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Saudi Arabian Water Environment Association (SAWEA)

Wastewater Treatment
Treatment Options & Key Design Issues

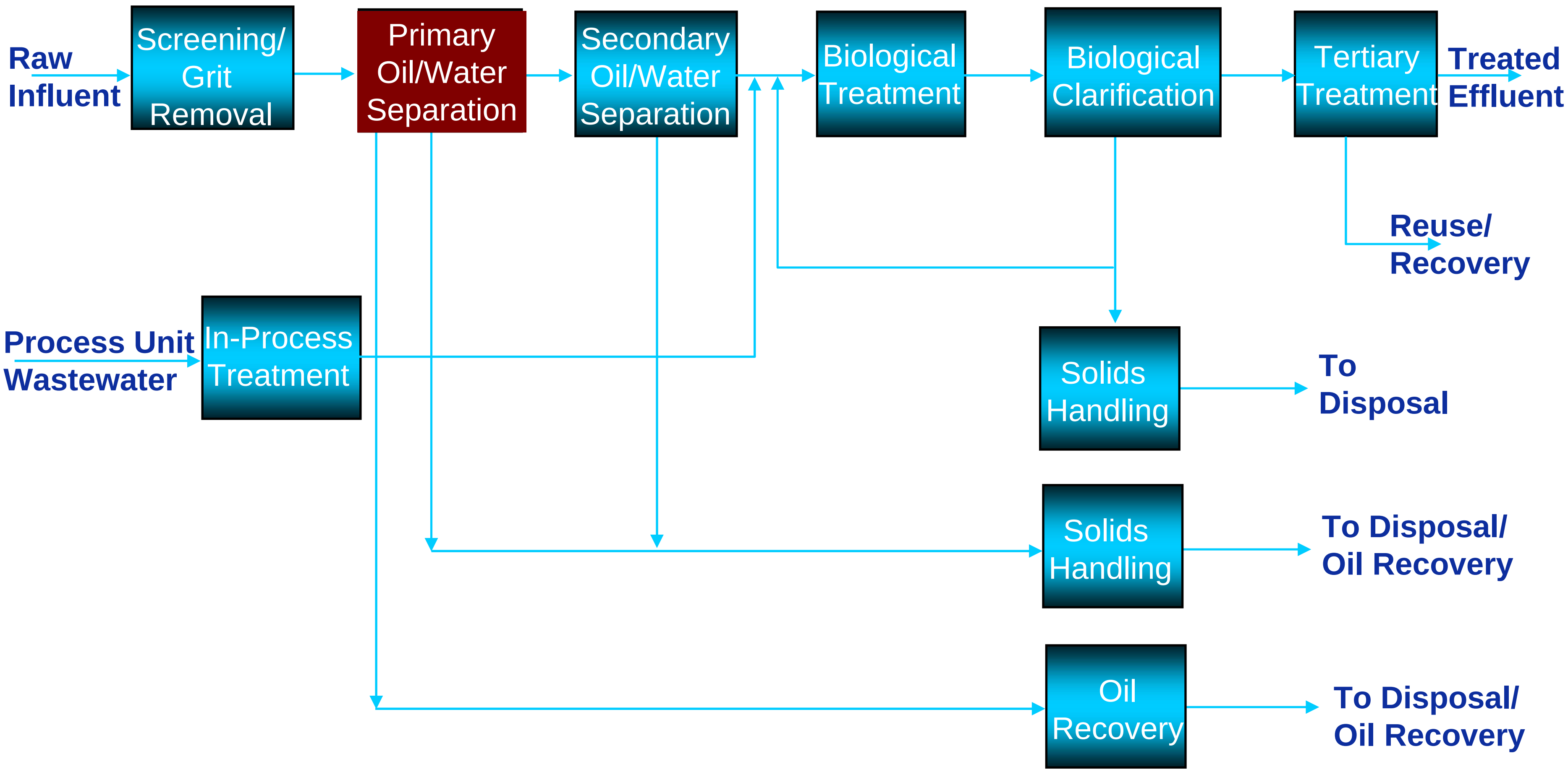
Agenda

Oily Wastewater Treatment

- Primary Treatment – Oily Wastewater
  - Primary Oil/Water Separators (Roughing Step)
  - Secondary Oil/Water Separators (Polishing Step)
- Wastewater Equalization
- Secondary Treatment - Biological Treatment Options
- Tertiary Treatment
  - Filtration
  - Activated Carbon

- **Wet Air Oxidation (Treatment of Spent Caustic)**

Typical Oily Water Treatment System



Treatment Objectives

- Screening/Grit Removal
  - Removal of large objects that might plug downstream treatment processes (Gloves, plastic bags, large debris)
- Primary Oil/Water Separator
  - Removal of large amount of oil and suspended solids from wastewater. Influent conditions are typically 300 to 10,000 ppm oil and TSS.
  - Effluent requirements are typically 100 - 300 ppm oil and TSS.
- Secondary Oil/Water Separator
  - Treatment objective is typically 5 to 30 ppm oil, dependent upon discharge requirements, or downstream treatment processes.
  - The amount of influent oil a process can withstand is 100 to 500 ppm, depending upon the process selected.
  - Typically would like to see oil < 30 ppm to a biological treatment process. Other discharge requirements may be more stringent.

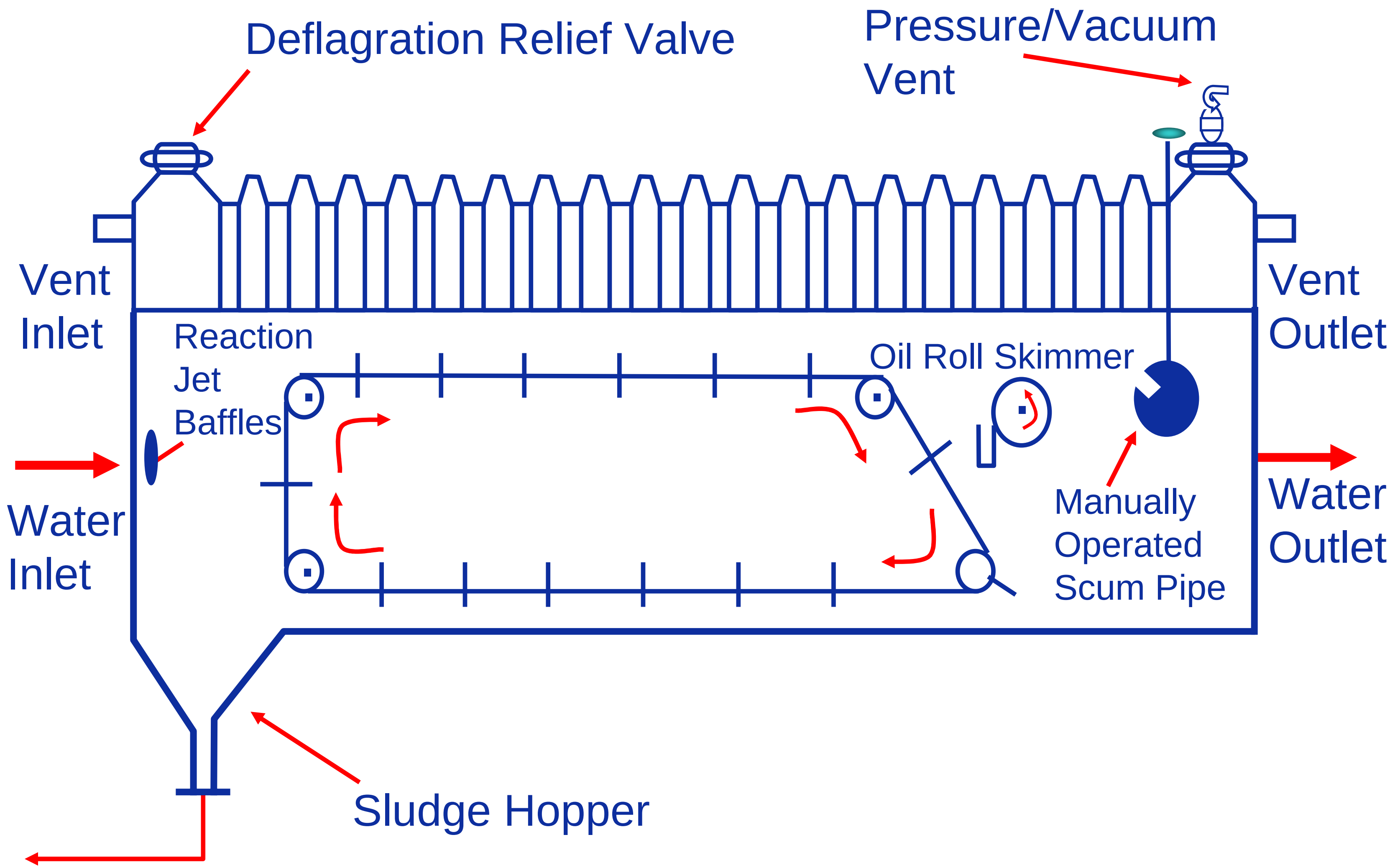
Primary Oil/Water Separator Options

- API Separator
- CPI Separator

- Both technologies provide oil and solids separation from water based on Stokes Law. In other words, they rely on the difference in specific gravity between oil, water and solids, to provide separation of these components in oily wastewater.

API Separator

Principles of Operation



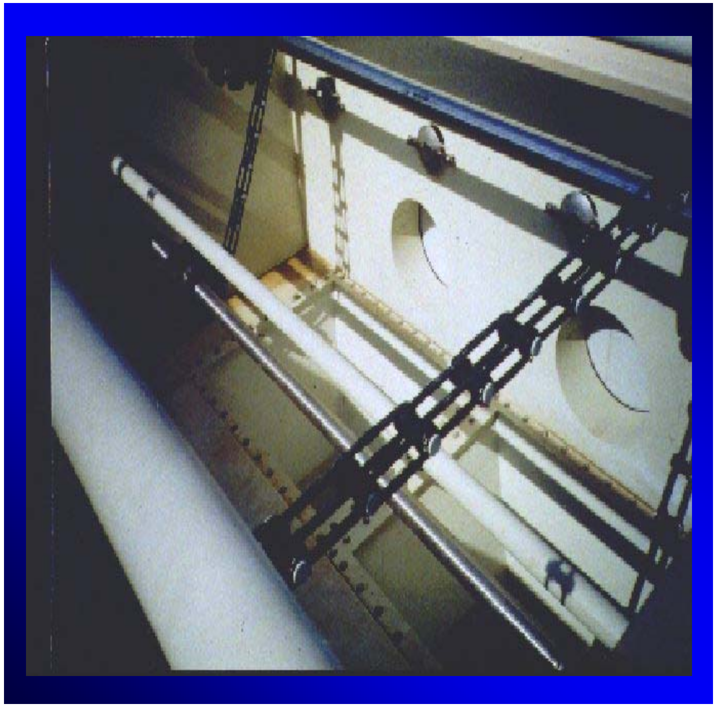
API Separator

■Typical Applications and Operating Conditions

- **Typically used in Petroleum Refineries and some Petrochemical Facilities.**
- **Influent Oil: 300 ppm to 10,000 ppm.**
- **Influent TSS: 300 ppm to 10,000 ppm.**
- **Effluent: 50 to 200 ppm oil and TSS.**

