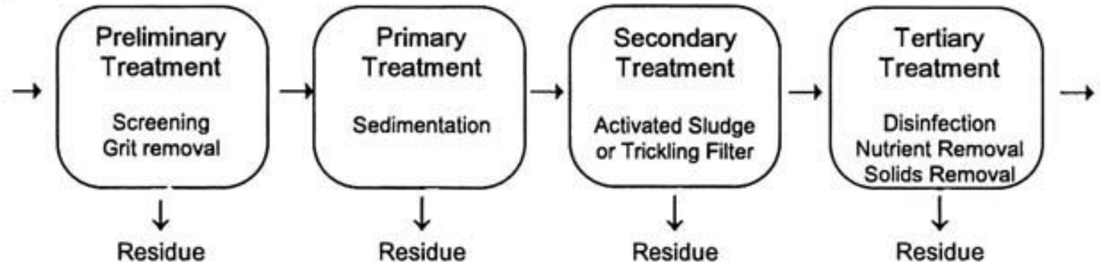
CHAPTER 5 (B)

BIOSOLIDS (SLUDGE)
Treatment & Management

Introduction

- Municipal wastewater treatment plant is engineered to remove BOD, nutrients and pathogens from wastewater:
  - **Primary treatment:** Physical removal of large objects and inorganic solids (grit or debris)
  - **Primary treatment:** Physical removal of organic suspended solids
  - **Secondary treatment:** Microbiological conversion of dissolved organic carbon suspended biomass cells (in addition to CO_2 , H_2O and NH3).
  - **Tertiary treatment:** Removal of Inactivated pathogens, N, P and toxins from wastewater before release to environment



Sludge Types / Sources

– ***Primary sludge***
  - 3 to 8% solids
  - About 70% organic material
  - usually have *strong odors*
– ***Secondary sludge***
  - Consists of *high concentration of wasted microorganism* & inert materials
  - About 90% organic material

- ***Goals of treatment*** are:
  1. Reduce odors,
  2. Remove water,
  3. Reduce volume &
  4. Decompose organic matter
- Untreated sludge are about 97% water
- Settling can reduce down to about 92% water
- dried sludge is called a *sludge cake*

Sludge Treatment

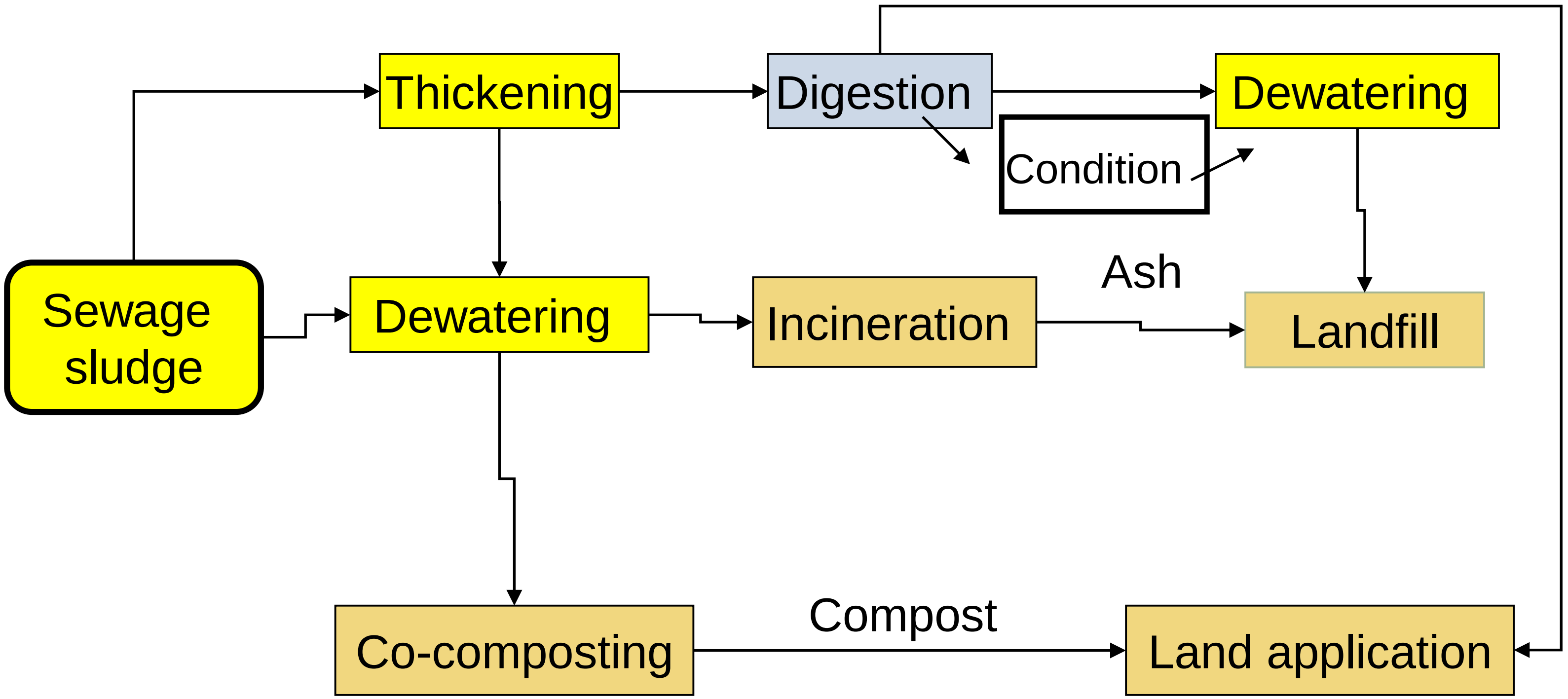


Figure: Alternative Pathways or Sewage Sludge Treatment and Disposal.

