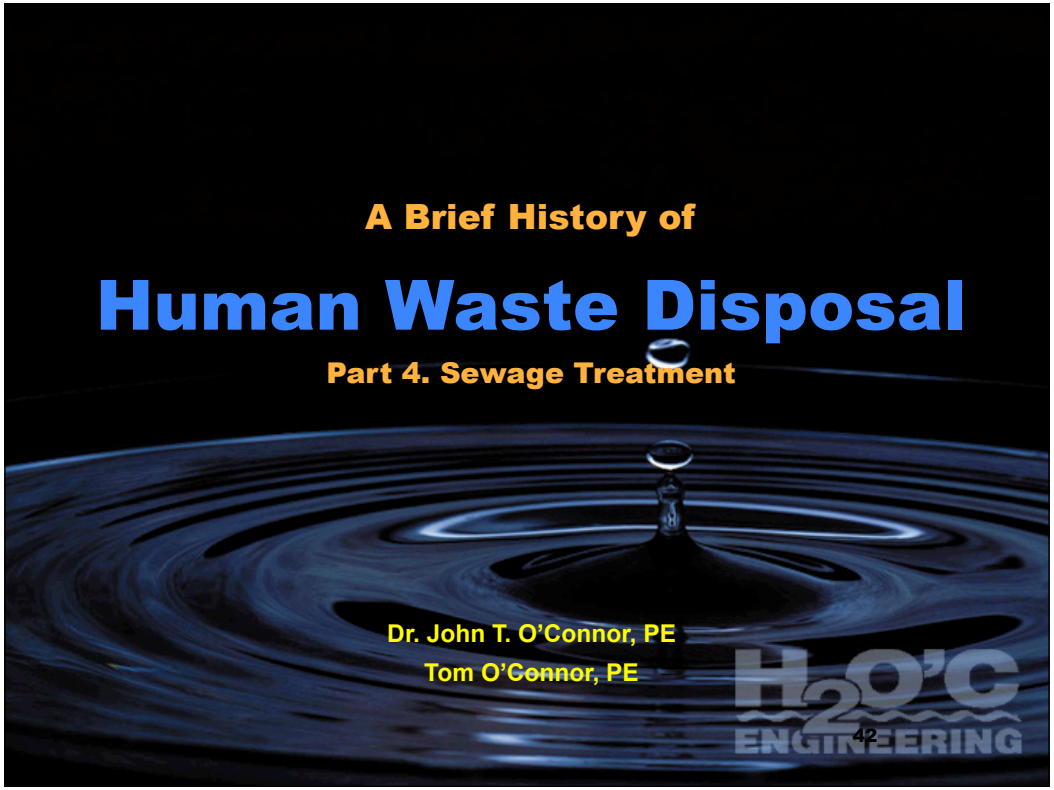
A Brief History of
Human Waste Disposal
Part 4. Sewage Treatment
Dr. John T. O'Connor, PE
Tom O'Connor, PE
H2O'C
ENGINEERING
42

Sewage Disposal to 1950

Storm Drains: Flushings to Streams

Dilution: Waste Assimilative Capacity
1887-1900: (Chicago) Rudolf Hering
Main Drainage Canal, Sanitary District

Broad Irrigation Land Disposal
1876: Soil Clogging, Harmful to Crops

Intermittent Filtration (Biological Treatment)
1887: Lawrence (Mass.) Experiment Station

Treatment Septic Tanks, Tile Fields


Residential Systems – 1910
Unsewered Households
Residential Waste Disposal:
Estimate Waste Quantities and Strength
Engineering of the Septic Tank
and Soil Absorption Systems
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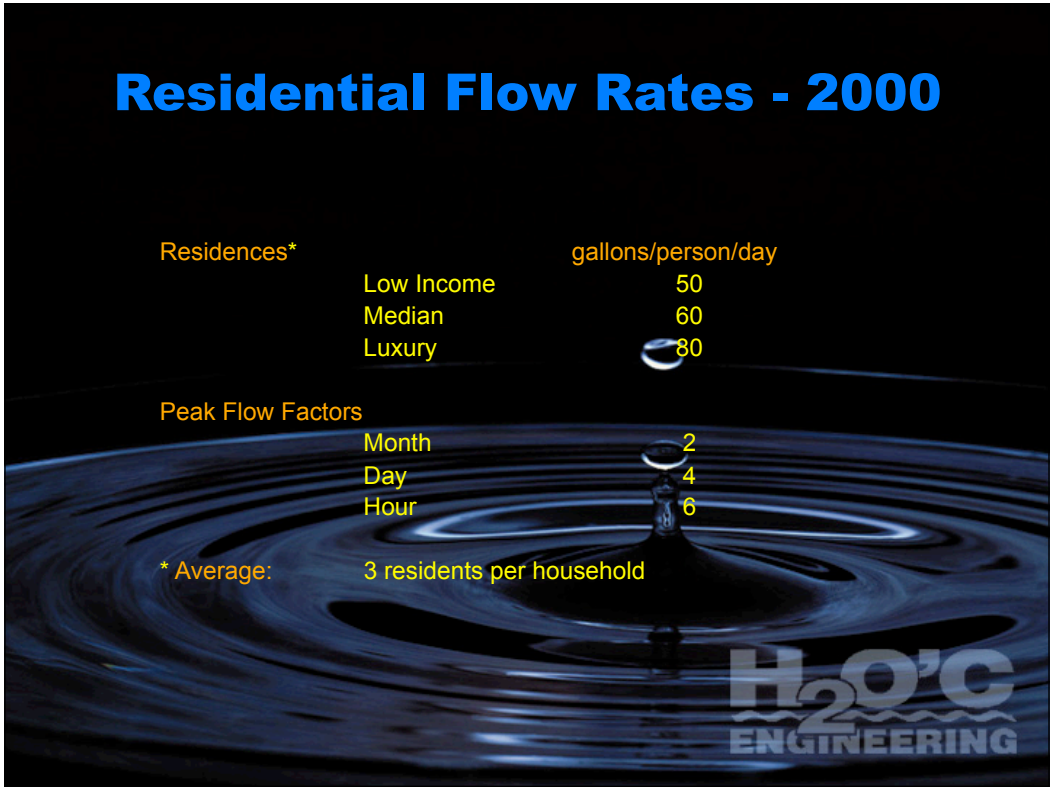
Residential Flow Rates - 2000

Residences*		gallons/person/day
	Low Income	50
	Median	60
	Luxury	80

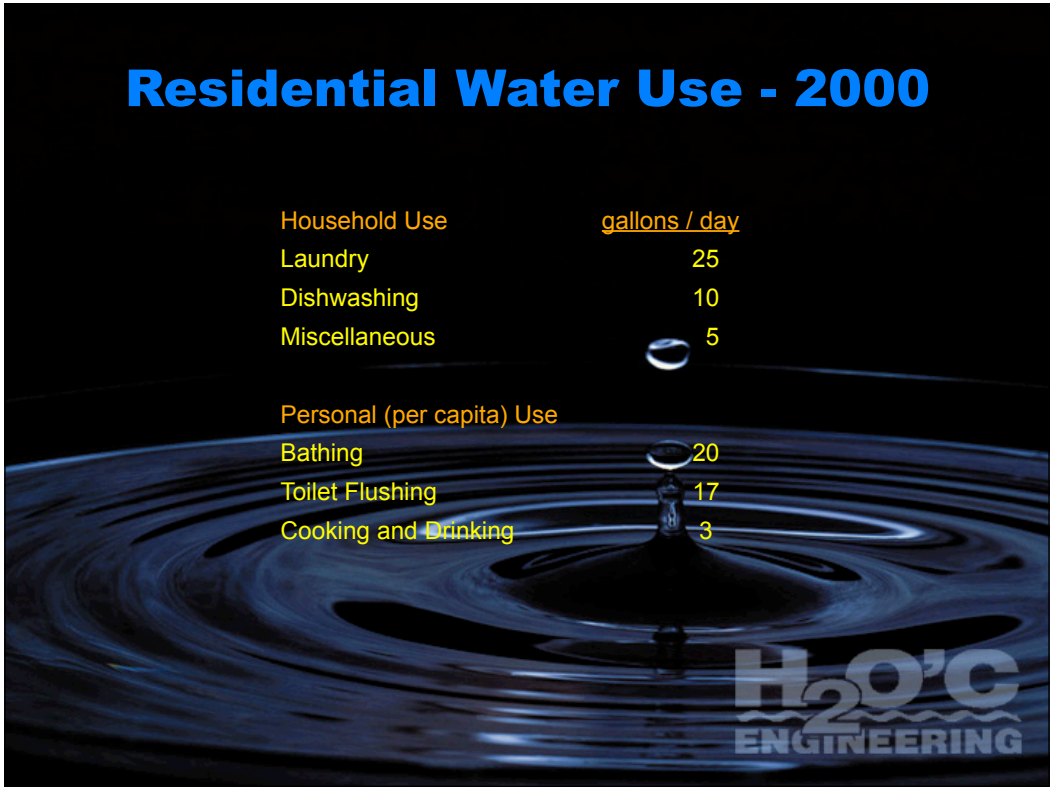
Peak Flow Factors		
	Month	2
	Day	4
	Hour	6

* Average: 3 residents per household



Residential Water Use - 2000

Household Use	gallons / day
Laundry	25
Dishwashing	10
Miscellaneous	5
Personal (per capita) Use	
Bathing	20
Toilet Flushing	17
Cooking and Drinking	3



Sewage Characterization

Circa 1900:

Nitrate, Ammonium Ion, Albuminoid N

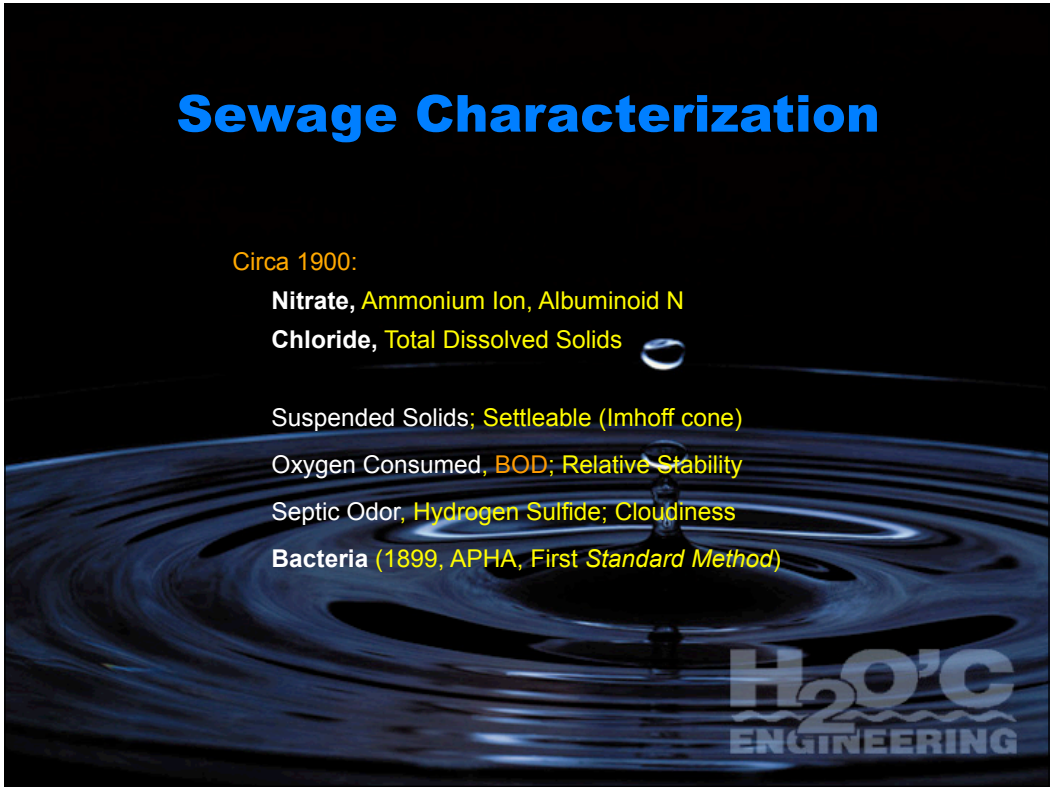
Chloride, Total Dissolved Solids

Suspended Solids; Settleable (Imhoff cone)