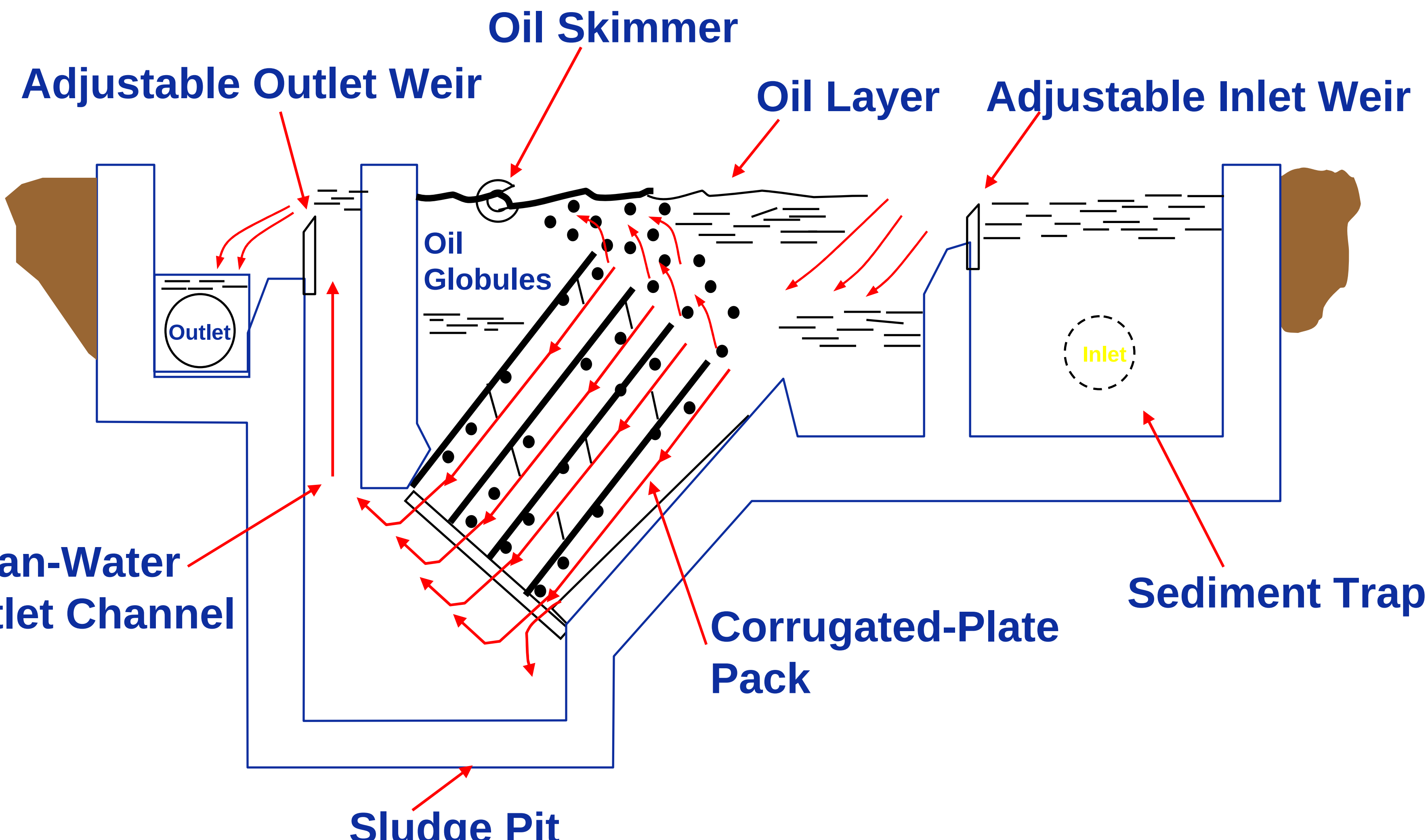
API Separator

- **Advantages**
  - **Ability to process wastewater with high TSS concentrations, up to 20,000 PPM.**
  - **Non-metallic collector component resist corrosion and are easy to install.**
  - **Concentrated oil removal.**
  - **Responsive to variations in flow and load.**