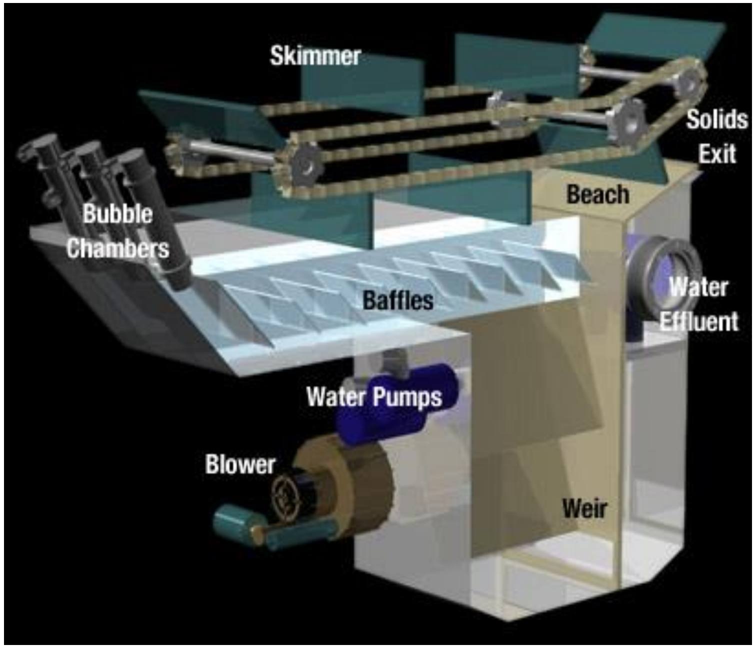
Sludge Thickening

– Reducing the water in primary and secondary sludges

– Methods:

1) ***Gravity thickening:*** *using an additional clarifier to remove more water:* Best with primary sludge

2) ***Dissolved air flotation (DAF):*** Especially effective on activated sludge.



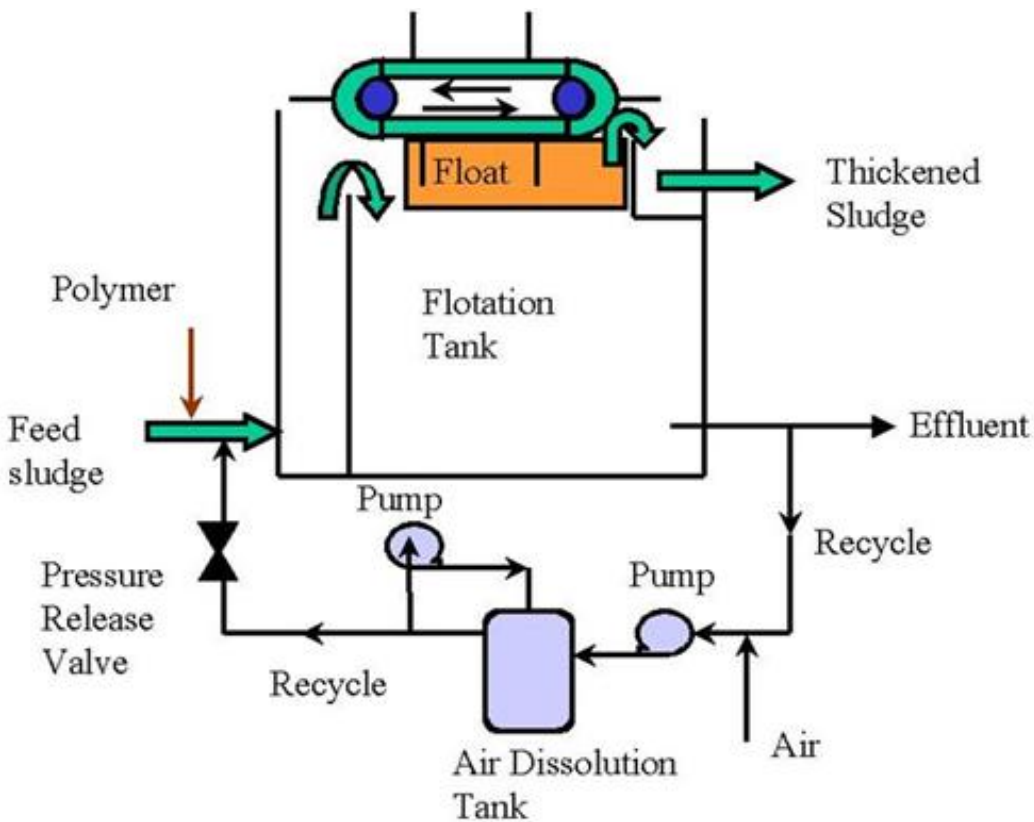
Dissolved Air Flotation (DAF)

- Pressurize total or only a small portion of the incoming sludge.
- Pressurize the recycled flow from the flotation thickener - preferred because it eliminates the need for high-pressure sludge pumps (see Figure next).
- <u>Steps</u>:
  - Sludge is pressurized and injected with air.
  - Releasing into a settling tank *(when the pressure is released, the extra air comes our of solution, attaching to the sludge particles as microscopic bubbles).*
  - The sludge is floated to the surface in a concentrated form.
  - The underflow returns to the head of the plant.

