OPERATION & MAINTENANCE
OF
WASTEWATER
TREATMENT PLANTS

WATER ARABIA – 2020

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Workshop Outline

08:30	Basic WW Treatment System Needs / Design
10:00	Break
10:30	Typical WW Treatment Systems Used in Saudi Arabia
11:30	Prayer/Lunch
13:00	Wastewater Treatment System Operations
14:30	Break
15:00	Wastewater Treatment System Troubleshooting
15:30	Workshop Conclusion & Q&A Session
16:00	Workshop Conclusion

Basic Wastewater Treatment System Needs / Design

Key Concepts Related to WW Treatment Plant:

Design & Operations

Goals for Workshop

Understand:

- Impact of Composition & Flowrate of Feed and Effluent
  - Determines Possible Unit Operations
- Typical WW Treatment Systems in Saudi Arabia
  - Identify Site Specific Issues & Design Considerations
- WW Treatment System Operations
  - Select Best Options for WW Treatment Needs & Facility Resources
- WW Treatment System Troubleshooting
  - Appropriate Monitoring – Identify Deviations from Norms

Session Topics

1^{st} Step
Goal for WW Treatment Processes =?

Typically

Contaminant Removal => Environmentally Safe Discharge

OR

Reuse of Effluent

Basic Wastewater Treatment Principals of Operation
Determine Treatment Steps

- 1st Understand WW Feed Characteristics
  - Define/Characterize WW - Composition / Flow Rate ****
- 2nd Understand How Unit Operations Work
  - What they Can & Cannot Do
- 3rd Each Step Prepares WW for Next Step
  - Select Proper Unit Operations Sequence => Final Effluent
- 3rd Understand Normal Operations
  - Monitoring & Preventative Maintenance Needs
  - Monitor Daily / Weekly / Monthly – Required for Evaluation
- 4th Troubleshooting Upsets of Unit Operations
  - What Changed to Impact Basis of Operation???

First Need to Understand What We Have

Analysis & Flowrate

NOT SO SIMPLE

Establish a Solid Base

Projects Often Miss This Step

Understanding the WW Feed – What & Why?

- ***Understand the WW Feed Composition –> Unit Op. Selection***
  - ***Entrained / Suspended Contaminants***
  - ***Dissolved Contaminants***
- ***WW Flowrates – Simplified Eq. Sizing***
  - ***Monthly Average***
  - ***Hourly Maximum***
  - ***Peak Flowrate***
- ***WW Flow & Composition Variability – Eq. Sizing & Impacts Steps Req'd***
  - ***Summer / Winter***
  - ***Batch Operations & Other Variables***
  - ***Vacuum Trucks***

WW Feed Characteristics

Entrained / Suspended Contaminants

Breakdown / Remove Complex or Harmful Solids

- ***High*** *Concentration of Pollutants => Lowest Cost Removal Options*
- *Typically Used Prior to More Expensive Treatment Options*

- *Unit Operations Providing* ***Physical Removal*** *of Solids ($)*
  - *Settling Tanks, Screens & Filters – Options Using Physical* ***Size & Density***
  - *Oil Separators, Settling Tanks, Grit Removal & Centrifuges – Options Using* ***Density*** *Differences*
    - *Chemical Addition – Enhances Settling / Flotation*
- *Unit Operations Providing* ***Biological Breakdown*** *Of Suspended Solids ($$)*
  - ***Biological Oxidation*** *– Aerobic Systems (Use Biomass & Oxygen)*
  - ***Biological Reduction*** *– Anaerobic Systems (Oxygen Poison / Typically Use Biomass & Sulfur)*
  - ***Biomass Digestion*** *with Ultimate Solid Wastes Removed / Disposed*
- *Unit Operations Using* ***Chemical Addition*** *($$$)*
  - *Chemical Addition –* ***Chemical Oxidation***
  - *Chemical Addition – Enhance Settling w/* ***Increase Density Differences***
  - *Solvent Addition –* ***Improves Movement*** */ Separation*

WW Feed Characteristics - **Dissolved** Contaminants

Breakdown / Remove **Dissolved** Chemicals

- *High Concentration of Pollutants –> Lowest Cost Removal Options*
- *Typically Used Prior to More Expensive Treatment Options*

- *Unit Operations Providing Biological Breakdown Of Dissolved Chemicals ($$)*
  - ***Biological Oxidation** – Aerobic Systems (Biomass & Oxygen)*
  - ***Biological Reduction** – Anaerobic Systems (Oxygen Poison / Biomass & Sulfur)*
  - ***Biomass Conversion & Solids Removal** – Solid Wastes Removed / Disposed*
- *Unit Operations - Chemical Breakdown Dissolved Chemicals ($$$)*
  - *Chemical Addition – **Chemical Oxidation -** Less Complex / Toxic*
  - *Chemical Addition – **Chemical Precipitates -** Allow Concentrated Solid Removal*
  - *Electrical / Radiation Addition – **Breaks Chemical Bonds =>** Less Complex / Toxic*

Understanding the WW Feed – What & Why?

- *Understand the WW Composition – Unit Op. Selection*
  - *Dissolved Contaminants*
  - *Entrained / Suspended Contaminants*
- *Required to Select Unit Operations*
- *WW Flowrates – Used for Rough Eq. Sizing*
  - *Monthly Average*
  - *Hourly Maximum*
  - *Peak Flowrate*
- *WW Flow & Composition Variability – Eq. Sizing & Impacts Steps Req'd*
  - *Summer / Winter*
  - *Batch Operations & Other Variables*
  - *Vacuum Trucks*

Equipment Sizing Criteria per WW Flowrates
Key Flowrate Requirements

- ***Monthly Average*** (**Design**) – ***Treatment Capacity***; *BOD, TSS Removal*
  - *Treat the Normal Waste Load – Basis for Operating Costs*
  - *Sum of Daily Flowrates / Mass Loadings Divided by Number of Days*
- ***Hourly Maximum*** – ***Hydraulically Size*** Pumps, Piping, etc.
  - *Pass the Max Hydraulic Flowrate – No Tanks Overflowing, Lines Backing-up*
  - *Process Evaluation / Best Estimate if no Data*
- ***Peak Flowrate 24 hr.*** – *Size* ***Emergency Storage***
  - *Handle Worst Event in X Years - Incorporates the Hrly. Max. Capacity*
  - *Historical Data / Best Estimate*
- ***Diurnal Flow & Loadings*** – *Size* ***Equalization Capacity***
  - *Flow & Load Fluctuations During the Day*

Understanding the WW Feed – What & Why?

- WW Composition – Unit Op. Selection
  - Dissolved Contaminants
  - Entrained/Suspended Contaminants
- WW Flowrates – Simplified Eq. Sizing
  - Monthly Average
  - Hourly Maximum – Peak Flowrate
- WW Flow & Composition Variability – Variables to Consider
  - Summer / Winter - Seasonal Variability
  - Batch Operations & Other Variables
  - Vacuum Trucks
  - Unknowns –Wash Downs, Equipment Cleaning, Water Lines Draining, ???

WW Flow & Composition Variability

- Flow & Composition Variations Impacting Treatment Needs:
  - Summer / Winter – Differences in Cooling
    - Temperature Criteria – Unit Operation Selection / Cooling Requirements
    - Algae Growth – TSS / Plugging
  - Process Operations – Batch Processes Running or Down
    - Different Flowrates - Sizing
    - Different Composition – Unit Operation Selection
    - Rarely Reported as a Flow Variable
  - Irregular Discharges – Vacuum Trucks
    - Different Flowrates & Composition – Sizing / Unit Operation Selection
    - Potentially Toxic – Unit Operation Selection
    - Potentially Different Unit Operations Required
    - Rarely Reported as an Increased Flow

Understanding the WW Feed – What & Why?

- ***WW Composition* – *Unit Op. Selection***
  - ***Dissolved Contaminants***
  - ***Entrained/Suspended Contaminants***
- ***WW Flowrates* – *Simplified Eq. Sizing***
  - ***Monthly Average***
  - ***Hourly Maximum – Peak Flowrate***
- ***WW Flow & Composition Variability* – *Eq. Sizing & Impacts Steps Req'd***
  - ***Summer / Winter***
  - ***Batch Operations & Other Variables***
  - ***Vacuum Trucks***

----- Review -----

Influent Characteristics Driving the Design

- Identify Key Contaminants that Determine Unit Operation Needs
  - Floating Oils / Solids
  - Solids Settling
  - Suspended Solids / Oil Emulsions
  - Dissolved Organics
  - Dissolved Inorganics
- Identify Flowrates that Determine Sizes
  - Monthly Average (Design)
  - Hourly Max. Flowrate
  - Peak Flowrate
  - Diurnal Changes

First Need to Understand What We Have

Analysis & Flowrate

NOT SO SIMPLE

Establish a Solid Base

Background Info –> Seat-of-Pants Evaluations

Interactive Discussion on Sampling & Flowrate

***Sampling, Analysis and Flow* Measurement**

Discussion

Both Industrial & Sanitary

GOAL: Gain an understanding of the activities needed & the amount of effort required to obtain USEABLE composition & flowrate data

Very Important

Requires Some Knowledge of Testing

***Most Overlooked* Part of Design**

--- Group Discussion ---
Determining WW Composition - Refinery WW

Refinery Management wants to know how well the existing Refinery WW Treatment Plant is operating so that they can determine whether they need to request any design changes to an Existing WWTP.

To provide the Manager with an answer:

1) Where would you sample and what parameters would you sample for at those locations?

2) Are there any simple changes that can be made to get better information?

Determining WW Composition – Refinery WW

Where would you Sample?

- ***Refinery Inlet line 24” Partially-Full Gravity Flow Line***
  - ***Sample Pt. A - Bottom of the 24” line***
  - ***Sample Pt. B - Top of the 24” Line***
  - ***Sample Pt. C - A Grab Sample of the WW Falling, open air, into the API Inlet Chamber***
- ***API Separator***
  - ***Sample Pt. D - A Dipped Sample from below the Surface***
  - ***Sample Pt. E - A Dipped Sample from the Surface***
  - ***Sample Pt. F - The 12” Suction Line to the Effluent Transfer Pump***
  - ***Sample Pt. G - The 8” Discharge Line on the Effluent Transfer Pump***
- ***Walnut Shell Filter***
  - ***Sample Pt. H – The Sample on the 8” inlet line to the WSF***
  - ***Sample Pt. I – The Sample Pt. on the effluent line from the WSF***
- ***An Equalization Tank 12 – 24 hour capacity (depending on number of units operating)***
  - ***Sample Pt. J – The Sample Pt on the Inlet Line to the Tank***
  - ***Sample Pt. K – A Grab Sample from Below the Surface of the EQ Tank***
  - ***Sample Pt. L – The Sample Pt. on the Effluent Line from the Effluent Transfer Pump***
- ***A biological WW Treatment Plant w/Gravity Flow Between Aeration and Clarifier Tanks***
  - ***Sample Pt. M – Sample Pt. on the overflow line between the Aeration & Clarifier Tanks***
  - ***Sample Pt. N – Sample Pt. on the discharge of the Effluent Lift Station Pumps going to the Evaporation Ponds***

WHAT TYPE OF SAMPLE…

Would you Request a Grab, a 24 hr. Composite Sample or do a field analysis / reading?