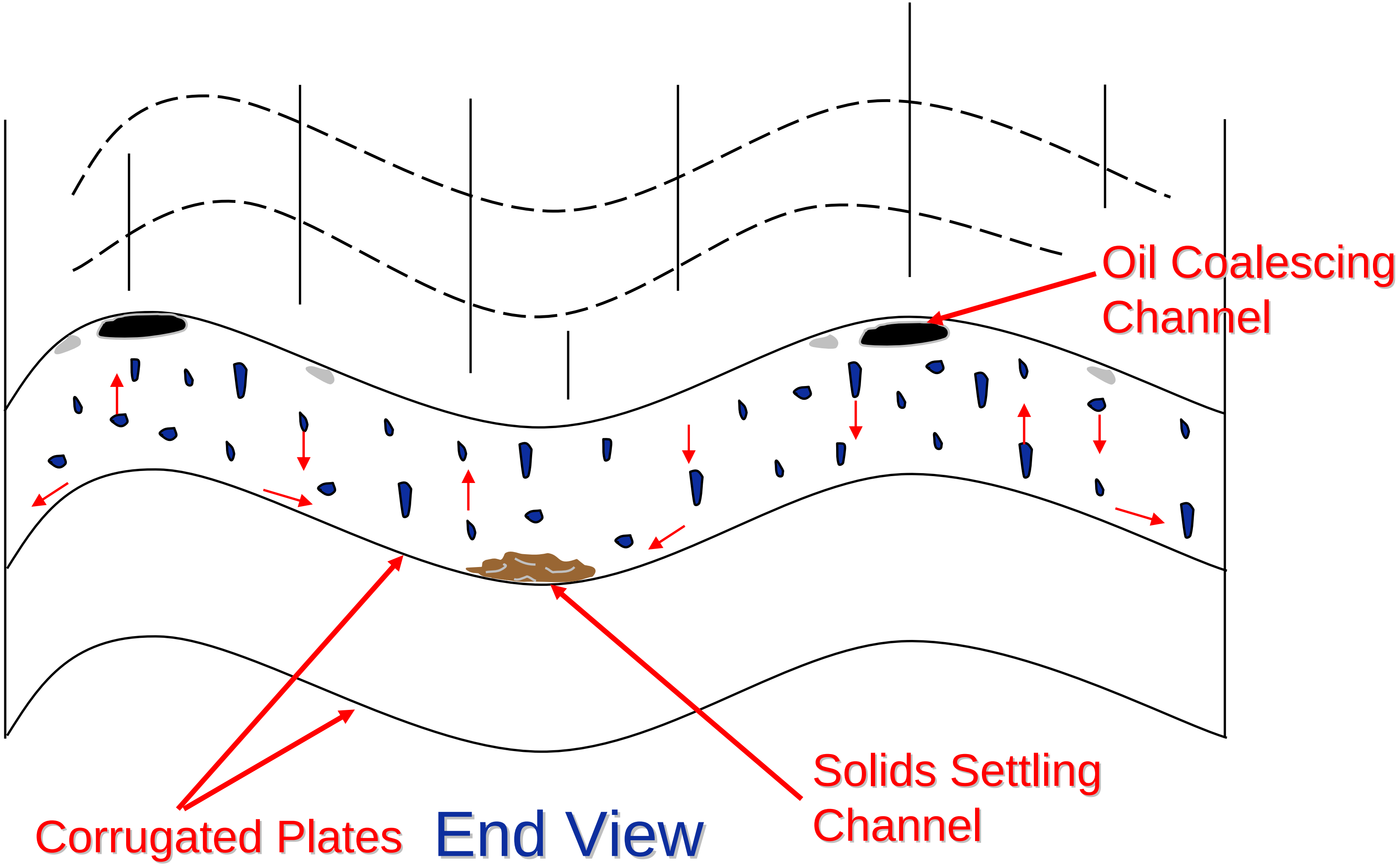


- **Disadvantages**
  - **Large area required.**
  - **Higher costs.**

CPI Separator
Principles of Operation



CPI Separator
Principles of Operation



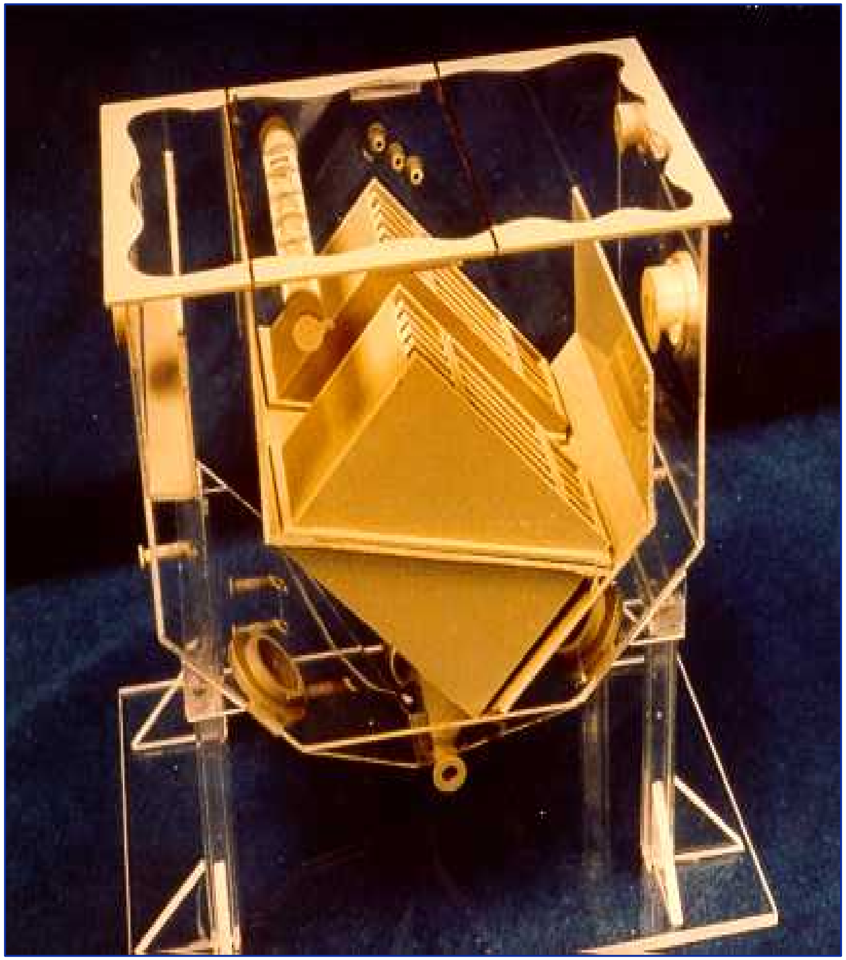
CPI Separator

■Typical Applications and Operating Conditions

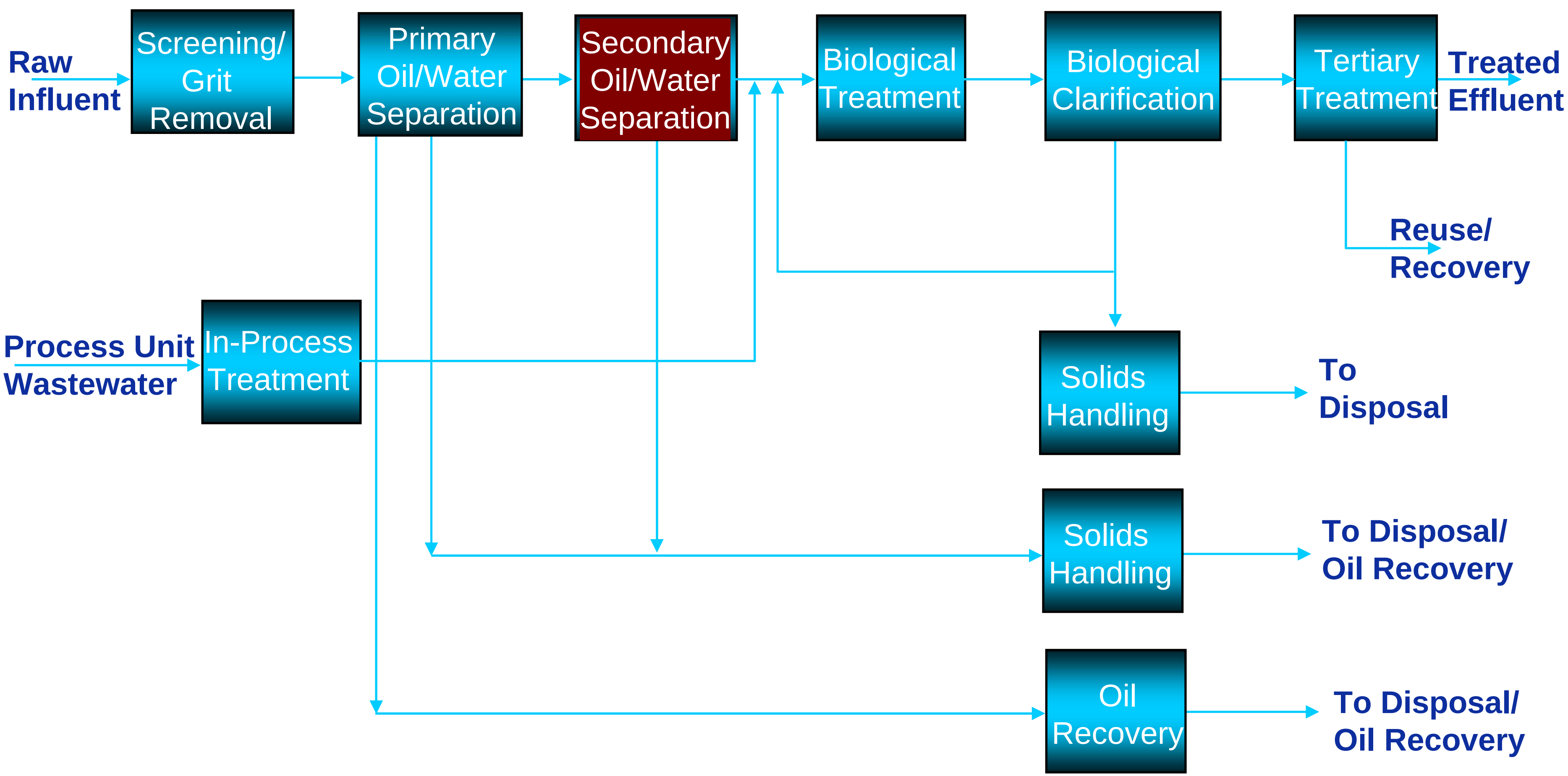
- Normally used in petrochemical plants with low TSS wastewater or in treatment of produced water in oil fields after production separators.
- Influent oil: 200 to 10,000 ppm.
- Influent TSS: Less than 100 to 200 ppm, dependent upon type of oil present.

CPI Separator

- **Advantages**
  - **Very small space requirements.**
  - **Low capital costs.**
  - **Easy to cover for VOC and odor control.**
- **Disadvantages**
  - **Not recommended for TSS concentrations above 100 to 200 ppm.**
  - **Not tolerant to variations in flow and load.**



Typical Oily Water Treatment System



Secondary Oil/Water Separator

- Dissolved Air/Gas Flotation Separator (DAF or DGF Separators)
- Induced Air/Gas Flotation Separator (IAF or IGF Separators)
- Walnut Shell Filter

- Relies on a some other mechanism, other than gravity, to assist with removal of oil and suspended solids from wastewater.

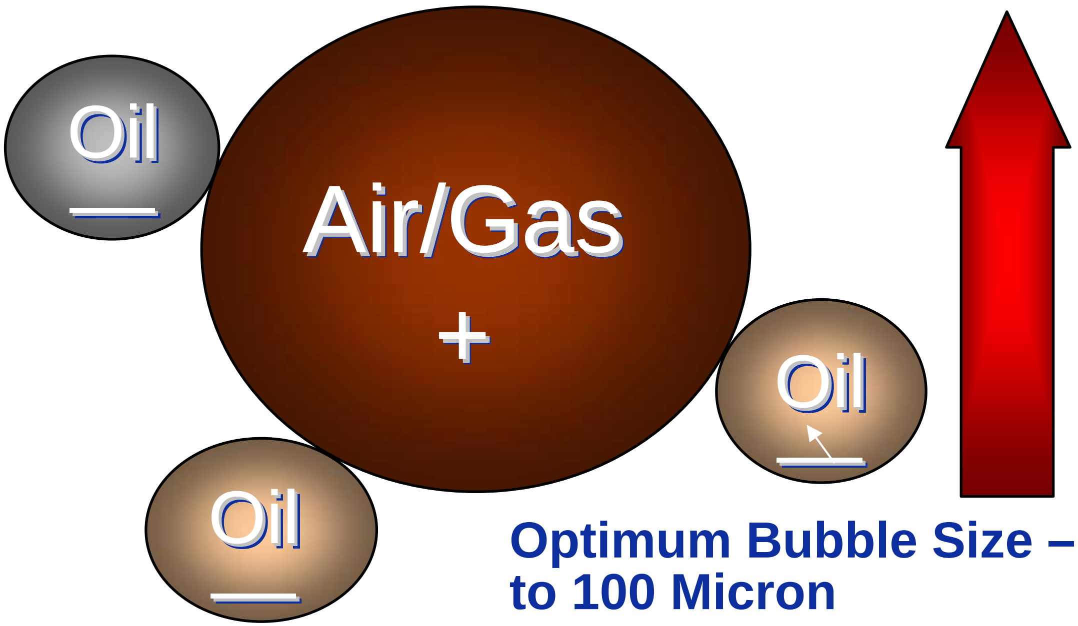
DAF/DGF Separators

- **Principle of Operation**

The "Soda Water" Effect

Pre-dissolves Gas in Wastewater

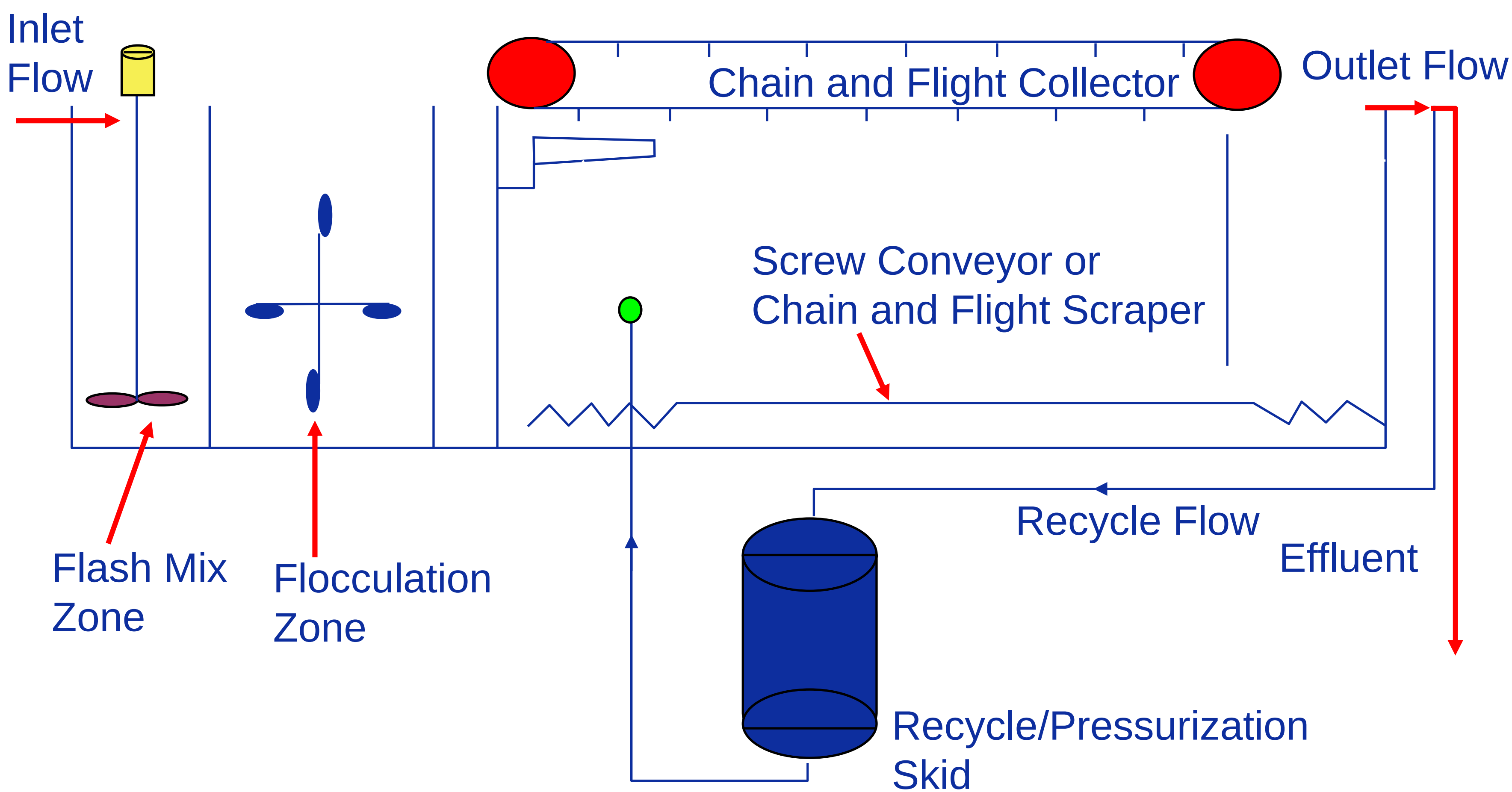
Uses bubble attachment to oil/solids particles to "float" particles from wastewater



Optimum Bubble Size – 50 to 100 Micron

DAF/DGF Separators

Principle of Operation



DAF/DGF Separators

■Typical Applications and Operating Conditions

- **Most common method of oil and TSS removal in refineries and petrochemical plants.**
- **Influent oil and TSS concentrations up to 500 ppm.**
- **Up to 95% removal of oil and TSS**

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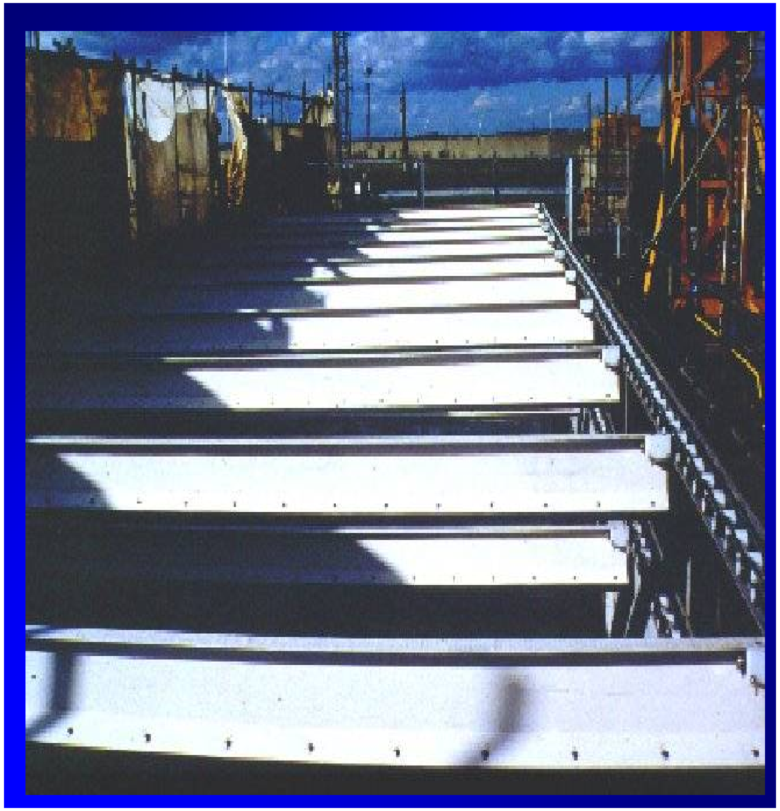
DAF/DGF Separators

- **Advantages**
  - Tolerant of changes in wastewater strength and flow.
  - Integral chemical conditioning provides good removal of oil emulsions.
  - Low sludge production, 0.1 to 0.5% of forward flow.
  - Consider non-metallic collector components for corrosion resistance.



