Sludge Treatment & Disposal

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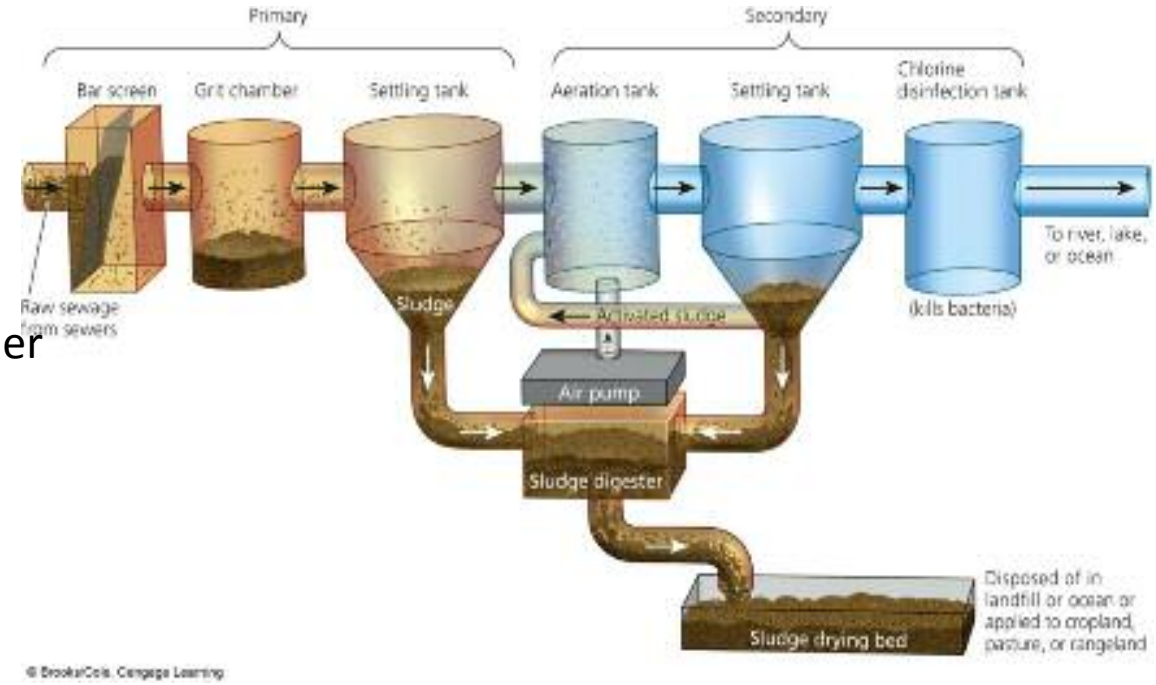
Sludge Sources

Sources of sludge

- Primary sedimentation tank
- Aeration basin or secondary clarifier
- Screening and grinder
- Filter backwash water



Sludge must be treated because:

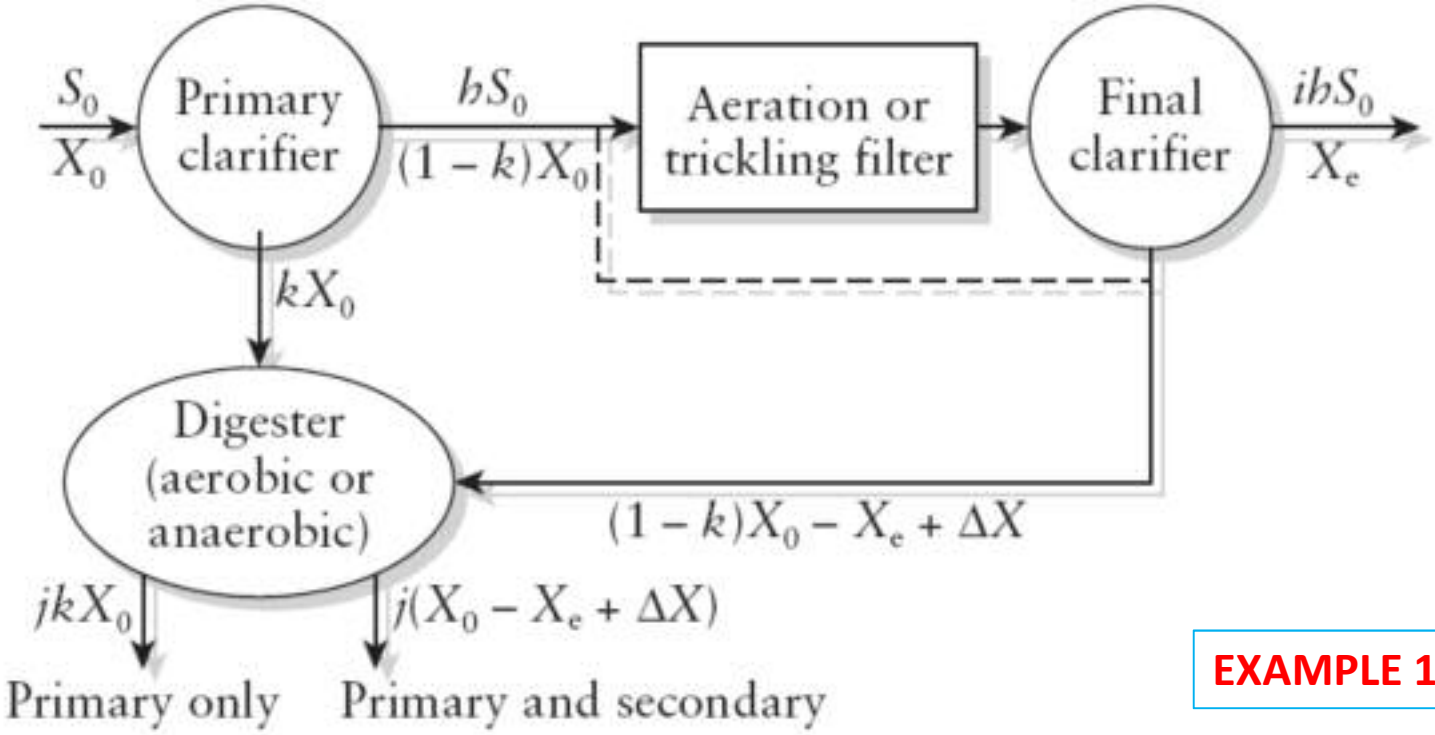
- they are aesthetically displeasing,
- they are potentially harmful,
- and they contain too much water.

Sludge Types

- No two wastewater sludges are alike in all respects.
- Sludge characteristics change with time.
- There is no “average sludge.”

- **Primary sludge**
  - 3 to 8% solids
  - About 70% organic material
- **Secondary sludge**
  - Consists of wasted microorganisms and inert materials
  - About 90% organic material
  - Trickling filter sludge: 2-5% solids
- **Tertiary sludge**
  - If secondary clarifier is used to remove phosphate, this sludge will also contain chemical precipitates (more difficult to treat)
  - De-nitrification sludges -similar to WAS sludge

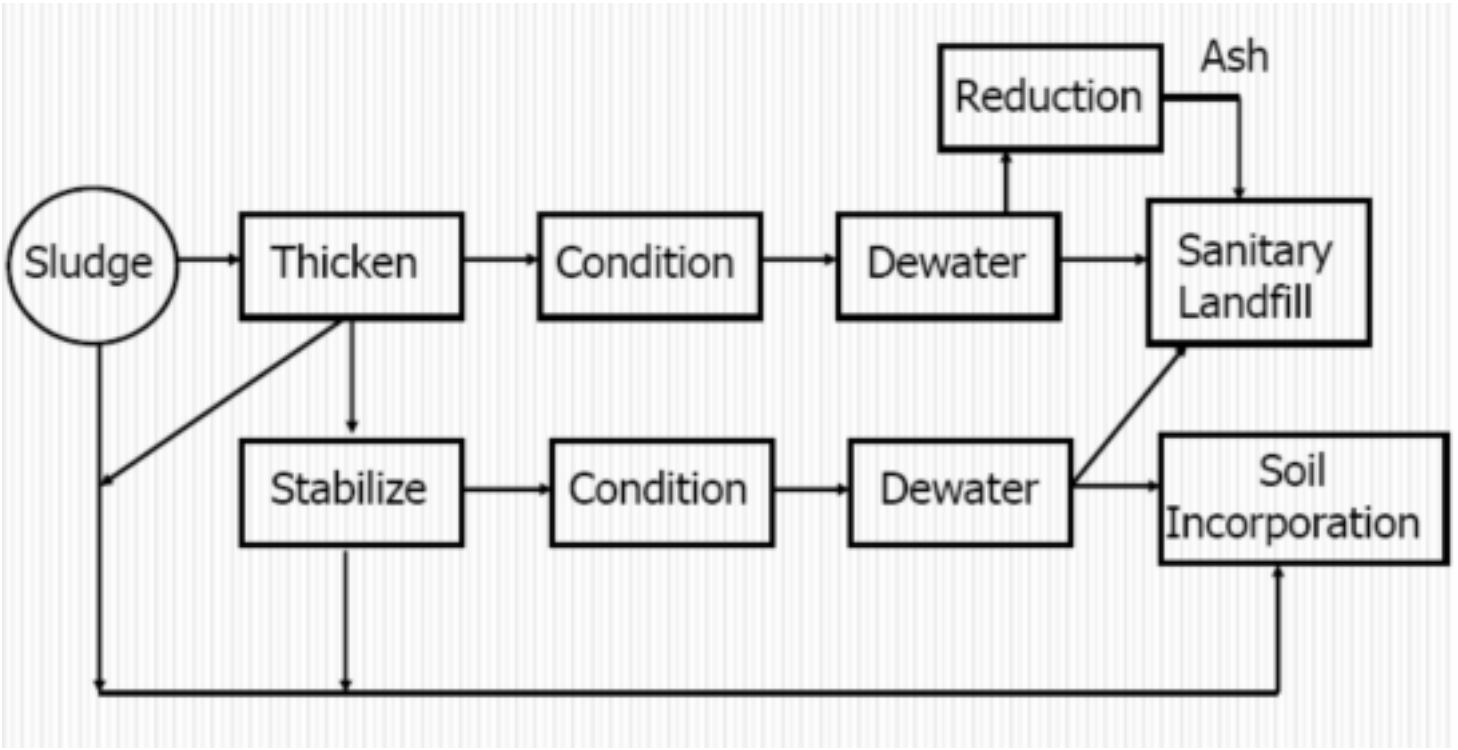
The quantity of sludge produced in a treatment plant