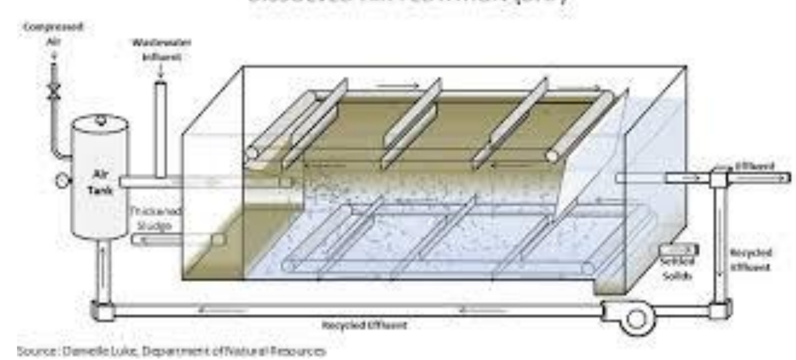
Design of Flotation Systems

Process flow with recycle:

- Primarily used to thicken the solids in chemical and WAS
- Separation of solids achieved by introducing fine air bubbles created under pressure of several atmosphere into the liquid, attaching to solids to cause flotation of solids
- Degree of thickening: 2-8 times the incoming solids concentration



DISSOLVED AIR FLOTATION (DAF)

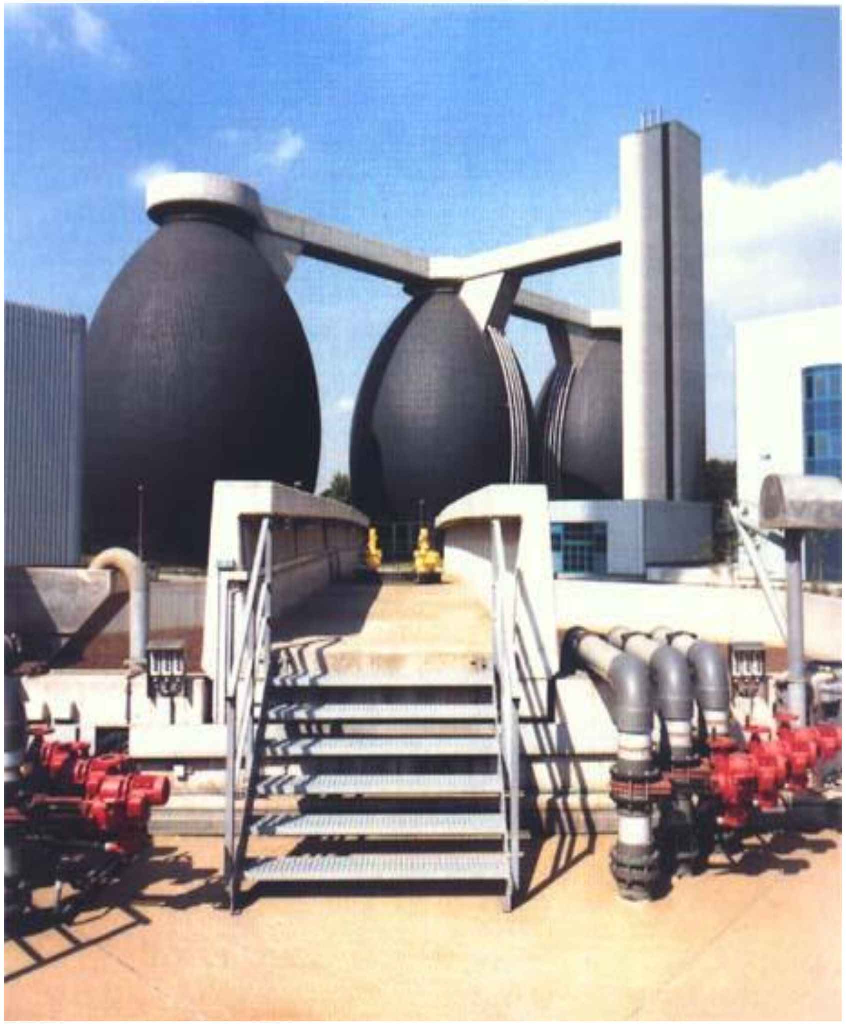


Typical solids content of sludge

Type of sludge	Sludge concentration %	
	Un-thickened	Thickened
Separate		
Primary sludge	2.5 - 5.5	8 - 10
Trickling-filter sludge	4 - 7	7 - 9
Activated sludge	0.5 - 1.2	2.5 - 3.3
Pure O_2 sludge	0.8 - 3	2.5 - 9
Combined		
Primary and trickling-filter sludge	3 - 6	7 - 9
Primary and modified-aeration	3 - 4	8.3 - 11.6
Primary and air-activated sludge	2.6 - 4.8	4.6 - 9

Anaerobic Digestion: Sludge Stabilization

- Two stage: acid fermentation followed by methane production
- Advantages:
  1) produce methane
  2) do not add oxygen
- Supernatant goes to headworks (wastewater influent).