Typical Analyses for Each Refinery Sample

What Type of Analyses Would You Request?

Well Mixed **

- Total Oil & Grease
- Free Oil
- TSS & TDS
- MLSS
- COD
- BOD_5
- Total Metals

** Composite Sample - Mixed

Field Analysis **

- Dissolved Oxygen
- Temperature
- pH
- Total Residual Chlorine

** Multiple Sample – Ave.

Determining WW Composition – Sanitary WW

Utilities Management wants to know how well the existing Sanitary WW Treatment Plant is operating so that they can determine what equipment changes are needed in an upcoming Capital Project to increase the capacity and add denitrification capability.

To provide the Management with recommendations:

1) ***Where would you sample and what parameters would you sample for at the following Equipment & Sampling Locations associated with a traditional STP?***

2) ***Are there any simple changes that can be made to the sampling options to get better information?***

Determining WW Composition – Sanitary WW

- A 48” Partially-Full Gravity Flow Line passing through a Manual Bar Screen & Parshall Flume
  - Sample Pt. A; A Grab Sample upstream of the Bar Screen
  - Sample Pt. B; A Grab Sample from Discharge of the Flume
- Distribution Box
  - Sample Pt. C; A Grab Sample of the WW in the Inlet Chamber
  - Sample Pt. D; A Grab Sample Dipped from below the Surface of the Inlet Chamber
  - Sample Pts. E – H; A Grab Sample of the WW in the Effluent Chambers of one of the 4 Discharges
  - Sample Pt. Comp. # 1; A 24-Hr. Composite Sampler drawing Suction from the Inlet Chamber (sub-surface suction line)
- Aeration Tanks (4)
  - Sample Pts. I – L; A Grab Sample Dipped from Below the Surface of the Mixed Liquor in each of the Aeration Tanks
  - Sample Pts. M – P; A Grab Sample Taken from the Sample Pt. on the Aeration Tank Overflow Line going to its Respective Clarifier
- Clarifier / Settling Tanks (4)
  - Sample Pts. Q – T; A Grab Sample (Dipped from below the Surface of the Respective Clarifier)
  - Sample Pts. U – X; A Grab Sample from the Sample Pt. on the Overflow Line from each of the Clarifiers
- Effluent Collection Sump
  - Sample Pt. AA; A Grab Sample from the discharge of the Effluent Sump Transfer Pump
  - Sample Pt. Comp. #2; A 24-Hr. Composite Sampler drawing Suction from the Effluent Collection Sump (sub-surface suction)
  - Sample Pt. BB; A Sample Pt. on the Discharge Line on the Effluent Transfer Pump
- Chlorine Contact Tank
  - Sample Pt. CC; The Sample Pt. on the Discharge of the Effluent Transfer Pumps going to the Irrigation Storage Tanks

Typical Analyses for Each Sanitary WW Sample

- ***Total Oil & Grease***
- ***Free Oil***
- ***TSS & TDS***
- ***MLSS***
- ***COD***
- ***BOD_5***
- ***Total Metals***
- ***Dissolved Oxygen***
- ***Temperature***
- ***pH***
- ***Total Residual Chlorine***

Sampling Locations – Possible Sources of "Errors"

- *Tanks – single / two-phase liquid / Solid Suspension*
  - *Surface - dipped sample*
  - *Subsurface – sample container*
  - *Tank Complete Mix or a [variable] - Rxn based on time and concentration swings?*
  - *pH impact on suspensions*
- *Pump suction / discharge*
  - *Well mixed – is that what the process needs to be treat?*
- *Pipe*
  - *High enough flowrate to prevent settling?*
  - *Horizontal Pipe – Top; air bubble? / Bottom; solids collecting?*
  - *Flowrate in center vs. gradients along inside of the pipe; which closer to the average?*
- *Batch / Continuous process – Which is More Representative?*
  - *Continuous - Flow never constant; pumps starting & stopping to control flow or level*
  - *Composition changing based on controllers seeking set points – Use 24 hr. Composite Samplers*
  - *Are all processes operating at the same capacity?*
  - *Are the Lift Stations sized for only process flows or also storm & fire water flows?*

WHAT IS THE LEVEL OF ACCURACY FOR EACH ANALYTICAL METHOD??? BEST CASE…..

WERE SAMPLES TAKEN EXACTLY THE SAME FOR ALL DATA POINTS? AMOUNT OF FLUSHING???

Determining WW Flowrate

The WW Treatment Plant has several installed mag flow meters (recently purchased and installed). You have been given flowrate information on each location. Should you have any concerns with the data reported? If so, what would you do differently? What Questions need to be answered?

Sample Location =???

- *A Large 24" Normally-Full Gravity Flow Line*
  - *A horizontal section of pipe*
  - *A vertical section of this pipe with upward flow*
  - *A vertical Section of pipe with downward flow*
- *A Transfer Pump*
  - *The Suction line to the pump – ½ meter from the Pump*
  - *The Suction Line to a pump several meters of straight pipe to the pump*
  - *The Discharge Line from a pump – ½ meters from the Pump*
  - *The Discharge Line from a pump – several meters from the Pump but just after a partially open Gate Valve*

First Need to Understand What we Have

Analysis & Flowrate

NOT SO SIMPLE

Establish a Solid Base

Determining WW Composition & Flowrate

Want Representative Samples

SOME POINTS TO THINK ABOUT…. WHENEVER SAMPLING

- Proper location for Sampling or Flowrate Measurement – What do you Need to Determine?
  - Is the WW two-phase @ the location?
  - Will Meter Location impact results?
  - Will Meter Type impact results?
- Representative Data for Measurements
  - Field reading of flowrate or average 24 hr.?
  - Grab or Composite Sample?
  - Right time to take sample or flow measurement?
  - How much data is needed to be representative?
- Gov. mandated Analytical Methods or Laboratory
  - PME Requirements – How you are Judged
  - Laboratory Methods – Quick & Inexpensive
- Appropriate sample preparation/storage
  - Will the Temperature change the Composition?
  - Will Wait Time before Analysis change the Composition?
  - Is Sample Degradation taking place?

Typical Analytical Decisions

- *Sample – original sample single/two-phase – the same after settling?*
  - *Does the Lab skim & analyze the top or bottom layer? EXAMPLE - Oily WW samples*
  - *Sample hold times EXAMPLE – VOC's, BOD/COD*
  - *Does the sample change over time? How long to analysis? EXAMPLE– TSS & ALGAE*
- *Analyze an extract?*
  - *If so, how is it related to the concentration in the aqueous phase? EXAMPLE - TCLP*
  - *What information do you need for the design? Does the sample analysis give you what you need for design or operation?   EXAMPLE - TCLP*
- *Analytical method*
  - *Simple/quick method – labs want to use simple methods Gov. Reporting wants complex methods that can be reproduced   EXAMPLE – COD, TOC*
  - *Method used for Gov. reporting – best way to control for compliance*
  - *Accuracy of method*

UNDERSTAND WHAT THE ANALYTICAL RESULTS ARE REPORTING – TCLP – OTHER EXTRACTIONS

DOES the RESULT MAKE SENSE ???

Typical Flow Measuring Decisions

Location of flow meters:

- *Pump suction / discharge*
- *Pipe*
  - *Vertical / Horizontal*
  - *Top / Bottom*
  - *Distance from pumps, valves & fittings*

When to measure:

- *Batch / Continuous process*
- *Summer / Winter*

Type of flow meters:

- *Flow displacement*
- *Mag meter*
- *Ultrasonic*
- *Other*

Accuracy = ???

WW Flowrate & Composition Variability

- *Intermittent flowrate & composition changes*
  - *Summer / Winter Operations*
    - *Impacts of Cooling Water – Exchanger Flushing Summer*
  - *Changes in raw materials or Upstream flows*
  - *Process design changes*
  - *Processes running / not running*
  - *Tanks being drained*
    - *Flowrate & composition*
    - *Equalization rarely meets the needs – Very Rarely*
  - *Pumps running / not*
    - *Lift Stations – Cumulative Impact*
    - *Cooling*
    - *Chemicals being added to adjust composition, pH, solids separation*

BEST ESTIMATES

DESIGN FLOWRATES & COMPOSITIONS ARE ***ESTIMATES - NOT EXACT #'s***

The current situation is ***ALWAYS DIFFERENT*** *from the design*

Understanding these issues can help with meeting effluent specifications

Variability - Impact on Design & Operations

- Which variables are most important
  - Design for LT Ave flow & not handle the peak flowrate? Cheaper but…..
  - Design for high or low concentrations of key pollutants?
    - What will happen downstream if some of it passes through?
  - Is there enough Equalization to smooth the variability?
- Understand the Designer's Motivations & the Operations needs
  - Typically different
  - Can often explain why the process isn't achieving the effluent specifications
    - Both groups blame the other for any problems
- When reviewing a proposed design….
  - It is Very important to assure that Operations gets what the process needs to meet specifications with all possible feed & operating conditions

BREAK

RETURN
BY
10:30

Typical Wastewater Treatment Systems Used in Saudi Arabia

Session B

Understanding Principles of Unit Operations
&
Motive Forces that Drive Them

A "Big Picture" View of WW Equipment Design

Key Points

- ***Having an Understanding of the Following Principles Will Allow you:***
  - ***To Determine the Best Technology for a Specific Need***
  - ***To Determine the Causes of Operational Upsets***

Wastewater Treatment - Principals of Operation
What Provides the Driving Forces??