EXAMPLE 11.9

S_0 = influent BOD, lb/d (kg/h)
X_0 = influent suspended solids, lb/d (kg/h)
h = fraction of BOD not removed in the primary clarifier
i = fraction of BOD not removed in activated sludge system
X_e = plant effluent suspended solids, lb/d (kg/h)
k = fraction of influent solids removed in the primary clarifier
ΔX = net solids produced by biological action, lb/d (kg/h)
Y = yield, or the mass of biological solids produced in the aeration tank per mass of BOD destroyed, or

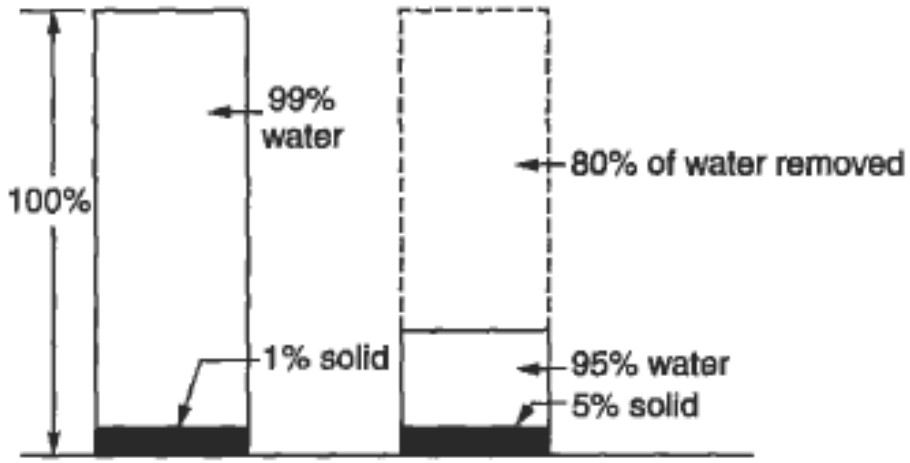
Sludge Treatment



Sludge Thickening

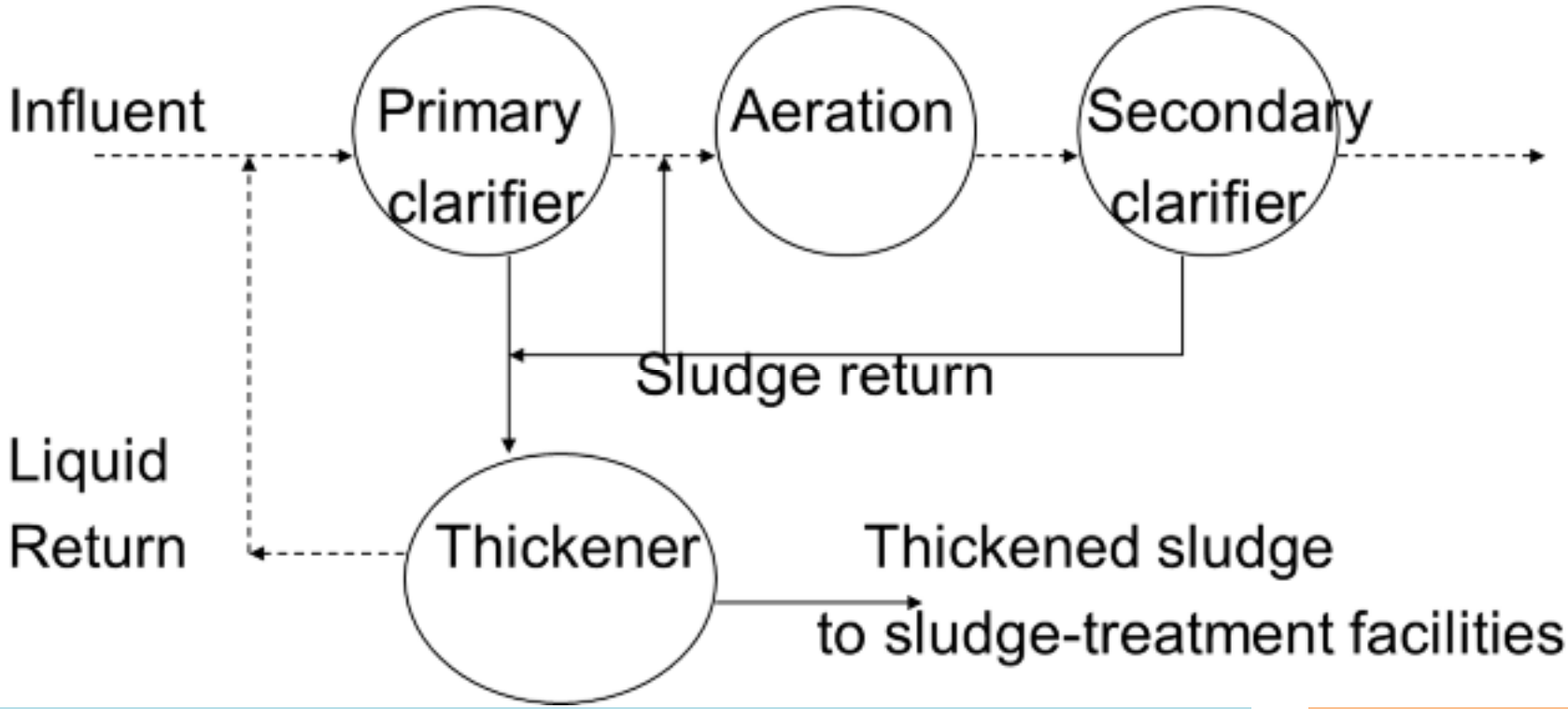
- Sludge thickening is a process in which the concentrations of solids is increased and the total sludge volume is decreased, but the sludge still behaves like a liquid instead of a solid.

- The advantages of sludge thickening are substantial. When sludge with 1% solids is thickened to 5%, the result is an 80% reduction in volume. Reducing from 1 % solids to 20% solids, which might be achieved by sludge dewatering, would result in a 95% reduction in volume. The volume reduction translates into considerable savings in treatment, handling, and disposal costs.



Sludge Thickening

- **Reducing the water in primary and secondary sludges.**



Sludge Thickening Methods

Methods

- Gravity thickening : using an additional clarifier to remove more water

- Dissolved air flotation (DAF)

  - Used to concentrate secondary sludges

  - Sludge is pressurized and injected with air; releasing into a settling tank (when the pressure is released, the extra air comes out 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.