Oxygen Consumed, BOD; Relative Stability

Septic Odor, Hydrogen Sulfide; Cloudiness

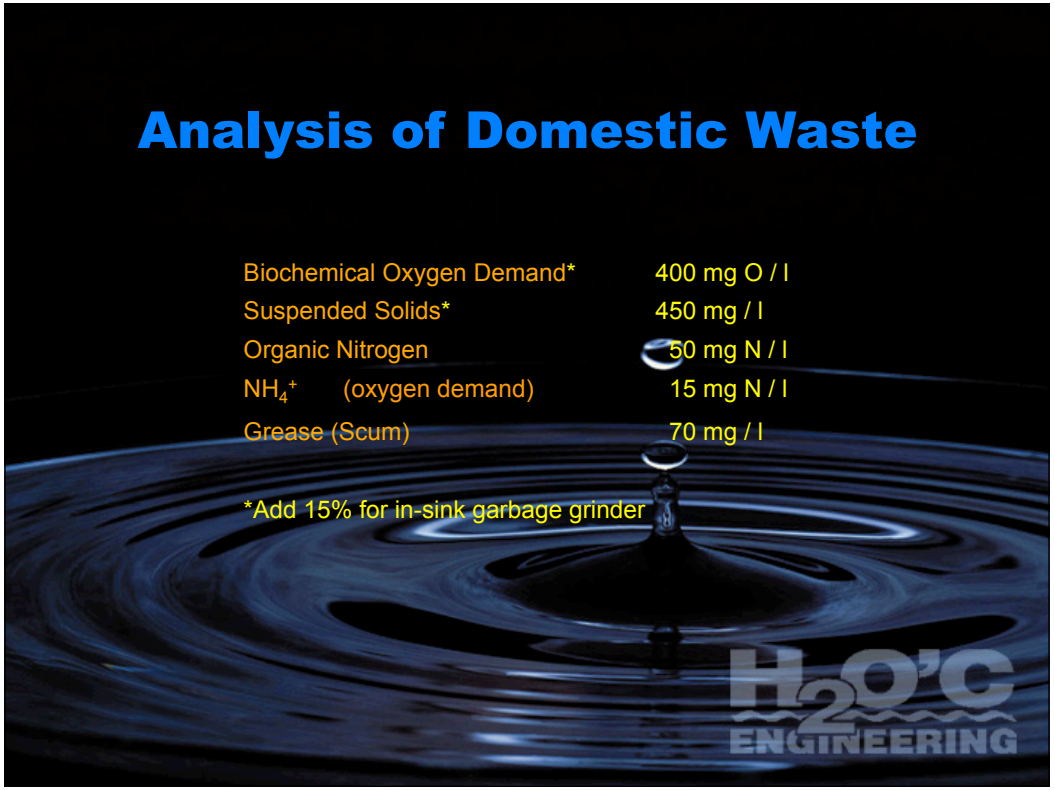
Bacteria (1899, APHA, First *Standard Method*)



Analysis of Domestic Waste

Biochemical Oxygen Demand*	400 mg O / l
Suspended Solids*	450 mg / l
Organic Nitrogen	50 mg N / l
NH_4^+ (oxygen demand)	15 mg N / l
Grease (Scum)	70 mg / l

*Add 15% for in-sink garbage grinder



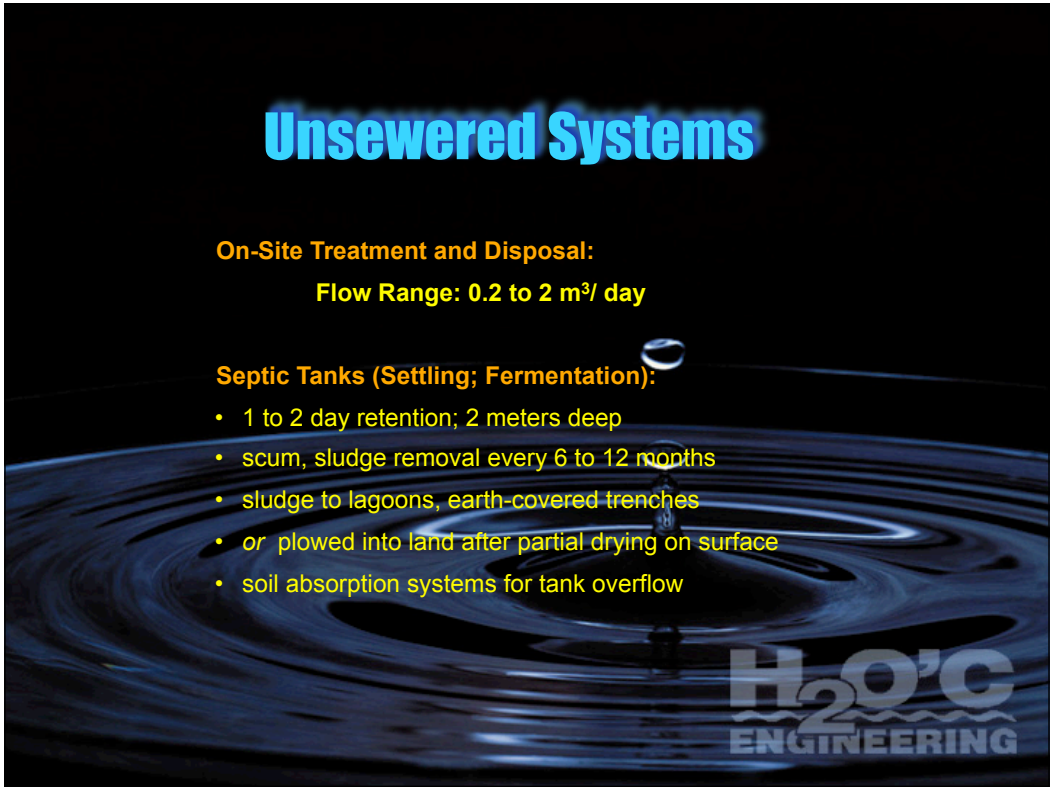
Unsewered Systems

On-Site Treatment and Disposal:

Flow Range: 0.2 to 2 m^3/ day

Septic Tanks (Settling; Fermentation):

- 1 to 2 day retention; 2 meters deep
- scum, sludge removal every 6 to 12 months
- sludge to lagoons, earth-covered trenches
- *or* plowed into land after partial drying on surface
- soil absorption systems for tank overflow



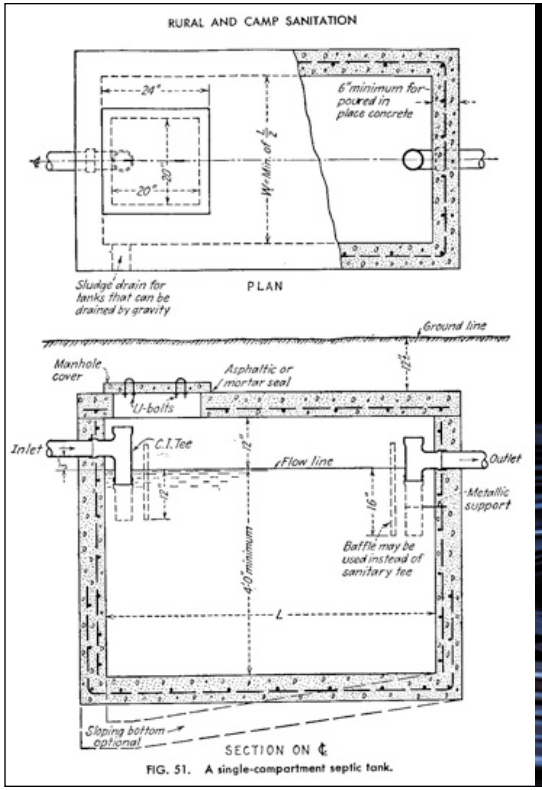


FIG. 51. A single-compartment septic tank.

Septic Tank

Unit Capacity:

4 to 16 people

500 - 2000 gallons

90 -300 cubic feet

1-3 compartments

L/W: 3/1; D: 4-6 ft.

Scum, gas baffles

Filter Vault

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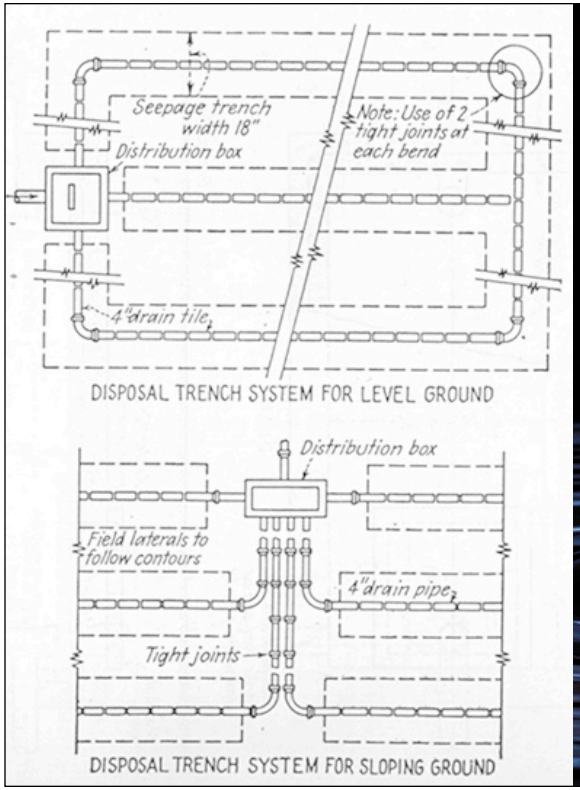

Tile Fields

Sub-Surface Disposal

Gravel-filled Trenches

Open-Joint Tiles

Infiltration to Vadose Zone

Biological Slime Formation

Mineral Precipitates, FeS

Release of Gases, H_2S, CH_4

Soil Acceptance Rate:

0.3 to 0.5 gpd/sf

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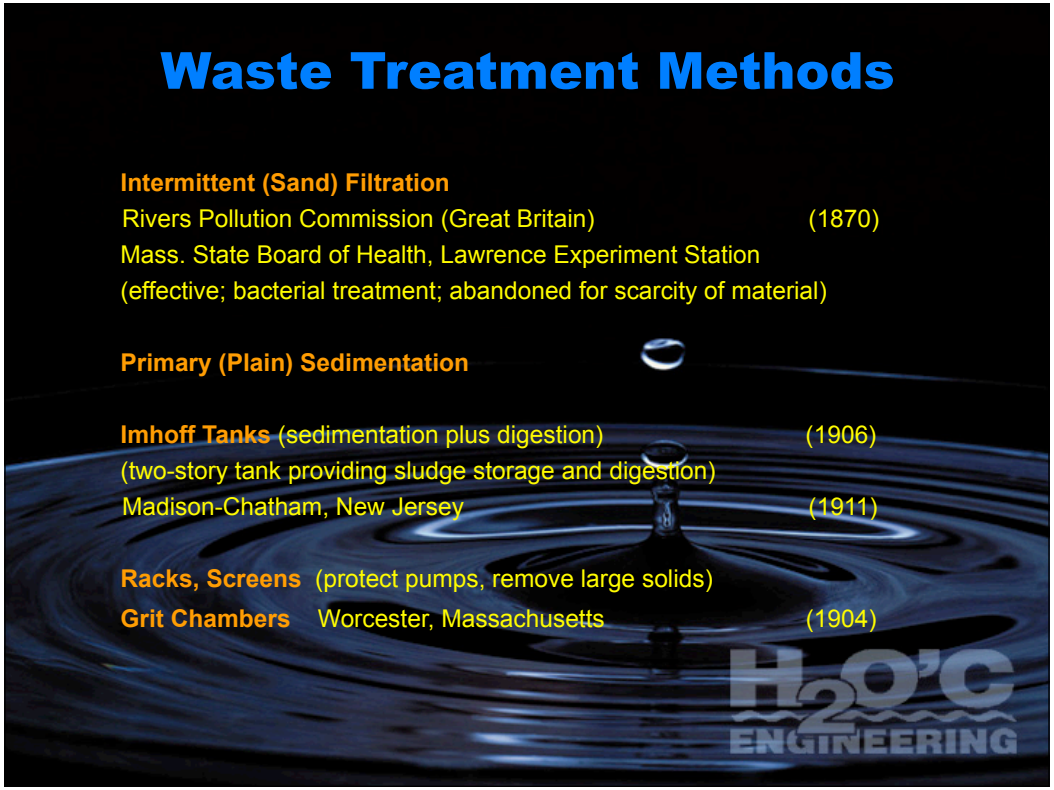
Waste Treatment Methods

Intermittent (Sand) Filtration
Rivers Pollution Commission (Great Britain) (1870)
Mass. State Board of Health, Lawrence Experiment Station
(effective; bacterial treatment; abandoned for scarcity of material)

Primary (Plain) Sedimentation

Imhoff Tanks (sedimentation plus digestion) (1906)
(two-story tank providing sludge storage and digestion)
Madison-Chatham, New Jersey (1911)

Racks, Screens (protect pumps, remove large solids)
Grit Chambers Worcester, Massachusetts (1904)



Early Sewage Treatment

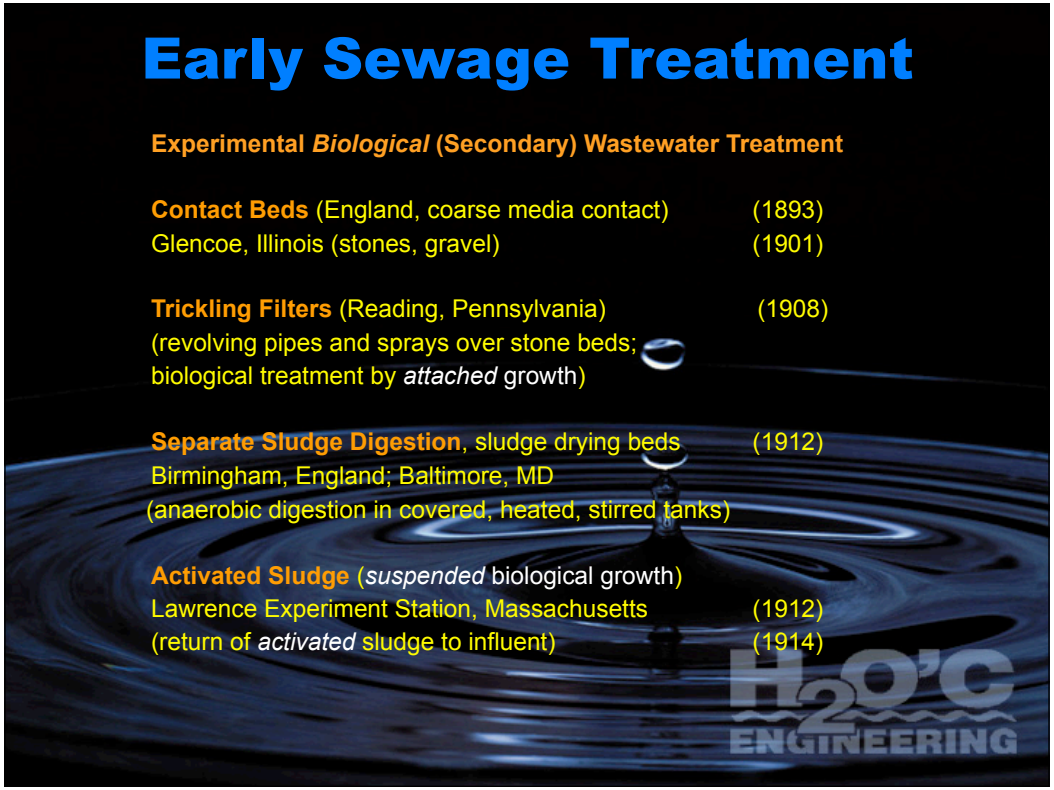
Experimental *Biological* (Secondary) Wastewater Treatment

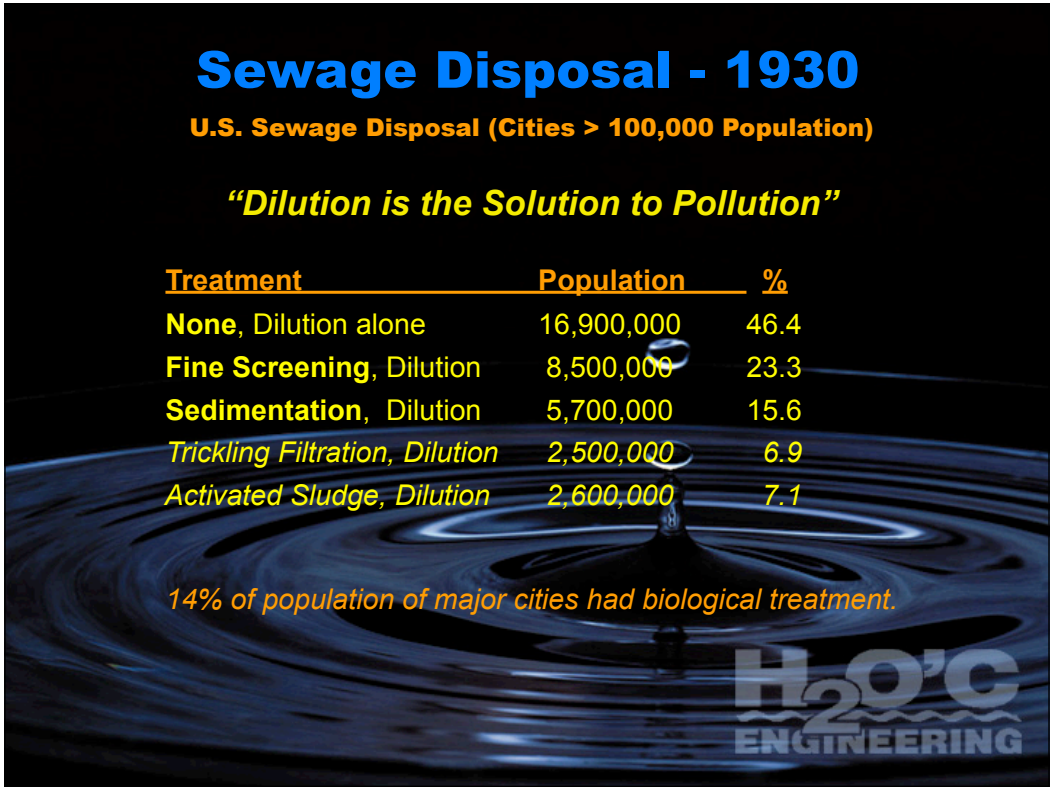
Contact Beds (England, coarse media contact) (1893)
Glencoe, Illinois (stones, gravel) (1901)

Trickling Filters (Reading, Pennsylvania) (1908)
(revolving pipes and sprays over stone beds;
biological treatment by *attached* growth)

Separate Sludge Digestion, sludge drying beds (1912)
Birmingham, England; Baltimore, MD
(anaerobic digestion in covered, heated, stirred tanks)

Activated Sludge (*suspended* biological growth)
Lawrence Experiment Station, Massachusetts (1912)
(return of *activated* sludge to influent) (1914)




Sewage Disposal - 1930
U.S. Sewage Disposal (Cities > 100,000 Population)
"Dilution is the Solution to Pollution"
Treatment Population %
None, Dilution alone 16,900,000 46.4
Fine Screening, Dilution 8,500,000 23.3
Sedimentation, Dilution 5,700,000 15.6
Trickling Filtration, Dilution 2,500,000 6.9
Activated Sludge, Dilution 2,600,000 7.1
14% of population of major cities had biological treatment.
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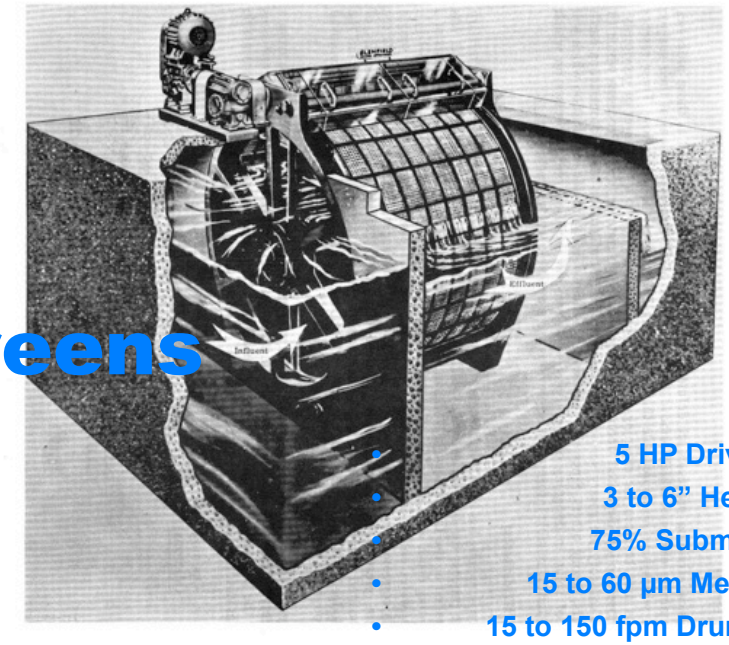
oscreens



- 5 HP Drive Motor
- 3 to 6” Head Loss
- 75% Submergence
- 15 to 60 µm Mesh Sizes
- 15 to 150 fpm Drum Speed
- 10’ Diameter for 3 to 10 mgd
- 5% Backwash Flow @ 15 psi

Karl Imhoff

1906: Taschenbuch der Stadtentwasserung

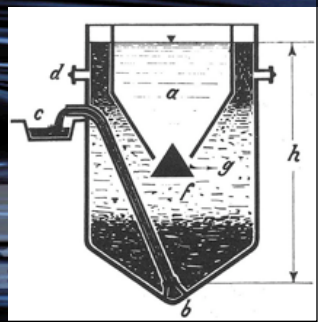
Sewers:Open ditches with concrete slabs

Two-Storied Settling and Digestion Tanks

1913-1934: 70 works constructed, Ruhr River

1929 : Karl Imhoff and Gordon Fair (Harvard)