Driving Forces Available for WW Unit Operations

- Separation – Stokes Law
  - Gravity – Inexpensive & Plentiful
    - Most Common Driving Force in WWTP's
  - Filtration – Requires Pressure Drop
- Oxidation
  - Chemical / Electrical
  - Biological
- Flow Control
  - Gravity Flow
  - Siphon Systems
  - Level Controls

Stokes Law – Gravity Settling

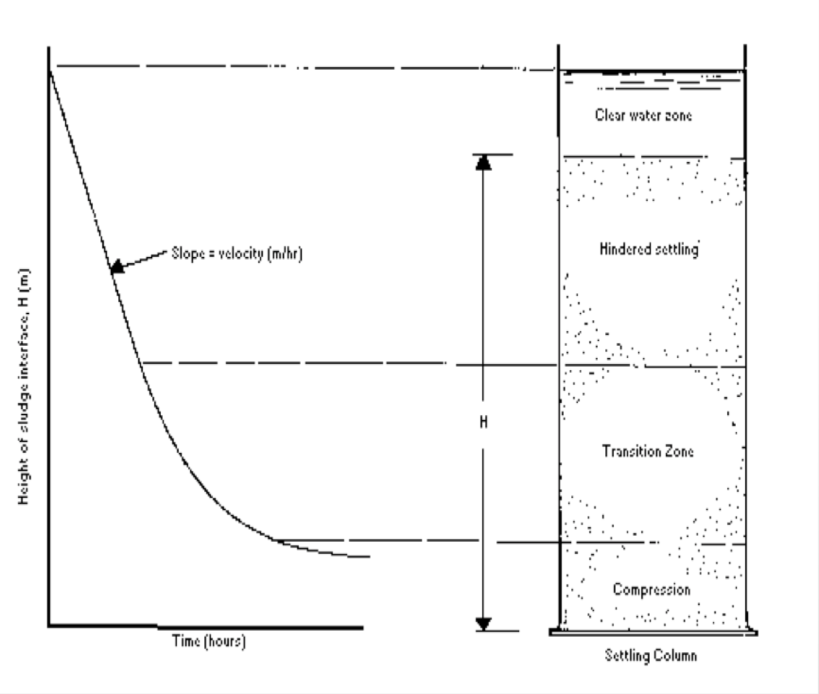
$$F_g = (\rho_p - \rho_f)\, g \,\frac{4}{3}\pi R^3,$$

F_g = Motive Force -> Settling Velocity

R = Radius of Particle

g = Gravity

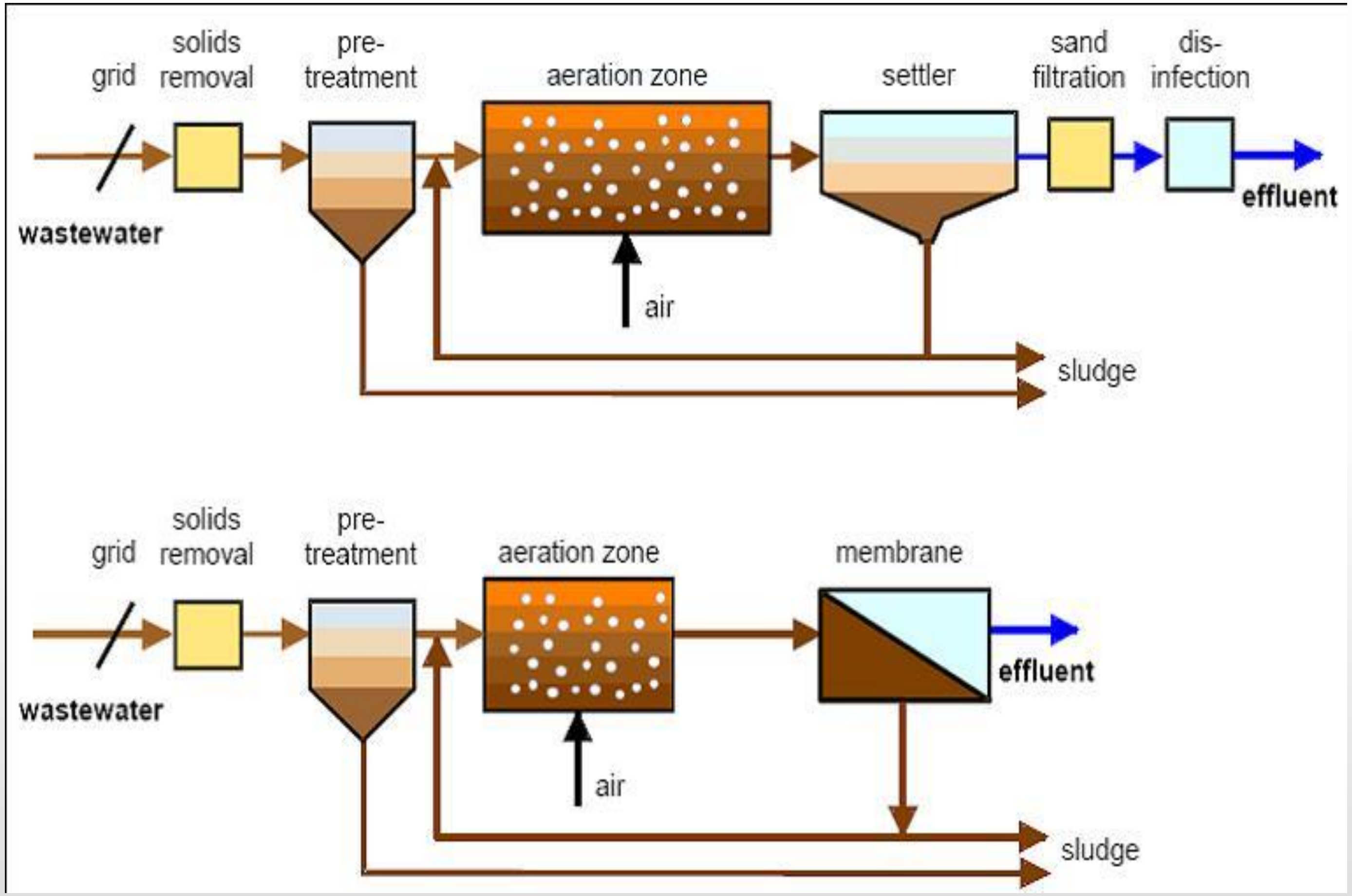
$(p_p - p_f)$ = Density Difference



Basis of Most WW Technology

Physical / Settling Unit Operations

- Settling Unit Operations
  - Solids Removal
  - Pre-Treatment
  - Settler / Clarifier
  - Grit Removal
- Filter Unit Operations
  - Bar Screen
  - Sand Filtration



Examples of Stokes Law – Using Oil

While the Following Examples Deal with Oil, the Same Principles Apply to Solid Particles

Gravity Oil / Water Separation

Density Differences ***Provide Motive Force – Liquid/Liquid Separation***

Very Simple Example – Most everyone has seen something like this:

Mix Oil & Water Stir

- ***Oil Mixes With the Water***
- ***Mixture then Settles into two Separate Layers***

Principle:

- ***Oil droplets < Dense than water***
  - ***Stokes Law***
    - ***Oil droplets rise @ Rate Proportional to their difference in density***

Separation by Density
Gas / Liquid - or - Solid / Liquid

Air Bubbles
Less Dense than Water – Floats

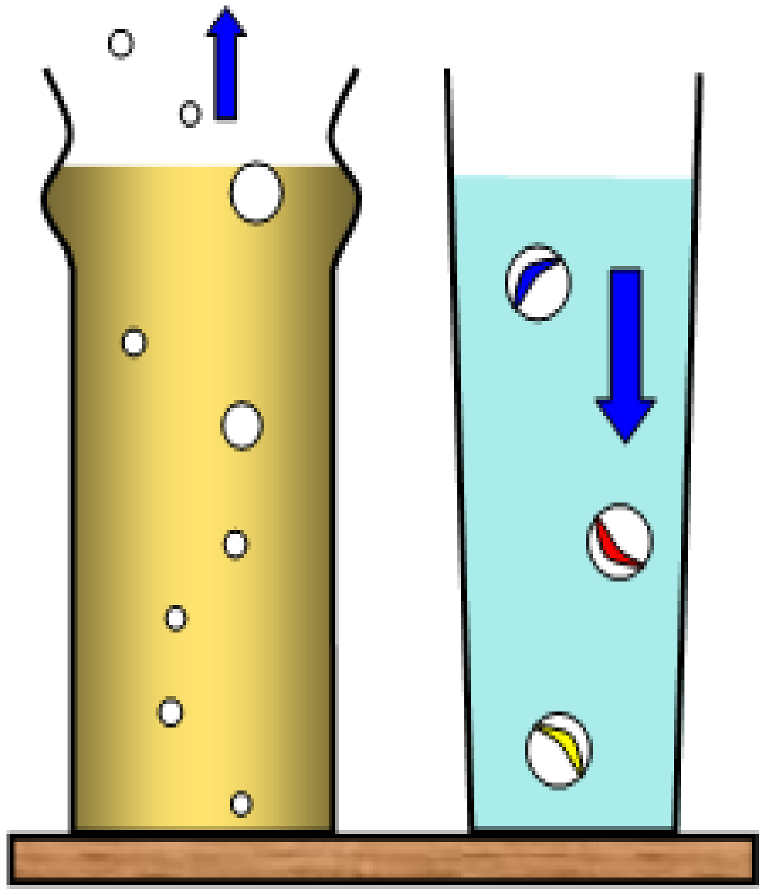


Figure 1

Solids
More Dense than Water - Sinks

Oil / Water Separation – Impacting Agents to Avoid

Physical Separation: *Oil Droplet Size (R^3 from Stokes Law Smaller) - Emulsifiers*

- ***Emulsifier*** *(Caustic or Other Emulsifier)* **Introduced into WW Mixture**
  - *Emulsifiers Reduce Diameter of* Oil Droplets
  - *Reduction in Motive Force Available for Separation => R^3 - Reduced*
  - *R^3 – The Relationship is a Cubed Function – Not Linear*
  - *Requires More Time for Same Separation*