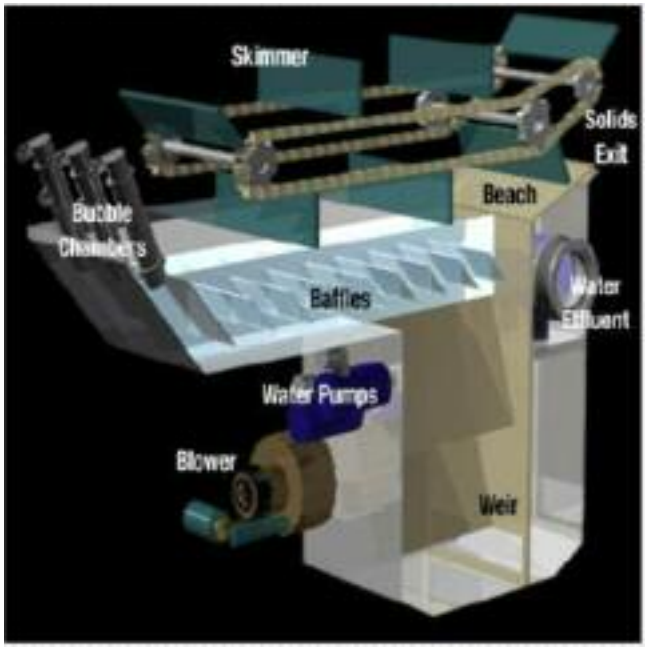
Gravity Thickener

Gravity thickening

- Best with primary sludge
- Increases solids content from 1-3% to 10%

Flotation

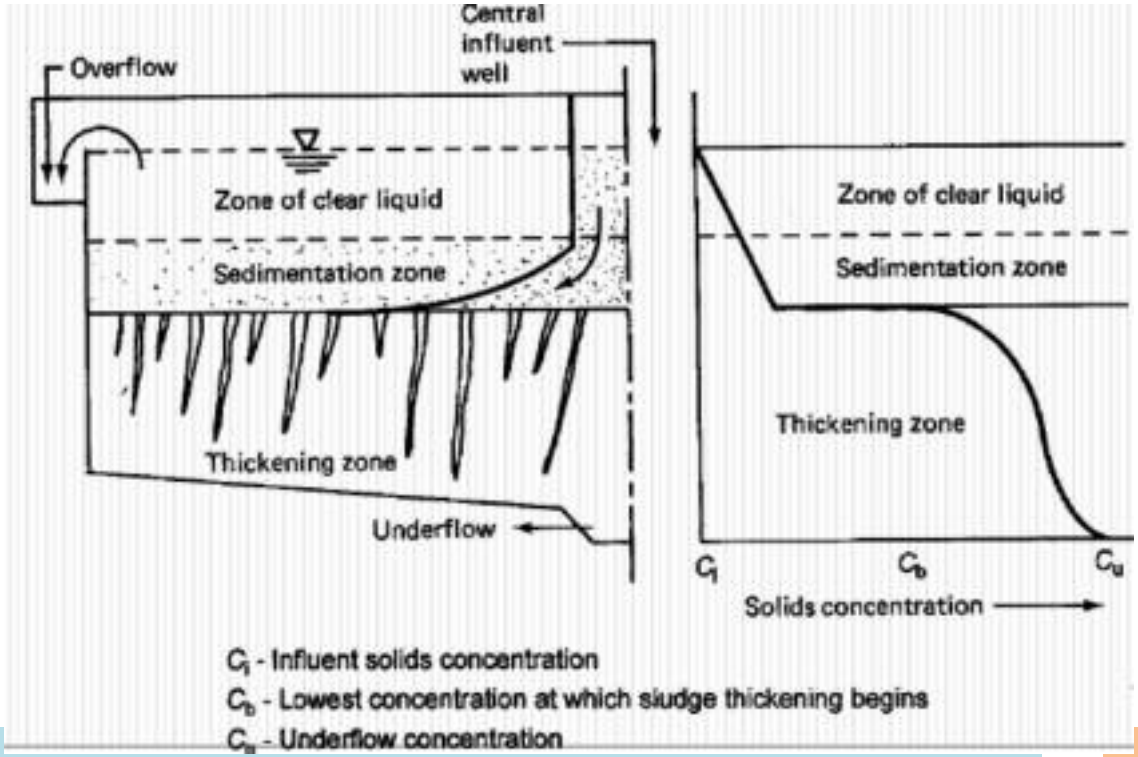
- Especially effective on activated sludge
- Increases solids content from 0.5 -1% to 3-6%



Flotation

Gravity Thickening

- Accomplished in circular sedimentation basins
- Degree of thickening: 2~5 times the incoming solids conc.
- Max. achievable solids concentration: < 10%
- Chemical and waste activated sludges are difficult to thicken under gravity.



Gravity Thickener Equipment

- Generally circular concrete tanks with bottom sloping toward the center.

Equipment

- Rotating bottom scraper arm
- Vertical pickets
- Rotating scum-collection mechanism with scum baffle plates
- Overflow weir

Other configurations

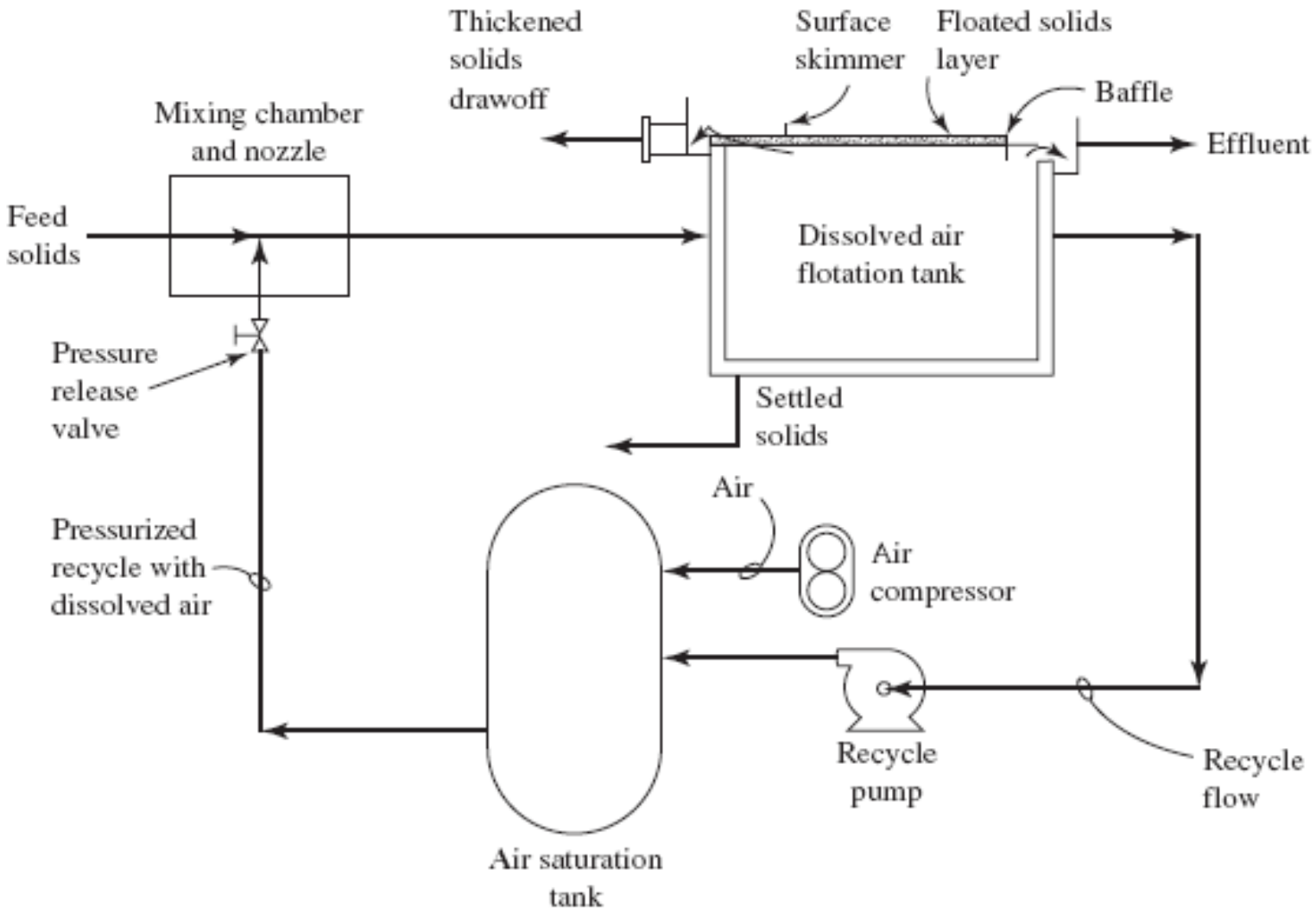
- Circular steel tank: Generally cheaper because of simplicity of construction, equipment installation, and operation and maintenance

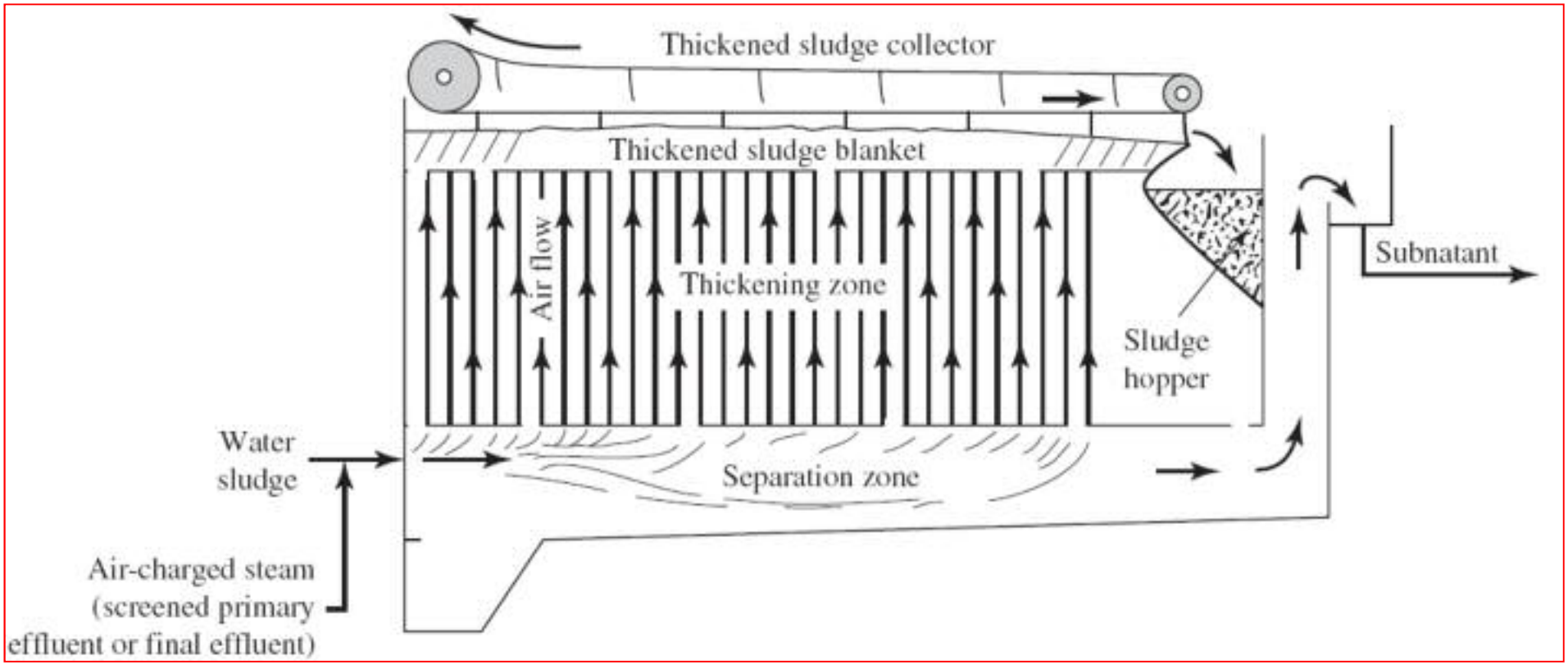
- Rectangular concrete and steel tanks

Dissolved Air Flotation (DAF)