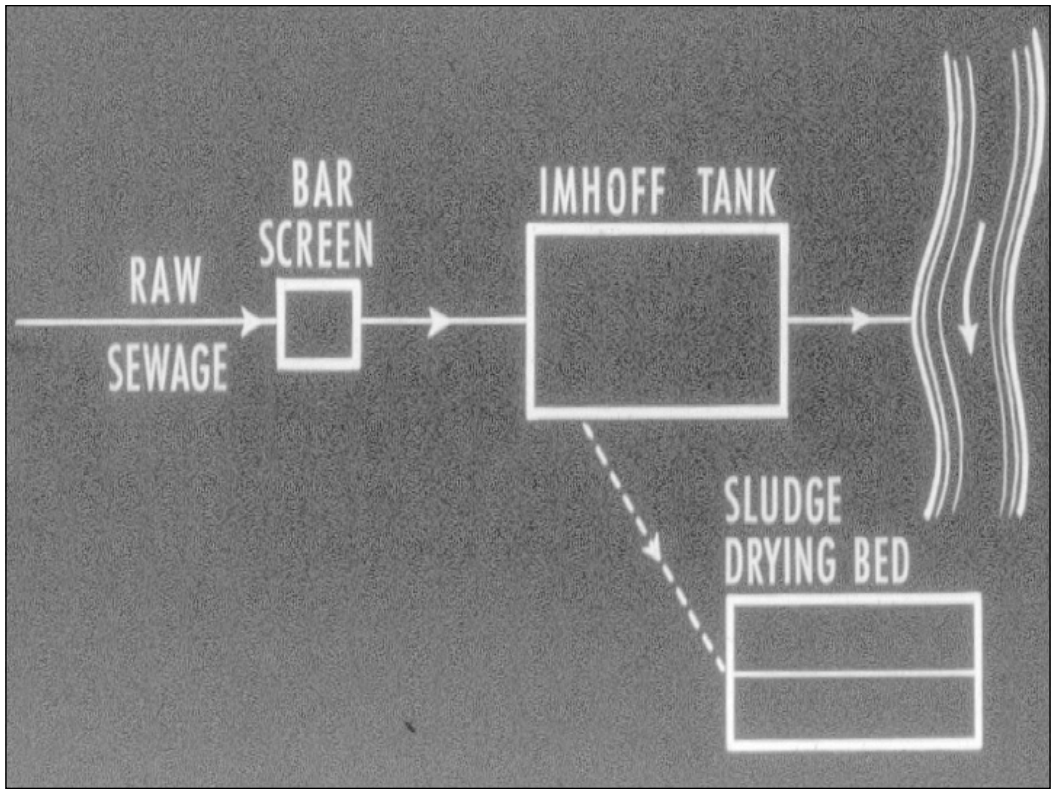
The Arithmetic of Sewage Treatment Works



Imhoff Tank patented in 1906; first operated in 1908

Imhoff Tank Treatment Plant

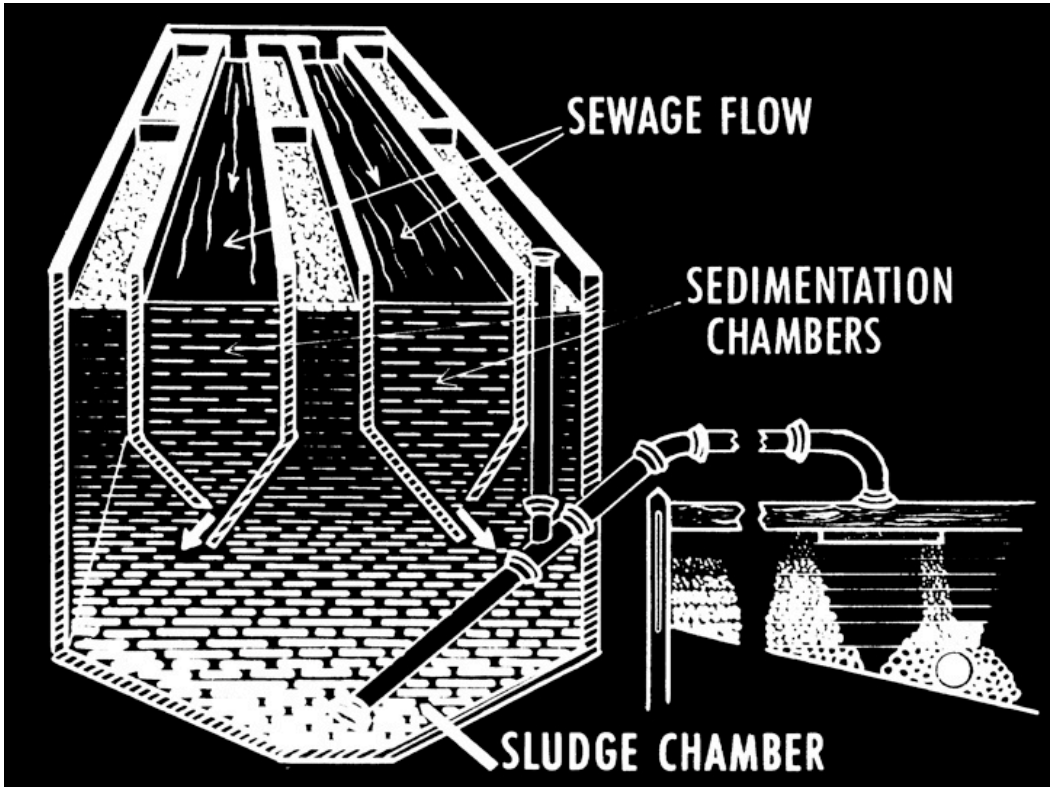
Population: 1000 40,000 gpd


BAR
SCREEN
IMHOFF TANK
RAW
SEWAGE
SLUDGE
DRYING BED

Manually-Cleaned Bar Rack

Imhoff Tank

Settling Compartments and Gas Vents


SEWAGE FLOW
SEDIMENTATION CHAMBERS
SLUDGE CHAMBER

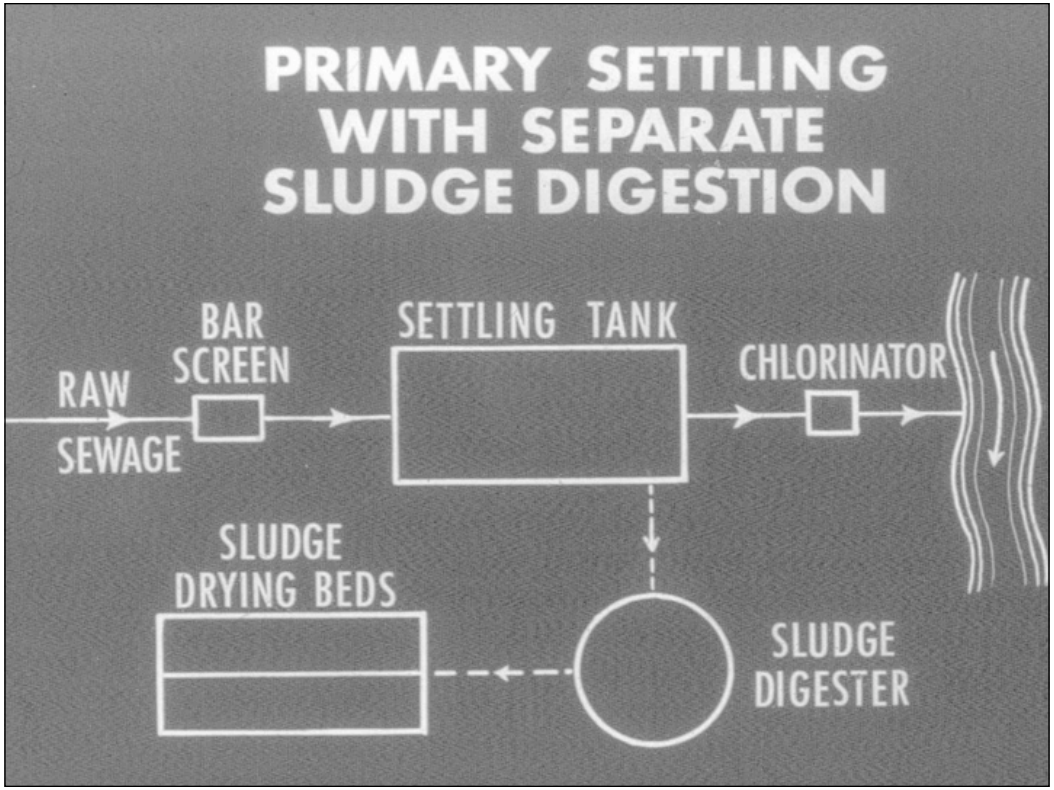

Gas Rising from Gas Vent

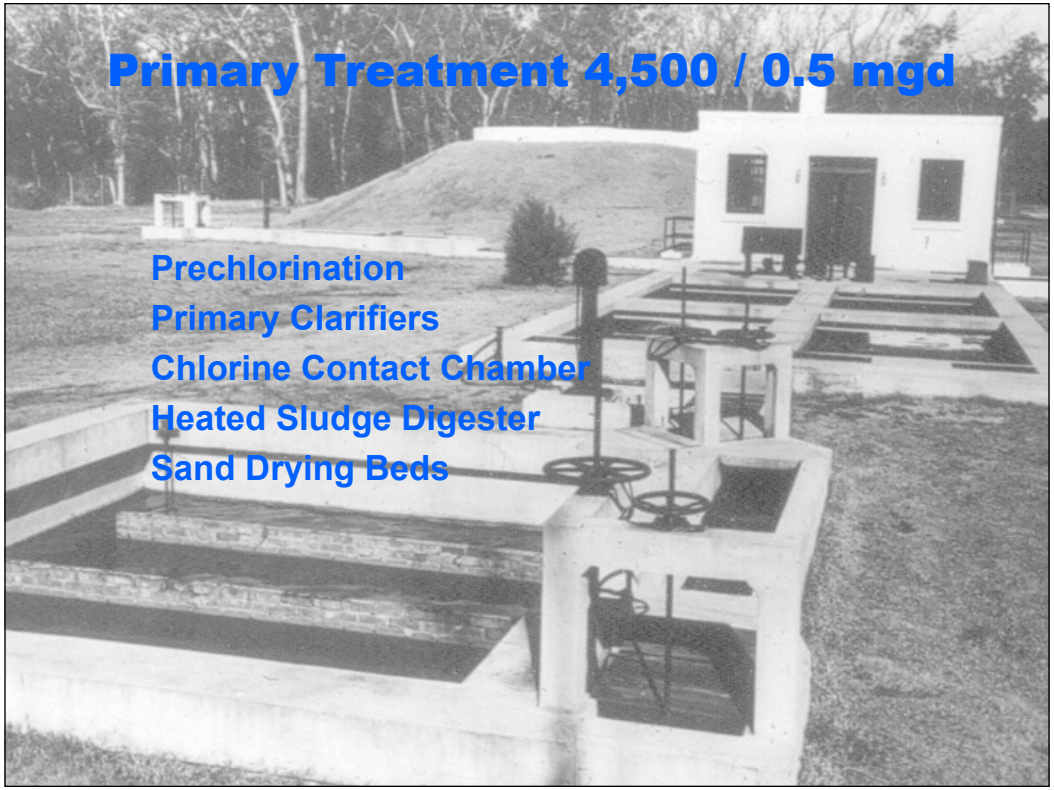

Raw Sludge Drying Beds

Sewage Effluent entering Stream

50% Suspended Solids Removal

50% Reduction in Oxygen Demand


PRIMARY SETTLING
WITH SEPARATE
SLUDGE DIGESTION
RAW
SEWAGE
BAR
SCREEN
SETTLING TANK
CHLORINATOR
SLUDGE
DRYING BEDS
SLUDGE
DIGESTER