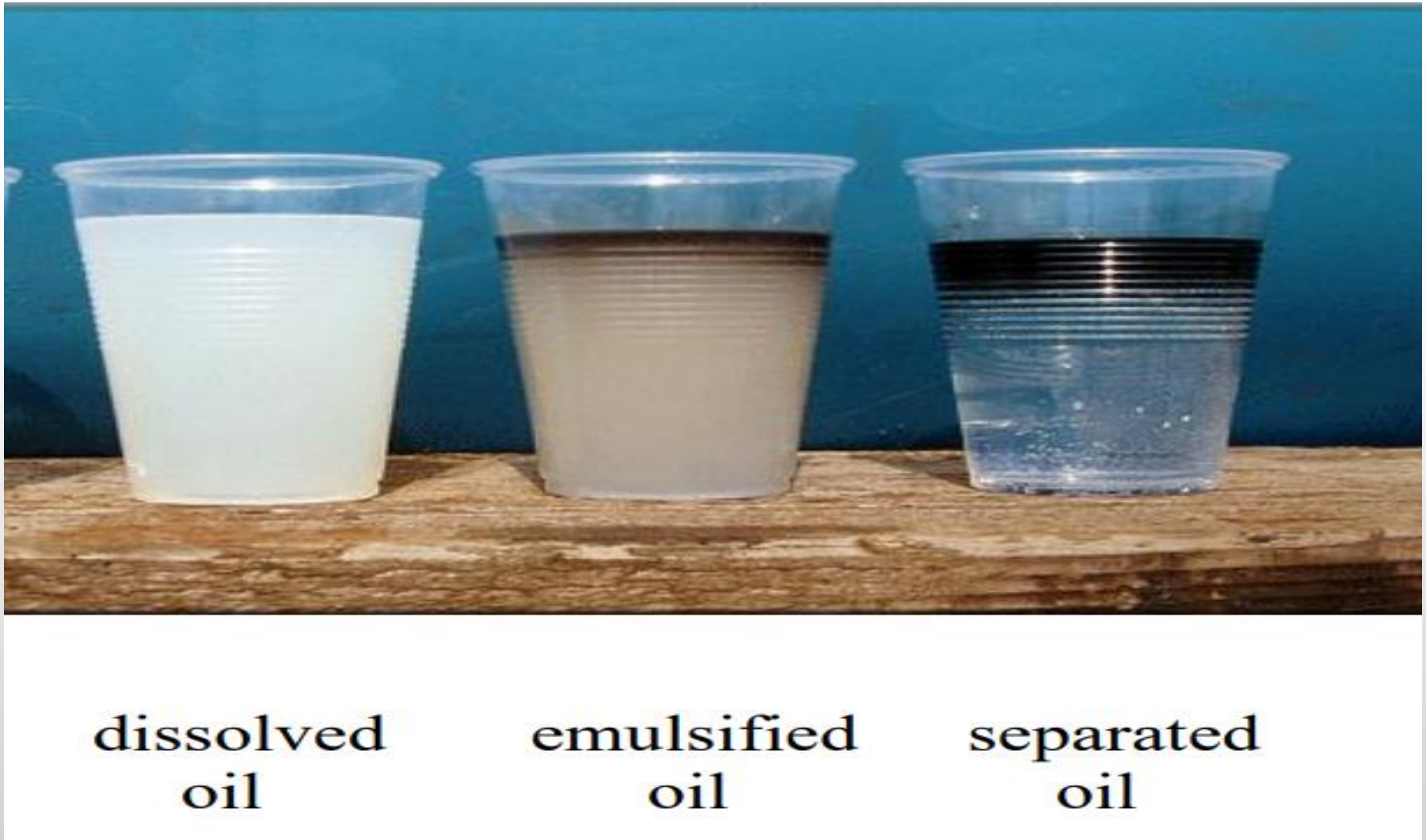
Principle:

- *Emulsifiers Increase the Concentration of Small Oil Droplets*
- *Per Stokes Law:*
  - *Motive Force (F_g) is Proportionately Less (per the smaller R^3)*
  - *Oil droplets rise Slower - Proportional to the Cube of difference in Radius & F_g*

Solution: *To increase/Speed Separation*

- *Eliminate Emulsion forming Chemical(s)*
- *Increase Separation Time*
- *Increase Density Difference*
- *Increase Driving Force (Centrifuges, Hydro cyclones, etc.)*

Emulsion – Stages of Separation



Oil / Water Separation – Impacting Agents to Avoid

Physical Separation: *WW & Waste Densities Similar (F_g Small) Densities: Waste & WW*

- ***WW Medium Changes (Decreased Density Difference)***
  - ***Reduction in Motive Force Available for Separation => Delta Rho (Density)***
  - ***Density Difference is a Linear Function – Less Impacting than Droplet Size***
  - ***Less Density Difference = More Time Needed for Same Separation***

Principle:

- ***Decreased Density Difference (F_g from Stokes Law is Reduced)***
- ***Per Stokes Law:***
  - ***Motive Force (F_g) is Proportionately Less (per the smaller Density Difference)***
  - ***Oil droplets rise Slower - Proportional to the Reduced F_g***

Solution: To increase/Speed Separation

- ***Eliminate Emulsion forming Chemical(s)***
- ***Add a Solvent to Increase Density Difference***
- ***Increase Separation Time***
- ***Increase Density Difference***
- ***Increase Driving Force (Centrifuges, Hydro cyclones, etc.)***

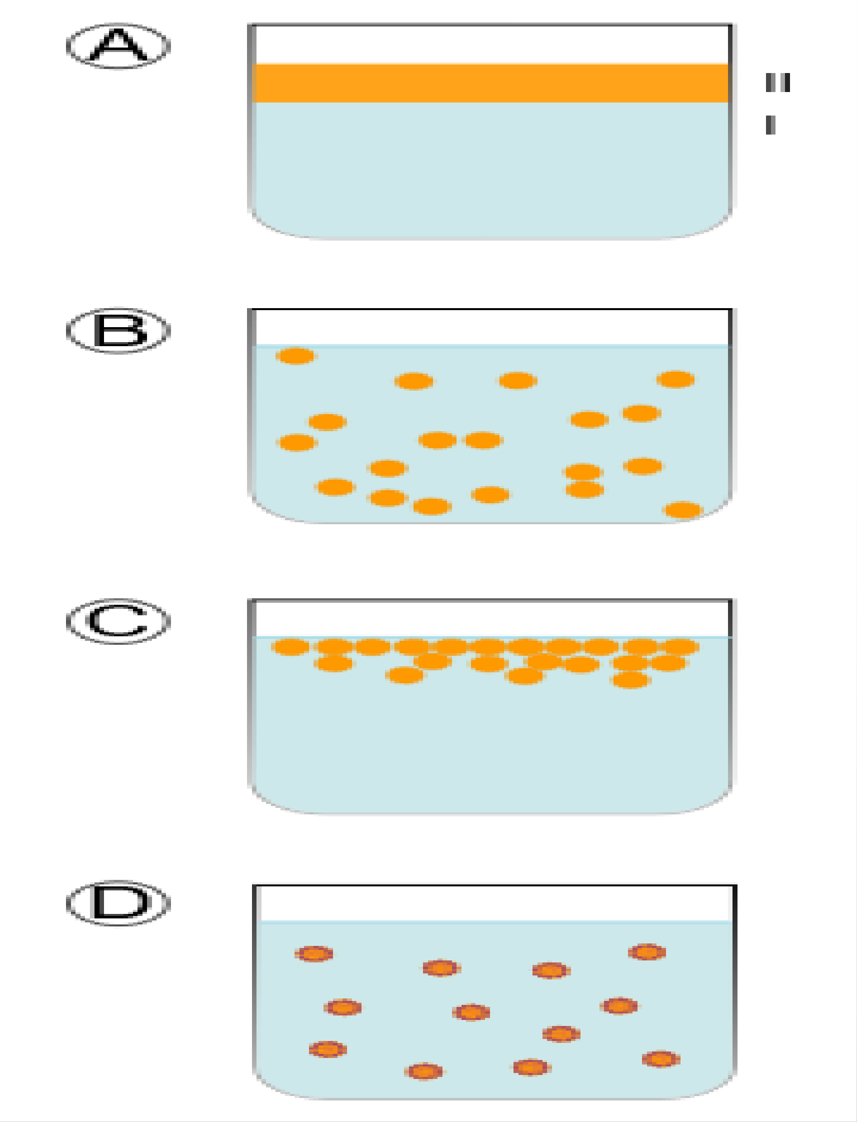
Gravity Oil & Water Separation - Technology

Oil Layer Separated & Floating at the Surface – A

Oil Droplets Start to Separate – B

Oil Droplets Collect at Surface – C

Oil & Water Combined & Well Mixed – D



Oil / Water Separation – Impacting Agents to Avoid

Physical Separation: *Oil Droplet Size (R^3 from Stokes Law Smaller) - Agitation*

- *Increased Agitation* *(Pumps & Piping)* **Applied to WW Mixture**
  - **Mixing/High Shear Reduces Oil Droplet Diameter & Consequently R^3**
  - **Reduction in R^3 Reduces the Motive Force => Less Separation**
  - *R^3 – The Relationship is a Cubed Function – Not Linear*
  - *Requires More Time for Same Separation*

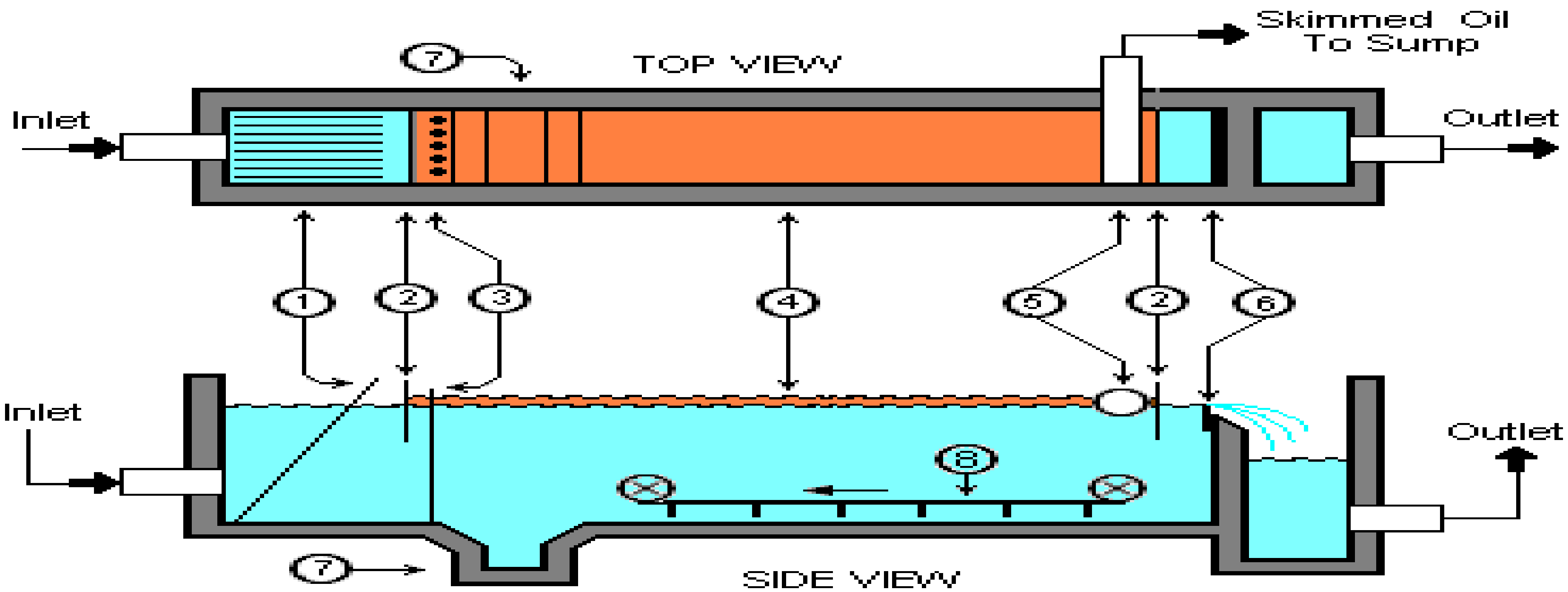
Principle:

- *Agitation Increases the Concentration of Small Oil Droplets*
- *Per Stokes Law:*
  - *Motive Force (F_g) is Proportionately Less (as the Difference in Density gets smaller)*
  - *Oil droplets rise Slower - Proportional to the difference in Density*