Egg Shape Digester

Anaerobic Digestion Reactions

Main reactions

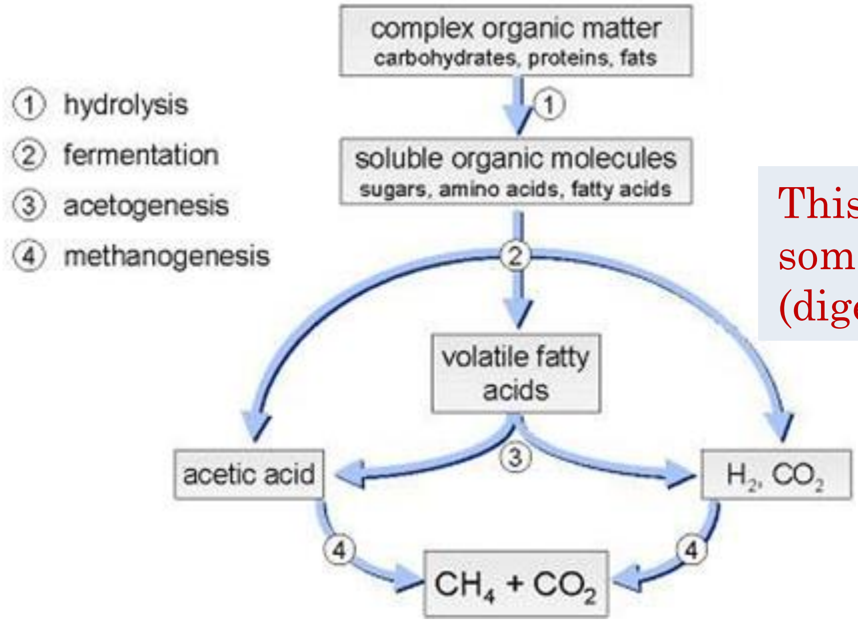
$CxHyOz \rightarrow CH_3COOH$ acetogenesis

$CH_3COOH \rightarrow CO_2 + CH_4$ methanogenesis

Undesirable reactions

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$



This is not a complete conversion: some organic matter will remain (digestate)

Note that biogas is a mixture (not only the useful CH_4) Depending on the substrate there can be other gases too

Processes in Anaerobic digester

$$2\ C_5H_7NO_2 + 8\ H_2O \rightarrow 5\ CH_4 + 3\ CO_2 + 2\ NH_4^+ + 2\ HCO_3^-$$

Q: Calculate the volume composition of biogas produced by 2 moles of C2H7NO2

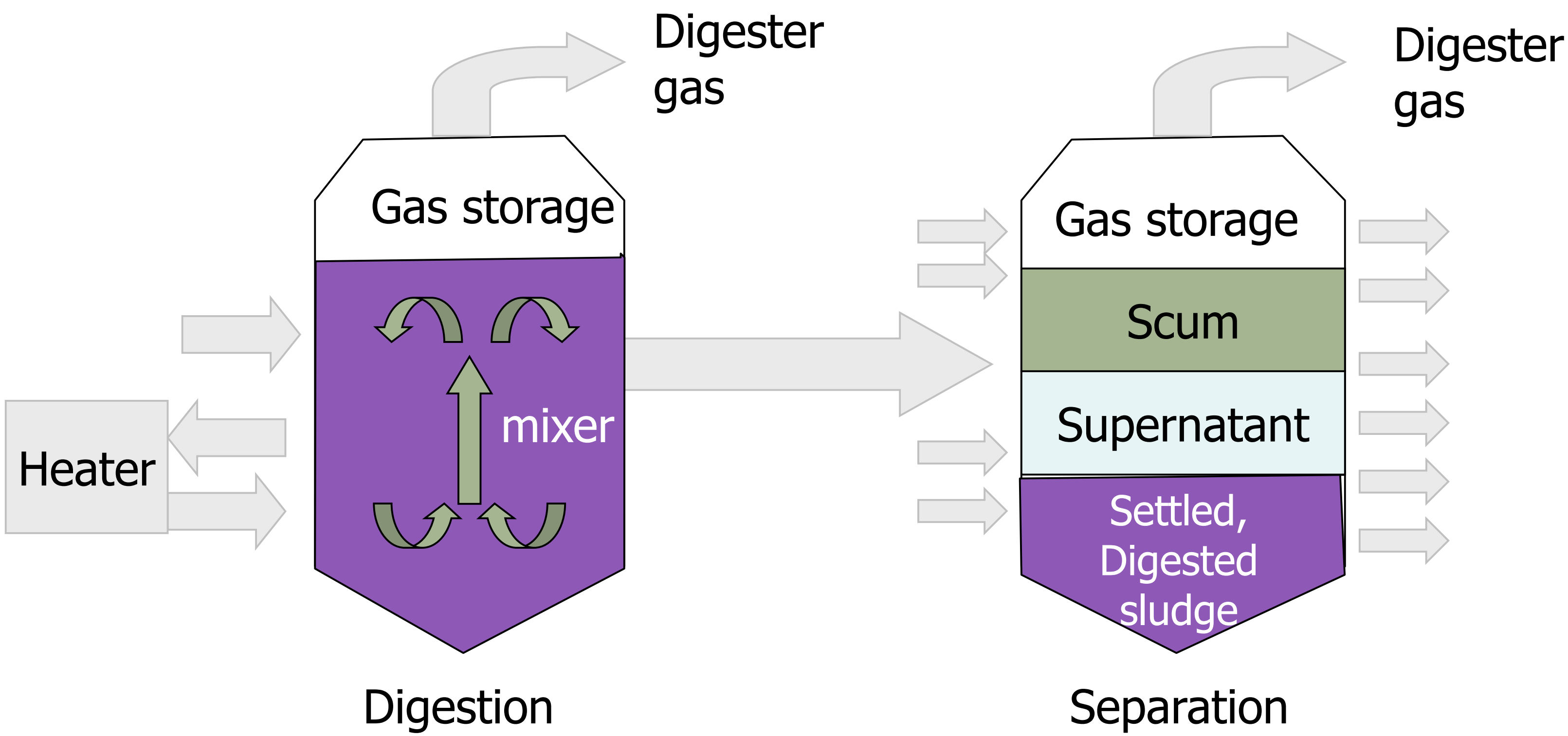
- Degradation of organic substances of approx. 50%
- **Biogas** production: 63% CH_4 (Methane)
  35% CO_2
  2% other gases (N_2, H_2, H_2S)

  → electricity and heating
- Organic nitrogen is converged to NH_4^+

  → N-loading of WWTP

Anaerobic Digestion

Complete mix, or high-rate anaerobic digester



- Heated to 35 – 40°C, process rates are higher compared to ambient
- Content of digester is mixed → Sludge and water obtain a similar residence time