Primary Treatment 4,500 / 0.5 mgd
Prechlorination
Primary Clarifiers
Chlorine Contact Chamber
Heated Sludge Digester
Sand Drying Beds

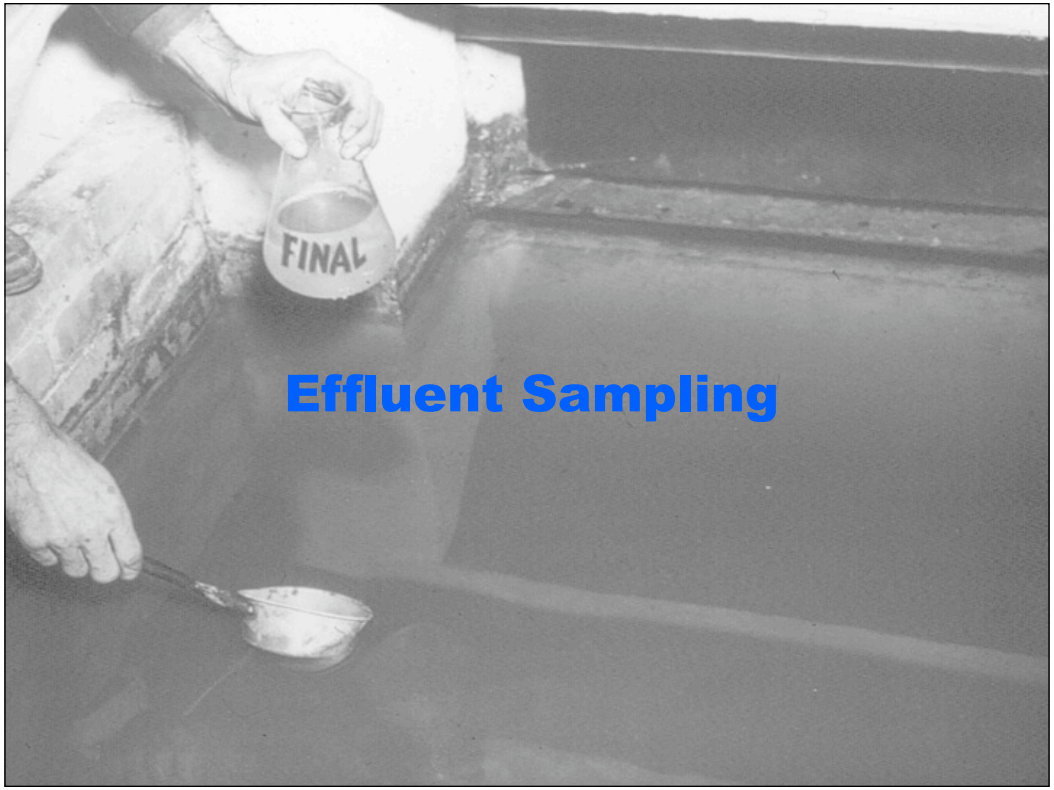
Prechlorination and Sampling

Dual, Manually-Cleaned Bar Screens

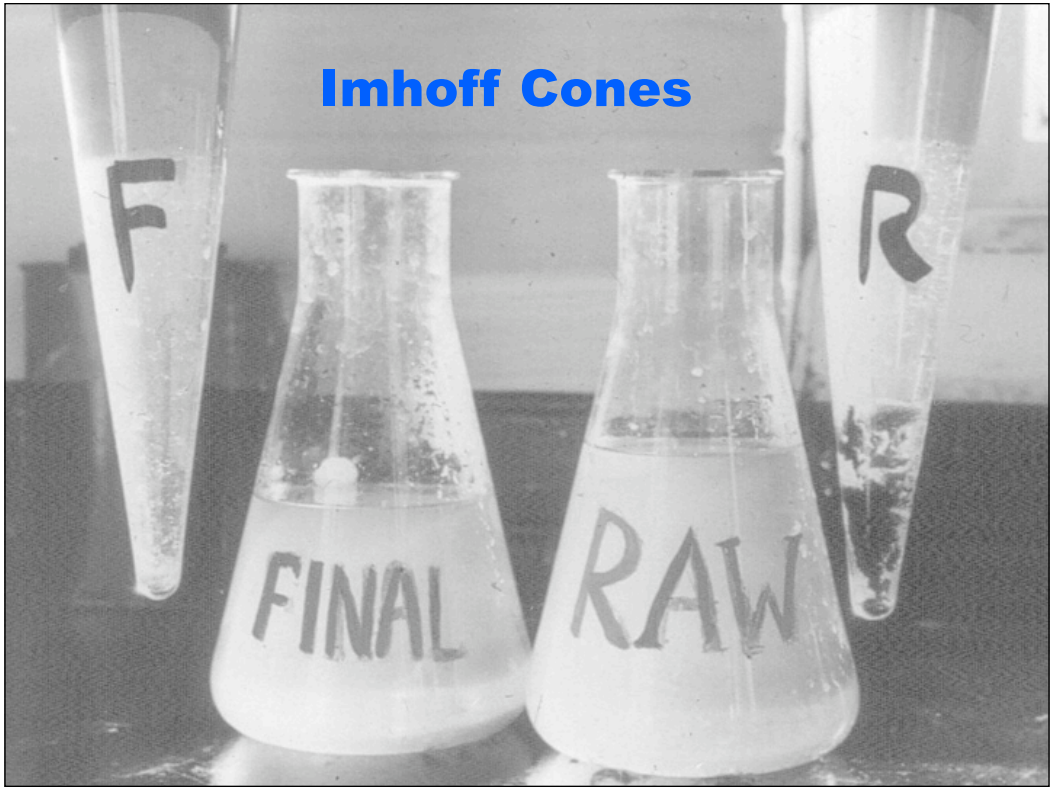

Rectangular, Mechanically-Cleaned Clarifiers

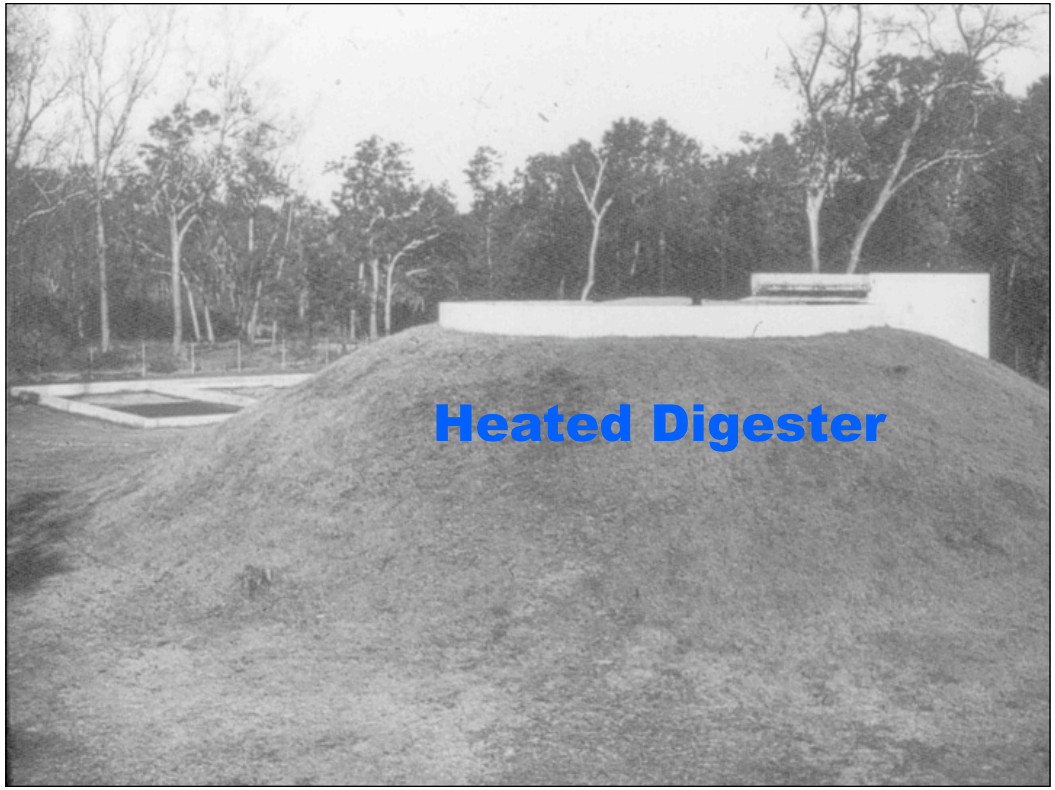

Scum Removal

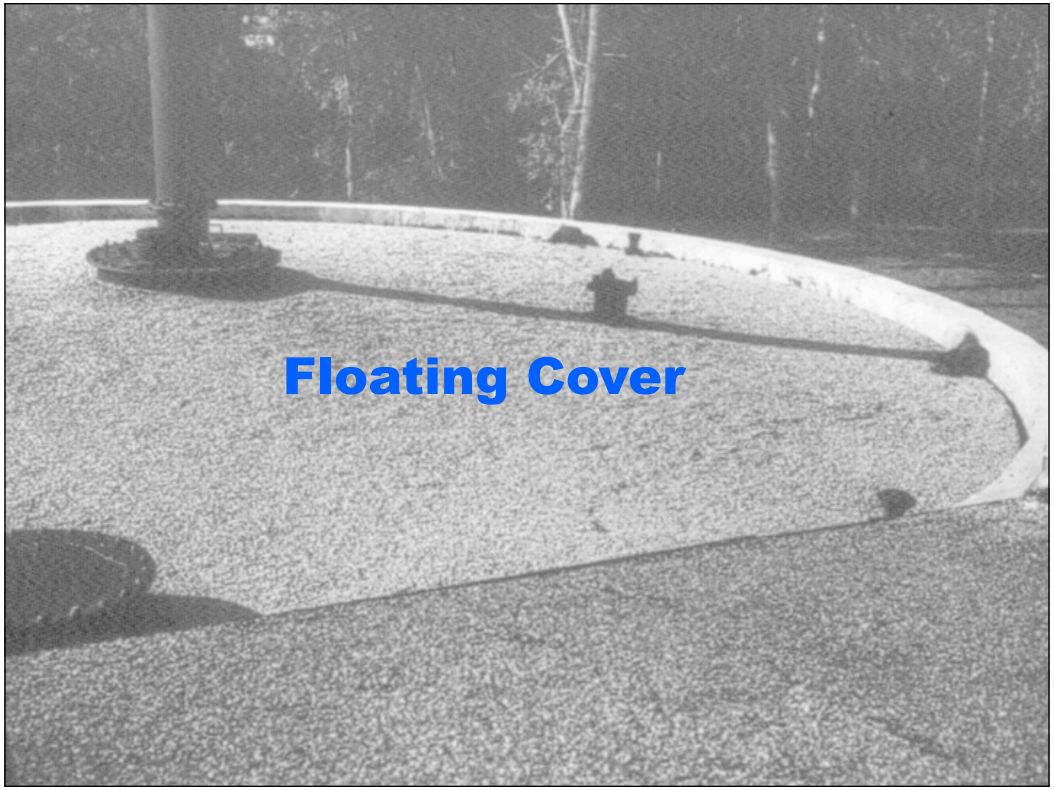

Chlorine Contact Chamber


FINAL
Effluent Sampling

