Elements of Process Control©

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TWC Enterprises

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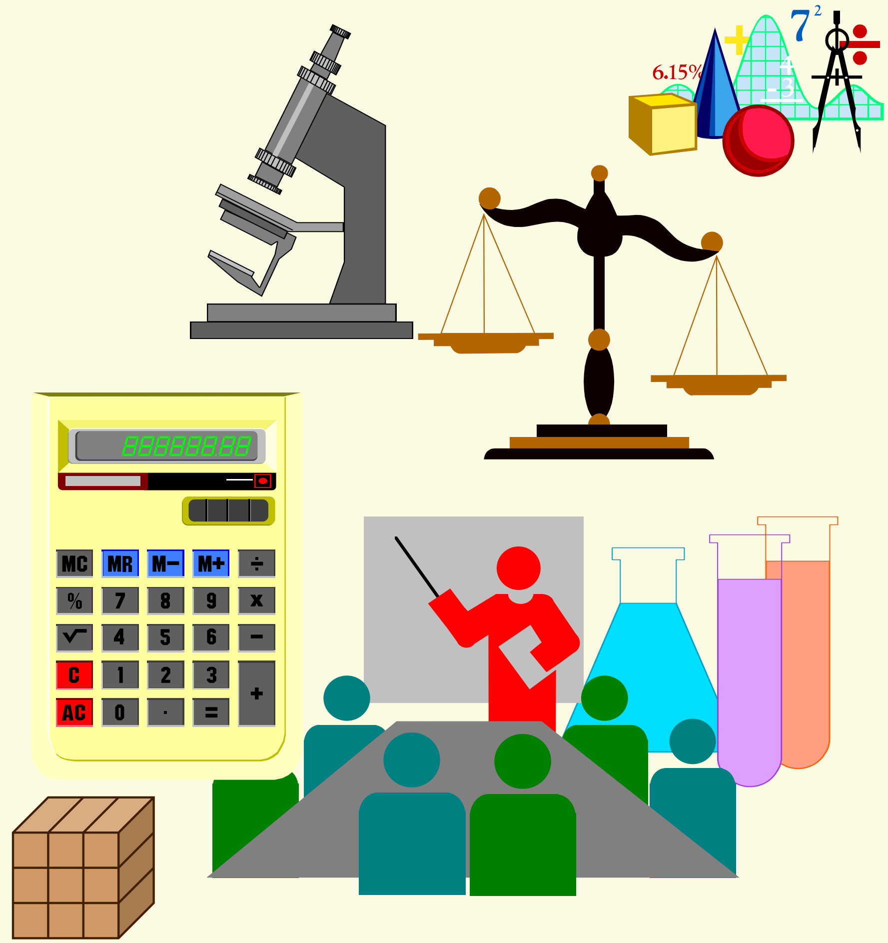


History of NPDES

- 1970-US EPA
- 1972-Clean Water Act
- Mid-70s- US EPA Construction Grants

  > $100 Billion!
- Late-70s- 87% USA WWTPs in non-compliance
- Why?

National O&M Cause and Effect Survey

1. Operator Application
2. Testing
3. I&I
4. Basic Understanding
5. "Misinformation" from "authoritative sources"

Al West Method: Sludge Quality

- Early-seventies

Al West and staff in NFIC (enforcement)

Troubleshooting plants

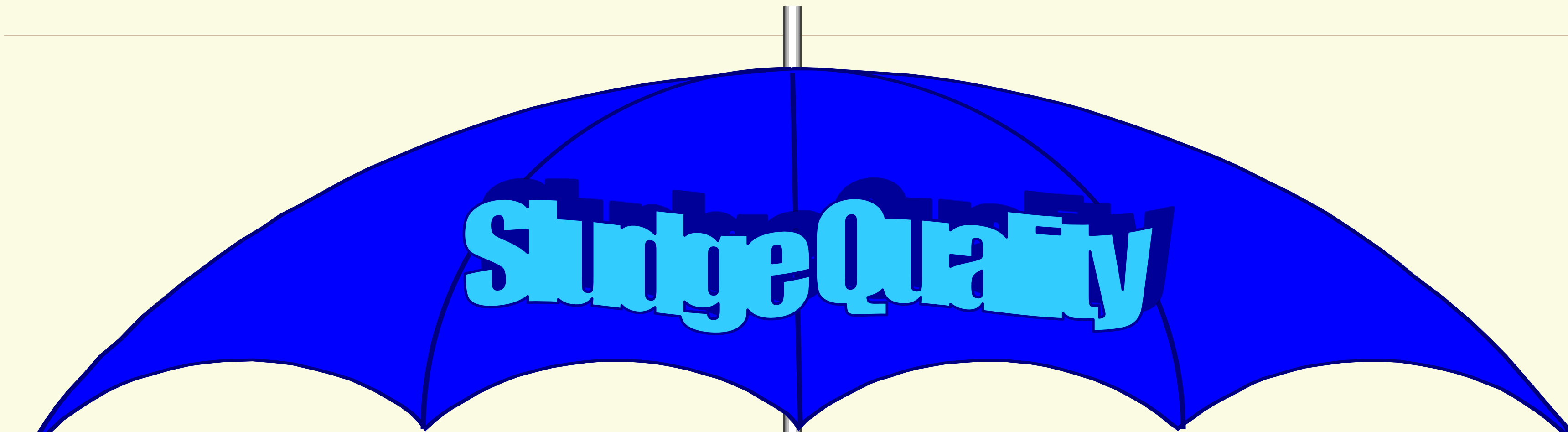
Published Activated Sludge Operational Control pamphlet series

- Late-seventies

Al West and staff in NTOTC (training)

Training operators in-house and at plants around USA

Process Control Strategy or Plan

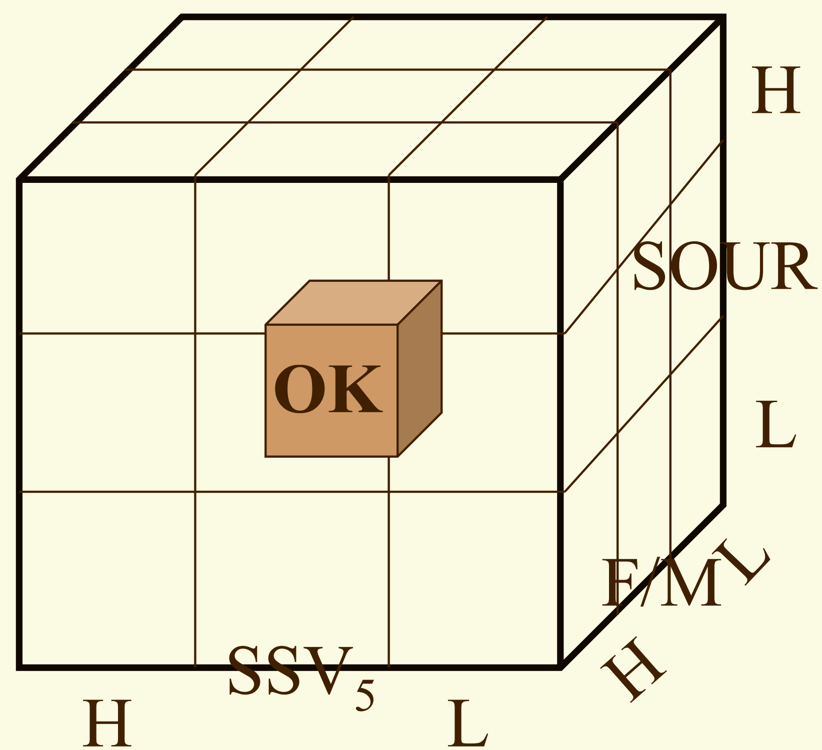


- Constant MLSS
- Detention Time
- Food/Microorganism
- Sludge Age/Inventory
- Sludge Units
- Sludge Volume Index
- Process Control Index
- Alkalinity
- Hillsboro, OR Cube
- ORP, etc., etc., etc.

