WASTE TREATMENT OF METALWORKING FLUIDS

6th International Metalworking Fluids Conference

Quaker Houghton™
Forward Together™

John Burke CMFS, FSTLE

Wastewater Treatment Options

- Basic Thermal Evaporation
- Vapor Compression Distillation
- Ultrafiltration
- Chemical Treatment
- Oil Sludge Treatment

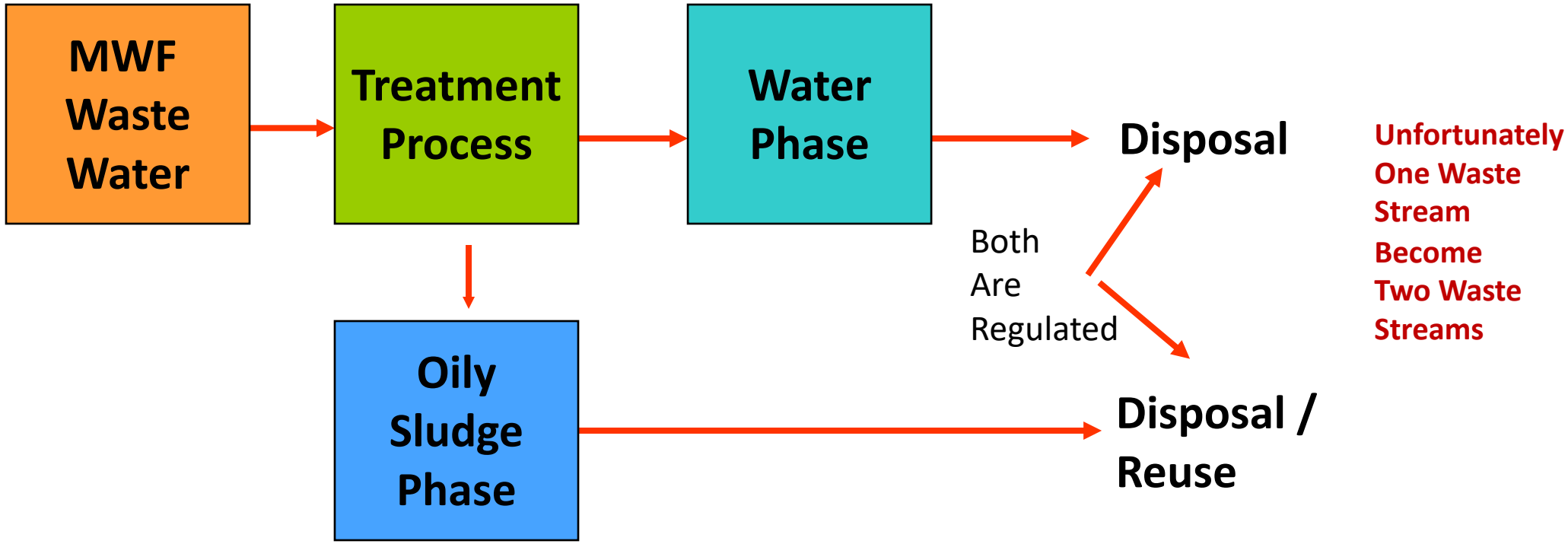
THE PERFECT METALWORKING FLUID:

Biostable
No corrosion
Minimal residue
No dermatitis – excellent worker acceptance
Low foaming
Excellent tool life and surface finish
Competitive cost