Solution: *To increase/speed Separation*

- *Decrease Agitation – Pumps & Piping*
- *Decrease Emulsifier Concentrations (If Present)*
- *Increase Separation Time*
- *Increase Surface Area used for Coalescing of Oil (if Applicable)*
- *Increase Driving Force (Centrifuge)*

Basic API Separator - Application



1 Trash trap (inclined rods)
2 Oil retention baffles
3 Flow distributors (vertical rods)
4 Oil layer
5 Slotted pipe skimmer
6 Adjustable overflow weir
7 Sludge sump
8 Chain and flight scraper

Application of Stokes Law
Gravity Solids / Water Separation
30 Minute Settleability Tests

Density Differences => Motive Force – Solids & Liquid Separation

Mixed Liquor (Bio-Mass) -> Graduated Cylinders

- Settle for 30 Minutes

Principle:

- Bio-mass More Dense than Water (Cells Contain Salt Water)
  - Stokes Law
    - Solids Settle @ Rate Proportional to Their Difference in Density
- Low TDS Water – Greater Density Difference = Better Separation
  - Two Separate Layers
- **Predicts Operation of a Clarifier / Settling Tank**

Mixed Liquor

Example of Bio-Mass From Aeration Tank =>

---------------------------------- Start of Test ----------------------------------

High TDS Low TDS Close-up High Close-up Low

Start of Test

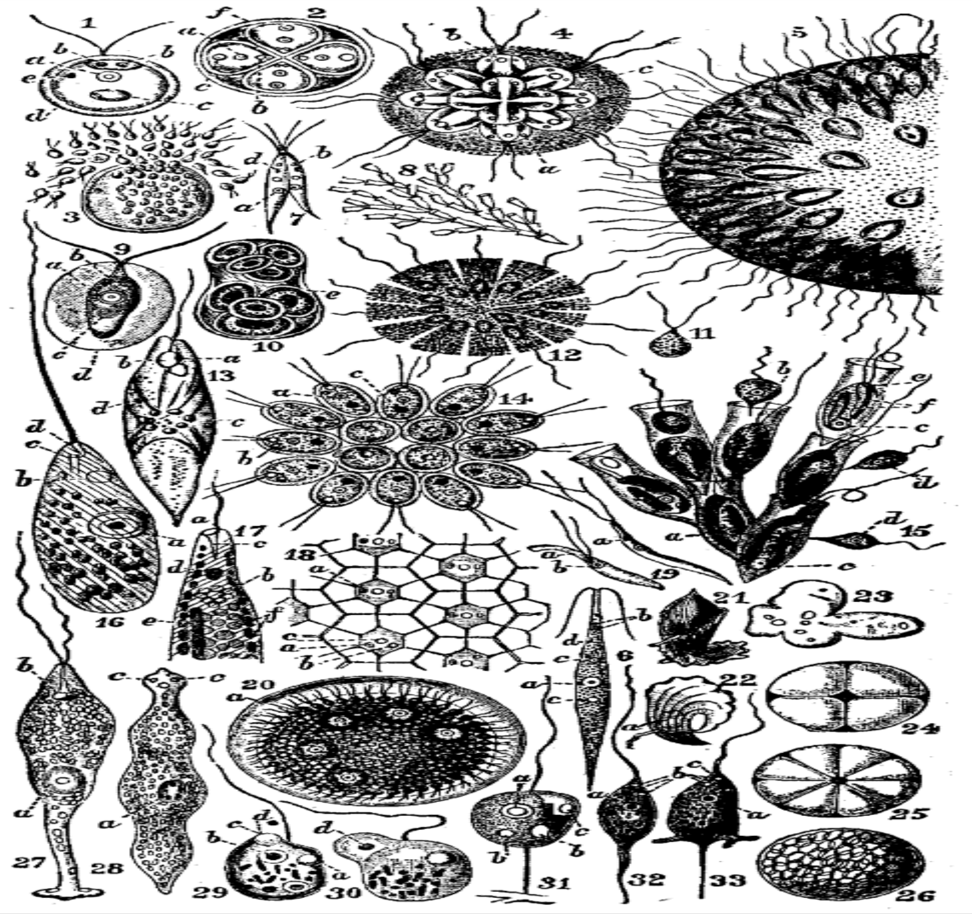
After 30 Minutes

Left High TDS | Right Low TDS | Left High TDS | Right Low TDS

Bio-Mass & Stokes Law

Bio-Mass

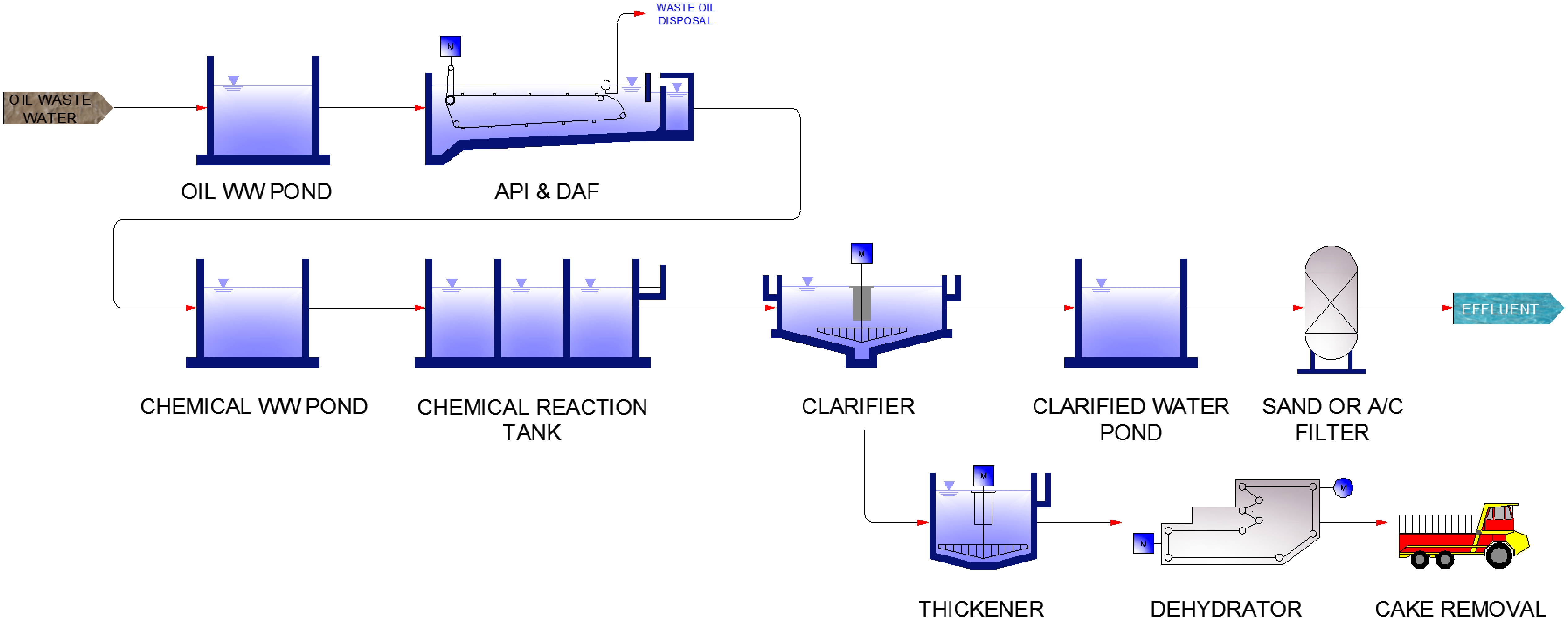
- Living Organisms
- Originated in Early Seas
  - Inside of Cells Contain Salt Water
  - Density > Fresh Water
    - So, Bio-Mass More Dense => Settles
- Upsets
  - Sick / Dying Cells => Rupture & Fluids Leak
    - Extra Cellular Polymeric Materials
  - Population of Bio-Mass Changes
    - Long Chains / Clumps of Bio-Mass



WWTP's Operate Using Gravity as Motive Force (Predominantly)

Some Common Examples of WWTP Equipment….

Examples of Solids Settling Equipment
Most Common WW Technology



Common Clarifier / Settling Tank Design

- *Same Principle as 30 Minute Settleability*
  - *Aeration Tank MLSS Enters Center*
  - *Water Density Less –> Floats*
    - *Overflows Tiger Teeth -> Effluent Trough*
  - *Density of Bio-Mass Higher - Settles*
    - *Rakes Drag Sludge to Collection Sump*
  - *Upsets*
    - *Bio-Mass Doesn't Separate & Settle – WHY?*
      - *TDS Change? High pH, Emulsifier Present?*
      - *Bio-Mass Changes???*
      - *Significant Increase in Flowrate?*
      - *[MLVSS] Too High?*
      - *Sludge Age?*
    - *Bio-Mass Floats & High TSS in Discharge*

When Would a Gravity Based Treatment Step be Used?

Trick Question

- ***Almost All WWTP Equipment is fully or partially Dependent on Gravity***
  - ***Either Flow between Tanks***
  - ***Or as the Motive Force to Drive the Desired Unit Operations***

Solids Filtration

Physical Separation – Solid Particles Diameter Larger than Filter Openings

Used to Simulate how WW Changes will Impact Field Equipment

Typical Laboratory Test: WW With Solids -> Filter Paper over a Beaker

- *Weigh Clean Filter Paper*
- *Waste Water Passes through Filter Paper*
- *Solids Larger than Pores are Stopped by Filter Paper*
- *Filter Paper Dried & Weighed*