Charles Manson Process Control: Helter Skelter

Example: Hillsboro, OR Cube

- Zickafoose, et.al. developed this control schematic to keep 3 important operational parameters within acceptable ranges, i.e. the center cube.
- This strategy is at least <u>three</u> times better than <u>one</u> magic number!



Example: PCI

- The Process Control Index was developed by an operator that understood the effects of temperature on the process and attempted to incorporate the effect into a control parameter

- Pro: It is the only control strategy in the literature (?) that uses the mixed liquor temperature in the calculation of the control number
- Con: It is still only one “magic” number

Sampling

Types of samples

- Grab
- Composite
- Flow Proportional

Types of Containers

- Glass (oil & grease)
- Autoclaved (bacterial)
- Organic-free (carbon)
- Clean, but not with detergent for phosphorous samples

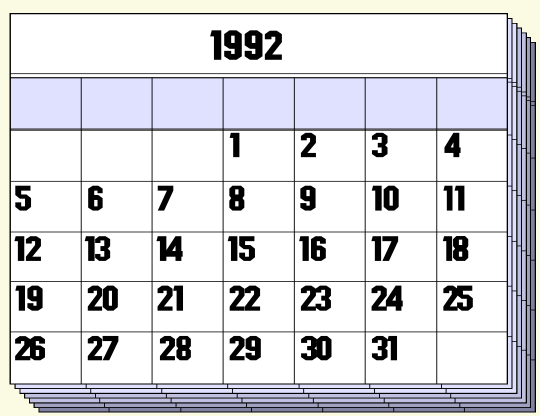
Testing: Qualitative/Quantitative

- Qualitative testing tells us about process
- Eyeball, Nose and Ear Test: Physical Observations
- Where?

- Quantitative testing tells us about process too but also…
- Puts a number on it!
- How much?
- How long?

Monitoring Tests

- Quantitative tests
- Used to tell us how adjustment worked



Example:

Effluent Samples

- BOD_5
- Coliforms
- Turbidity

Most monitoring information typically untimely and not very useful for control adjustments

Process Control Testing

“You can’t control what you don’t measure!”

Solids Inventory Control

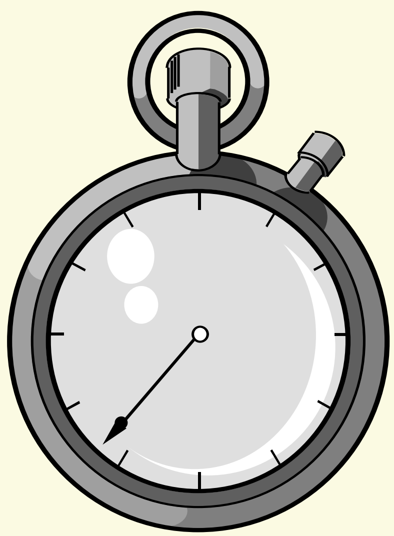
- Where are the solids?
- How much is there?
- For how long

Ammonia Control

- <1.0 mg NH_3-N?

Control Tests

- Quantitative tests
- Used to make timely adjustments



- Flow Rates
- Settleometer
- Centrifuge
- Sludge Blanket
- pH & C/N/P
- Dissolved Oxygen
- ORP
- Oxygen Uptake
- Microscope, etc.

Data Interpretation

- Hardest part of process control to learn and become proficient
- Usually takes more than a year

Involves simple arithmetic and graphic skills

- calculations of control parameters
- use of spreadsheets
- plotting of trend charts

Requirements for efficient process treatment

- Food - Measured by BOD, TSS & N in influent
- Bugs - Measured by MLSS and ATC
- Air - Measured by air flow rates, DO & ORP
- Mixing - keeps bug in contact with food and air (oxygen) for synthesis
- Time - bug needs adequate time to break down food and to synthesize

Activated Sludge: A suspended growth biological treatment process

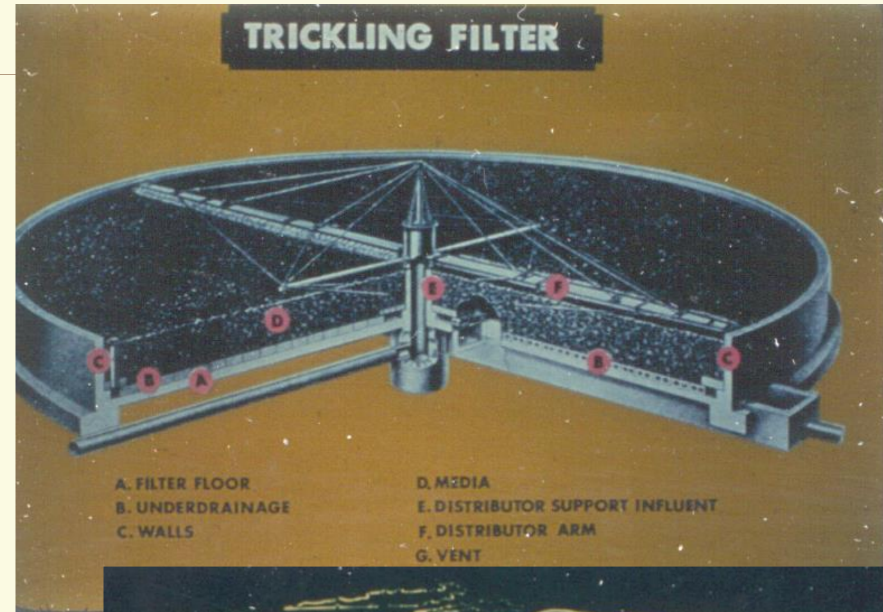
- Activated sludge (**suspended growth**) suspends the biological solids in the reactor
- In **attached growth** systems (trickling filters, RBCs*, etc.) the biological solids grow on some type of media

Here's a plant in Ohio with both, attached and suspended growth systems

* ***Rotating Biological Contactors***

Select the right process for the job!