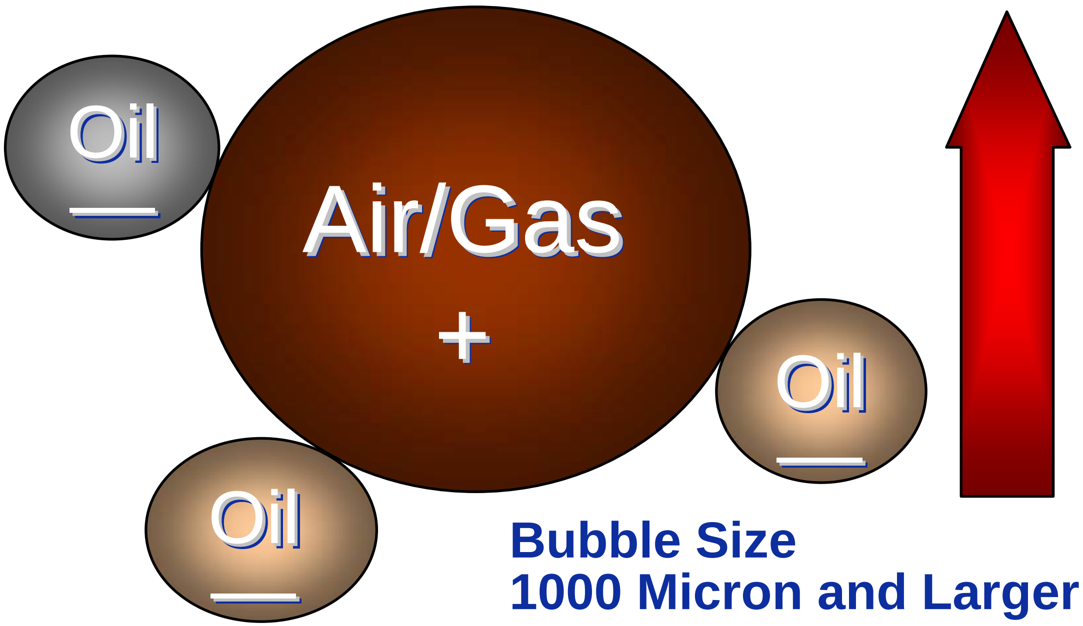
- **Disadvantages**
  - Higher cost and larger footprint compared to other technologies.

IAF/IGF Separators

- **Principle of Operation**

Gas is Dispersed into Small Bubbles

Uses bubble attachment to oil/solids particles to "float" particles from wastewater

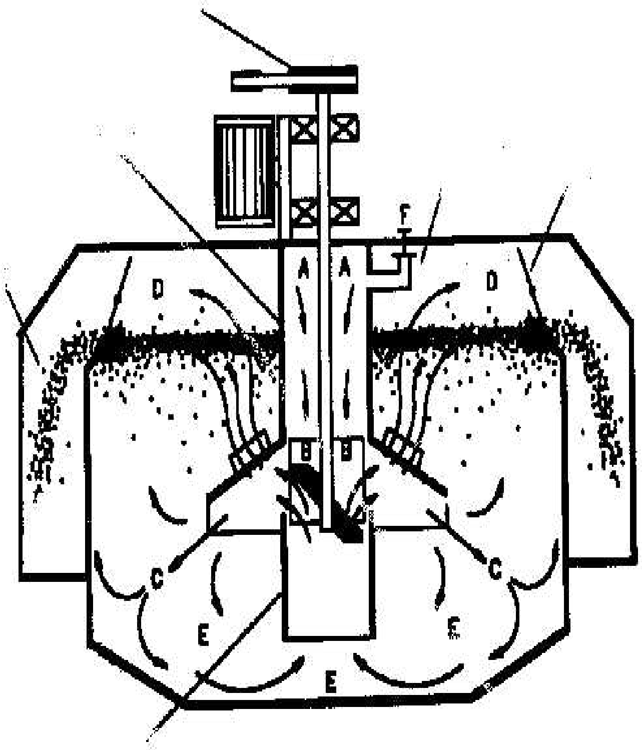


Bubble Size
1000 Micron and Larger

IAF/IGF Separators

Principle of Operation

- The gas is educted into the wastewater using either a mechanical mixer (shown) or a recirculation pump.
- The gas is then dispersed into small bubbles using the mechanical mixer (shown) or an impingement plate.
- Creates a frothing effect, whereby oil is removed from the wastewater.



IAF/IGF Separators

■Typical Applications and Operating Conditions

- Typically used in oil production with some minor applications in refineries and petrochemical plants.
- Works best on applications with consistent wastewater characteristics and no oil emulsions.
- Influent oil concentrations less than 300 ppm.
- 90 to 95% removal of oil.
- Not designed to remove TSS (TSS less than 100 ppm).

IAF/IGF Separators

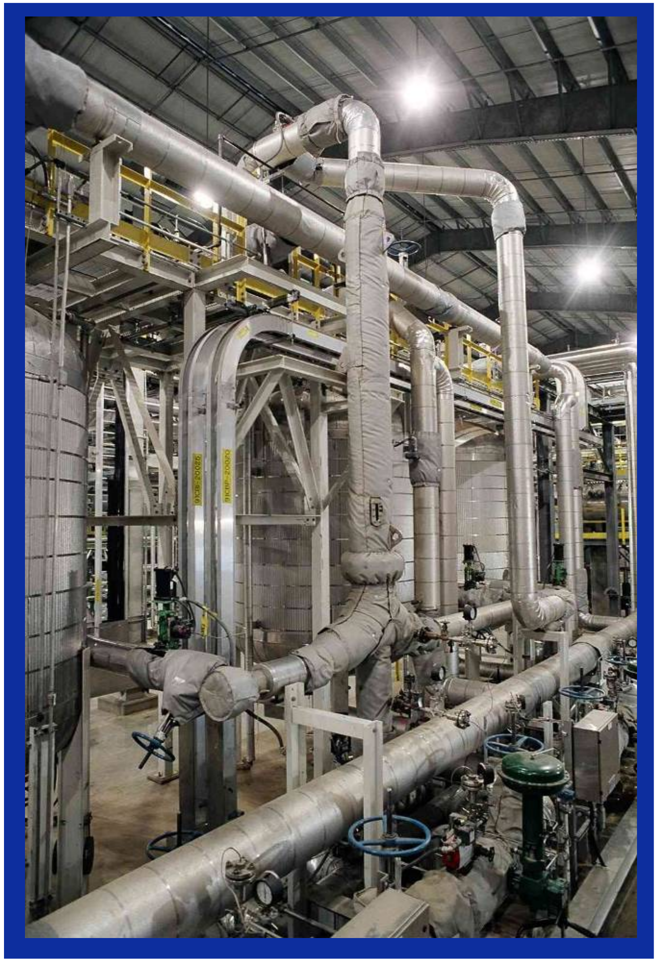
- **Advantages**
  - **Small footprint.**
  - **Lower costs.**

- **Disadvantages**
  - **Higher sludge production, 2 to 10% of the forward flow.**
  - **Less tolerant of flow and load variations.**
  - **Poor removal of oil emulsions.**
  - **Limited TSS removal efficiency.**

Walnut Shell Filters

■Principle of Operation

- Operates very similar to a media filter, except the media is crushed walnut shells.
- Walnut shells have very high affinity to attract oil.
- Once the oil adsorption capacity of the walnut shells is reached, based on differential pressure, the walnut shells are hydraulically removed from the filter where the oil is centrifugally removed from the media. The walnut shells are then sluices back into the filter vessel.



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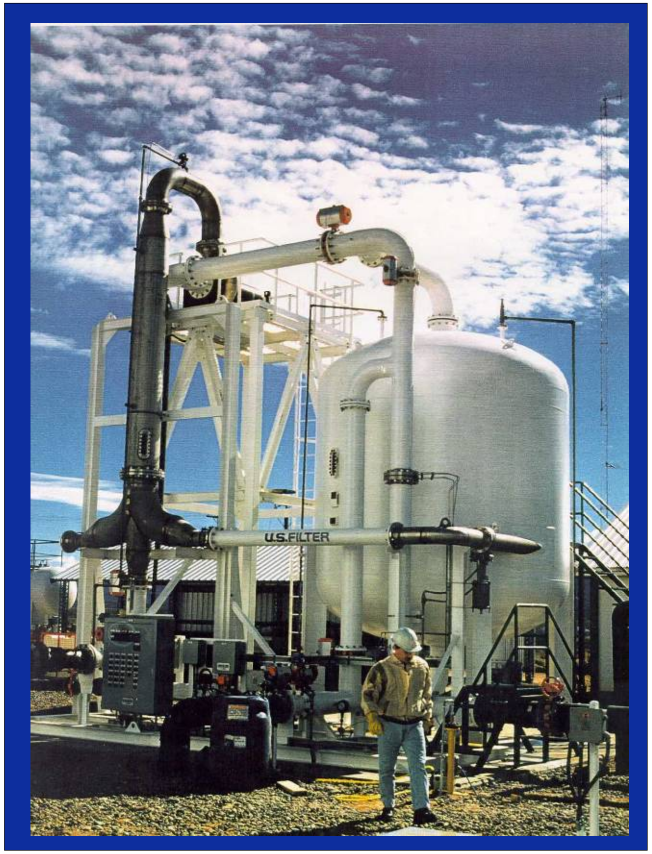
Walnut Shell Filters