Design of single stage high rate digesters

- **Solids Retention Time**

$$V_{CH4} = (0.35)[(S_o - S)(Q)(10^3 g/kg)^{-1} - 1.42P_x]$$

V_{CH4} = volume of methane produced at standards conditions (0°C and 1atm)
0.35 = theoretical conversion factor for the amount of methane produced, m^3, form the conversion of 1kg of bCOD at 0°C (conversion factor at 35°C = 0.40)
Q = flowrate, m^3/d
S_o = bCOD in influent, mg/L
S = bCOD in effluent, mg/L
P_x = net mass of cell tissue produced per day, kg/d

$$P_x = \frac{YQ(So - S)x(10^\wedge 3g/kg) - 1}{[1 + Kd(SRT)]}$$

Y = yield coefficient, gVSS/g bCOD
K_d = endogenous coefficient, d^{-1}
SRT= solids retention time

Anaerobic Digestion: Sludge Stabilization

- Among the oldest process used for stabilization of solids
- Decomposition of organic matter and inorganic matter (sulfate)
- Most common process to stabilize sludge
- Important environmental factors:
  1. *Solids retention time*
  2. *Hydraulic retention time*
  3. *Temperature (29-35 ℃)*
  4. *Alkalinity (1000-5000mg/L as CaCO3)*
  5. *pH (6.7-7.4)*
  6. *Presence of inhibitory substances (ammonia, sulfide gas, some metals)*
  7. *Bioavailability of nutrients and trace metals*

Anaerobic Digestion: Sludge Stabilization

Advantages

1. High degree of waste stabilization at high organic loading rates
2. Very little sludge production (< 5% of biodegradable organic matter being converted to cell material)
3. Easy dewatering of the excess sludge
4. Low nutrient requirement
5. No aeration equipment
6. Methane production – very low energy input (if the methane gas is used to heat the digester)

Disadvantages

1. Low bacterial yield
   - prolonged periods of biomass build-up,
   - requiring longer start-up period (8 to 12 weeks).
2. Temperature, pH, toxic sensitive
3. Inherent process instability
4. High capital costs
5. Complex operation requiring skilled operators

Digester Heating

– To raise the incoming sludge to digestion tank temperatures, to compensate for the heat losses through the walls, floor, and roof of the digester, and to make up the losses that might occur in the piping between the source of the heat and the tank.

– Internal or external heat exchangers

– Heat requirements

$$\mathbf{q = U\ A\ \Delta T}$$

where

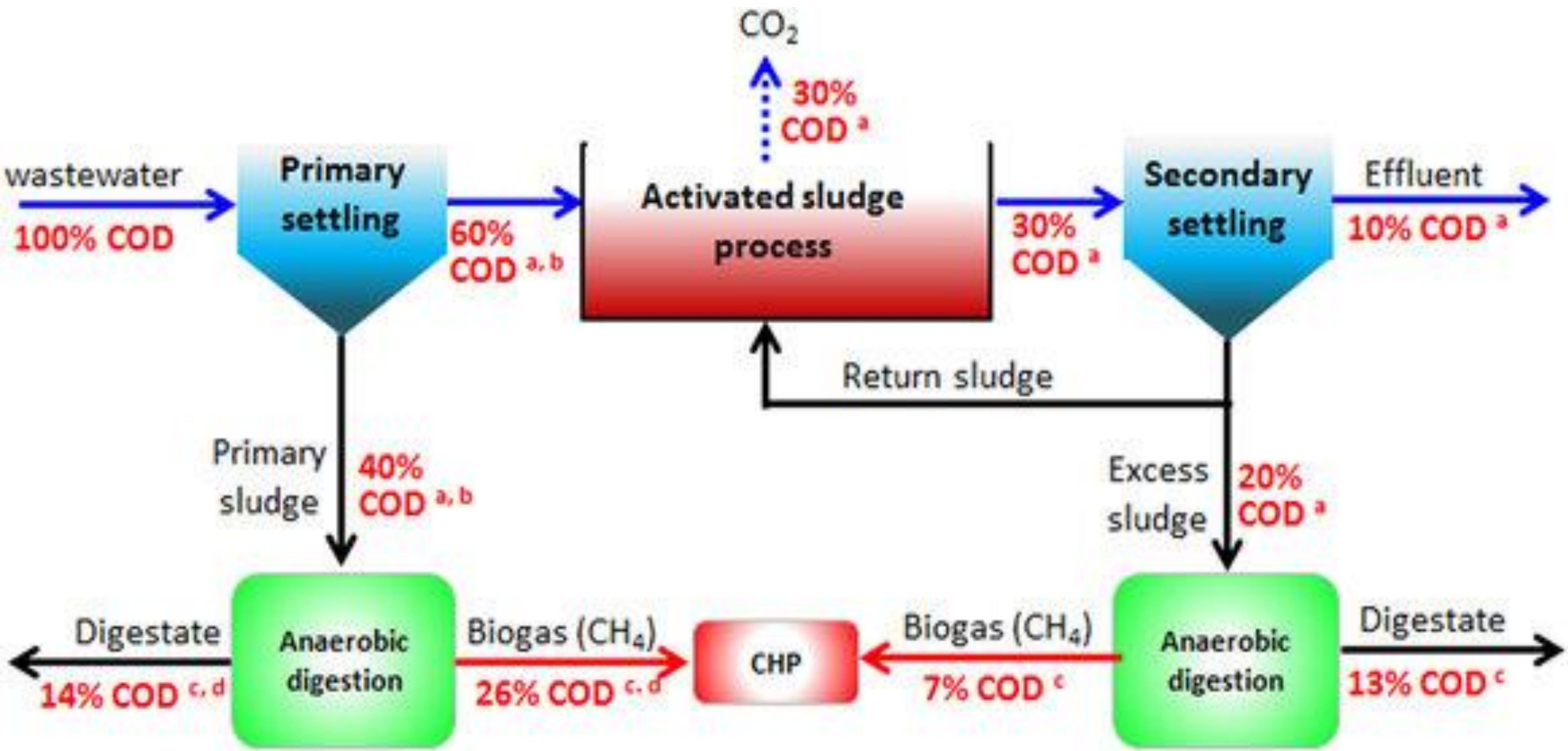
q = heat loss, (W);