- **Attached growth** for extremely high strength organic waste
- **Suspended growth** for consistently producing excellent effluent quality



Fixed nozzles and redwood media in Fremont, NE

Aerobic Biological Treatment

Conversion of organic material to sludge

- Attached Growth: conversion occurs on media
- Suspended Growth: conversion occurs in the aeration tank

Separation of sludge from the wastewater

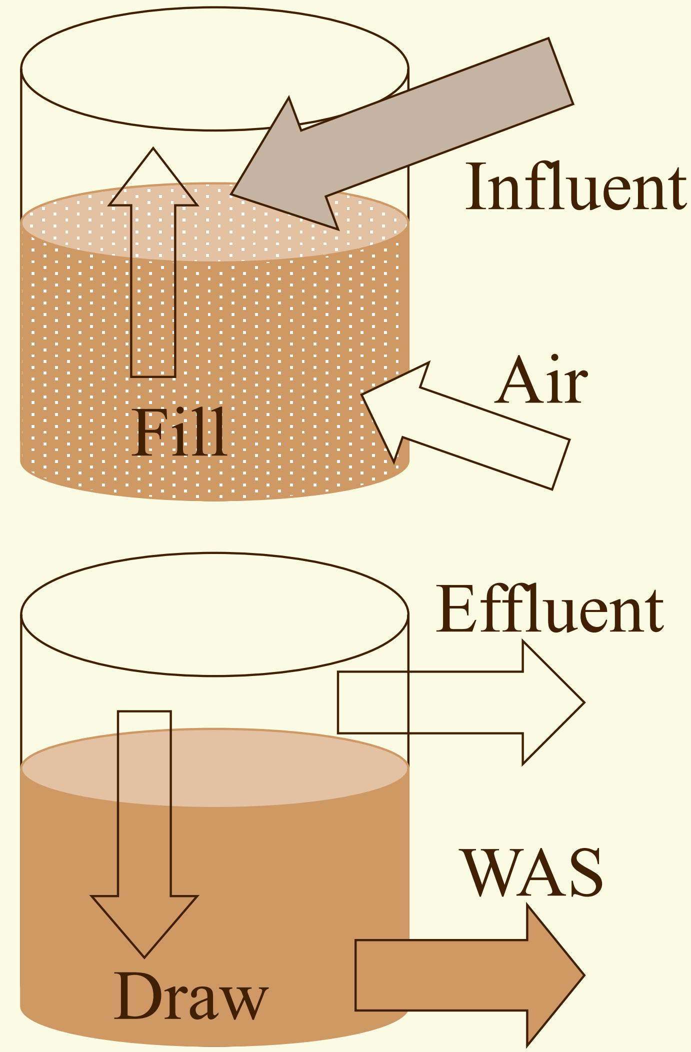
- Attached Growth: biosolids formed are dense and separate readily in clarifier
- Suspended Growth: biosolids formed are lighter and may not settle well

Controls for Activated Sludge

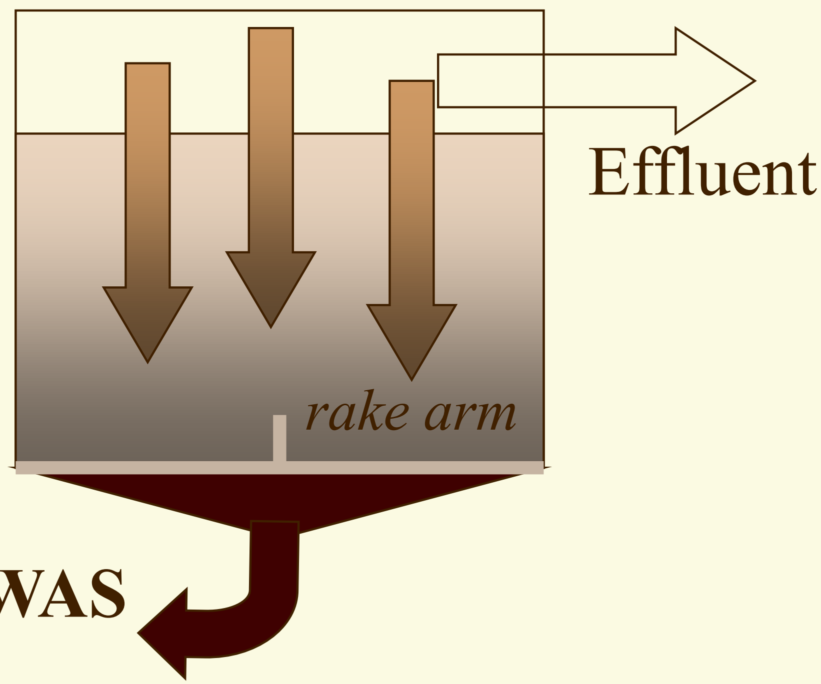
- **Mode Control**: Controls the point of food application and the amount of food at the point. This is very powerful!
- **WAS**: Changes the age of the biomass, altering its characteristics
- **RAS**: Controls the length of time allotted for the biosolids to settle
- **Air**: Provides O_2 for the process

Sequencing Batch Reactor (SBR)

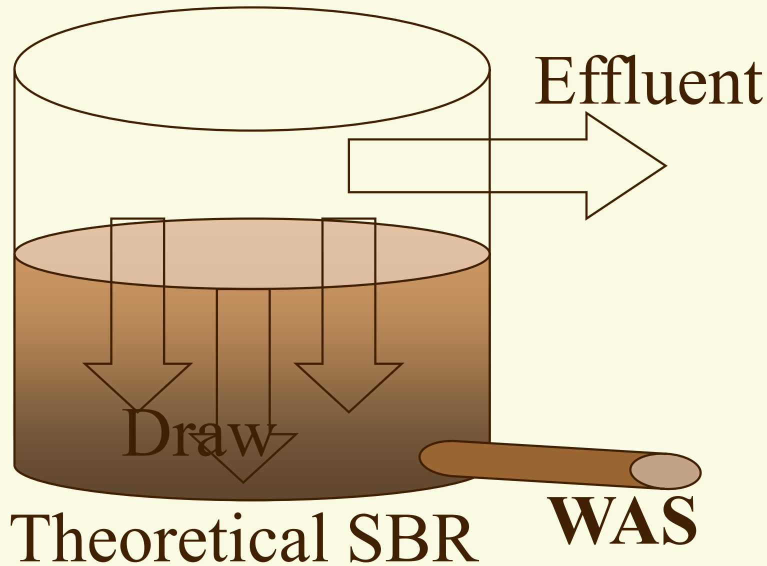
- The simplest of the various activated sludge designs
- It combines Conversion and Separation into one tank
- Cycles commonly called Fill & Draw



SBR: You have to waste MLSS

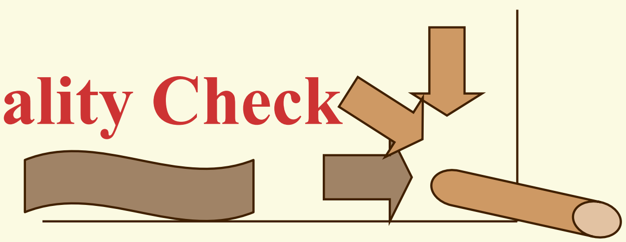


Typical Clarifier
(continuous operation
with positive collection)



Theoretical SBR
(batch operation)

Reality Check



positive collection?