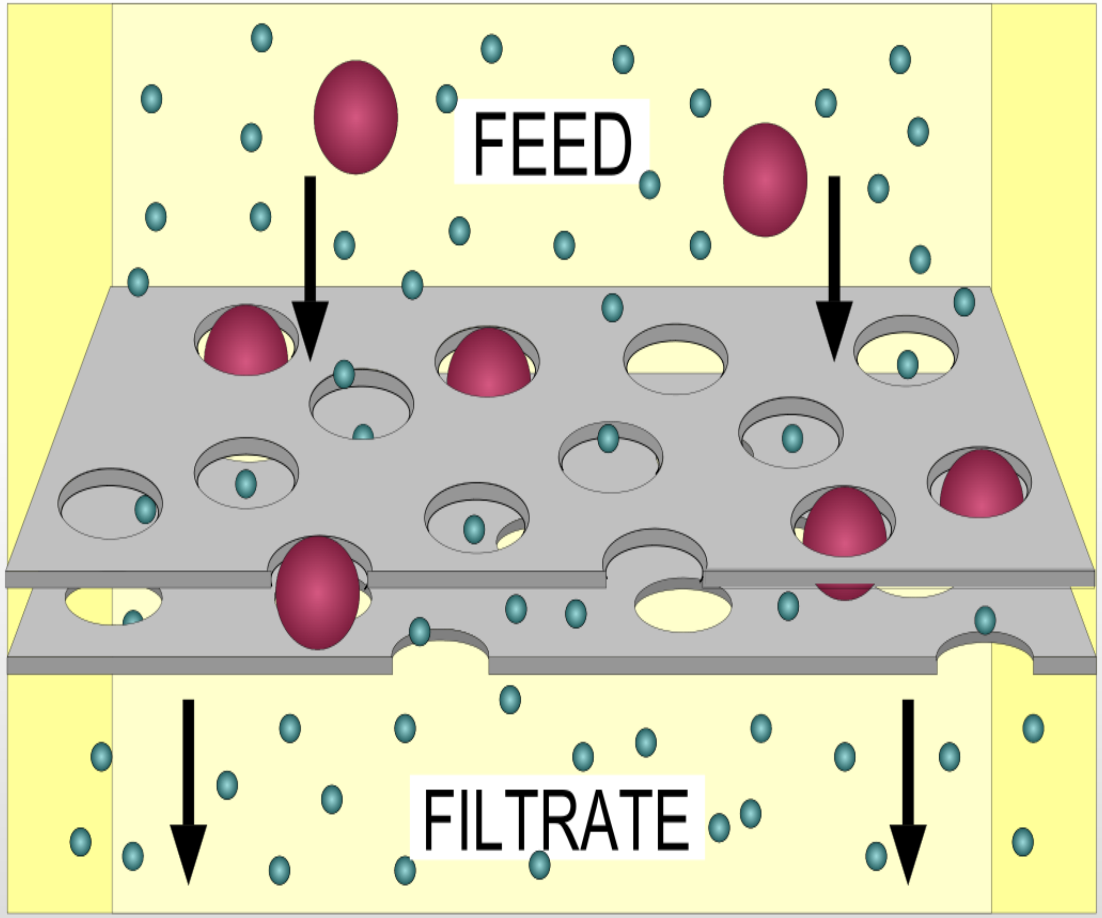
Principle:

- *Paper Stops Particles With Diameter > Pore Size*
- *Increased Weight of Filter Paper provides a Solids Concentration for WW Tested*

Physical Separation – Filtration

Filtration

- Principles Involved – Physical Separation
  - Pressure Drop Across Media
  - Particle Size Distribution
  - Motive Force Could Use:
    - Gravity
    - Pump – Pressure
  - Chemical Addition
- Alternative Physical Separation
  - Centrifuge



Filter Options

Filter Types

- Media – Single / Multi
- Belt
- Bag
- Cartridge
- Drum
- Membrane – Reverse Osmosis
- Ultra / Nano
- Etc…….

Each Best Suited for a Specific Application

Control Variables for Physical Separations

Previously Discussed Some Variables Related to Separations…..

- *Density Difference of Chemicals / Materials to be Separated*
- *Chemical Addition – Coagulation/Precipitation/Electro Potential*
- *Emulsion Breakers – Polymers & Ionic*
- *Feed / Flux Rate*
- *Centrifugal Spin Rate -> Pressure*
- *Contact Time with Plate Packs*
- *Filter Media*
    - *Pore Size of Openings on Separation Media*
    - *Flux Rate Through the Separation Media*
    - *Pre-Coating of Material on Media*
    - *Pressure Drop Across Filter*
- *Residence Time in Treatment Step*

Biological Wastewater Treatment Principals of Operation

Driving Force for WW Unit Operations:

- Separation
  - Gravity
  - Filtration
- Oxidation
  - Chemical / Electrical
  - Biological
- Flow Control
  - Gravity Flow
  - Siphon Systems
  - Level Controls

Chemical Oxidation & Reduction Reactions

- Chemical Oxidation -> Breakdown Complex Chemicals to Simple Ones
  - Oxygen Consumed
  - Chemical Oxidizers Consumed in Some Rxns.
- Oxidize Metals -> Typically to More Stable / Less Toxic Forms
- Can Treat High Concentrations of Chemicals
  - Only Limited by Stoichiometry & Vessel Constraints
- Typically More Expensive than Biological Oxidation
- Chemical Reduction Also Used
  - Often for More Refractory (Difficult-to-Treat) Chemicals / Materials

Oxidation / Reduction of Chemicals in WW

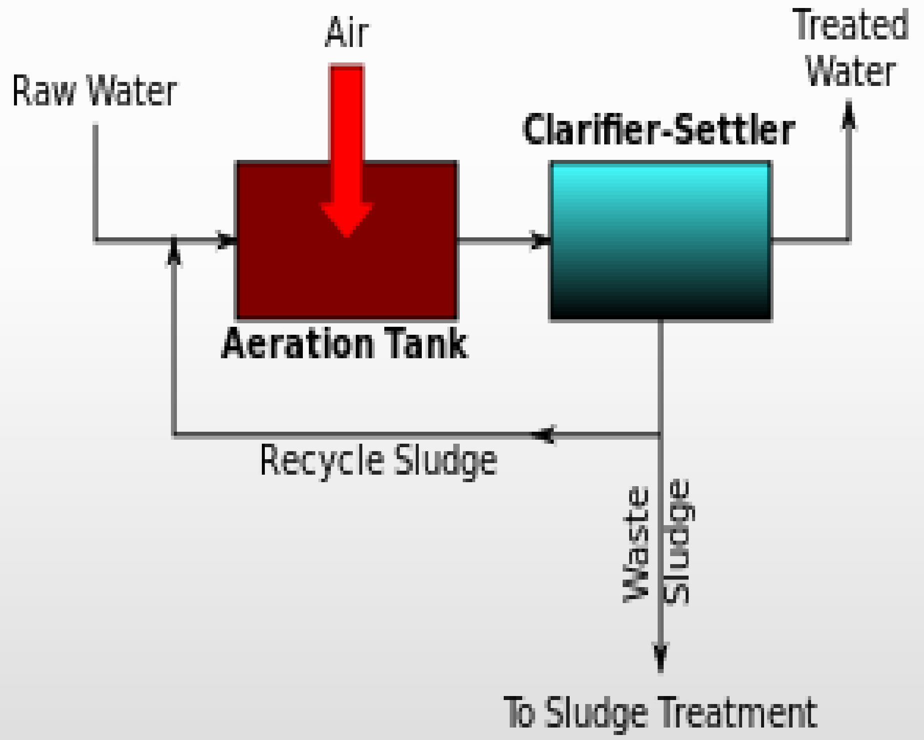
- Biological Oxidation - First Used (Least Expensive)
  - Cell Bodies use Organic Compounds as Food
    - $CO_2 + H_2O$ are Waste Products – Returns Chemicals to Nature
    - Also need other Nutrients (N, P, etc.) for Cell Reproduction
    - Sanitary WW Part of Food Chain – Easiest to Treat
    - Industrial Chemicals not Found in Nature – Harder to Treat (Refractory)
- Chemical Oxidation / Reduction Rxn. –> Electron Exchange
- Complex Organic Compounds & Strong Oxidizers ◊ $CO_2 + H_2O$ + ??
  - Hydrogen Peroxide
  - Permanganate
  - Ozone
  - Others

Control Variables – Oxidation or Reduction Rxns.

- Variables to Control Oxidation Reactions
  - Select Chemical Agents with Greater Electro Potentials
  - Increase Contact/interation Between Chemicals
    - Reduce Particle Size – More Total Surface Area in Contact
    - Provide Additional Mixing
    - Increase Concentrations of Reactants
    - Increase Contact Time = Greater % Completion of Rxn.
  - Stoichiometric Ratios in Chemical Rxn. Equations
    - Higher Concentrations of Reactants Push Equilibrium => Completion
      - Remove Rxn. Products Pulls Equilibrium To Completion
    - Provide Catalysts When the Reaction Chain When Required

Biological Oxidation
Alternative to Chemical Oxidation

- ***Chemicals in WW***
  - ***Bio-Mass Takes the Place of the Chemical Rxns in a Physical / Chemical Process***
  - ***Waste Chemicals are the Food / Energy Source for the Bio-Mass – When Acclimated***
  - ***Bio-Mass Uses O_2***
    - ***For Respiration***
    - ***Break Down / Oxidize Complex Chemicals to:***
      - ***Water (H_2O)***
      - ***Carbon Dioxide (CO_2)***
      - ***Nitrogen (N_2 gas)***
      - ***Other Less Complex Molecules***



Biological WW Treatment - Basic

Treatment Capabilities – Dissolved Compounds & Some Solids

- *Typically Can treat:*
  - *[BOD_5] < 400 – 600 mg/L – Higher in Some Cases*
  - *[COD] < 900 mg/L*
  - *TDS < 6,000 mg/L*
- *Converts:*
  - *Carbon Compounds to CO_2 & Hydrogen containing to H_2O*
  - *Basic Process - Ammonia / Nitrogen containing Compounds to Nitrates*
  - *MLE Process – Ammonia Compounds to Nitrogen (g)*
  - *Others to…. Oxides or Simpler Compounds*
- *Concerns: Many Situations Can Upset or Kill the Biology w/out Warning*
  - *High Waste Concentrations*
  - *Oil & High TSS concentrations*
  - *Metals & Refractory or Toxic Compounds*
  - *Highly Variable Feed *

Process is a Living Organism – Need to Nurture it Accordingly

- *Upsets => TSS Carry-Over or Inadequate Treatment of Harmful Chemicals*
  - *Effluent Pathogens – Bacterial & Viral*
    - *Potentially Harmful to Humans*

Basic Wastewater Treatment Principals of Operation

Driving Force for WW Unit Operations

- *Separation*
  - *Gravity*
  - *Filtration*
- *Oxidation*
  - *Chemical / Electrical*
  - *Biological*
- *Flow Control*
  - *Gravity Flow*
  - *Siphon Systems*
  - *Level Controls*

Gravity Flow Systems vs. Level Control Systems

- WWTP's Typically Use Gravity Overflow Between Steps
  - Simplest System Possible
  - Perfectly Matches Influent Flow
    - Level Control Systems Are Never Fully Stable – Levels Moving Up & Down; Constantly
- Disadvantages of a Level Control
  - Level Constantly going Up or Down - Seeking the Set-Point
    - System is Always Seeking a Stable Operation – Never Actually Achieves
  - Larger Tanks => Greater Variations
  - Significantly more Pumps, Instruments and Control Loops
  - If Nitrogen Blanketing is Required, This System will Maximize N_2 Requirements
- Advantages of a Gravity Flow System
  - Very Simple System – Lowest Cost
  - Minimizes Pumps, Control Systems & Instruments
  - Perfectly Maintains Levels – Most Reliable

Control Variables – Gravity Flow Control

Gravity Flow

- Motive Force is a Function of:
  - Gravity & Difference in Elevations
  - Pressure Drop in Transfer Lines
- Difference In Head MUST be > Pressure Drop
  - This Difference in Head is Between the Surfaces of the Two Connected Tanks
- Very Important to Design for Peak Hourly Flow
  - Available Head MUST be > or = Pressure Drop @ Peak Flow
    - Or Tank Overflows