U = overall coefficient of heat transfer, ($W/m^2 \cdot {}^{\circ}C$);

A = cross-sectional area through which the heat loss is occurring, (m^2); and

ΔT = temperature drop across the surface in question, (${}^{\circ}C$).

Anaerobic Sludge Digestion



CHP: Co-generation or combined heat and power

http://www.nature.com/articles/srep25054

Sludge Conditioning

- **<u>Chemical Conditioning</u>**
  - Add lime, ferric chloride, or alum
  - Can also add polymers
  - Chemicals are added just prior to de-watering stage

- **<u>Heat Treatment</u>**
  - High temperatures (175-230 ^oC)
  - High pressures (10 to 20 atmospheres)
  - **Advantages**
    - *bound water is released and sludge is easily dewatered*
  - **Disadvantages**
    - *complex process*
    - *highly concentrated liquid stream*

Dewatering and Drying

- ***By using mechanical dewatering equipment***
  - Used in medium size plants, larger POTWs
  - The sludge is applied to a metal, cloth or synthetic rubber surface
  - This equipment is automated, but an experienced, well-trained operator is required.

- ***By applying the sludge to sand drying beds***
  - Consist of a layer of sand with an underdrain system
  - The sludge is pumped onto the bed
  - The sun and wind action dry the material further
  - Used at smaller POTWs

Dewatering & Drying

Centrifuge

- Centrifugation is the process of separating solids from liquids by the use of centrifugal force.
- The centrifuge is a cylindrical drum that rotates to develop the separating force. When the slurry enters the interior of a rotating.

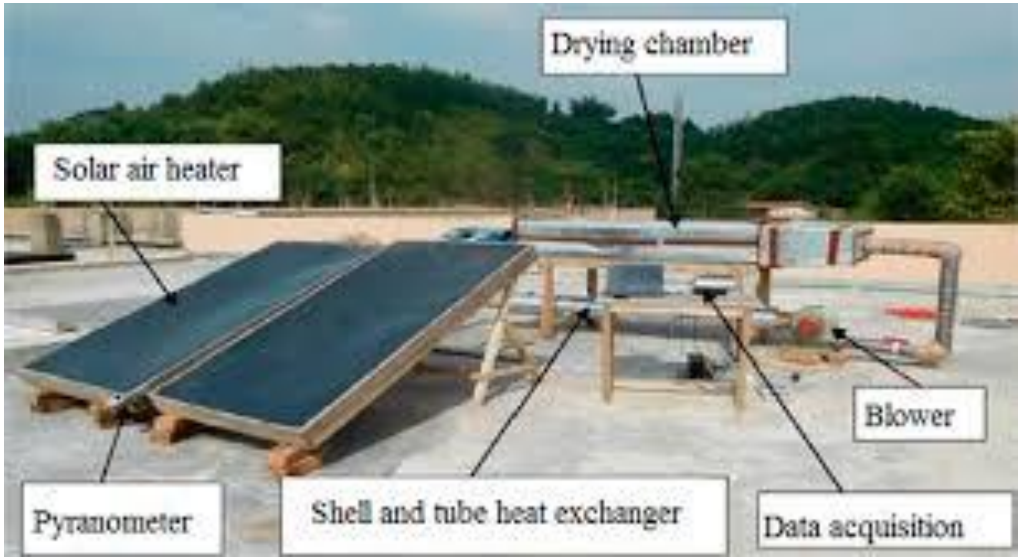
Filtration

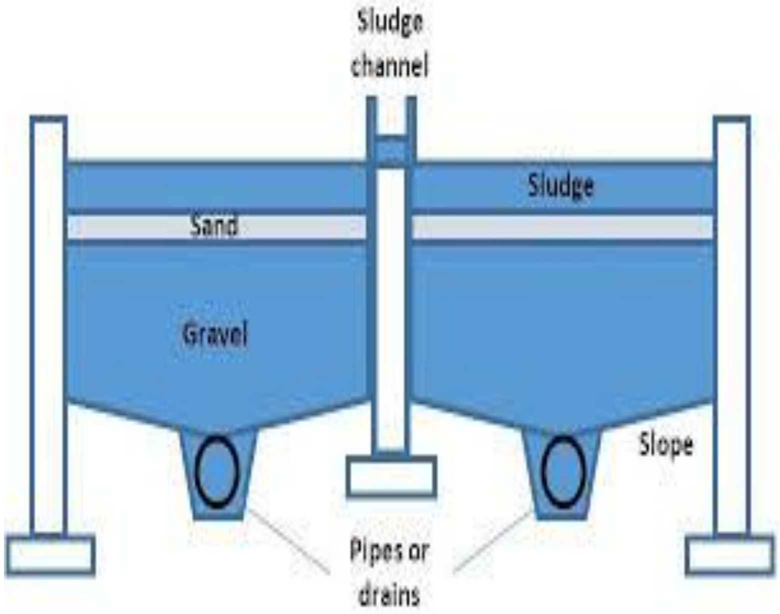
- Apply vacuum to pull out water
- Force out water by essentially squeezing water between two moving filter belts