■Typical Applications and Operating Conditions

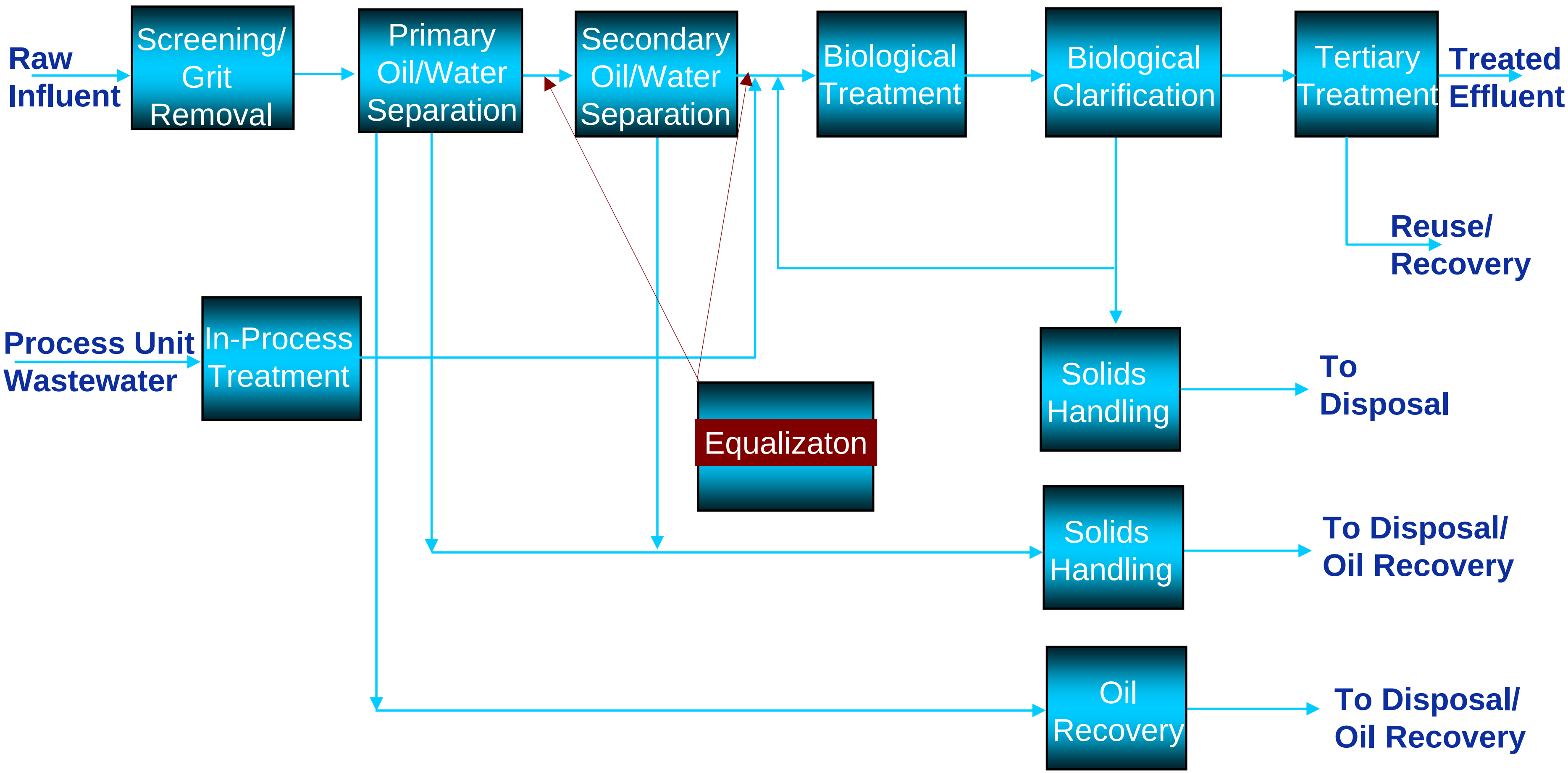
- Typically used in facilities with strict oil discharge requirements, that do not have downstream treatment processes, such as biological treatment.
- Sometimes used with systems that have downstream membrane processes such as MBR.
- Influent oil concentrations less than 100 ppm.
- Effluent oil less than 5 ppm.



Walnut Shell Filters

- **Advantages**
  - Can achieve very low effluent oil concentrations, 1 to 5 ppm.
- **Disadvantages**
  - Not a good TSS removal device.
  - High capital cost.

Typical Oily Water Treatment System



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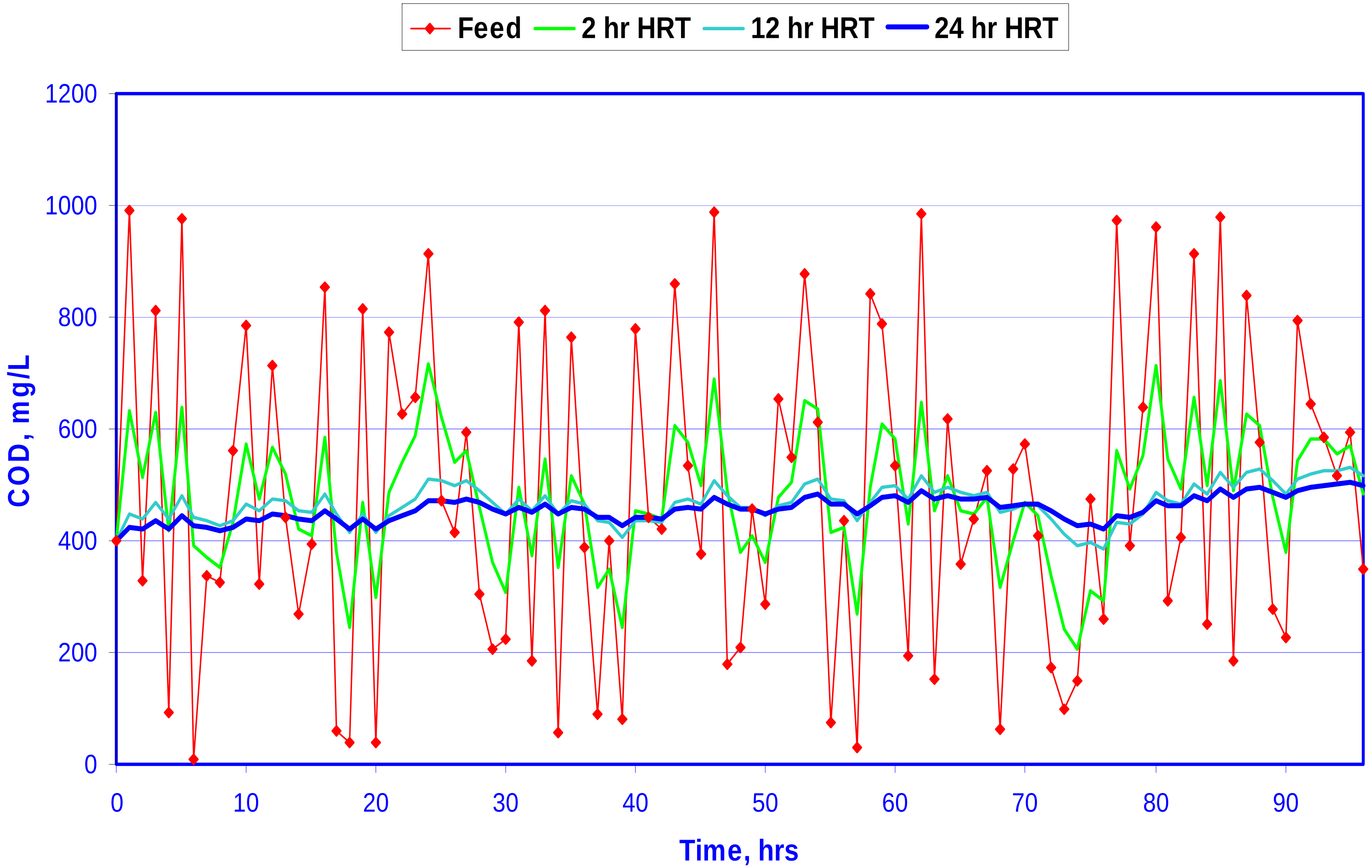
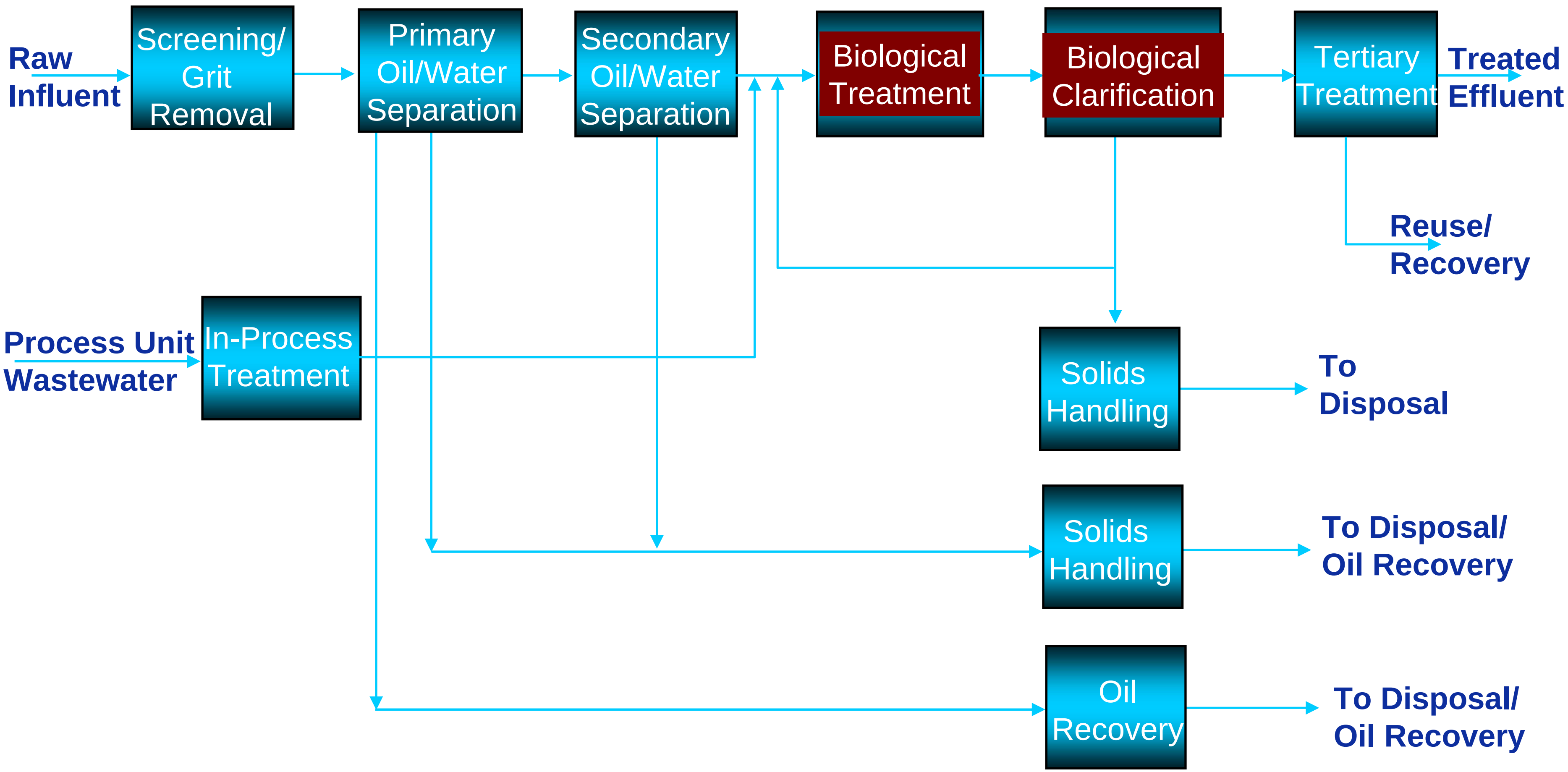
Wastewater Equalization

- Purpose
  - Smooth out variations in flow and contaminants
  - Minimize hydraulic shock loading to WWTP process equipment
  - Minimize contaminant shock loading to biological treatment
- Methodology
  - Typically located after the oil/water separators
  - Flow diversion/control of stormwater
  - Completely mixed fixed volume tank
- Effective volume (retention time)
  - Magnitude of contaminant variation
  - Duration of contaminant variation
  - For petroleum facilities, 12 to 24 hours is desired.