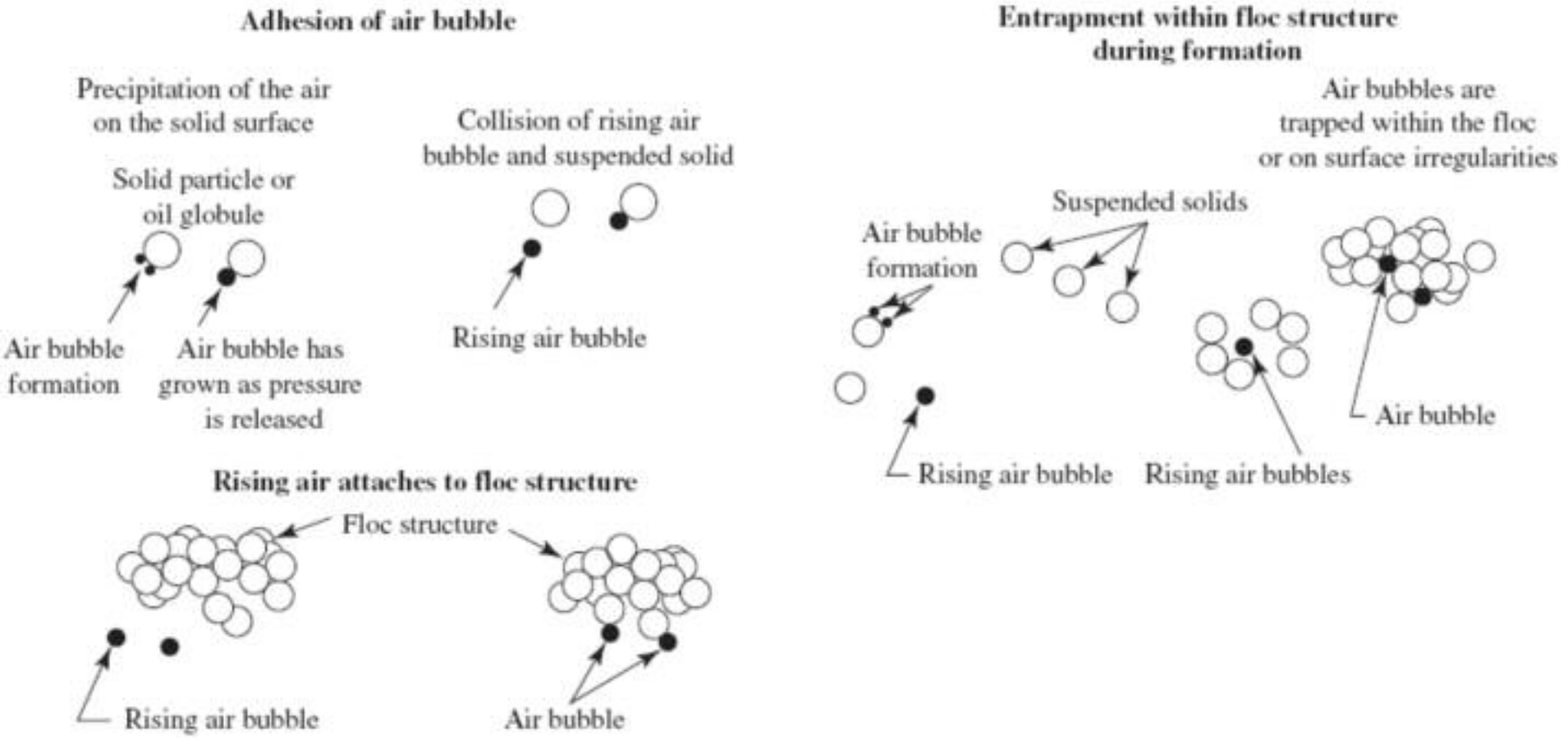
- Primarily used to thicken the solids in chemical and WAS
- Separation of solids is achieved by introducing fine air bubbles created under pressure of several atmosphere into the liquid, attaching to solids to cause flotation of solids
- Degree of thickening: 2~8 times the incoming solids concentration
- Max. solids concentration: 4~5%
- DAF Variations
  - 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.

Schematic of DAF thickener system




Thickened sludge collector
Thickened sludge blanket
Air flow
Thickening zone
Sludge
hopper
Subnatant
Water
sludge
Separation zone
Air-charged steam
(screened primary
effluent or final effluent)

Solid- Air bubble contacting mechanisms



POULTRY PROCESSING SLUDGE

Advantages of DAF

- Space requirements are minimal.
- Low retention time from wastewater stream to effluent ejection.
- Superior clarification of most waste streams.
- Easy to clean and maintain.
- Higher density sludge / low water content.
- Installation cost is low for low flows.

Sludge Stabilization

- The objective of sludge stabilization is to:

  ✓ Break down the organic solids biochemically so that they are more stable
  ✓ reduce the problems associated with: sludge odor and the presence of pathogenic organisms.

- Stabilization alters the characteristics of sludge so it can be returned to the environment with a minimum of environmental and health risks.

Sludge Stabilization Means

- **Biological Treatment**

  1. Aerobic Digestion
  2. Anaerobic digestion
  3. Lagoons
  4. Composting

- **Chemical Treatment**

  1. Wet combustion
  2. Lime stabilization
  3. Chlorination
  4. Heat stabilization
  5. Irradiation

Lime stabilization is achieved by adding lime to the sludge, which raises the pH to about 11 or above. This significantly reduces the odor and helps in the destruction of pathogens. The major disadvantage of lime stabilization is that it is temporary. With time (days), the pH drops and the sludge once again becomes putrescent.

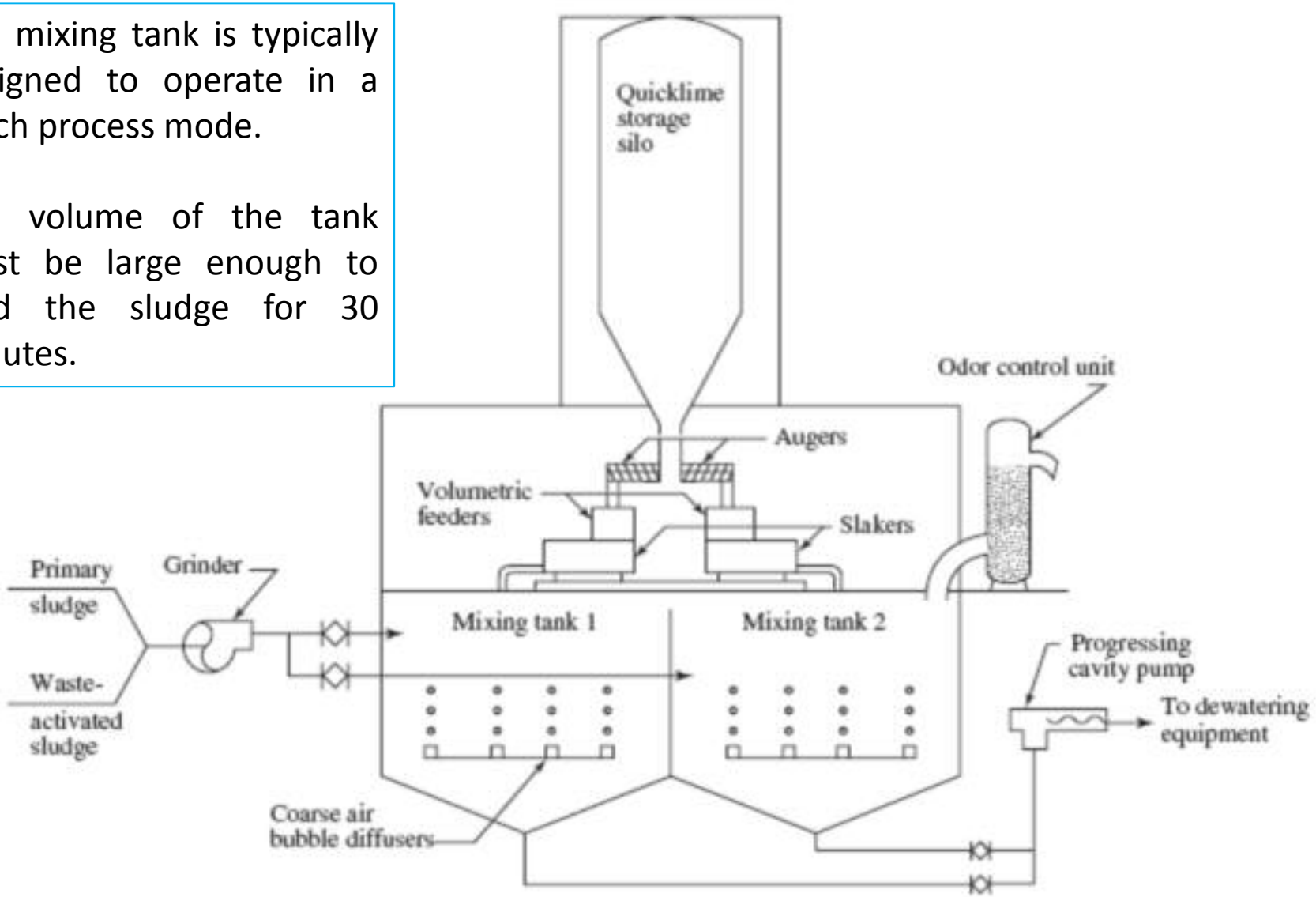
Aerobic digestion is merely a logical extension of the activated sludge system. Waste activated sludge is placed in dedicated aeration tanks for a very long time, and the concentrated solids are allowed to progress well into the endogenous respiration phase, in which food is obtained only by the destruction of other viable organisms.