Imhoff Cones

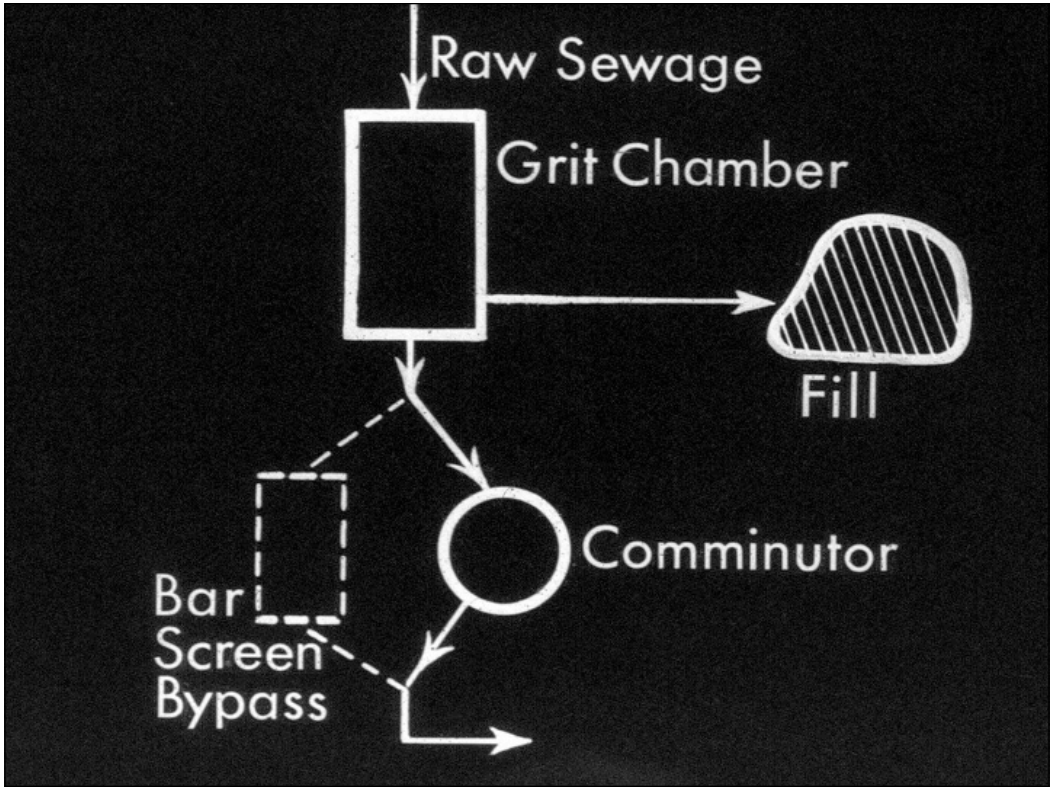


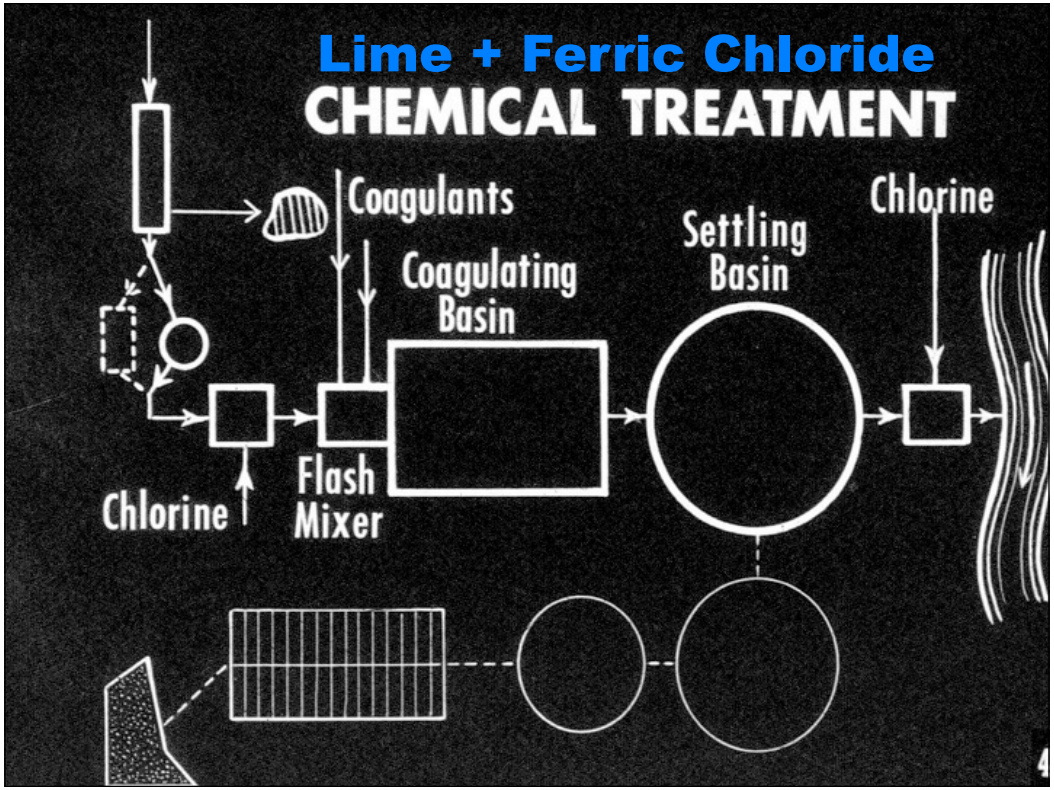

Heated Digester

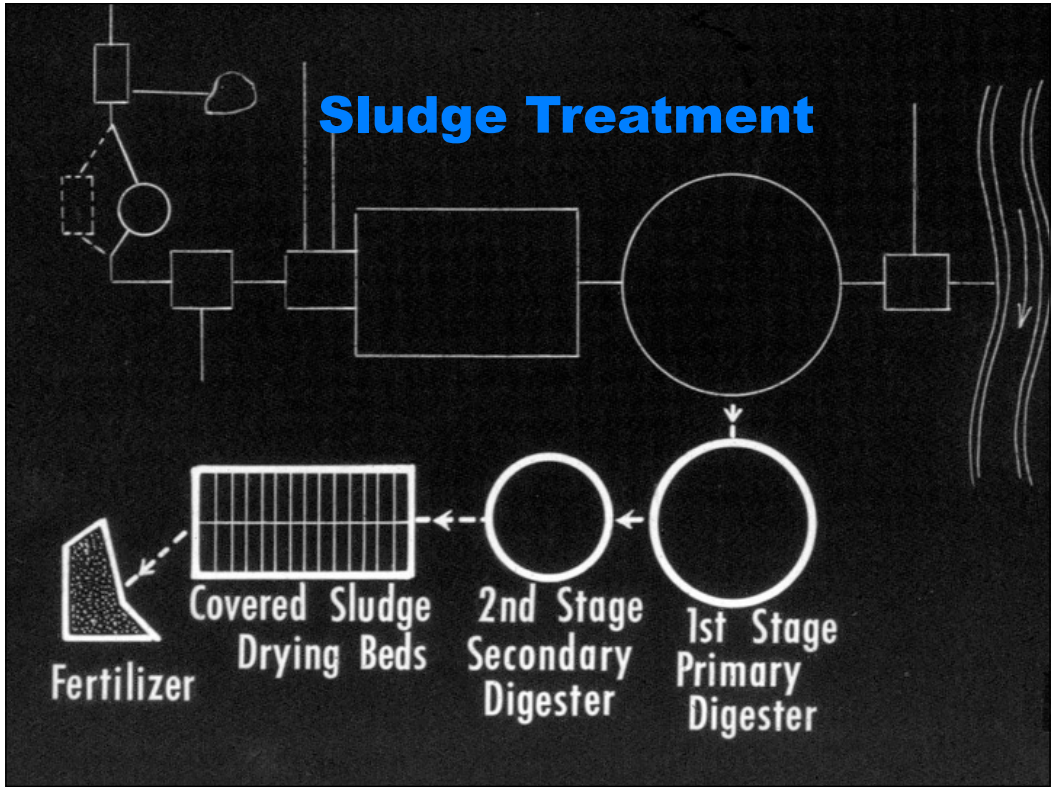

Floating Cover

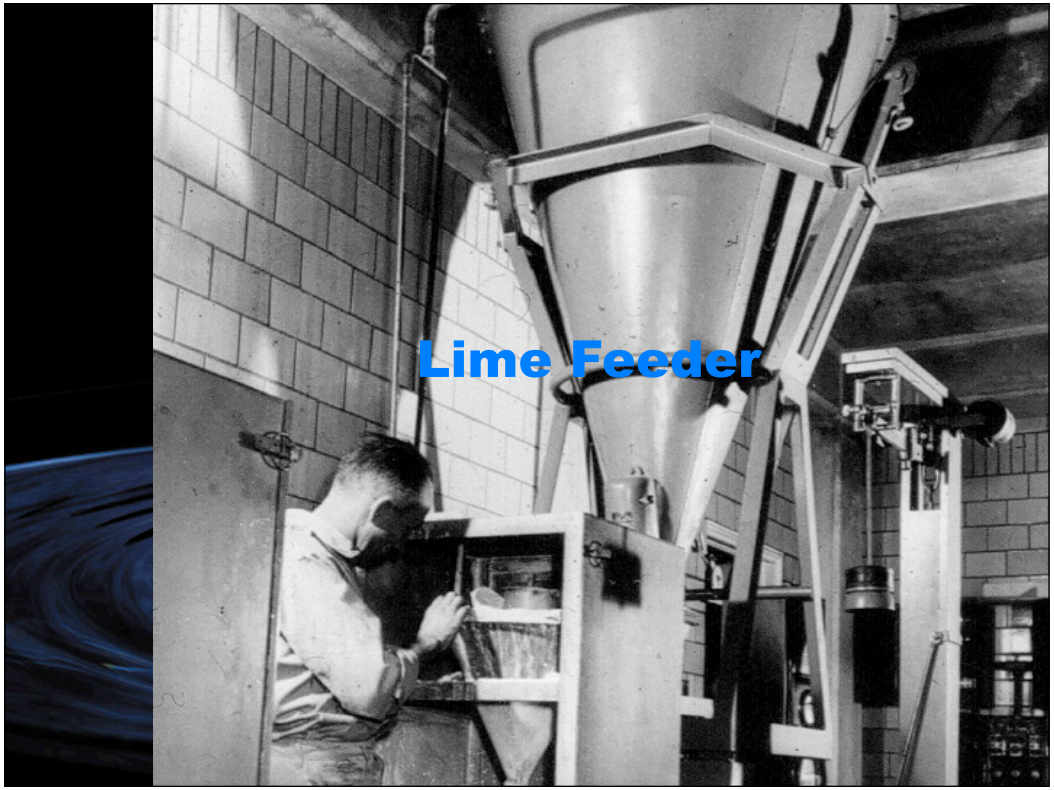

Sand Drying Beds

40
Chemical Treatment


Raw Sewage
Grit Chamber
Fill
Comminutor
Bar
Screen
Bypass

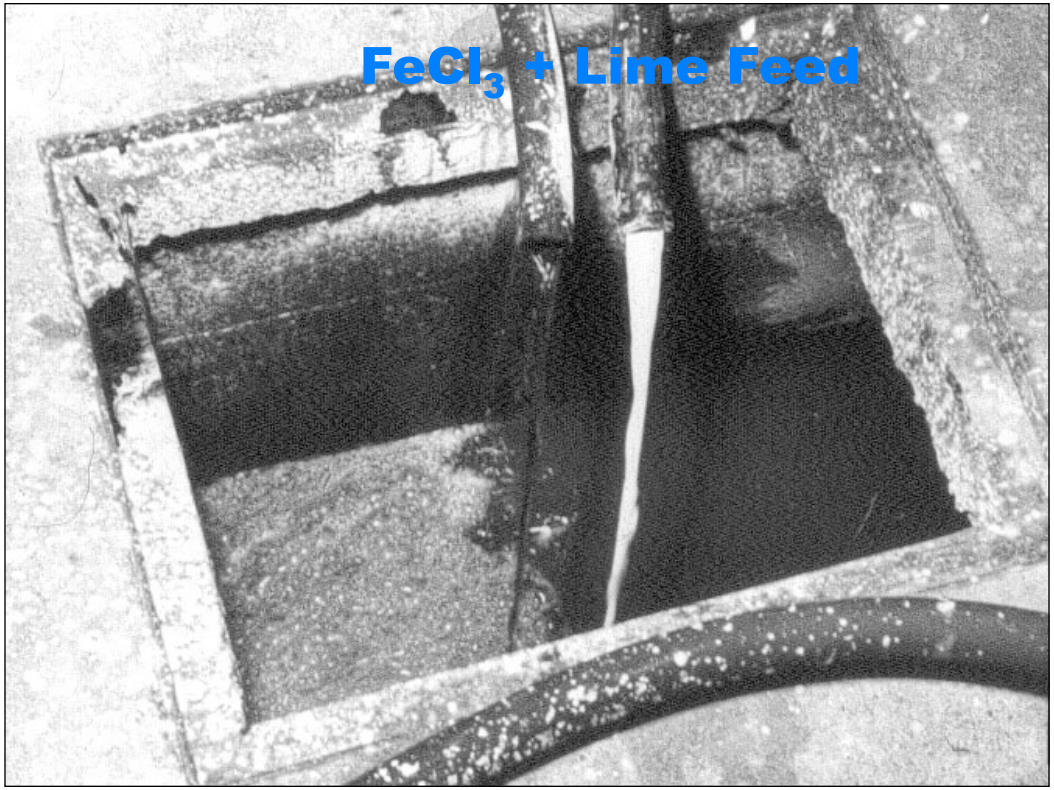

Lime + Ferric Chloride
CHEMICAL TREATMENT
Coagulants
Coagulating Basin
Settling Basin
Chlorine
Chlorine
Flash Mixer


