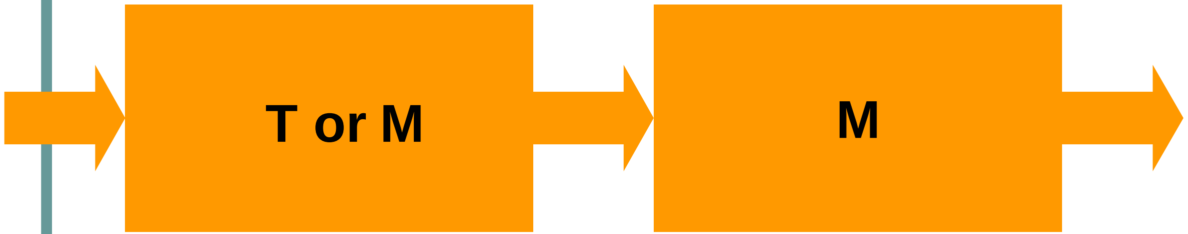
→ **Thermophilic** → **Mesophilic** →

55°C **3-5 d SRT**	**35°C** **10 d SRT**	**Total SRT of** **approx. 15 d**

The process can also be operated as Mesophilic/Thermophilic configuration. It offers a better overall cost-efficiency

Thermophilic conditions enhance microbial activity and favor solid and pathogen removal. However, heating is costly.

Metabolically-staged anaerobic digestion



pH 6

1-3 d SRT

35°C
10 d SRT

Total SRT of approx. 15 d

The first stage is used for hydrolysis and acidification (production of VFAs).

The second stage is used for methanogenesis.

Basic design parameters classical anaerobic digestors

Parameter	Unit	Value
Primary sludge volume	m^3/capita	0.03 – 0.06
Primary sludge + activate sludge	m^3/capita	0.07 – 0.11
Sludge loading rate	kg VSS /(m^3-d)	1.6 – 4.8
VSS removal	%	56-65
SRT	d	15 - 30

Metcalf and Eddy (2003)

The sludge loading should be optimized: the highest possible to minimize reactor size and heating without having NH_3 inhibition problems.

Aerobic digestion

The NH_3 formed during biomass ($C_5H_7NO_2$) digestion is further oxidized to nitrate, and this nitrate is used for biomass digestion!

1: $C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3$

2: $NH_3 + 2O_2 \rightarrow NO_3^- + H_2O + H^+$

1 + 2 (3): $C_5H_7NO_2 + 7O_2 \rightarrow 5CO_2 + 3H_2O + NO_3^- + H^+$

4: $C_5H_7NO_2 + 4NO_3^- + 4H^+ \rightarrow 5CO_2 + 2N_2 + NH_3 + 4H_2O$

4 + 2 (5): $C_5H_7NO_2 + 3NO_3^- + 2O_2 + 3H^+ \rightarrow 5CO_2 + 2N_2 + 5H_2O$

3(3) + 5: $4C_5H_7NO_2 + 23O_2 \rightarrow 20CO_2 + 2N_2 + 14H_2O$

About 75-80% of the cell tissue can be oxidized aerobically, the remaining fraction is made of inert compounds and non-biodegradable organic compounds.

Aerobic digesters

- Traditionally limited to small WWTPs
- Operated as batch or continuous
- Alternating mixing and aeration can improve denitrification
- Classified between “classical”, “high purity oxygen” and “autothermal”
- Addition of alkalinity ($CaCO_3$) is sometimes needed to avoid drops in pH.

Autothermal digester

Must be insulated and operated at high VSS load under intensive aeration (this often requires the use of pure O_2)

High temperature $\Rightarrow$ nitrification is inhibited $\Rightarrow$ NH_4^+ formation $\Rightarrow$ the pH can rise to 8 – 9, NH_3 is found in the reactor effluent and the off gas

High O_2 demand $\Rightarrow$ microaerophilic (or even anaerobic) conditions might occur $\Rightarrow$ production of fermentation and odorous products

Basic design parameters of classical aerobic digestors

Parameter	Unit	Value
SRT	d	40 (20°C) 60 (15°C)
Volatile solid loading	kg/(m^3-d)	1.6 - 4.8
Reduction of VSS	%	38 - 50
Oxygen requirement	kg O_2/kg VSSremoved	1.6 – 2.3

Metcalf and Eddy

Basic design parameters of autothermal digestors

Parameter	Unit	Value
SRT	d	4-30
Volatile solid loading	kg/(m^3-d)	3.2 – 4.2
Temperature	°C	35 - 70

Metcalf and Eddy (2003)

Normally, 2-3 reactors are used in sequence!!

Composting

- Organic material undergoes biological degradation to a stable humus-like product that can be used as fertilizers

- Efficient pathogen removal is achieved through temperature increase (50 – 70°C).

- Can be operated anaerobically, but aerobic processes are more common (less risk for odors).

- Often used as post-treatment after digestion

Principle

Due to the low water content, the design of the pile and the high C-and nutrient contents, rapid aerobic growth on easily biodegradable organic matter generates heat, resulting in an increase of Temperature.

This favors the growth of thermophilic fungi that degrade the less biodegradable organic matter: cell debris, cellulose and persistent hazardous pollutants.

Basic design

The sludge (often thickened) is mixed with a bulking agent whose purpose is to improve the porosity of the mixture, to avoid compaction (better O_2 transfer), to maintain moisture and to provide nutrients.

The mixture is then placed as piles which dimensions should be chosen to ensure microbial heat generation is greater than heat dissipated through the surface

The pile is aerated by mixing (windrow system), venting (piles) or both

The material is composted for 21-28 days and left for maturation (curing phase) for 30 days.

Composting can also be done in special reactors (in-vessel composting)

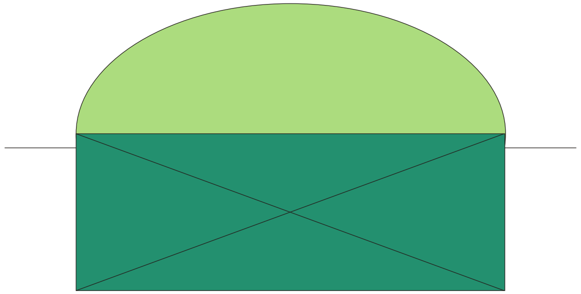
Windrow

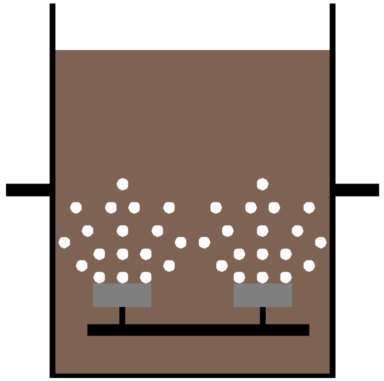
Design considerations

Item	Comment
Bulking agent	Should be inexpensive and readily available (wood chips)
C/N ratio	20:1 – 35:1
VS	VS should be at least 30% of TS
Moisture	< 60% for static piles and windrows
pH	6 - 9
Temperature	50 – 60°C (70°C if pathogen removal is a priority)
Mixing, turning	Needed to prevent drying, caking, air channeling
Site constraints	Weather, area…

In BioWin3

Biowin 3 contains both Aerobic and anaerobic Digester





<u>Anaerobic Digester operates as a CSTR</u> and requires:

- Tank Dimensions
- T of operation
- Initial Values for simulation
- Outflow (overflow, cte outflow)

<u>Aerobic Digester operates as CSRT</u> and requires:

- Tank Dimensions
- Aeration Methods (DO or air supply set point)
- T of operation
- Kinetics and Aeration Parameters