This results in a net reduction in total and volatile solids. Aerobically digested sludges are, however, more difficult to dewater than anaerobic sludges.

Conceptual design for a lime stabilization facility

The mixing tank is typically designed to operate in a batch process mode.

The volume of the tank must be large enough to hold the sludge for 30 minutes.



Anaerobic Digestion

The anaerobic treatment of biological sludges involves three distinct stages:

- In the first stage, complex waste components, including fats, proteins, and polysaccharides, are hydrolyzed to their component subunits.
- The second stage is commonly referred to as acid fermentation. In this stage, organic material is simply converted to organic acids, alcohols, and new bacterial cells.
- In the third stage, the end products of the second stage are converted to gases (mainly methane, CH_4 , and carbon dioxide, CO_2) by several different species of strictly anaerobic bacteria.

Theory of Anaerobic Digestion

1. Acid forming bacteria break down complex organic substances to simpler compounds, notably fatty acids.

   Carbohydrates $\longrightarrow$ fatty acids

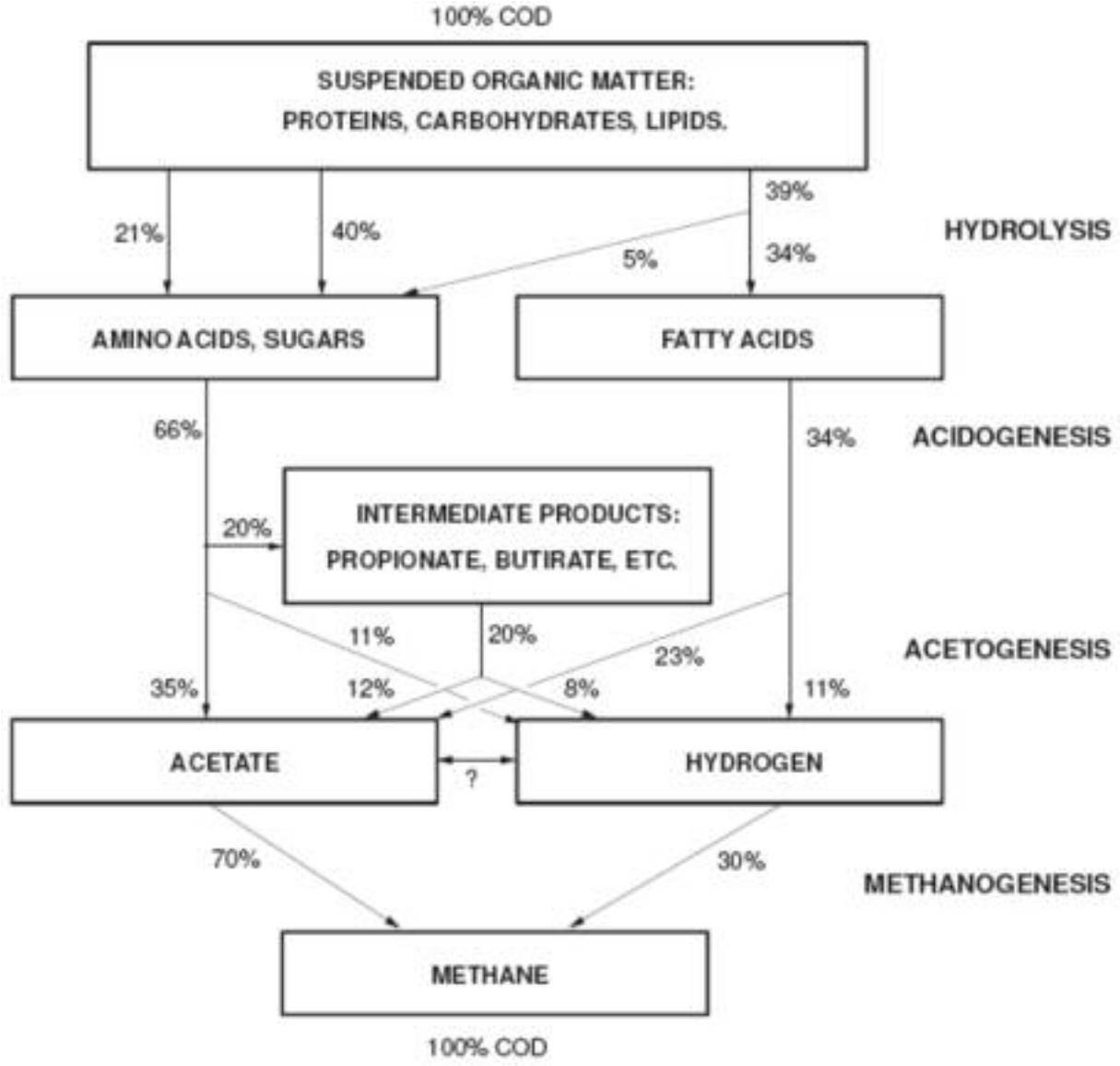
   Proteins $\longrightarrow$ Amino acids $\longrightarrow$ NH_3 + fatty acids

2. Products of the first stage are further broken down, by methane forming bacteria, to methane and carbon dioxide.

   NH_3 + fatty acids $\longrightarrow$ $CH_4 + CO_2$

- Methane forming bacteria work in pH range 6 to 8 (better in 7.2 – 7.4).
- Lime is added to adjust pH.