Gravity Flow vs. Level Control

- Gravity Flow Between Tanks
  - Saves Money
    - Eliminating Pumps, Sumps, Piping & Control Loops, etc….
    - Reduces Maintenance Needs - Fewer Level Control Loops
  - Smoothest Possible Transfer of WW   In = Out ~ Constant Levels
- Level Control Systems
  - By Definition / Designed to Constantly Change Tank Levels
  - Requires Regular Calibration
  - Causes a Cascade-Type of Impact on Downstream Equipment
    - The More Level Control Systems Upstream of an Unit Operation the More Unreliable it is

PRAYER/LUNCH

RETURN
BY
13:00

Wastewater Treatment System Operations

Putting the Various Options Together to Produce a Target Effluent

Determine the System Operations Required

Overall Strategy

- *Using Flow & Composition Criteria – Discussed this Morning*
  - *Select General Treatment Train*
    - *Use Technologies Required to Add to a Final Effluent*
  - *Select Individual Unit Operations*
    - *Each to Provide a Treatment Need or Needs to Prepare for the next Steps*
  - *Adjust to Meet Specific Needs / Preferences*
    - *All WWTP's are Unique – Must Accommodate Site Specific Needs*
      - Each Step may Require some *Modifications to Work Properly*
    - *Assumptions => Errors*
      - Many Projects Unwilling to do *a Proper Needs Evaluation*

Identify Design Targets / Constraints

Start "Big Picture" & Gradually Narrow Focus on Technology Options

- Gov. Compliance Dictates Treatment Steps Leading to Final Effluent
  - Government Regulations: PME / GAMEP / Royal Commission / Others??
  - Internal Company Commitments
- Reliability of Effluent Compliance – Personal/Company Preference
  - Determines Excess Equipment Capacity
  - Narrows Project Cost > Compliance – Useless if Not Compliant
  - Operational Ease – Compliance & Operational Costs
- Construction Capital Costs
  - Meet Treatment Needs W/O Excess
- Operational Costs – More Important than Capital Costs
  - Materials, Training & Staffing

Applying Wastewater Treatment Principals To Design

Almost All WW Unit Operations are Driven by or Use One of these

- Separation
  - Gravity
  - Filtration
- Oxidation
  - Biological
  - Chemical / Electrical
- Flow Control
  - Gravity Flow
  - Level Controls

Types of WW

1st Evaluate Influent Data – Is It More Sanitary or Industrial WW

Sanitary WW

- Contains Materials that are or can be part of Food Chain
  - Excess Food
  - Wastes from living organisms
  - Dead organisms
- C:N:P-> 100:16:1; Redfield Ratio
- Typically Easy to Degrade/Eat
- Rarely Toxic – Exceptions Metals

Industrial WW

- Not typically part of Food Chain
- Often V. High concentrations
- Doesn’t Conform to Redfield Ratio
  - Requires Nutrient Supplementation
- Often Toxic to biology
- Requires Acclimation

Types of WW – Treatment

Sanitary WW

- *Nature can handle – w/time*
  - *A Treatment Plant Imitates the Processes in Nature*
- *Treatment Plant Steps:*
  - *Accelerate Natural Processes*
  - *Smaller Footprint*

Industrial WW

- *Treatment Plant Typically Needed*
  - *Wastes Not Found in Nature*
  - *Natural Processes Can't Treat Them*
- *Nutrient Addition for Bio. V. Common*
- *Lowest or Highest price options*
  - *Depends on WW*

Sanitary WW Treatment Unit Operations
Typical Unit Operation Selections

- Inlet Screening – Large Solids or Non Bio-degradable Solids
- Oil removal – Typically a Very Simple Skimming <400 - 500 mg/L
- Grit removal – Small Solids
- Removal of Dissolved Organic & Inorganic Compounds
  - Biological – Most Important Step
    - Converts to Complex Carbon Molecules to CO_2 & Water
      - Uses Biological Oxidation – Lowest Cost Option
      - Nitrogen Compounds -> Nitrates (Basic)
      - Nitrogen Compounds -> Nitrogen Gas (MLE)
    - Phosphate Removal – or Physical / Chemical
  - Physical / Chemical Treatment
    - In Place of the Biological Option
    - Typically More Expensive - Lots
  - Tertiary Filtration – Polishing the Effluent
  - Disinfection – Removing any Residual Pathogens - Reuse
  - Advanced Systems – Virus Filtering & Specific Chemical Compounds

Site Specific Issues Impacting Selection of Unit Operations

Issues Typical of Saudi Special Needs – Impacting Design Decisions

- Typically a Mixture of Sanitary & Industrial WW
- Almost Always Include some Vacuum Truck Discharges
- Oil Spikes More Common
- More Often a Mixture Could have almost anything in it
  - Very little Control of Contents
  - Flow & Composition Estimates Very Rarely Close to Reality
  - Older Chemicals (No Longer Manufactured – PCBs, TEL, DDT) Not Uncommon
- Sanitary WW Very Commonly Dilute
  - Often Requires Supplemental Food for Denitrification – Often Below 100 mg/L
- Desert Sand
  - Isn't really Sand – High Concentration of Calcium Carbonate
    - Often Contains Iron
    - A Sticky Mess when wet, Plugs Equipment
    - Mixes with any Oil to make an Oily Paste – Plugs Equipment
    - Not acceptable for Filter media, leach Fields, etc.
      - Design Contractors Make this Mistake on almost Every Project
  - Because of Carbonates, Assume Oily Sludge Present Everywhere – to Some Degree (CPI Separators Esp. Vulnerable)
  - Blower/Compressor Maintenance
  - COD Analysis – Sand/TDS/Chlorides/Lab Techniques & QA/QC

Site Specific Issues Impacting Selection of Unit Operations

Issues Typical of Saudi Special Needs – Impacting Design

- Remote Areas with only a Few Workers – Septic Tanks & Leach Fields
  - Common Sewer Design has Sewer Running from Control Room to Septic Tank
    - Septic Tank then overflows to a Leach Field
    - Lack of a Hydraulic Profile Typically Results in Surcharged Sewer Systems
      - WW Backing up in Control Room Kitchens
  - Facilities with Biological WWTPs Struggle with Animals entering their Evaporation Pond areas to drink the Water – Big Liabilities
- WW TDS Higher – 3,500 to 5,000 mg/L Not Uncommon
    - Sabka Water Very High TDS
    - This Water Needs to be Treated before being used
      - Can't add it back to the influent of the WWTP with the Sanitary WW
        - Need to provide a Separate Evaporation Pond for it
- Cultural Concerns – WW Treatment Operations
  - Per Capita Water Consumption – Very High
  - Efforts at reducing this use of Water
- Temperature (35 -> 40 C / 95 -> 104 F) Mesophilic Activity Drops Rapidly
  - Bacteria Highly Adapted to Environment
- Operations & Preventive Maintenance => Reliability Most Important Criteria
  - Energy Costs Less Important
  - National Water Company Development Plans

Selection of Unit Operations

For Predominantly Sanitary WW

- Pick a Typical Treatment Train – Assume a Conventional or MLE
- Evaluate Unit Operations Required
  - Handle All Needs?
  - Add Extra Unit Operations – As Needed
    - Vacuum Truck Discharges of Oily Wastes – Closely Monitored Inspection Basin
    - Confirm Adequate BOD_5 for Denitrification
  - Some Steps Rarely used
    - Primary Clarifiers – Saudi WW Typically Low Strength
    - DGF's Difficult to Operate
    - Require a Large Amount of Nitrogen for Blanketing System
  - Discharge to be Reused
    - Add Denitrification => MLE System
    - Concentration of Phosphorus Typically Above Discharge Limit
      - If used for Irrigation, it takes the place of fertilizer
      - If Discharged to the Sea, it can cause Algae Blooms
    - Biological Phosphorus Removal – Higher Capital & Complex
      - Chemical Phosphorus Removal – Potentially Higher Operating Costs
      - Internal Company Policy Decision

Selection of Unit Operations

Predominantly Sanitary WW

- Assume a Conventional or MLE
  - Evaluate Unit Operations Required
    - Add Extra / Select Unit Operations – As Needed / Desired
      - Automatic or Manual Bar Screen?
      - Automatic Oxygen Concentration Control?
      - Tertiary Filter System – Government Determination / Company Determination
        - More Equipment to Operate & Maintain – Cost Benefit Analysis – Operations Decision
        - More Chemicals – Cost Benefit Evaluation – Cost Benefit Analysis
        - Higher Risk of Pathogen Transmission – Company Policy Decision
      - MBR – Government Determination / Company Determination
        - Lower Risk of Pathogen Transmission – Company Policy Decision
        - Fewer Unit Operations to Operate & Maintain – Cost Benefit Decision
      - Phosphorus Removal – Influent & Government Specification
        - Chemical Precipitation
        - Biological Removal
      - Sludge Centrifuge or Sludge Drying Beds?

Selection of Unit Operations

Predominantly Sanitary WW

- Evaluate Unit Operations Required
  - Add Extra Unit Operations – As Needed / Desired
    - Odor Control System?
      - Biological or Chemical?
    - Type of Disinfection
      - Chlorine Gas
      - NaOCl Liquid
      - UV Disinfection
- Decide on:
  - Materials of Construction – Liner Type
  - Design Eq. & Piping Safety Factors
  - Equipment Layout
  - ETC……….

Simple Process Design

Need to understand in order to Design & Operate

- Characterize WW Influent – Flow & Composition
- Identify Design Targets
- Select Type of Unit Operations
  - Sanitary WW
  - Industrial WW
- 1st Determine Ultimate Targets
  - Final Effluent meets Gov. or Internal Requirements
- 2nd Select the Unit Operations Needed For Each Removal Required
- 3rd Initial Ordering of treatment steps
  - Prepare WW for next step(s)****
- 4th Select Lowest Cost Oxidation method
- 5th Select Specific Unit Operational Technologies – Various Criteria

Unit Operations – Ordering/Selection

The Sum of the Unit Operations need to meet the Design Targets

- ***The final treatment step Typically set by the effluent specifications***
- ***Sanitary and Industrial WW Systems First Remove Highly Concentrated Wastes***
- ***The order of treatment steps and the type of Unit Operations are set by the Influent Specifications of the next Treatment Unit in the line***
- ***Most Important Treatment Step => Either Remove or Oxidize Organic & Inorganic compounds***
- ***Equipment & Operational Costs (within Reason) Typically Less Important than Reliability***
- ***The actual process brand/manufacturer – Typically per Operations Preference***

What is Needed to Finalize Design???