Wastewater Equalization



Typical Oily Water Treatment System



Biological Treatment

- Aeration Devices
- Membrane Bio-Reactors (MBR)

- This information is applicable to both oily wastewater and municipal wastewater treatment.

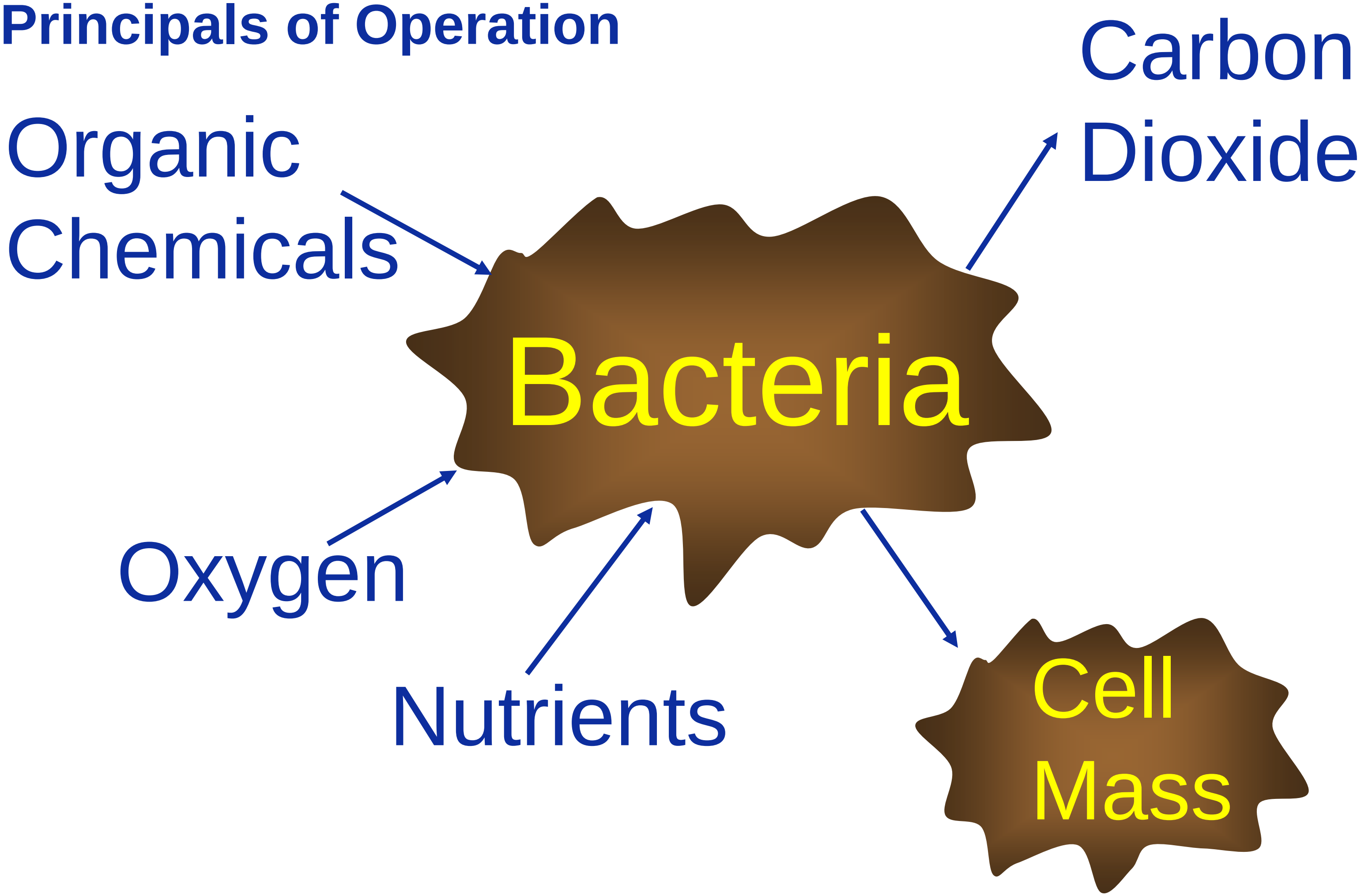
Biological Treatment

■Typical Applications and Operating Conditions

- Designed primarily for removal of biodegradable organic matter, nitrogen and phosphorus compounds, and N_2S
- Normally applied after primary treatment where inert solids and oils are removed from the wastewater.
- Used to achieve effluent BOD and TSS concentrations of 30 ppm or less.
- Effluent COD concentrations are dependent upon the application.

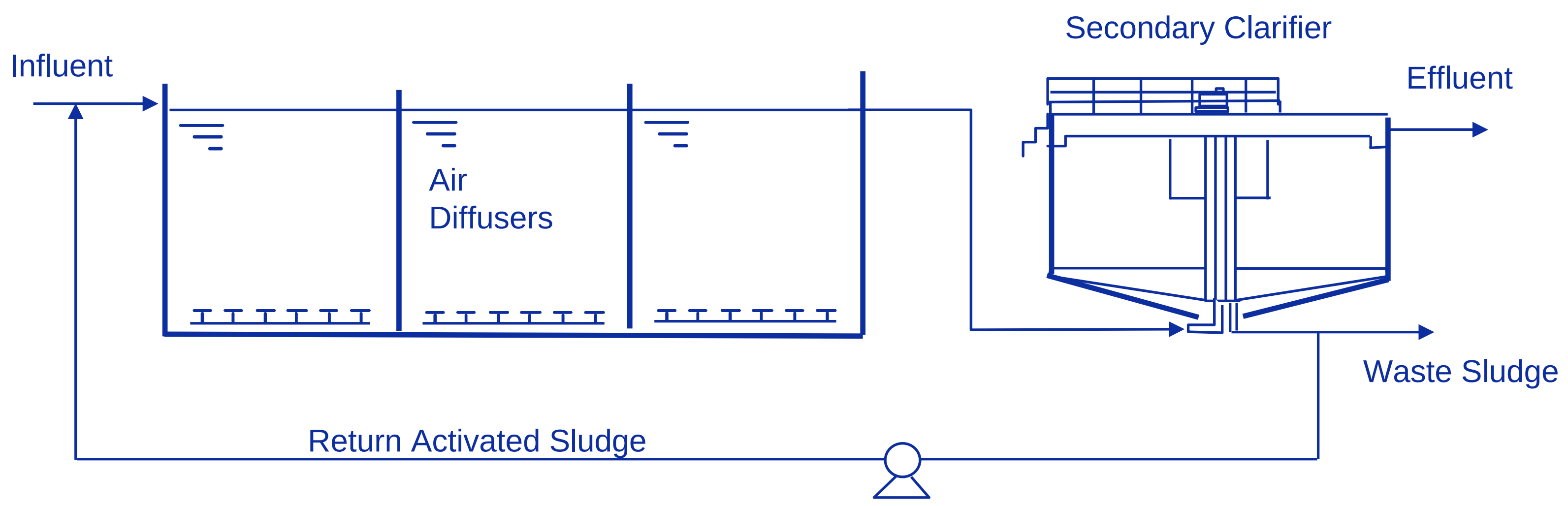
Biological Treatment

- **Principals of Operation**



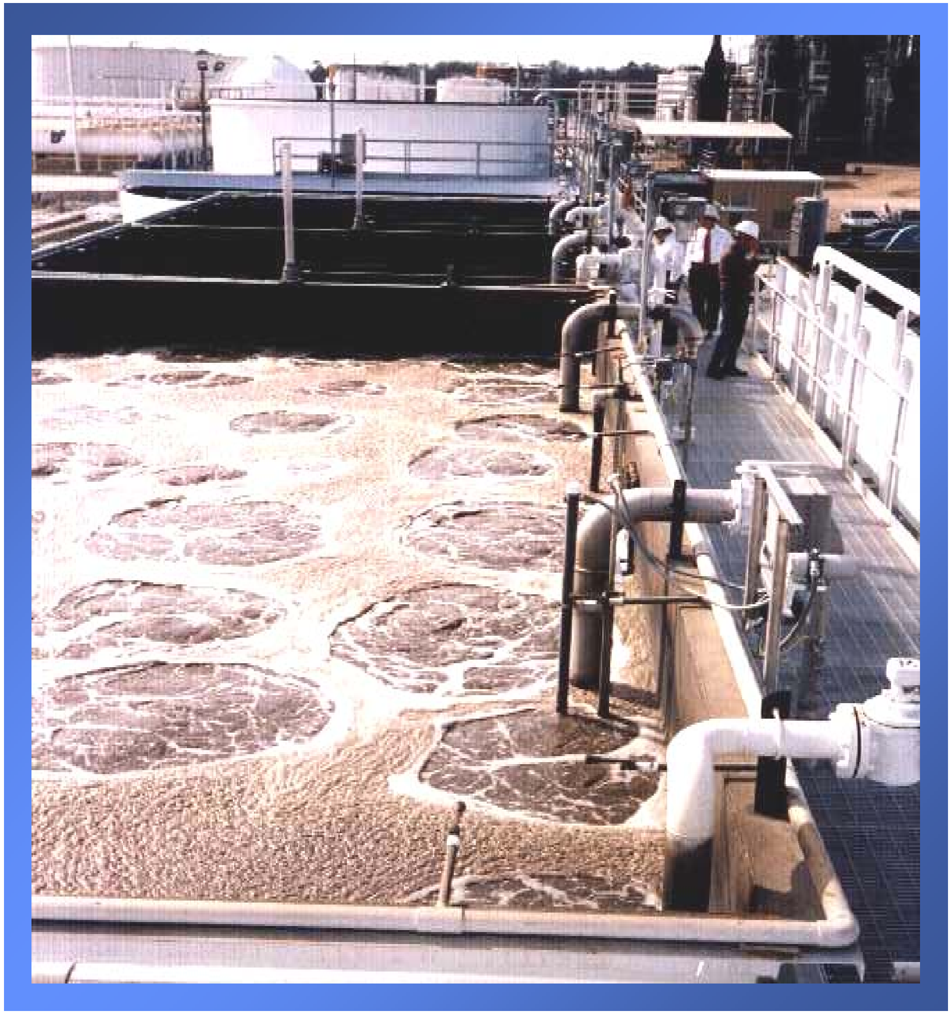
Biological Treatment

■Principles of Operation



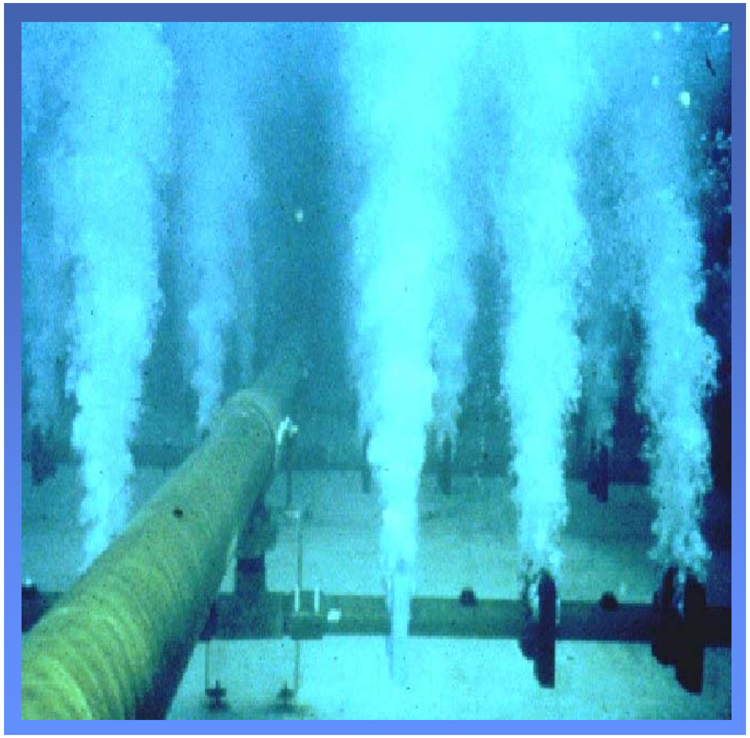
Biological Treatment Options
Fine Bubble Aeration