Decomposition of excess activated sludge

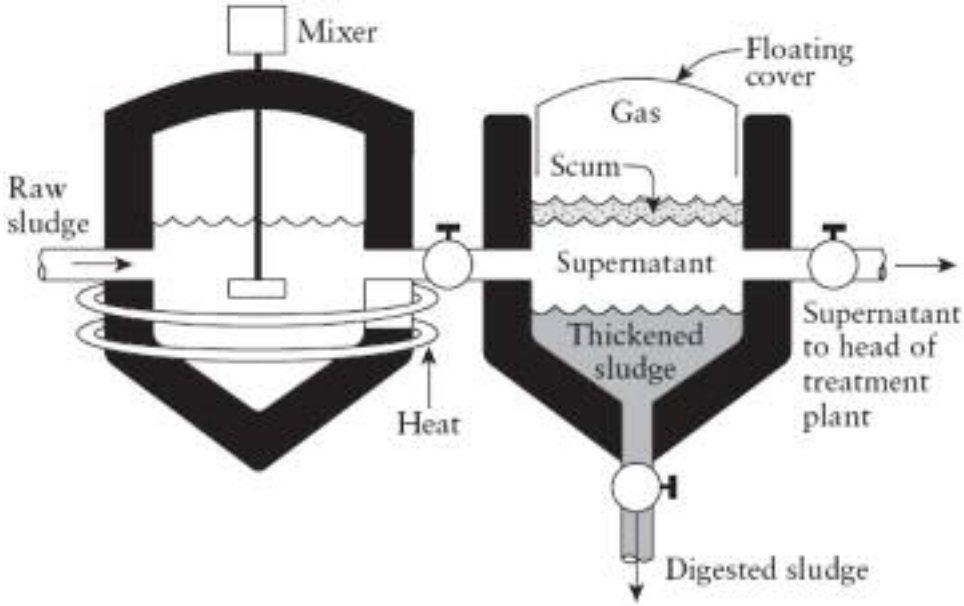


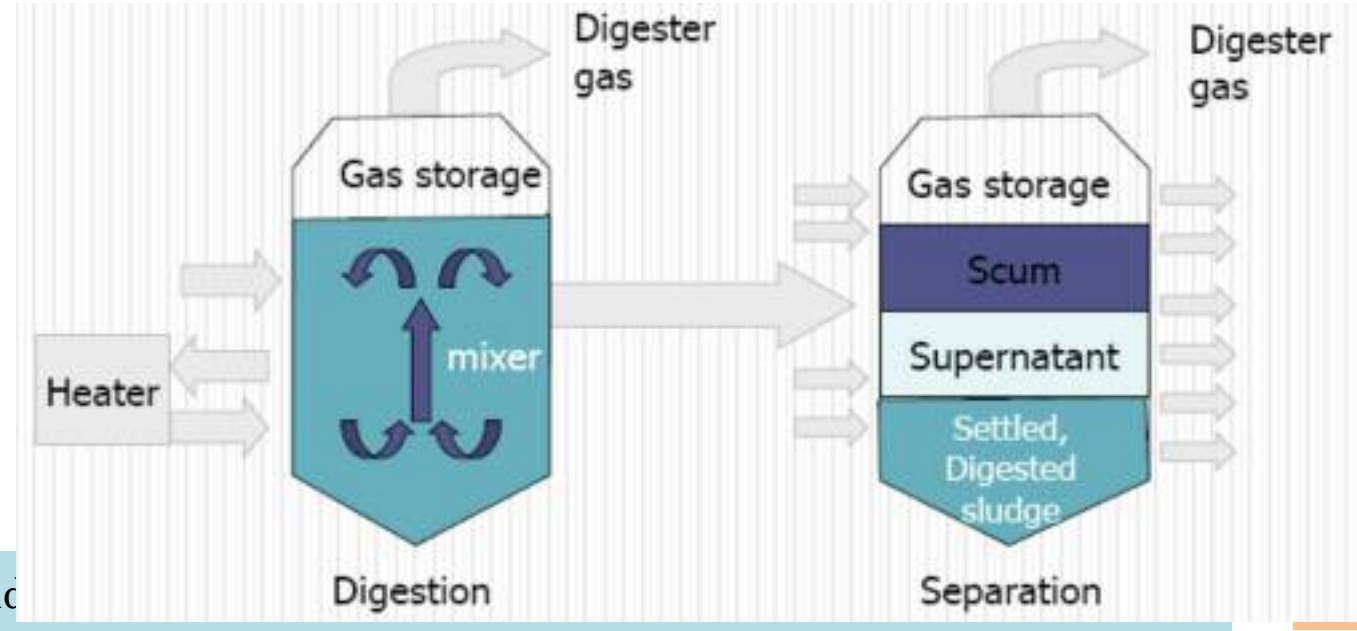
Anaerobic Digestion

- Anaerobic digestion of sludge decrease the volatile organics by 40-50% and reduce the numbers of pathogenic organisms in sludges.
- Accomplished by holding the sludge in closed tanks for periods of 10 to 90 days.

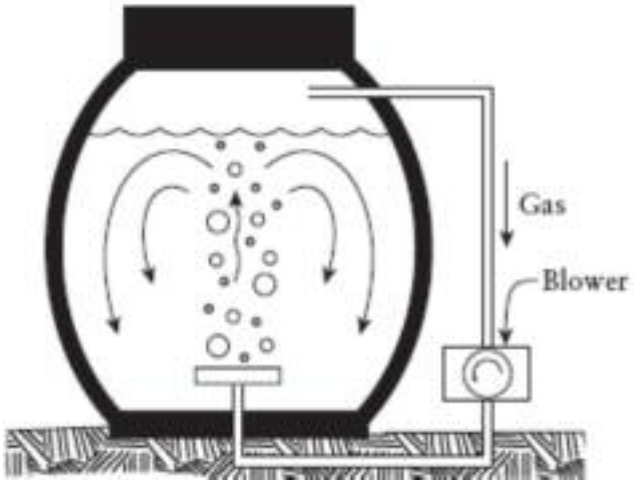
- Old process : unmixed, unheated, long detention time (30-90 days)
- Recent process : complete mixing, heating (35-45℃), detention time 10-20 days

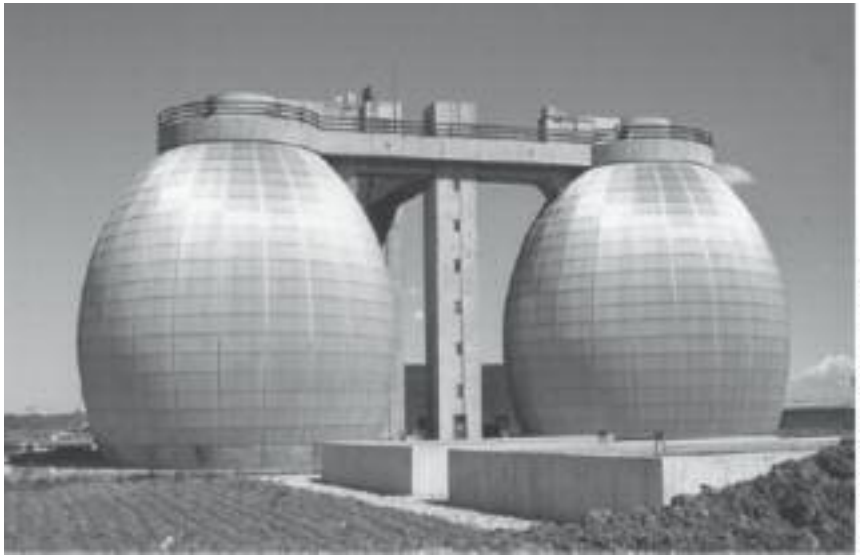
Two-stage anaerobic digestion





Egg-shaped anaerobic digesters





Egg-shaped anaerobic digesters

Advantages

- High degree of waste stabilization at high organic loading rates
- Very little sludge production (< 5% of biodegradable organic matter being converted to cell material) (10% of aerobic sludge production)
- Easy dewatering of the excess sludge
- Low nutrient requirement (10% of aerobic process requirement)
- No aeration equipment
- Methane production –very low energy input (if the methane gas is used to heat the digester)

Egg-shaped anaerobic digesters

Disadvantages

- Low bacterial yield
- prolonged periods of biomass build-up,
- requiring longer start-up period (8 to 12 weeks).
- Temperature, pH, toxic sensitive

- High capital costs
- 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

$$q = U A \Delta T$$

where

q = heat loss, BTU/h (W);

U = overall coefficient of heat transfer, BTU/ft^2·hr·°F (W/m^2·°C);

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

ΔT = temperature drop across the surface in question, °F (°C).

Sludge Conditioning

Chemical Conditioning: Chemical additives may be used to improve sludge dewaterability by acting as coagulants. Chemicals commonly used for this are ferric chloride (FeCl3), lime (CaO), and organic polymers

Physical Conditioning: Physical conditioning is primarily by heat. Heat conditioning involves heating at High temperatures (175-230 °C) and High pressures (10 to 20 atmospheres).

Dewaterability is improved dramatically and pathogens are destroyed as well.

Sludge Dewatering and Drying

- Dewatering reduces the moisture content of the sludge so that it can more easily be disposed of by landfill, incineration, heat drying, composting or other means.

- Unlike sludge thickening, where the treated sludge continues to behave as a liquid, dewatered sludge will behave like a solid after treatment. Dewatering is seldom used as an intermediate process unless the sludge is to be incinerated. Most wastewater plants use dewatering as a final method of volume reduction before ultimate disposal.

- The objective is a moisture content of 60 to 80 percent, depending on the disposal method.

- By applying the sludge to sand drying beds

- By using mechanical dewatering equipment

Dewatered Sewage sludge

Dewatering

The available dewatering processes include

- vacuum filters,
- centrifuges,
- belt filter presses,
- drying bends and
- lagoons.