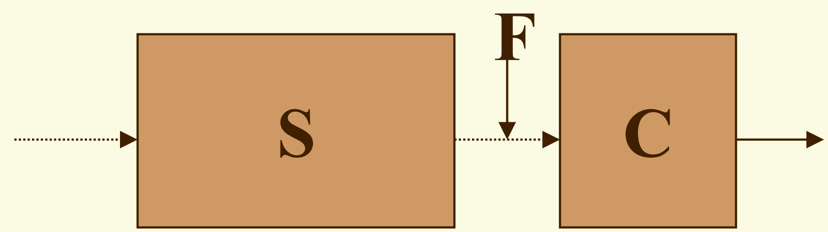
SBR: Known WAS Concentration?

- You have to know the amount of WAS AND the WAS Concentration (WSC)!
- When you try to waste during the Draw Cycle, the concentration changes anyway… and you don’t know what it is!
- When you waste MLSS during the Fill Cycle, MLSS stays at constant concentration due to aeration, it doesn’t thicken!

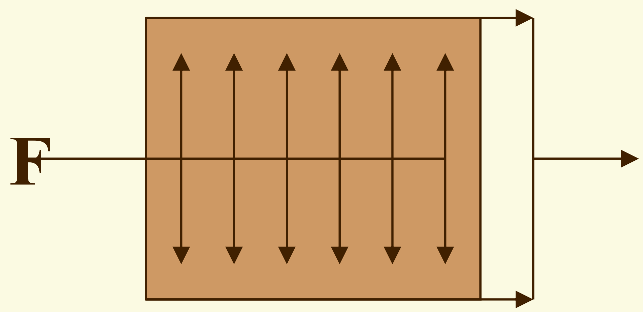
Mode Control: POWERFUL! Point of application of food (F)

<u>Plug-flow (conventional)</u>

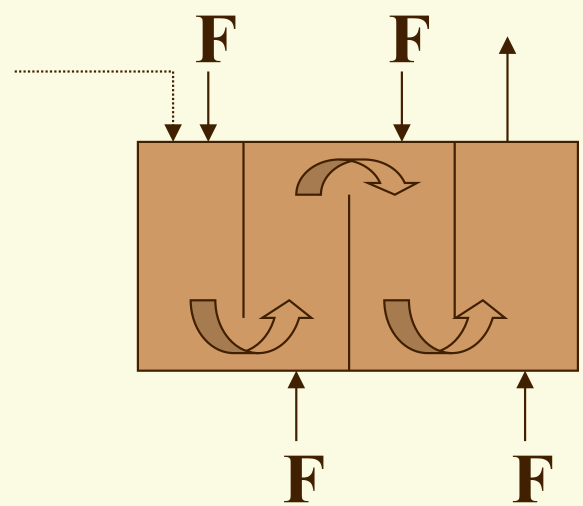
<u>Contact-Stabilization</u>



<u>Complete-mix</u>



<u>Step-Feed</u>



Length of time

Hydraulic Detention Time (HDT)

- time water is in a tank
- volume/flow rate (typically in hours)

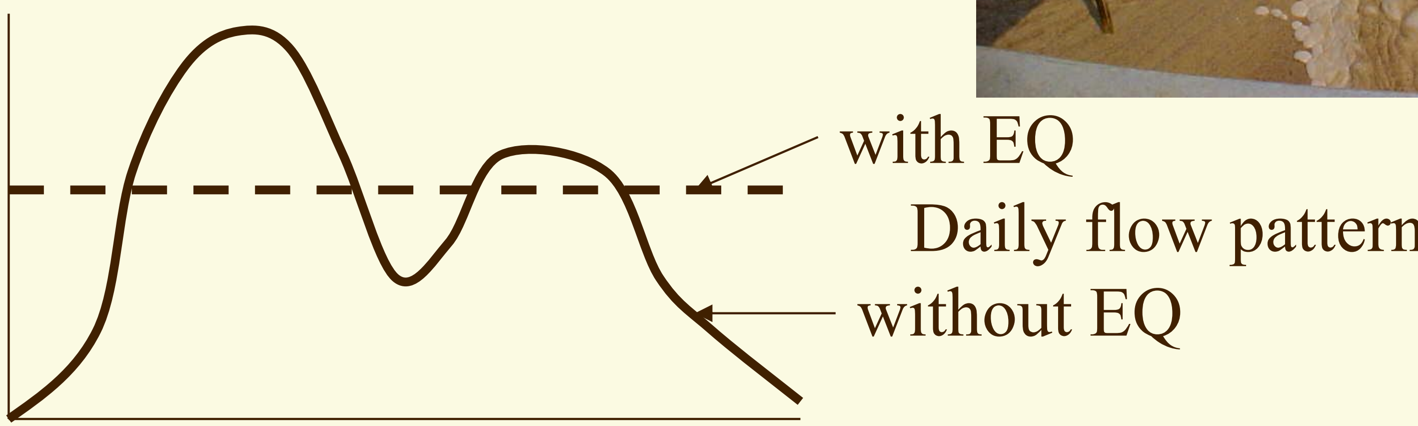
Sludge Detention Time (SDT)

- time solids are in a tank (SDT≥HDT)
- solids in tank/rate of withdrawal (hours)

Sludge Age (many different variations)

- Dynamic Sludge Age (DSA) best (days)

Equalization (EQ) Tank



Most municipal WWTPs do <u>not</u> have EQ.

Most industrial WWTPs <u>do</u> have EQ.