- **Advantages**
  - **Very high oxygen transfer efficiency (low energy consumption).**
  - **Low VOC and odor emmissions.**
- **Disadvantages**
  - **Diffusers require periodic cleaning.**
  - **The aeration device is submerged and must be removed from the tankage for cleaning.**
  - **Can add heat to wastewater.**



Biological Treatment Options
Coarse Bubble Aeration

- **Advantages**
  - **Non-plug design requires very little maintenance, if any.**
  - **Low O&M costs.**
- **Disadvantages**
  - **Not very energy efficient.**
  - **The aeration device is submerged and must be removed from the tankage for cleaning.**
  - **Can add heat to the wastewater.**
  - **Higher potential for VOC and odor emissions.**



Biological Treatment Options
Jet Aeration

- **Advantages**
  - Non-plug design requires very little maintenance
  - Low O&M costs.
  - Energy efficient.
  - Very good process flexibility.
- **Disadvantages**
  - The aeration device is submerged and must be removed from the tankage for maintenance.
  - Can add heat to wastewater.
  - Requires an external recirculation pump for jet mixing feature.

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Biological Treatment Options
Surface Aerators

- **Advantages**
  - Located above the water surface.
  - Can be maintained without draining the treatment basin.
  - Can provide cooling of hot wastewater.
  - Low costs
- **Disadvantages**
  - Very energy inefficient.
  - Very high potential for odors and VOC emissions.
  - Very large space requirements.

Biological Treatment Options
Oxidation Ditch

- **Advantages**
  - Aeration devices are above the water level and can be maintained without draining the tank.
  - Good process flexibility due to multi-channel design.
  - Can provide good cooling of warm wastewater.
  - Very energy efficient.
- **Disadvantages**
  - Large area requirement.
  - High potential for odor and VOC emissions.

Biological Treatment Options
Powdered Activated Carbon Treatment

- **Advantages**
  - Activated carbon is added to biological treatment systems to remove difficult to degrade organic compounds (COD).
  - Used in conjunction with all previously mentioned biological treatment devices.
  - Very good recovery to upset conditions.
- **Disadvantages**
  - Additional cost for activated carbon.
  - Greater sludge generation.

Biological Treatment Options
Membrane Bio-Reactor

- **Principle of Operations**
  - **Replaces the conventional gravity clarifier.**
  - **Provides an impermeable barrier for solids.**

Biological Treatment Options
Membrane Bio-Reactor

- **Typical Applications and Operating Conditions**
  - **Completely remove unwanted solids greater than 0.1 micron**
    - **Turbidity**
    - **Microorganisms**
    - **Biomass**
    - **Coagulated solids**
    - **Large molecular weight organics**
  - **Removal for**
    - **Meeting discharge regulations**
    - **Enhancing biological processes**
    - **Recycle / reuse opportunities**
    - **BOD < 5 mg/l, TSS < 1 mg/l**
    - **Turbidity < 0.2 NTU**

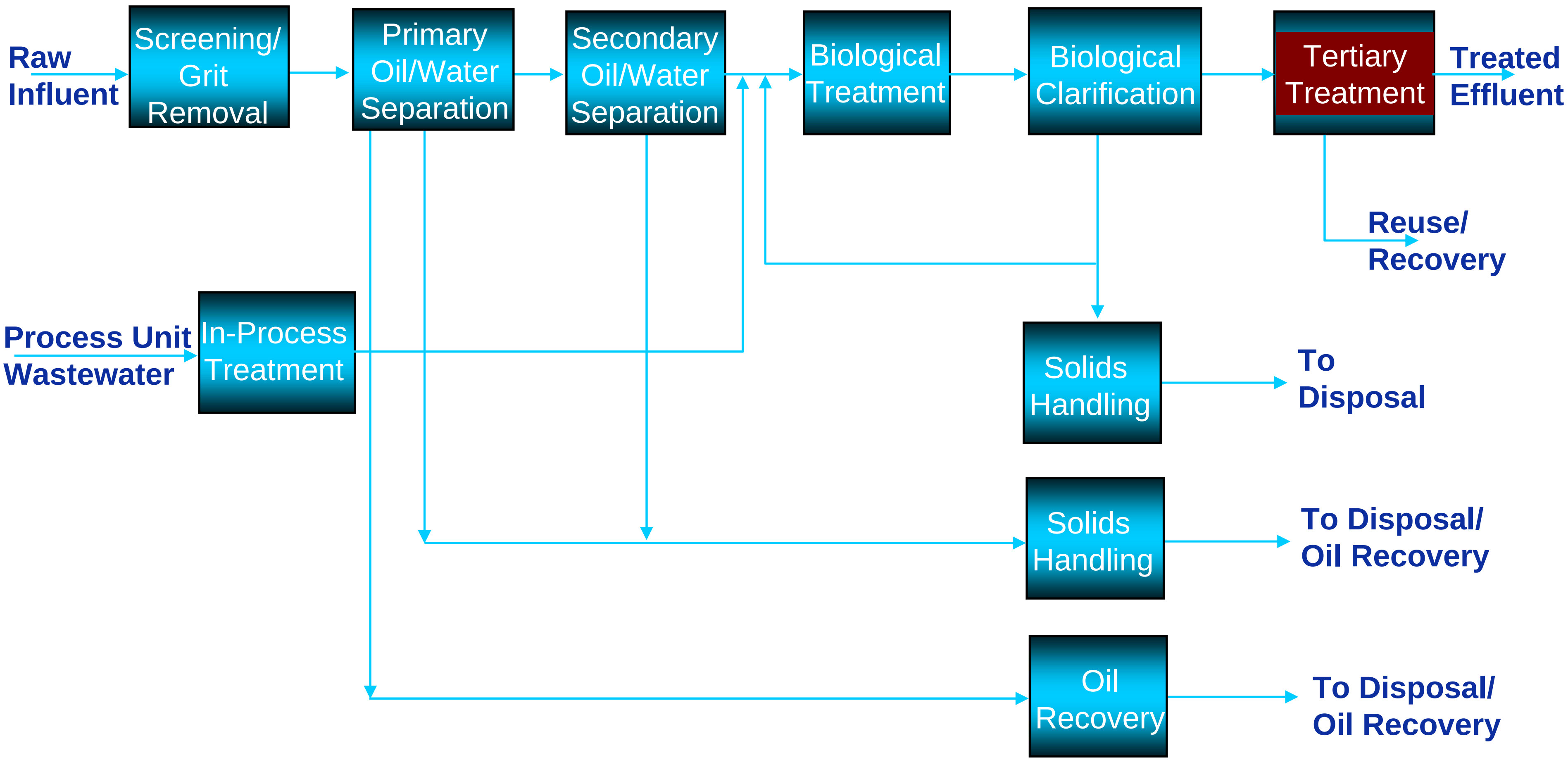
Biological Treatment Options
Membrane Bio-Reactor

- **Advantages**
  - Effluent quality
  - Smaller footprint
  - Lower sludge production.
  - Flexibility to be used with many different aeration processes to achieve desired treatment results.
- **Disadvantages**
  - Capital Costs
  - Chemical Cleaning
  - In petroleum applications, hydrocarbons can negatively impact non-metallic materials

Biological Treatment

Evaluation Parameter	Disc Aeration	Surface Aerator	Fine Bubble Aeration	Coarse Bubble Aeration	Jet Aeration	Sequencing Batch Reactor *	Membrane Bioreactor*	PACT *
Effective Bioassay/Toxicity Control	✓	✓	✓	✓	✓	✓	✓	✓
Effective BOD Removal Efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Effective COD Removal Efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Low O&M Costs				✓	✓			
Low Sludge Production							✓	
Low Sludge Disposal Costs							✓	✓
Good Operability: Winter					✓	✓	✓	
Good Operability: Summer	✓	✓	✓	✓	✓	✓	✓	✓
Good Performance: High Water Temperature	✓	✓					✓	✓
Good Performance: Low Water Temperature					✓	✓	✓	✓
Minimal Operator Attention								
Quick Upset Recovery						✓		✓
Easy Expandability								
Efficient Nitrification	✓		✓	✓	✓	✓	✓	✓
Easy to Cover for VOC Containment			✓	✓	✓			
Low VOC Stripping Potential			✓			✓	✓	✓
Easy Installation		✓						
Minimal Space Requirements			✓	✓	✓	✓	✓	✓

Typical Oily Water Treatment System



Tertiary Treatment

- **Typical Applications**
  - **Provide additional treatment to meet strict wastewater discharge requirements.**
  - **Provide additional treatment to allow wastewater to be reused.**
- **Typical Treatment Methods**
  - **Media Filtration**
  - **Activated Carbon**
  - **Microfilter Membranes**

Media Filters

■Principle of Operation

- Gravity or pressure design with granular media bed
- One to three layers (coarse to fine) of filtration media
- Flows from top, through media, out the bottom
- Large capacity and low pressure drop
- Suspended solids captured in media bed
- Suspended solids removed by backwashing
- Air scour may also be used to increase backwashing effectiveness

Media Filters

■Typical Applications and Operating Conditions

- Filtration of:
  - Biological effluent
- Inlet parameters
  - Solids < 30 mg/L
  - Turbidity < 30 NTU
  - Particles > 10 micron
- Outlet parameters
  - Solids < 5-10 mg/L
  - Turbidity < 1 NTU
  - Particles 2 - 5 micron
    98% removal
  - Requires coagulant or flocculent feed

Media Filters

- **Advantages**
  - **Can operate at very high rates approaching 10 gpm/ft2.**
  - **Very good turbidity control.**
- **Disadvantages**
  - **Not recommended for oil removal. High oil concentrations can plug and foul media to the point it needs to be replaced**

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Carbon Adsorption

- **Principle of Operation**
  - **Very high surface area per unit volume**
    - **One pound (one liter) has enough surface area to cover more than 80 soccer fields.**
  - **Hydrophobic surface**
    - **Poor affinity for water**
    - **Strong affinity for organic compounds.**
  - **Used for adsorption of organic compounds, particularly dissolved organics.**