Sludge Drying Beds

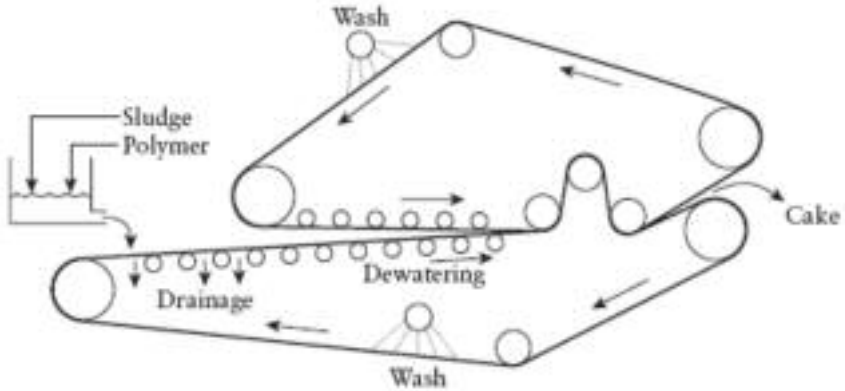
Vacuum Filtration

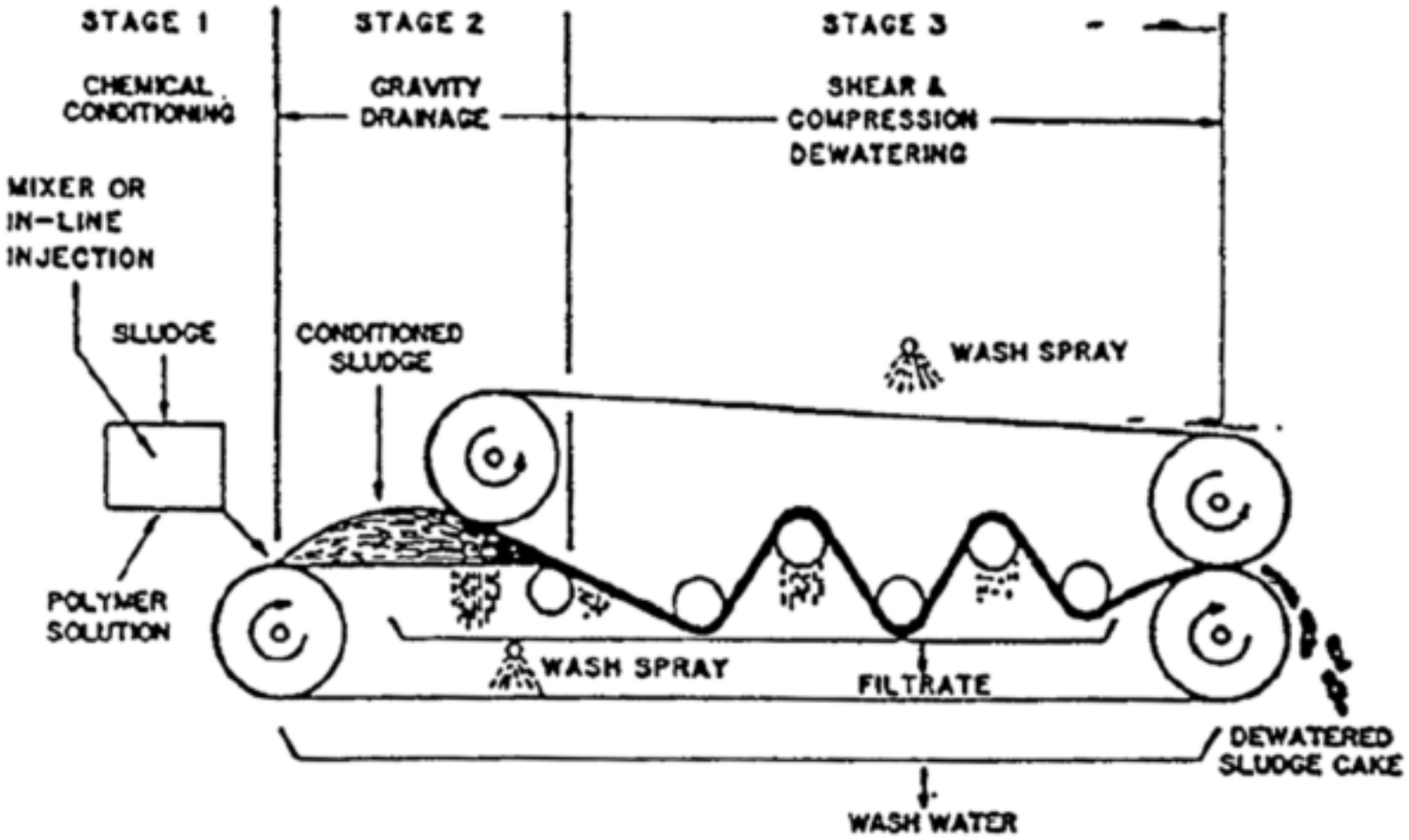
Belt Press Filtration

- Belt filter presses employ single or double moving belts to continuously dewater sludges through one or more stages of dewatering.

- All belt press filtration processes include three basic operational stages:

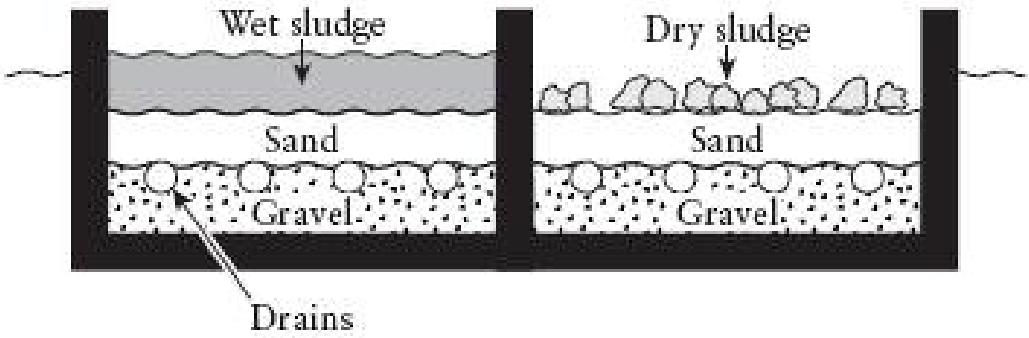
  - chemical conditioning of the feed sludge;
  - gravity drainage to a non-fluid consistency;
  - shear and compression dewatering of the drained sludge.

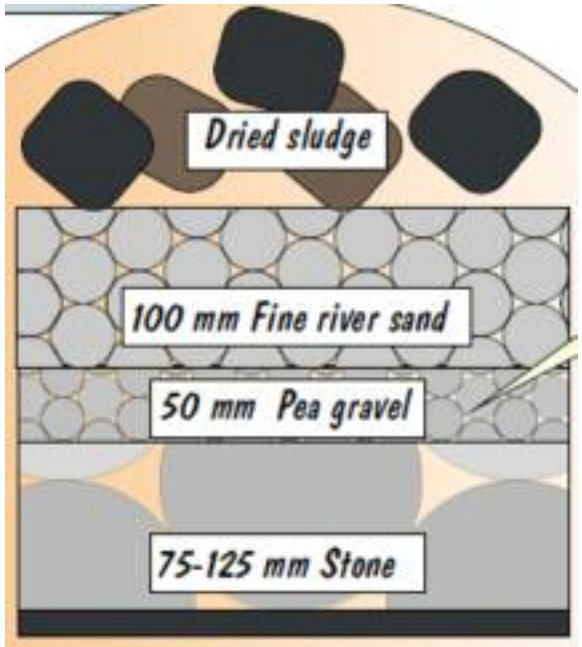


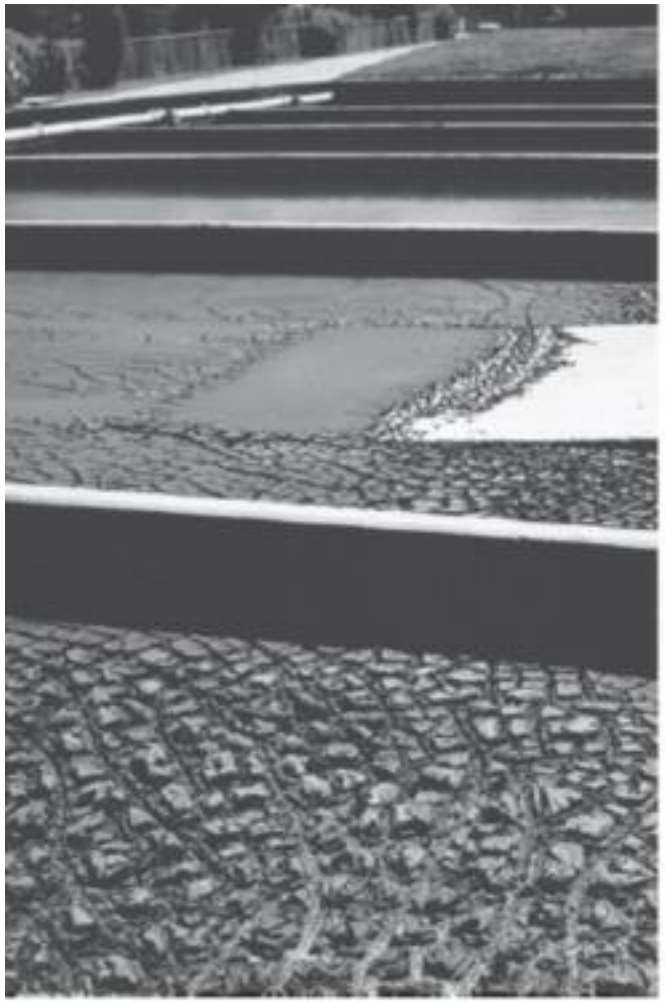

STAGE 1
STAGE 2
STAGE 3
CHEMICAL CONDITIONING
GRAVITY DRAINAGE
SHEAR & COMPRESSION DEWATERING
MIXER OR IN-LINE INJECTION
SLUDGE
CONDITIONED SLUDGE
WASH SPRAY
POLYMER SOLUTION
WASH SPRAY
FILTRATE
DEWATERED SLUDGE CAKE
WASH WATER

Sludge drying beds

- Sludge drying beds rely on drainage and evaporation to effect moisture reduction.
- These beds are open; and as such, are very susceptible to climatic conditions such as precipitation, sunshine, air temperature, relative humidity, and wind velocity. For example, sludge drying in 6 weeks in the summer would take at least 12 weeks to dry in the winter.
- Sludge bed drying efficiency can be improved significantly by covering the bed with glass or plastic and by providing artificial heat.
- Heat could be supplied using waste biogas as a fuel or waste heat from the base power plant.