Chemicals: Industrial- SOP, but Municipal- Emergency

Oxidants

- chlorine
- hypochlorite
- ozone
- peroxide
- permanganate

Reducing Agents

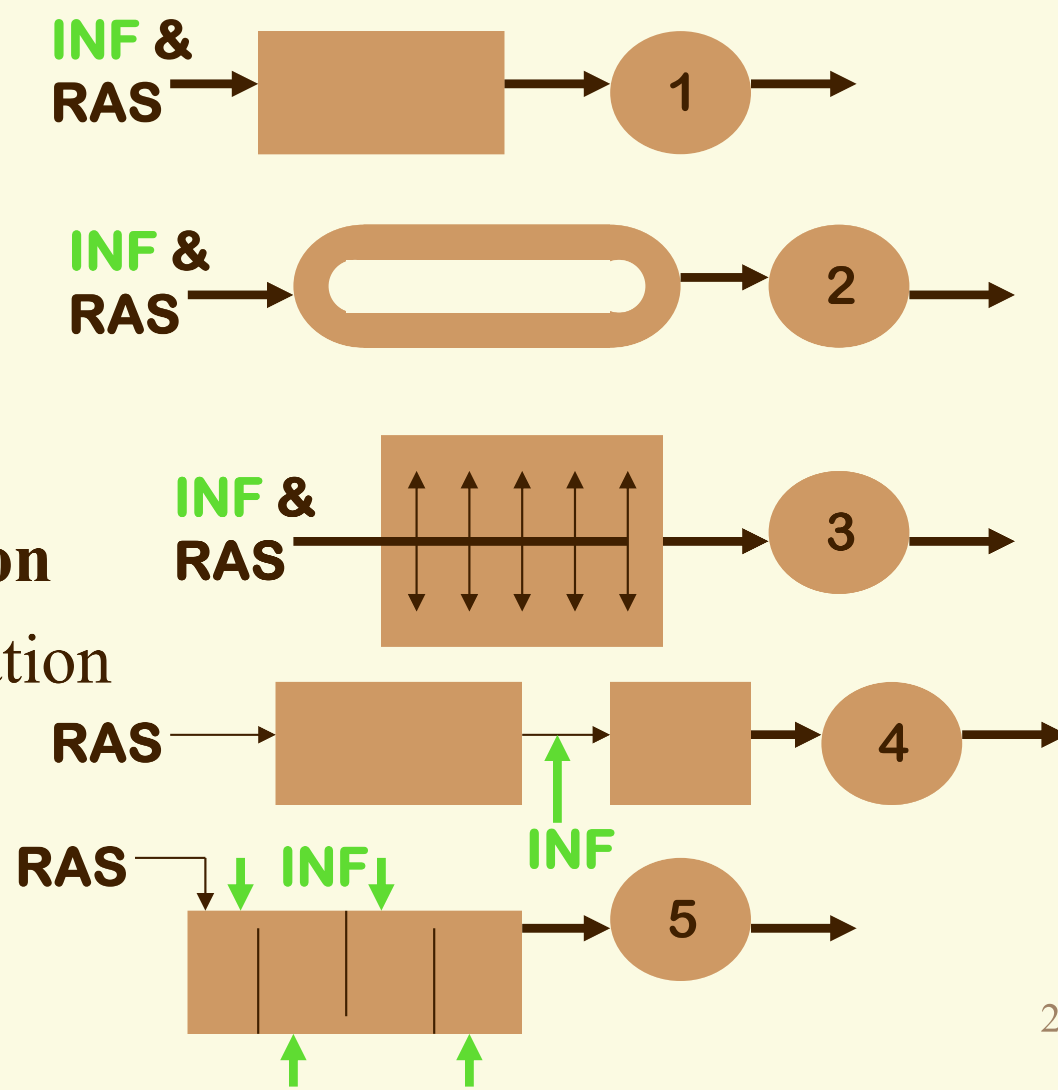
- sulfur dioxide
- bisulfite

Settling Aids

- **Polymers**
  - **cationic**
  - **anionic**
  - **non-ionic**
- **Iron salts**
- **Aluminum salts**
- **Lime (calcium oxide)**

Common Treatment Processes

1. **Conventional**
   - aka. Plug Flow
2. **Extended Aeration**
   - e.g. oxidation ditch
3. **Complete Mix**
4. **Contact Stabilization**
   - aka. Aeration/Reaeration
5. **Step Aeration**
   - aka. Step Feed

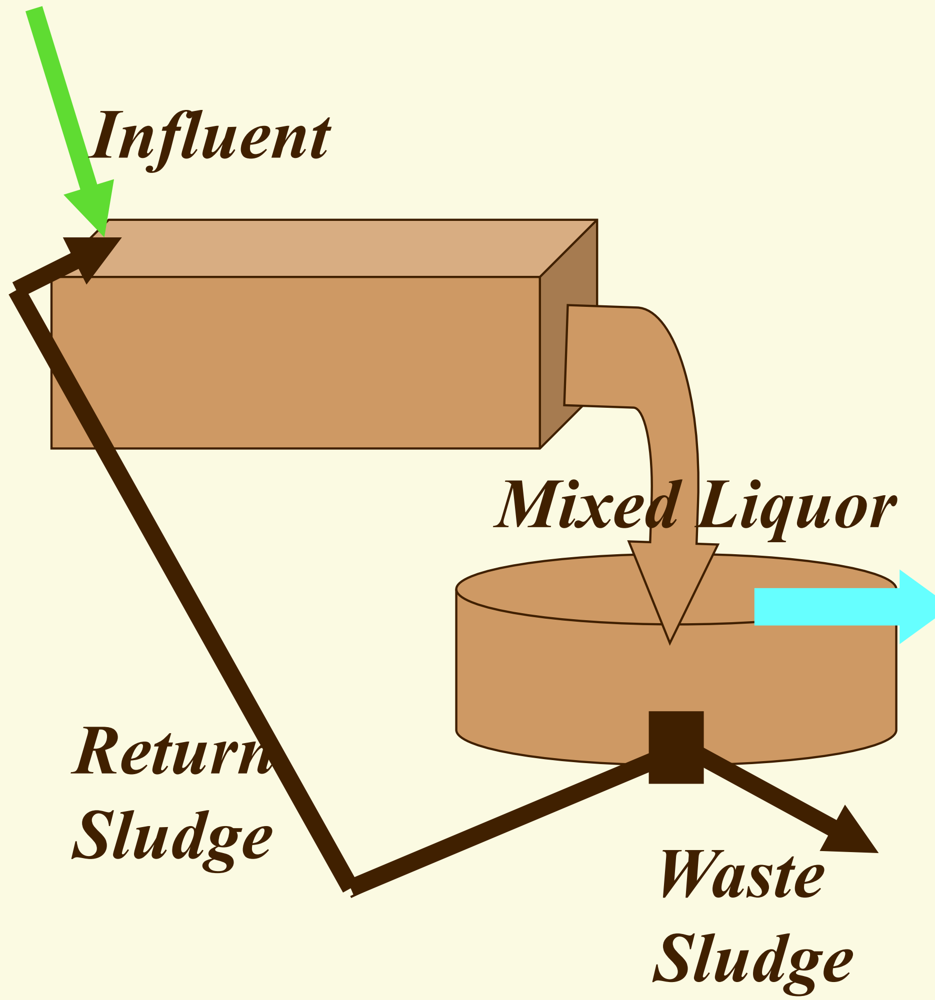


Uncommon Treatment Processes

6. **High Rate:** Older design that looks like conventional plug flow but designed with shorter detention time, e.g. 2 hrs., typically for pretreatment.
7. **Kraus:** Older design that looks like contact stabilization but designed with additional line to supplement anaerobic digester supernatant for nitrogen deficient feed.
8. **Pure Oxygen:** Current design that uses covered reactor to capture excess oxygen (instead of air) to provide smaller footprint. Uses cryogenic separation or molecular sieve.
9. **Trickling Filter - Solids Contact:** Current design that employs combination of suspended and attached growths.