Dewatering & Drying

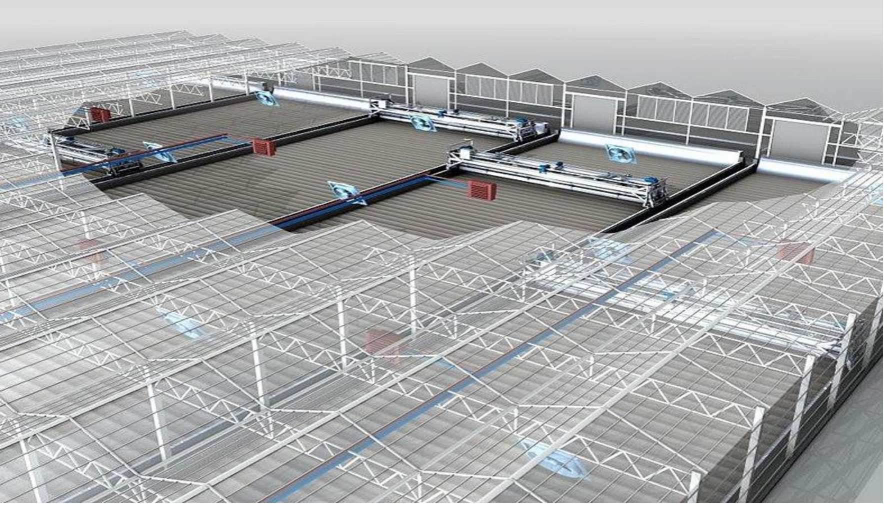
– Sludge Drying Beds

- Most popular method, Simple,
- Low maintenance, affected by climate

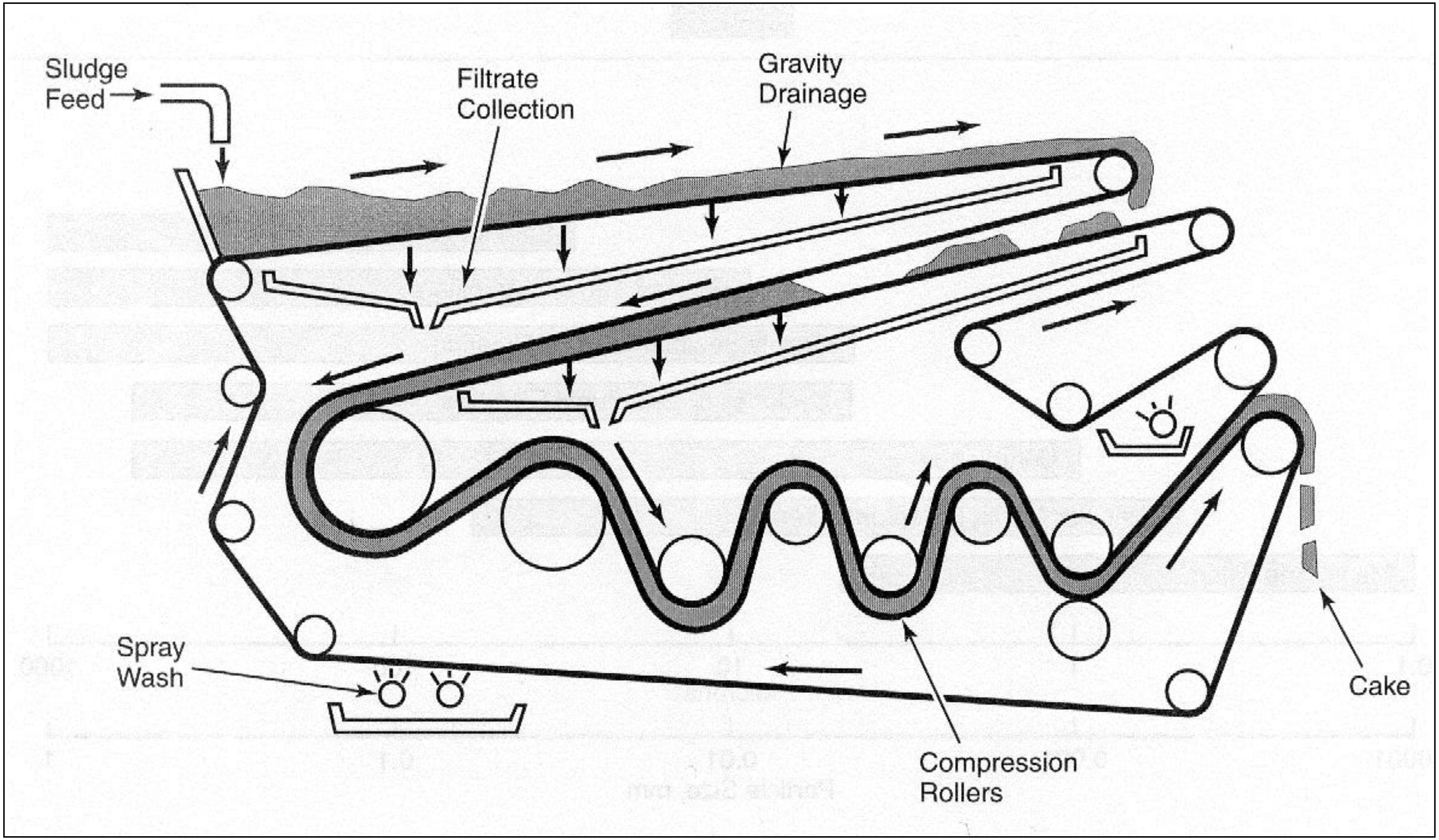




Dewatering & Drying



Dewatering & Drying



Sludge Volume Reduction

Incineration

- Complete evaporation of water from sludge
- Oxidizes organic content
- Requires fuel
- Solid material produced is inert ash
- Exhaust air must be treated prior to discharge