Carbon Adsorption

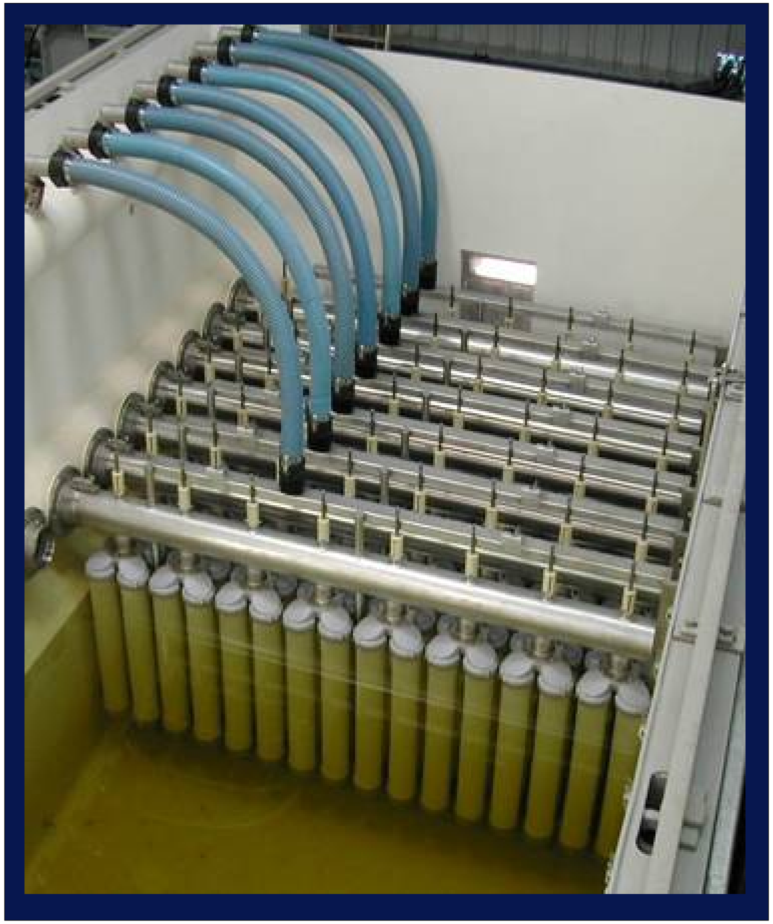
- **Typical Applications and Operating Conditions**
  - Wastewater treatment to remove difficult to degrade organic compounds after biological treatment.
  - Carbon can be added to the biological treatment as PACT (Previously discussed) or can used to polish biological effluent.
  - Typically used in low strength and low flow conditions to avoid high carbon consumption.
  - Carbon can be reactivated through incineration or steam contact.

Carbon Adsorption

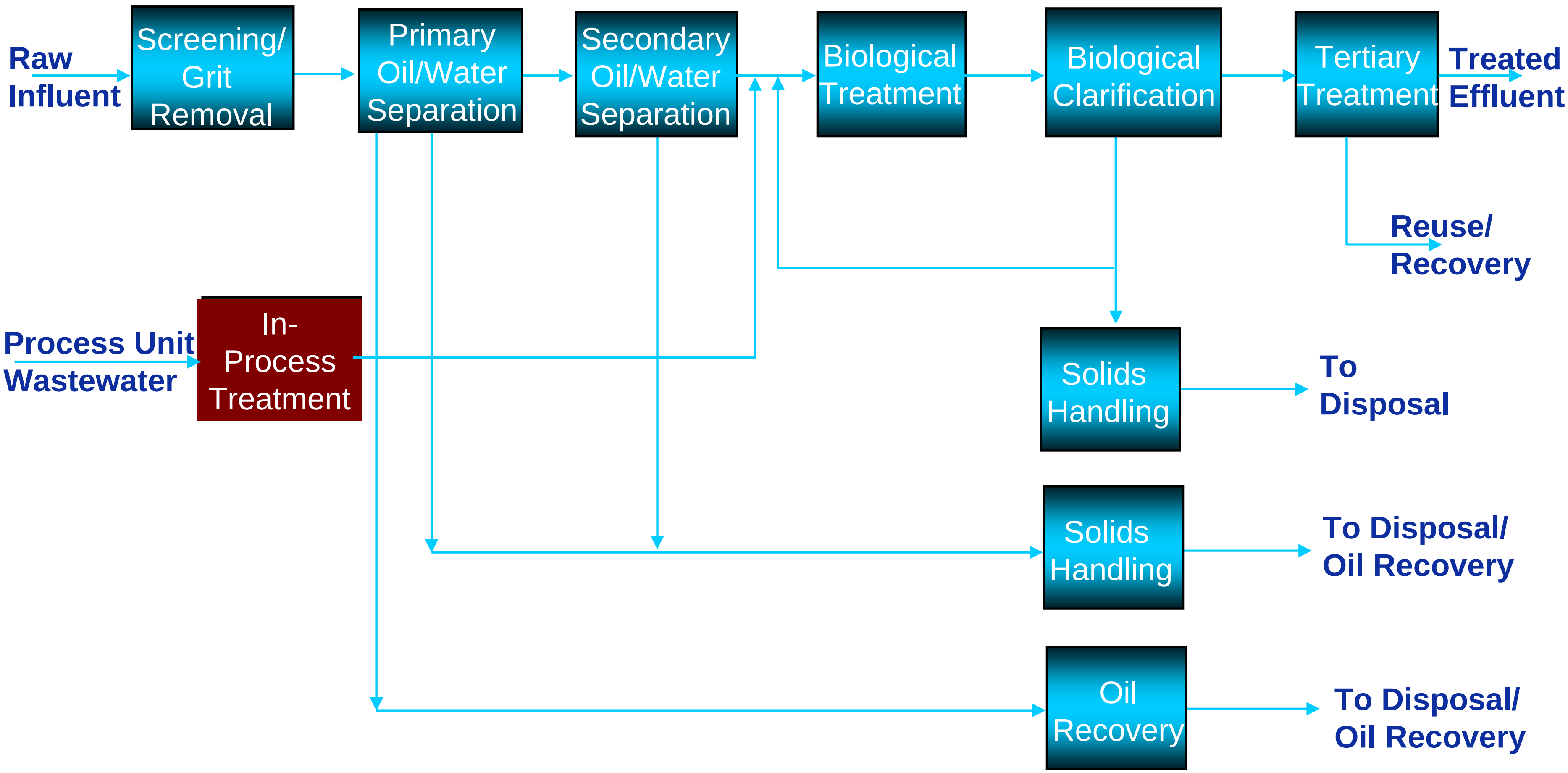
- **Advantages**
  - **Extremely high removal of non-biodegradable organic compounds.**
  - **Lower capital costs.**
- **Disadvantages**
  - **To keep operations costs low, a incineration reactivation facility should be close by.**
  - **High operating costs.**
  - **Carbon handling facilities required.**
  - **Requires media filters as pretreatment to remove TSS.**

Microfiltration

- **Typical Applications and Operating Conditions**
  - **Operates very similar to an MBR, but since the solids loading is lower, the flux rate is higher.**
  - **Completely remove unwanted solids greater than 0.1 micron.**
  - **BOD < 5 mg/l, TSS < 1 mg/l**
  - **Turbidity < 0.2 NTU**
  - **Higher capital costs than media filters or carbon filters.**
  - **Great for expansion of existing biological treatment systems**



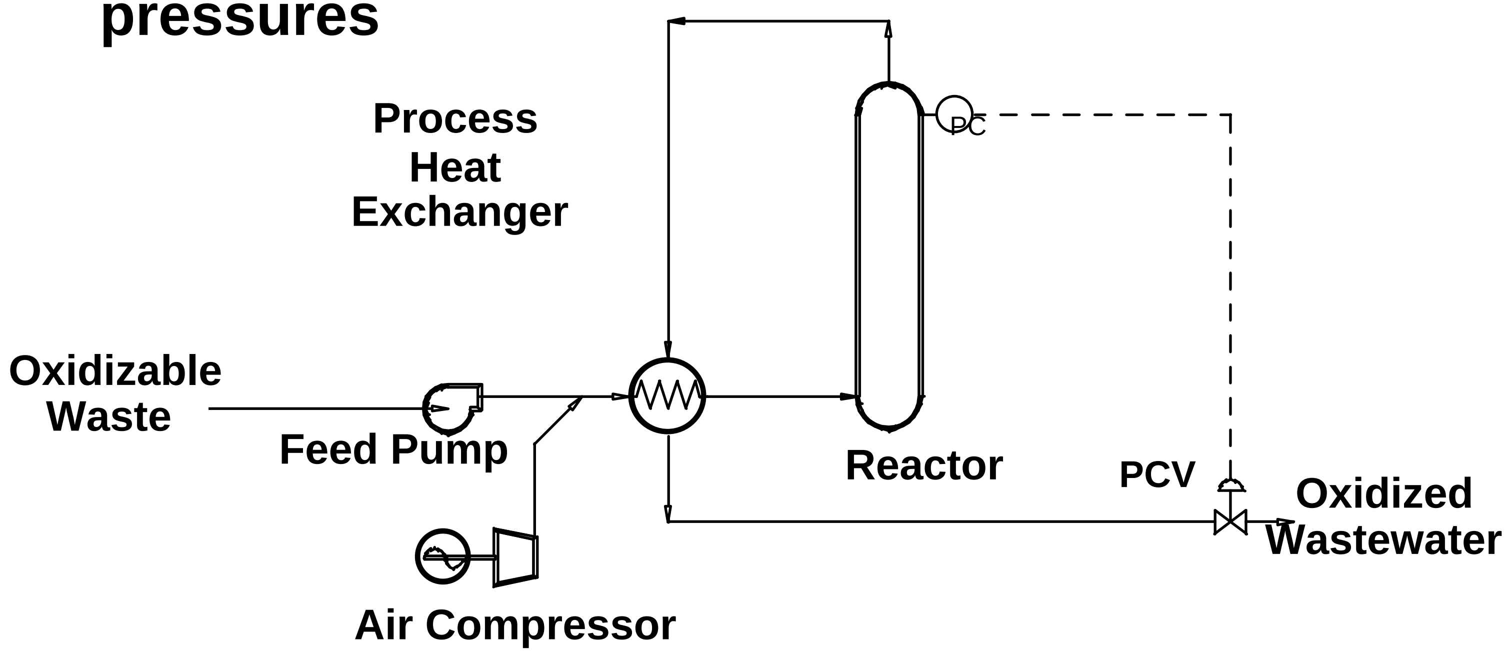
Typical Oily Water Treatment System



Wet Air Oxidation

■Principle of Operation

- Oxidation of soluble or suspended oxidizable components in an aqueous matrix
- Oxygen (air) is the oxidizing species
- Oxidation reactions occur at elevated temperatures and pressures



Wet Air Oxidation

■Typical Applications and Operating Conditions

- **Refinery and Ethylene Spent Caustic**
  - **Reactive sulfides - odor**
  - **Problematic for biological treatment**
  - **High COD load**
- **Refinery Spent Caustic**

Inorganic Sulfides as S %	0 to 4
Mercaptides %	0 to 4
Salts of Cresylic Acids %	0 to 20
Salts of Napthenic Acids %	0 to 10
NaOH %	1 to 15
COD mg/l	50,000 to 400,000
pH	13 to 14

Wet Air Oxidation

■Typical Results

Refinaria de Petroleos de Manguinhos S.A.
Rio de Janeiro, Brazil

	Feed	Effluent
COD, mg/l	114,000[1]	23,186
COD Reduction	NA	80%
Sulfide - S, mg/l	24,560	<1[2]
Phenol	456	<2[2]
Thiosulfate - S_2O, mg/l	2,460	<125[2]

[1] **Raw spent caustic COD at 186,500 mg/l diluted to 114,000 mg/l prior to wet air oxidation**
[2] **Detection limit**

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Thank You!