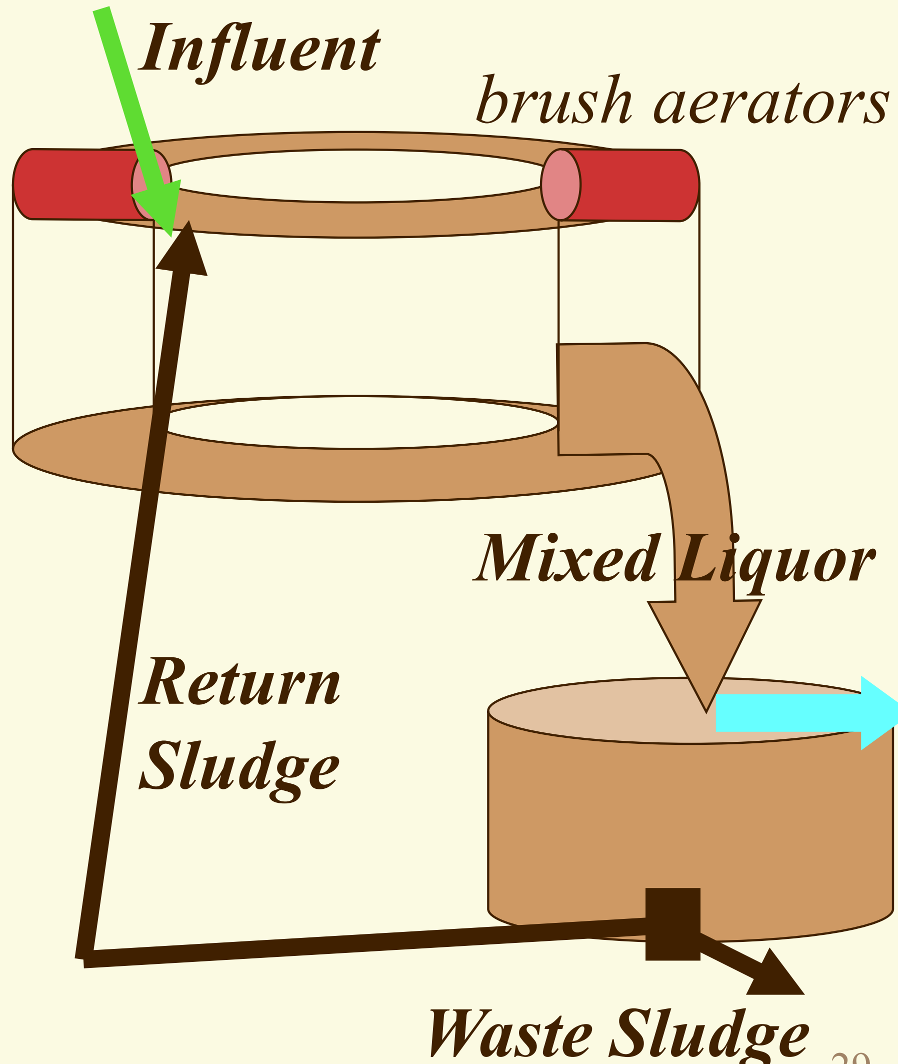
1. Conventional (Plug Flow)

- Used for typical municipal waste where domestic waste is major constituent
- With primary treatment, typically yields excellent effluent quality
- Average sludge production, e.g. 0.6 lb. dry solids per lb. BOD



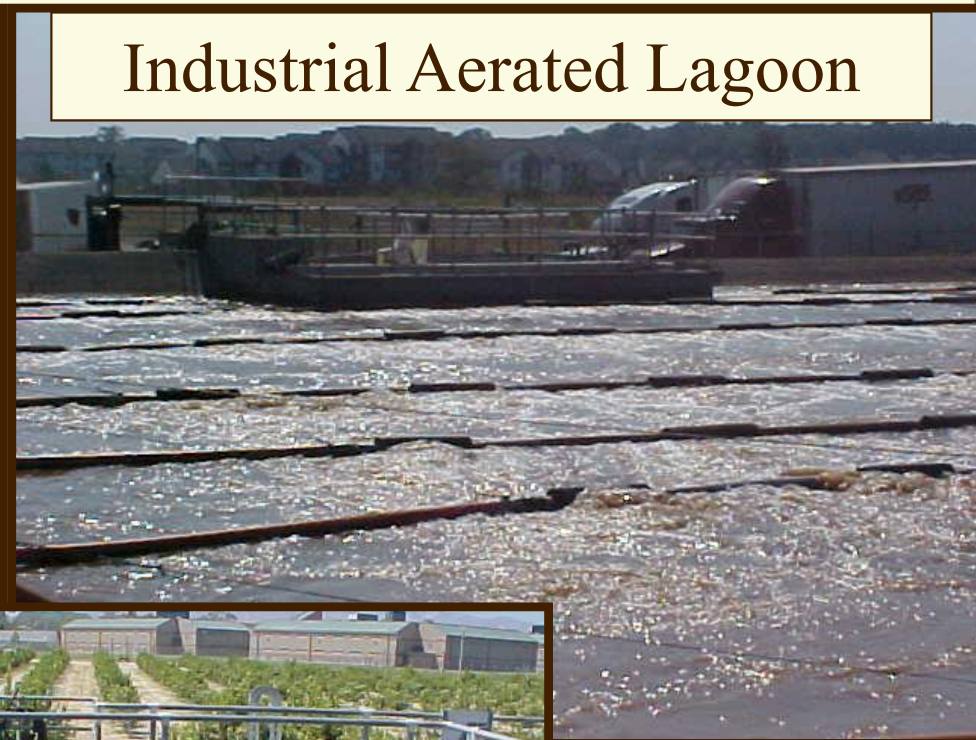
2. Extended Aeration: Oxidation Ditches, SBRs, Aerated Lagoons and Package Plants

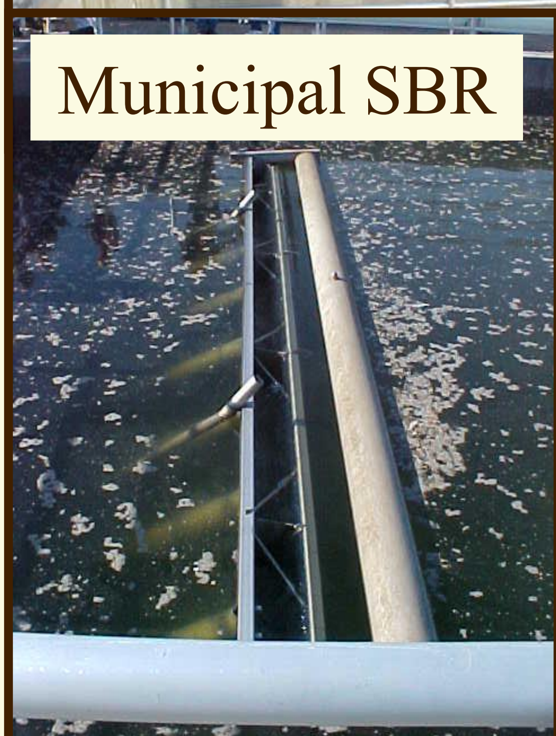
- Features 18-24 hour detention time
- Usually selected for ammonia removal since BOD is removed first, then NOD
- Extended aeration designs usually do not include primary treatment
- Sludge production is low due to endogenous respiration, e.g. <0.6 lb. dry solids per lb. BOD