Sludge Incineration Plant

Fluidized Bed Incineration

Sludge Disposal

- Ultimate disposal ➔ the return of the material to the environment.
  1. Incineration *(see Volume Reduction)*
  2. Composting *(conversion to soil-like fertilizer)*
  3. Sanitary Landfilling of the remaining fraction after incineration, ash *(same as in solid waste, Chapter 7).*
  4. Land application on:
  - *gardens*
  - *agricultural land*
  - *forest land*
  - *public recreational areas*

Composting

1. Aerobic process
2. Requires the correct mix of carbon, nitrogen, oxygen and water with sludge
3. Generate large amount of heat

Plants Grow Better with Compost

Land application of sludge must meet:

1. pathogen reduction requirements
2. vector reduction requirements (reduction of volatile solids)
3. metal loading limits
4. testing requirements (for the above):

Amount of Sludge applied (metric Tons/Year)	**Frequency of testing**
0 to 290	**Once per year**
290 to 1500	**Once per quarter**
1500 to 15,000	**Once per 60 days**
15,000 or more	**Once per month**

Land application of sludge

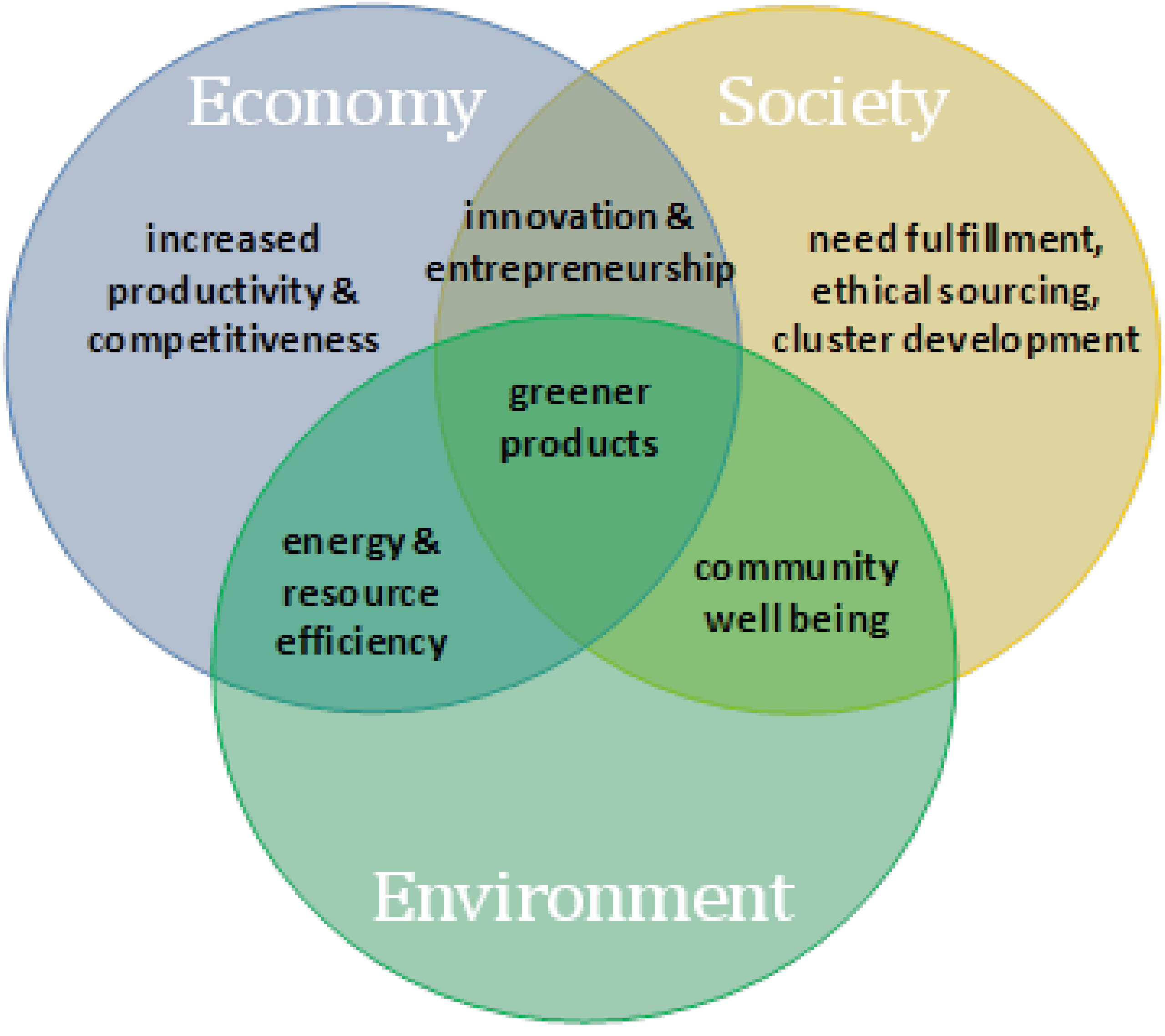
Benefits of biosolids to crops

- Nutrients
  - Nitrogen,
  - Phosphorous
  - Potassium
- Organic Nitrogen
- Micro Nutrients

Threats to Biosolids Recycling

1. Poorly Managed Operations
2. Odor Complaints
3. Poorly Sited facility
4. Public Perception

Sustainable Solution of Biosolids Management



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