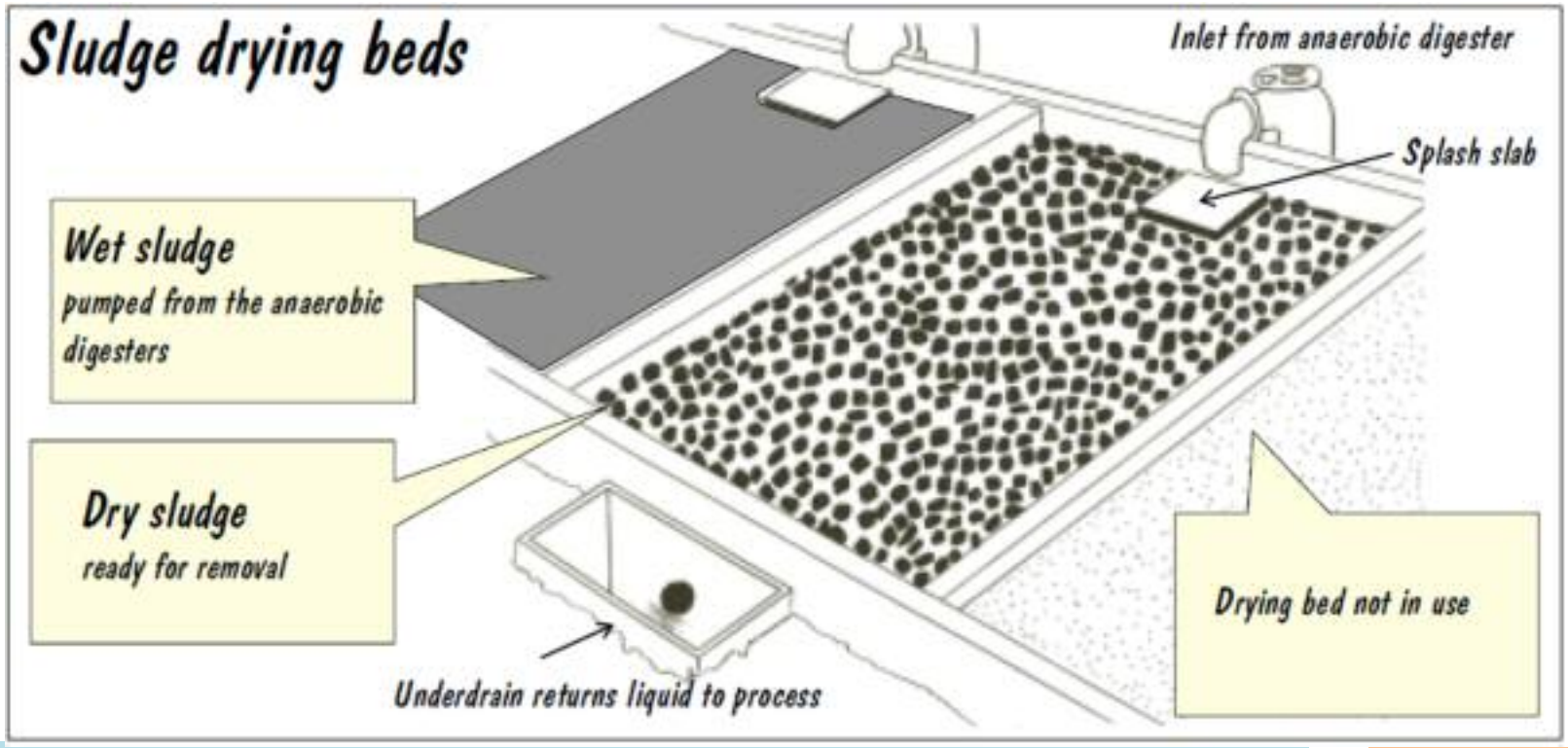

Wet sludge
Dry sludge
Sand
Sand
Gravel
Gravel
Drains


Dried sludge
100 mm Fine river sand
50 mm Pea gravel
75-125 mm Stone


© Courtesy of P. Aarne Vesilind

The principle advantages of drying beds

1. Low cost,
2. Infrequent attention required, and
3. High solids content in the dried product

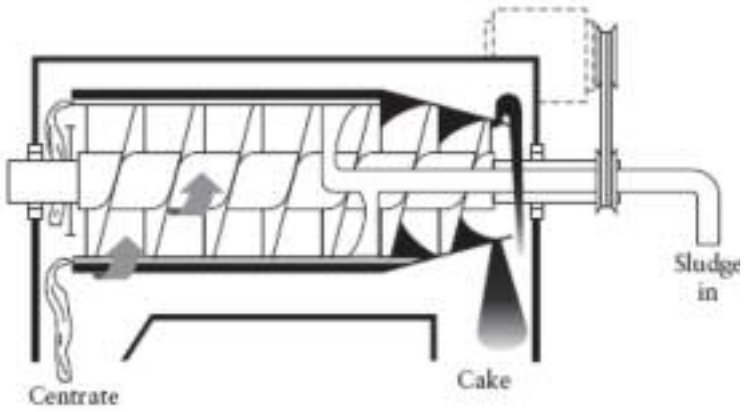


Centrifugal dewatering

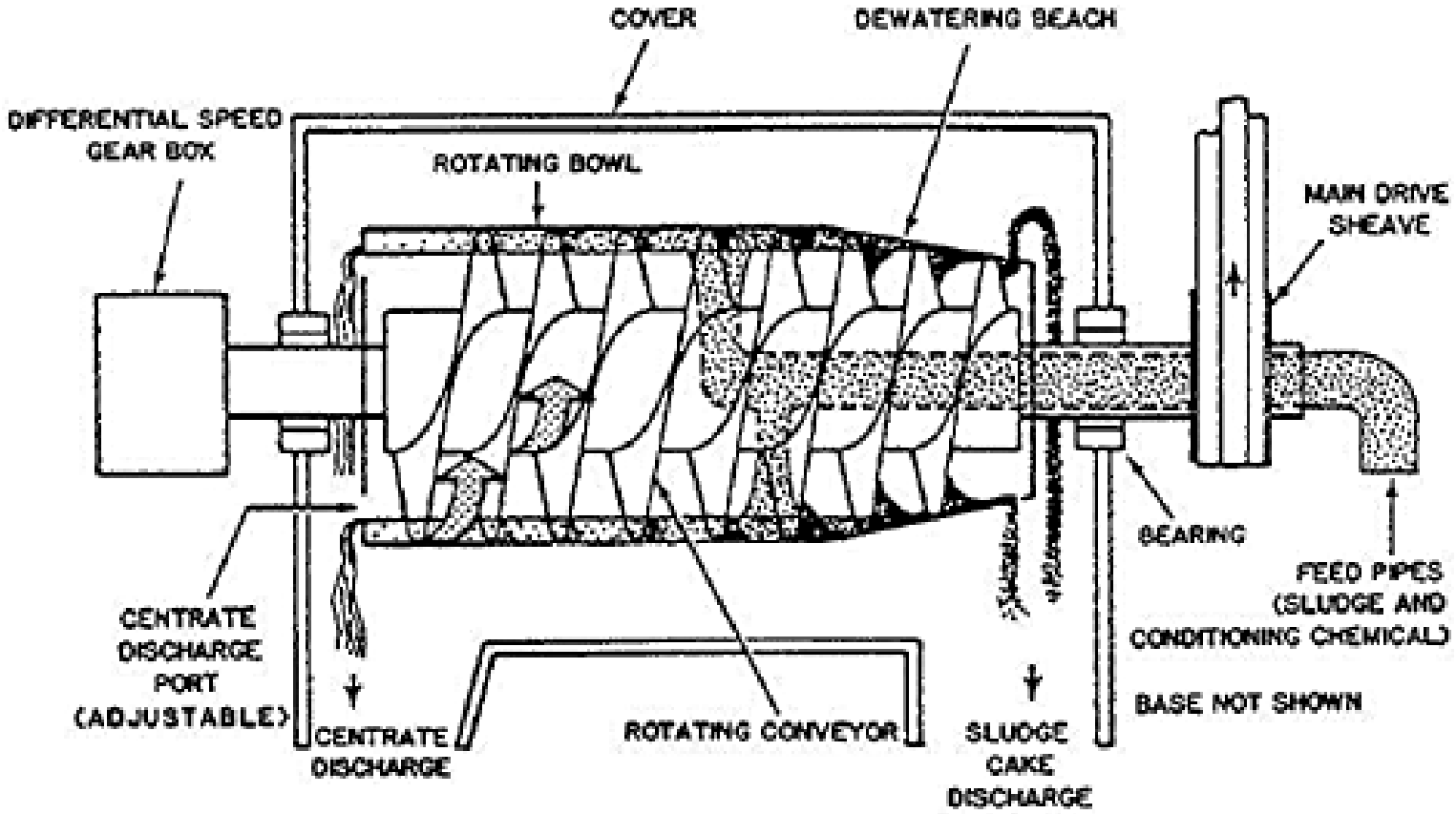
- Centrifugal dewatering of sludge is a process which uses the force developed by fast rotation of a cylindrical drum or bowl to separate the sludge solids from the liquid.

- In the basic process, when sludge slurry is introduced to the centrifuge, it is forced against the bowl's interior walls, forming a pool of liquid.

- Density differences cause the sludge solids and the liquid to separate into two distinct layers. The sludge solids “cake” and the liquid “centrate” are then separately discharged from the unit.



Continuous countercurrent solid bowl centrifuge



Sludge Volume Reduction

Incineration

- Complete evaporation of water from sludge
- Requires fuel
- Exhaust air must be treated prior to discharge

Sludge Ultimate Disposal

- Ultimate disposal: the return of the material to the environment.

- Landfilling
- Land application & Land Spreading:
    - gardens
    - agricultural land
    - forest land
    - golf courses and other public recreational areas
- Incineration
- Other methods

- Care must be taken in applying sludge to land, so that excessive concentrations of heavy metals or other toxic materials do not accumulate in the soil

- Incineration : larger municipalities

  - Maximum volume reducing, detoxification, and energy recovery

  - Capital and operating costs are high

  - There are environmental effects (air discharges, scrubber sludge generation), operation problems, and the continuing need for trained operating personnel.


+ Biosolids =