Sludge Treatment
Fertilizer
Covered Sludge Drying Beds
2nd Stage Secondary Digester
1st Stage Primary Digester

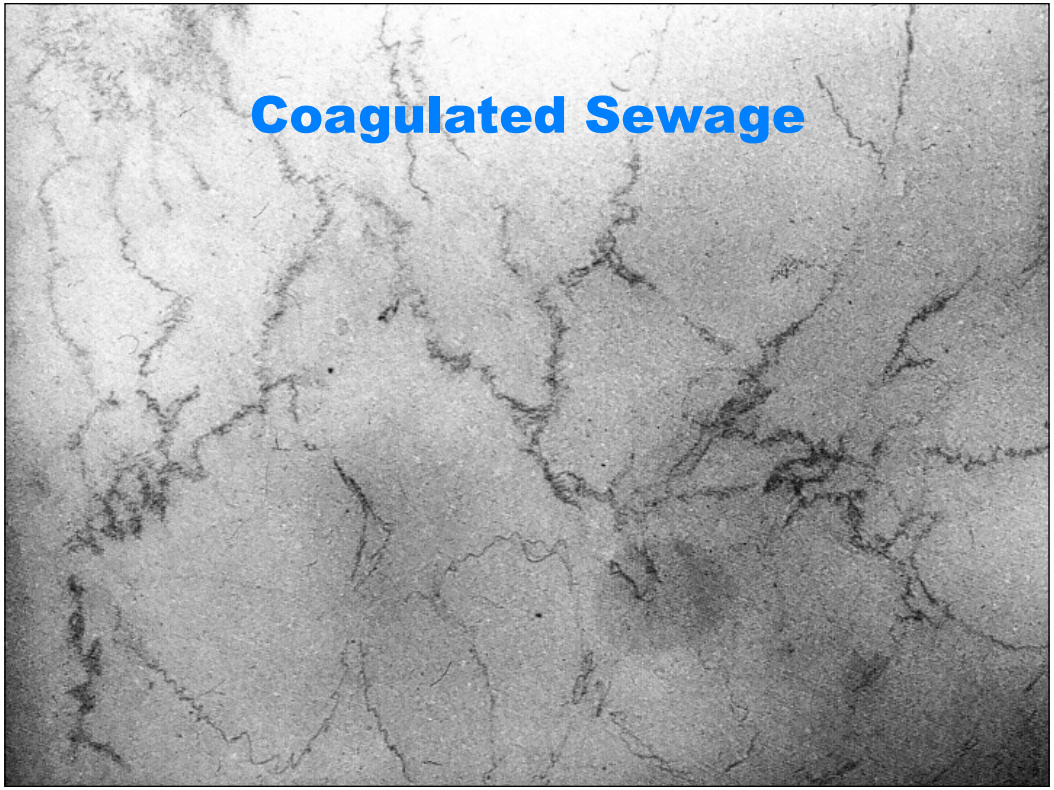

Lime Feeder

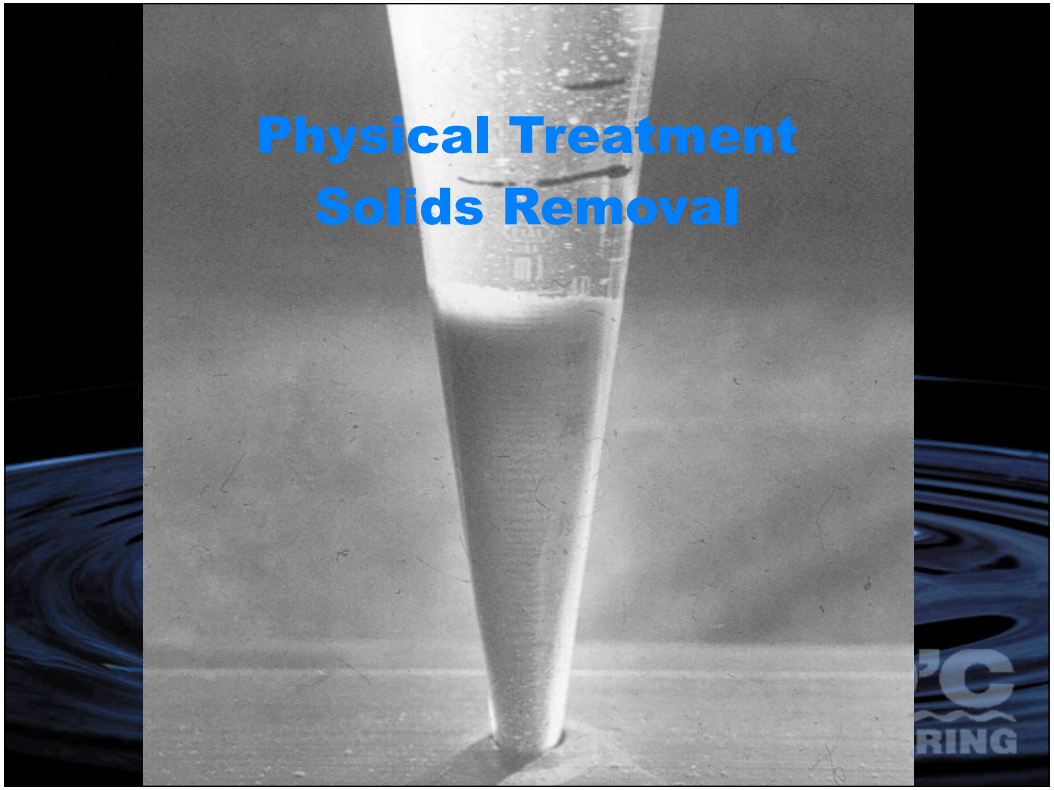

Lime Feed

Ferric Chloride


$FeCl_3$ + Lime Feed


Chemical Treatment Basin


Coagulated Sewage


Physical Treatment
Solids Removal

Biological Waste Treatment

England:

1893: Trickling Filter - *Attached Growth*

1914: Activated Sludge - *Suspended Growth*

United States:

1901: Trickling Filter - Madison, Wisconsin

1909: Imhoff Tank - *settling and digestion*

1914: Chlorination - *effluent disinfection*

1916: Activated Sludge - San Marcos, TX

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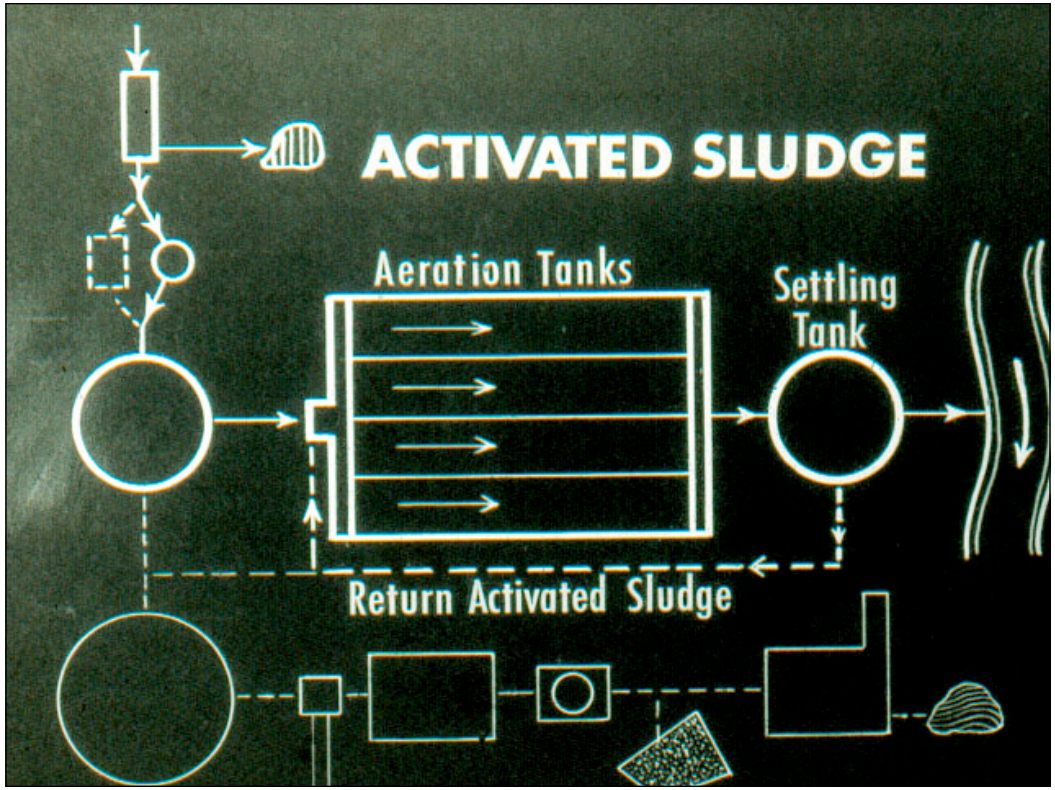
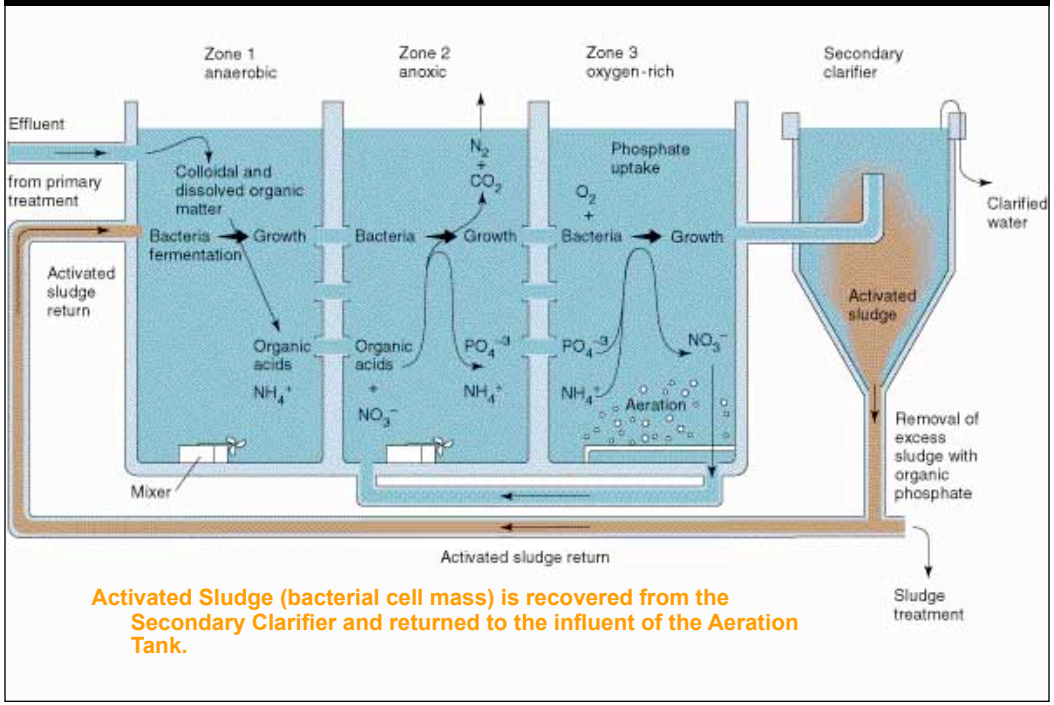
Trickling Filter
Popular with Birds - “BOD flies away”


Activated Sludge Plant

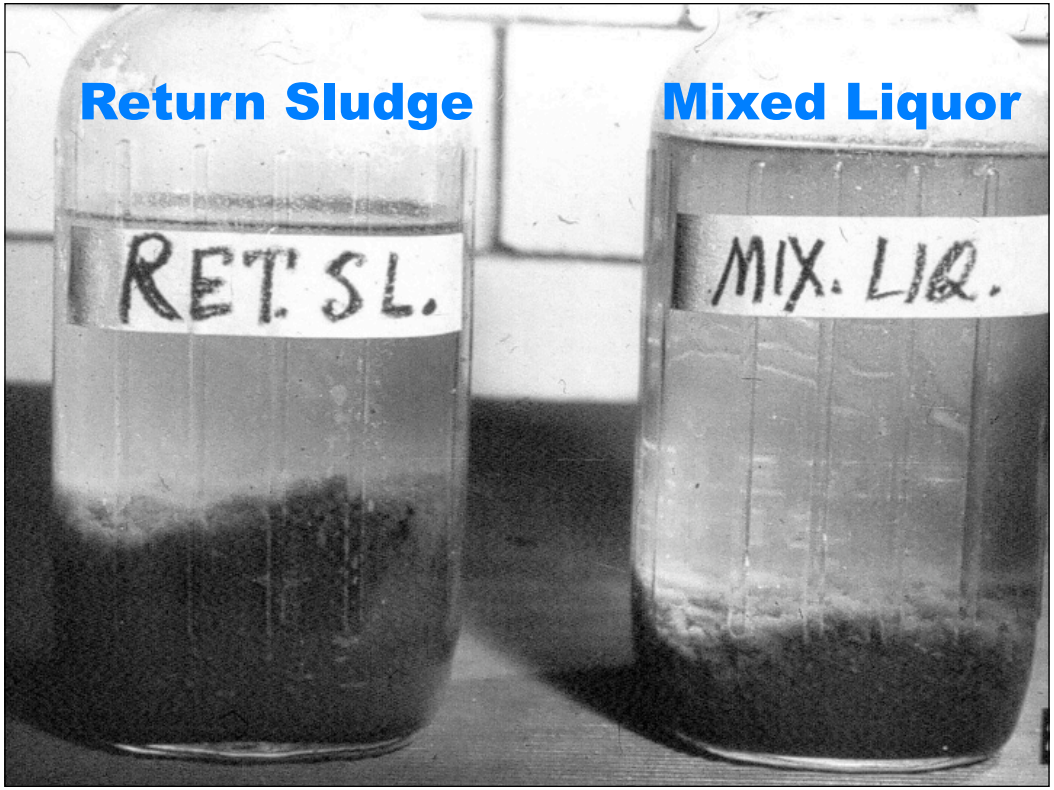

ACTIVATED SLUDGE
Aeration Tanks
Settling Tank
Return Activated Sludge

Activated Sludge Process

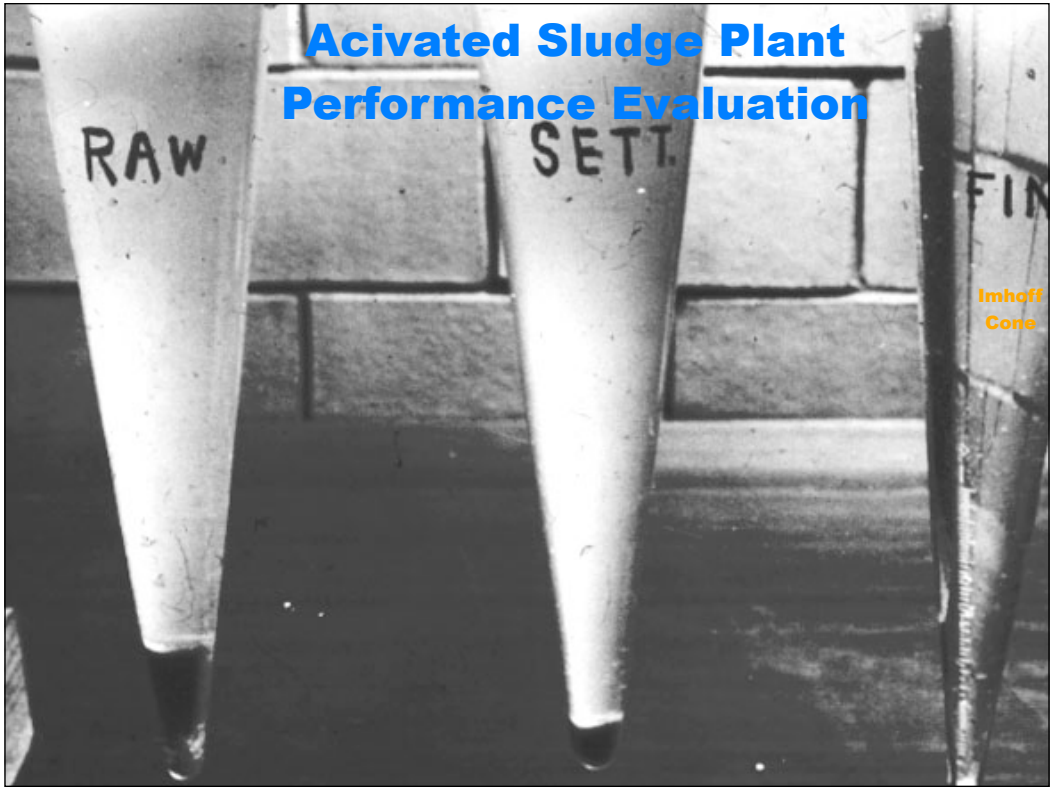


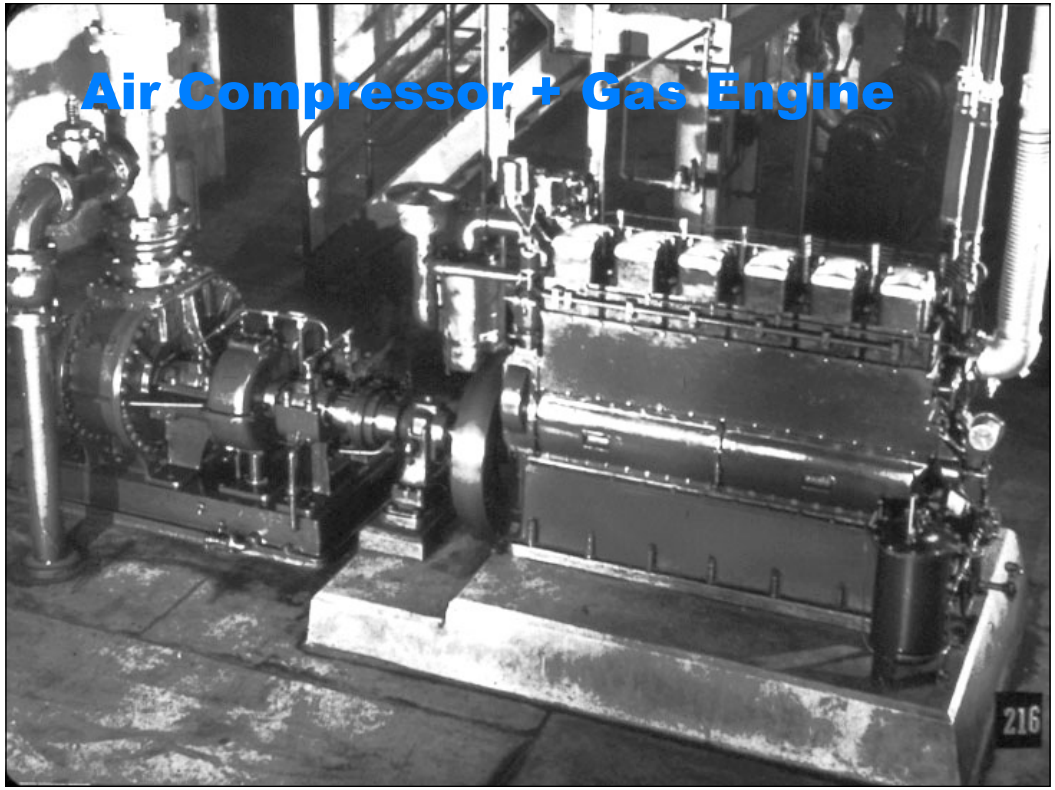
Activated Sludge (bacterial cell mass) is recovered from the Secondary Clarifier and returned to the influent of the Aeration Tank.


Aeration Tanks
208


Return Sludge
Mixed Liquor
RET. SL.
MIX. LIQ.

Acivated Sludge Plant Performance Evaluation




Air Compressor + Gas Engine
216


Covered Drying Beds

Community Water Supply - Wilder, TN. - 1942