WHEN YOU KNOW WHAT YOU WANT TO INSTALL…

- Do You Have Enough Data to Specify All of the Equipment?
  - Are you Certain of the Analysis & Flow???
    - Rarely Have Enough Data – Can Never Tell Until After
- Alternative Approach – Best Estimate & Worst Case Philosophy
- Assure that the Extremes are Covered – If Feasible
  - Determine the Variables you can Identify
    - What are the Max and Min Extremes for WW Variables?
  - How Are Unit Operations Impacted by Each Variable?
  - Identify Inherent Equalization Capacity – Sumps, Tanks, Reactors, Etc.
  - Can you Live With Worst Case?
  - Evaluate Cost of Safety Margins

Ask: if Worst Case Happens, Can I Live with the Consequences?

What options are Available to Mitigate?

Equalization Capacity – More is Better

Initial Selection of Unit Operations

For Predominantly Industrial WW

- Pick a Typical Treatment Train – Assume a Conventional or MLE Biological
- Based on Biological Plant Selection – Determine the Oil Removal Treatment Train
- Evaluate Unit Operations Required
  - Handle All Needs?
  - Add Extra Unit Operations – As Needed
    - Vacuum Truck Discharges of Oily Wastes – Inspection Basin
    - Enough BOD_5 for Denitrification?
  - If Some Steps Not Required, Remove
    - Primary Clarifiers – Saudi WW Typically Low Strength
  - Discharge to be Reused?
    - Add Nutrients to meet Redfield Stoichiometric Ratios
    - Add Denitrification – MLE System Typical
    - Low Concentration of Phosphorus –
    - High Concentration of Some Metals
      - Chemical Precipitation

Very Common Engineering Design Errors

An Error to Assume Conditions the Same as their Previous Jobs….

- Make Assumptions to Minimize Cost => Typical Design Mistakes
  - Challenge Site Specific Needs using Data from other Locations
  - Assume Operations can Replace Automation
  - Assume no Flow Composition or Flowrate Variations – Design Flowrate is NOT the typical flowrate to the equipment
  - Assume Mixing Immediate
  - Assume pH a linear Function
- Need to Understand "Design" Flowrate is NOT the Actual Flowrate to treat
  - Most Facilities have a Very High Variability in WW Generation
  - Almost all WWTPs are starting Capacity Upgrade Projects before the Last One is Running
  - Lift Station Pumps – Capacity & How Many Operating at any Time???
  - Level Control Start & Stop provides a "Design Flowrate"
- Assume pH is a linear Function – It's exponential
- Assume Instrument readings & Lab Reports are 100% Accurate
- Don't provide Sufficient Equalization to Resolve even minor Variability

Equipment Design Based on WW Characteristics

- Proper Unit Operations Design Criteria
  - Treatment Capacity Should be Based on the Average Flowrate
  - Piping & Pump Capacities Should be Based on Peak Hourly Flowrate
  - Emergency Storage Should be Based on Maximum Daily Flow
  - Lift Station & Tank Storage Should be Based on Diurnal Flow Max.
    - The 24 Hr. Rainfall Events are actually very high when compared with normal flowrates
- Sized Appropriately for WW Composition Needs
  - Treatment Capacity Unit Operations Need to Supply Capacity for Average
  - Everything Else is Simply Providing the Hydraulic Capacity as per Above
- Use Equalization (flow & composition) to Smooth Variability

Possible Information Sources

You will NEVER have all the information you need available

- ***Control Room** measured data*
- ***Field Measurements** – portable measurement devices*
- ***Design Specifications***
- ***Pump Curves** – Discharge Pressure or Amp Readings*
- ***Pressure Drop** through lines*
- ***Similar systems***
- ***Worst Case Extrapolations** – If It Can't be Worse – It should work*
  - *Find some **limiting variable** & use it to **set worst case***
- ***Heat & Mass Balances** – If you know some, you can calculate the others*

Routine Monitoring & Troubleshooting Upsets

- Monitor Process to Assure all of the Criteria for the Design Selection
  - Have Not Changed
  - If a Treatment Step isn't meeting it's Design Criteria, Check to see what has changed – Feed / Flow to the Unit, Is Something interfering with the Driving force for the Unit Operation not meeting its effluent specs.
  - The above evaluation should be Checked going in both Directions
- If Something has Changed from initial Design Values, Adjust back to original Value(s) & evaluate compliance (after obtaining Management approval)
  - Operations Will be Different
  - Document all Changes & Prepare a Report on why Changes were required
- To Return Unit Operations to Normal or a New Normal
  - Fix Whatever Changed
  - The Deviation Will Be One of the Unit Operation Drivers

Biological WW Treatment – Basic Monitoring

Capabilities – Dissolved Compounds

- *Need to know What is Normal in order to Determine if the system isn't running normal*
- *Create Log Sheets that indicate Typical Readings & Actions if they Deviate*
- *System Should treat Feeds of:*
  - *[BOD_5] < 400 – 500 mg/L*
  - *[COD] < 600 mg/L*
- *Log Sheets should Report the amount of: BOD and COD Removal Percentages*
- *Log Sheets should Report the amount of NH3 Converted to: either Nitrates or Nitrogen (g)*
- *Log Sheets should Report the concentrations of: Free Oil or Excess Solids*
- *Log Sheets should Report the concentrations of: Oil & TSS in the influent*
- *Log Sheets should Report the concentrations of: Metals & Toxic in the influent*
- *Log Sheets should Report the variation in the Waste Loading from day-to-day*
- *Log Sheets should Report any upsets that happened during the day*
- *Log Sheets should Report the concentration of: Effluent Pathogens*
- *Log Sheets should Report: Total Residual Chlorine*

BREAK

RETURN
BY
15:00

Operational Monitoring - General

Routine Monitoring of Equipment

Each Unit Operation – Key Operating Parameters

- Using the Data mentioned previously, the Following Evaluations should be performed:
  - Compare Values from Upset timeframe to Historical Flow Rates & Other Design Variables
  - Check Specific Design Variables against original Design
    - Check Depth of Sludge Blanket in Clarifiers & TSS in Effluent
    - Check MLSS, DO in Aeration Tanks
    - Check Oil Separation in API & CPI Separators
- Check Influent
  - Any Changes since the Initial Variables the Design were determined?
  - Any changes in the flow & Composition to any Treatment Steps?
- Check Effluent
  - What Effluent Criteria is changed
  - What Treatment step is responsible for the removal of that Effluent Constituent?

Typical MLE Biological

Operational Monitoring – Specific for MLE Biological

- *Influent – Compare the following to the Design Values*
  - Flow Rates
  - Concentrations of Contaminants
  - pH, Temperature
- *Intermediate Process– Compare the following to the Design Values*
  - Dissolved Oxygen in Aeration Basins
  - Reflux Flow Rates for RAS
  - Reflux Flow Rates for Effluent Recycle
  - Odor & Color of MLSS
  - Sludge Blanket Depth
  - 30 Minute Settleability
- *Effluent – Compare the following to the Design Value*
  - Contaminant Concentrations
- What Treatment Step is Required to achieve the appropriate effluent Concentration for any Deviations?

Biological WW Treatment – (MBR)

Operational Monitoring – Specific for MBR

- **Influent – Compare the following to the Design Values**
  - Oil Concentration
  - High COD Concentrations – Any Particularly Higher?
  - Emulsions
  - pH
  - [BOD_5] > 400 – 500 mg/L
  - [COD] > 600 mg/L
  - Hair or Fibrous Materials
- **Effluent**
  - All Parameters Required for Compliance

What part of the Treatment Train is Required to achieve the appropriate effluent Concentration for any Deviations in the Influent?

API Separator

Critical Operational Monitoring – API Separator Specific

- *Influent – Compare the following to the Design Values*
  - *Oil Concentration – API Feed & Effluent*
  - *High COD Concentrations – Any Particular Chemicals Significantly Higher?*
  - *Daily Average and Peak Daily Flowrate*
  - *Emulsions*
  - *Appearance – Milky Color?*
  - *Floating Materials – Wax or other materials*
  - *pH Daily Average and Peak High & Low Values measured*
  - *Temperature – Average and Peak High & Low Values*
  - *Difference in Water Elevation on Inlet & Outfall Sides of the Underflow Weir*
    - *If so, Oily Sludge Depth should be Measured and Reported on log sheets – both sides of Weir*
- *Effluent*
  - *Oil Sheen*
  - *Total Oil & Grease Conc.*

Headworks / Bar Screen

Critical Operational Monitoring – Headworks Specific

- ***Influent – Compare the following to the Design Values***
  - ***Bar Screen – Waxy Oil Deposits on Sides & Bars***
  - ***Materials Plugging Slots***
  - ***Relative Amount of Solids – High, Normal & Low (To be Defined by Management)***
  - ***Bad Odor – H_2S Anaerobic***
  - ***High COD Concentration***

Troubleshooting Upsets

Final Effluent Not Compliant

Evaluate each Unit Operation – Work Backwards from Effluent

- ***Identify any Operations Not Working***
- ***Compare Each Unit Operation to What it should be Discharging***
- ***Identify What is needed to Provide the Required Driving Force Needed to Produce Design Effluent for that Step***
- ***Does Unit react to Changes in Controls as it should?***
    - ***If not, Identify what isn't working***
- ***Make all Changes that appear necessary – if no Improvement Check for Impacts from other Unit Operations***

Normal Preventative Maintenance

Record Information for Each Unit Operation

- *Anything Out-of-Service?*
  - *What Caused Failure*
  - *Repair Damage & Confirm Unit Working Properly*
- *Lubrication Schedule*
  - *Maintain Pumps, Motors, Moving Equipment with Factory Recommended Lubrication*
  - *Maintain Records of Lubrication*
- *Cleaning – Follow Cleaning Schedule (Based on Initial Evaluation of these Needs – Adjusted as Required)*
  - *Bar Screens – Amount of materials removed*
  - *Sumps – Solids Build-ups*
  - *Pumps – Type of Repair & Pump Operating pressure*
  - *Instruments – Record readings before and after Calibration*
- *Equipment*
  - *Drain Collected Oil – API / CPI's*
    - *Record Amount of Oil from Each Unit Operation*
  - *Waste Clarifier Sludge to Maintain MLSS in Aeration*
    - *Record Amount of Sludge Wasted*
- *Adjust Recycle Rates*
  - *Effluent Nitrate Concentration*
    - *Nitrate Conc. Up => Increase Recycle Rate*
  - *Check for Visible Differences*
    - *Check for Something Visibly Different – Familiar with Week to Week*
  - *Check for Abnormal Noises*
    - *Bad Bearings / Seals / Shaft Out-of-Alignment, Misc.*

Questions & Answers

Personal Lessons Learned

- No system is designed for every situation
- No two systems are the same
- It is almost impossible to get enough accurate information to fully understand the needs

IMPORTANT TO LEARN TO:

- Understand how the system should respond to variations in flow & composition
- Use best estimates & worst case analyses to design & manage operations
  - Ask: Does this make sense?
  - Ask: What should it be / what should happen?
- Question, challenge (politely) when responses don't make sense
- Understand individual motivations
- Take advice from Operators & anyone familiar with the system