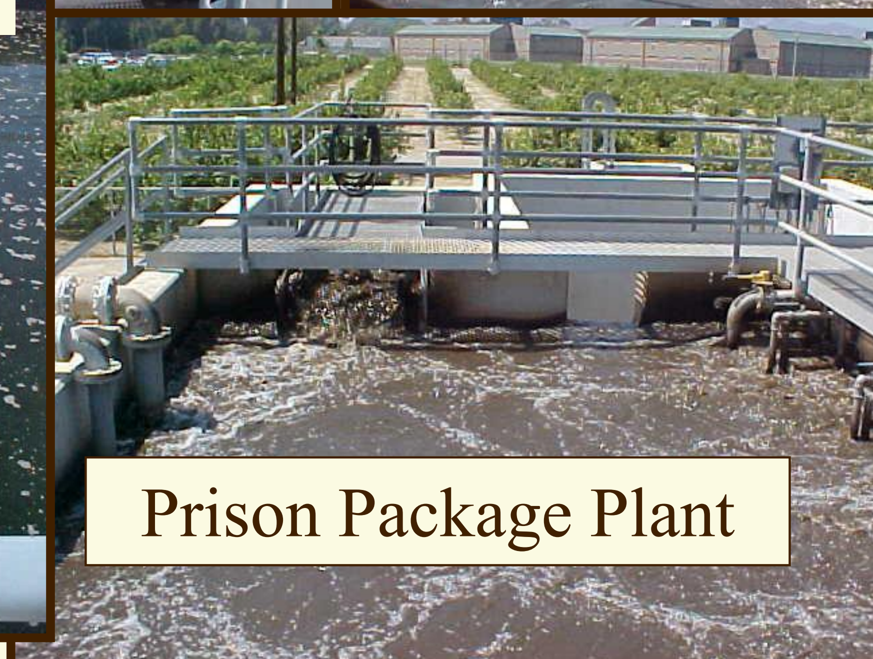


Examples of Extended Aeration Plants


Industrial Oxidation Ditch

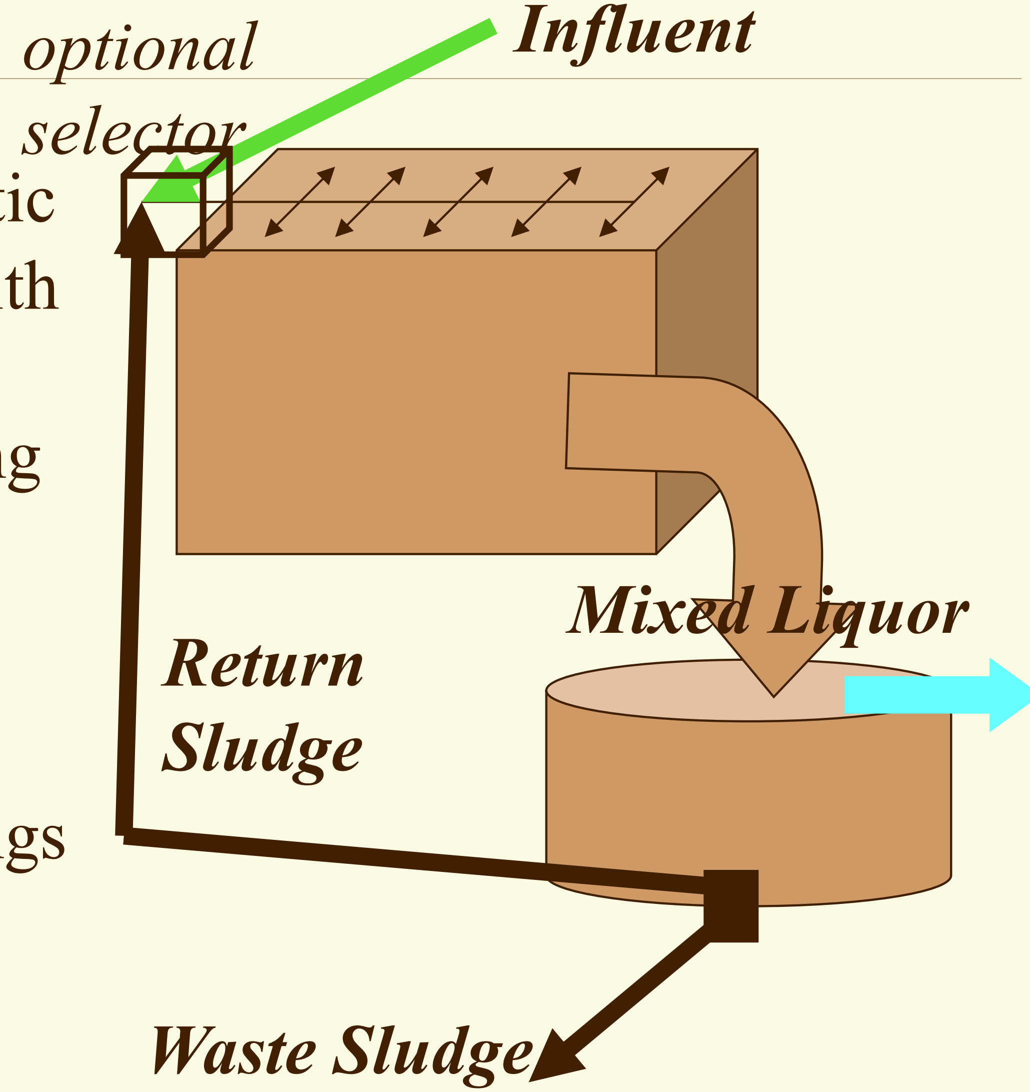

Industrial Aerated Lagoon


Municipal SBR


Prison Package Plant

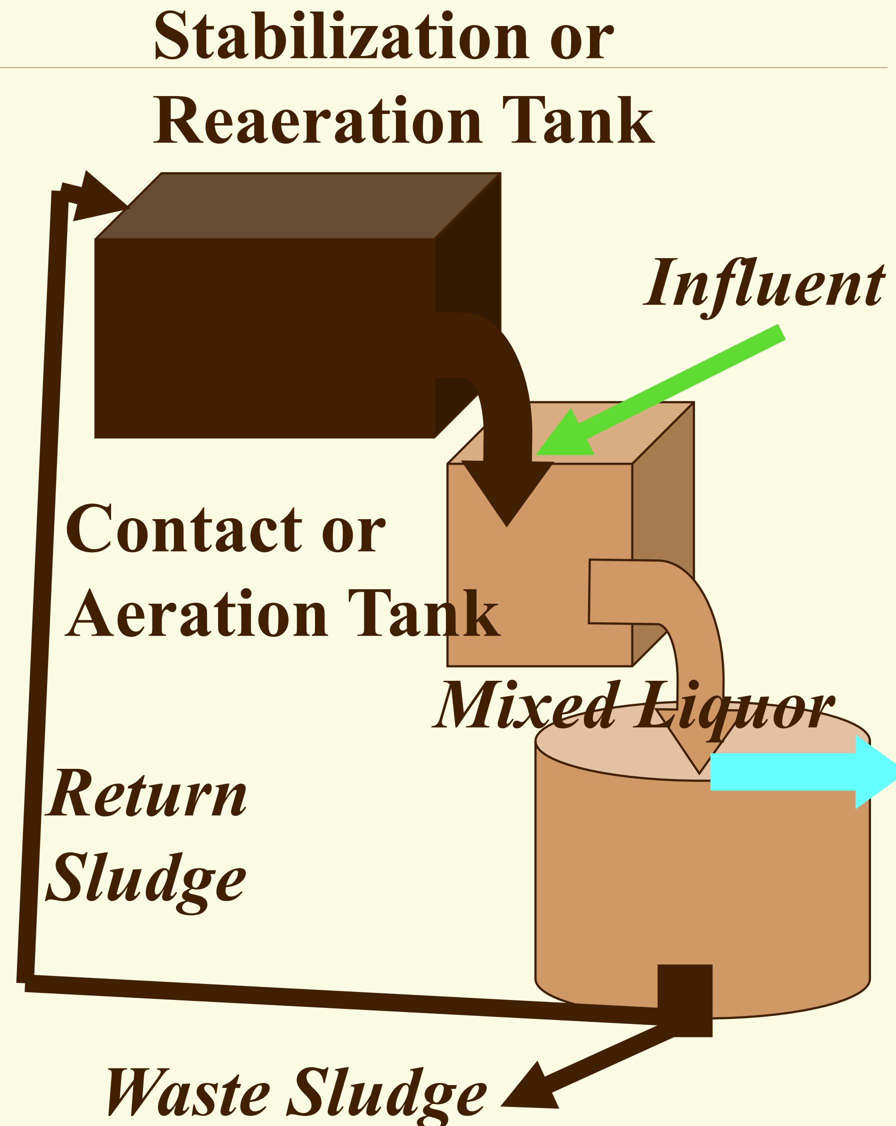
3. Complete Mix Activated Sludge

- For mixtures of domestic and industrial wastes with highly variable characteristics and strong concentrations
- Consider the use of biological selectors for moderate or light loadings



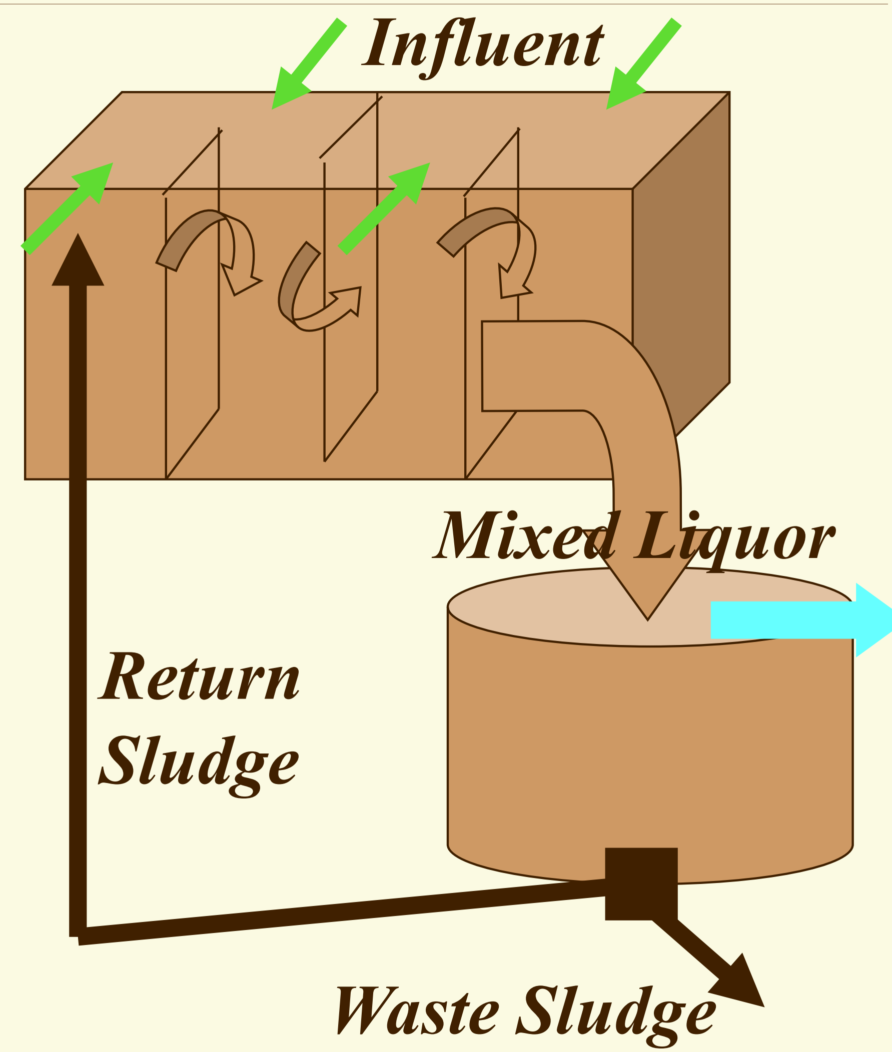
4. Contact Stabilization

- Design for wastes that are somewhat high in organic strength and/or colloidal material
- For communities receiving excessive infiltration or inflow that results in solids washout
- Sludge production can be excessive in plants without primary treatment



5. Step Aeration (Step Feed)

- This variation is the most flexible permitting the operator to select and change his basic process cycle to accommodate unexpected overloads, to adjust sludge solids distribution and to control mixed liquor sludge characteristics
- Its costs may be an 2-3% for extra piping?



Process Variations

	AHDT (hr.)	ASDT (hr.)	DSA (day)
High-Rate	2	2	3-5
Conventional	4-8	4-8	5-10
Complete Mix	3-8	3-8	5-10
Contact-Stabilization	.2-1.0	4-8	5-10
Step-Feed	.2-8	4-8	5-10
Extended Aeration	16-24	16-24	10-15
Kraus	.2-1.0	4-8	5-10
Pure Oxygen	2	2	2-5
Trickling Filter-Solids Contact	.5-1.0	days	very old

Summary

- Operator input critical
- Hold routine O&M meetings
- Process Supervisor
  - **Mode Changes**
  - **Wasting Decisions**
- Shift Supervisor
  - **RAS Adjustments**
  - **Air Adjustments**