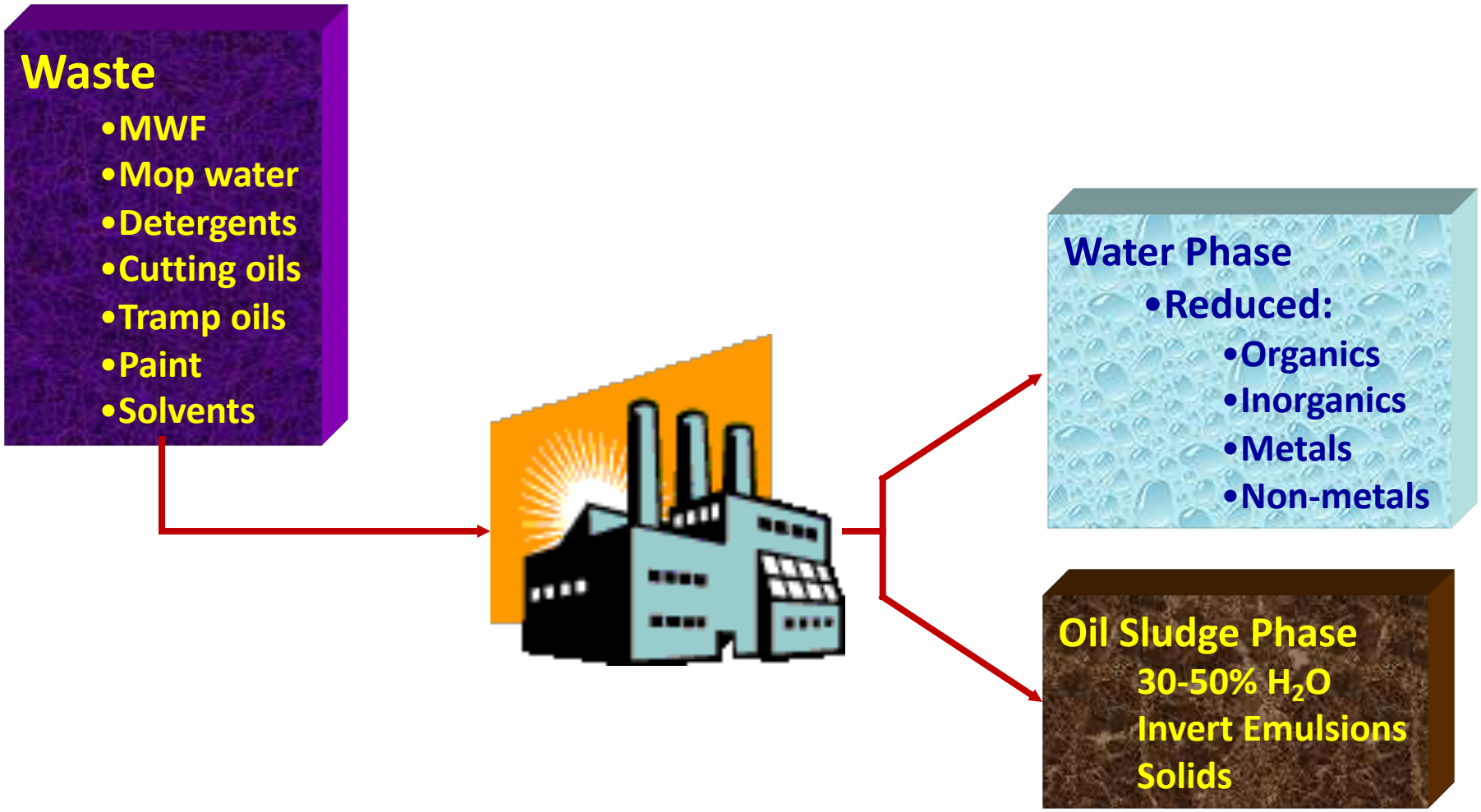
WARNING!

THAT PERFECT FLUID CAN BE REJECTED BY THE CUSTOMER IF IT CANNOT BE WASTE TREATED ON SITE OR IS TOO EXPENSIVE TO HAUL

MWF Waste Treatment



MWF Wastewaters Typically Include More Than MWFs



Contaminants In Metalworking Wastewaters

- Hydrocarbon Products (Floatable, Suspended / emulsifiable, and Settleable Organics)
  - Petroleum Oils, Vegetable Oils, Animals Oils, Waxes, Fatty Acid Soaps (Ca, Fe, Al), Chlorinated Esters and Paraffins
- Floatable, Suspended, and Settleable Solids
  - Graphite, Vibratory Debur, Floor "Dirt"
- Metals
  - Iron , Aluminum, Copper, Lead, Chrome, Zinc, Nickel, Manganese, Molybdenum
- Non-metals
  - Arsenic, Selenium
- Dissolved Solids
  - Salts (Sodium and Potassium Salts)
- Dissolved Organics
  - Amines, Amides, Esters, Glycols, Surfactants, Detergents, Fatty Acids, Fatty Alcohols, Antimicrobials, Phosphate Esters

Increasing Solubility

Increased Difficulty In Removal From Water

Commonly Regulated Organic Pollutants

- BOD_5 Biochemical Oxygen Demand – five day
- COD Chemical Oxygen Demand
- O&G Oil & Grease - Hexane Extractable Materials (HEM)
  - ➞ FOG Fats, Oil and Grease (Old terminology)
- TPH Total Petroleum Hydrocarbons, Silica Gel Treated (TPH SGT)
- TSS Total Suspended Solids
- TTO Total Toxic Organics (For Categorical Dischargers)

Commonly Regulated Inorganic Pollutants

- Al Aluminum
- Fe Iron
- Ag Silver
- Ni Nickel
- Pb Lead
- Zn Zinc
- Cu Copper
- Cd Cadmium
- Hg Mercury

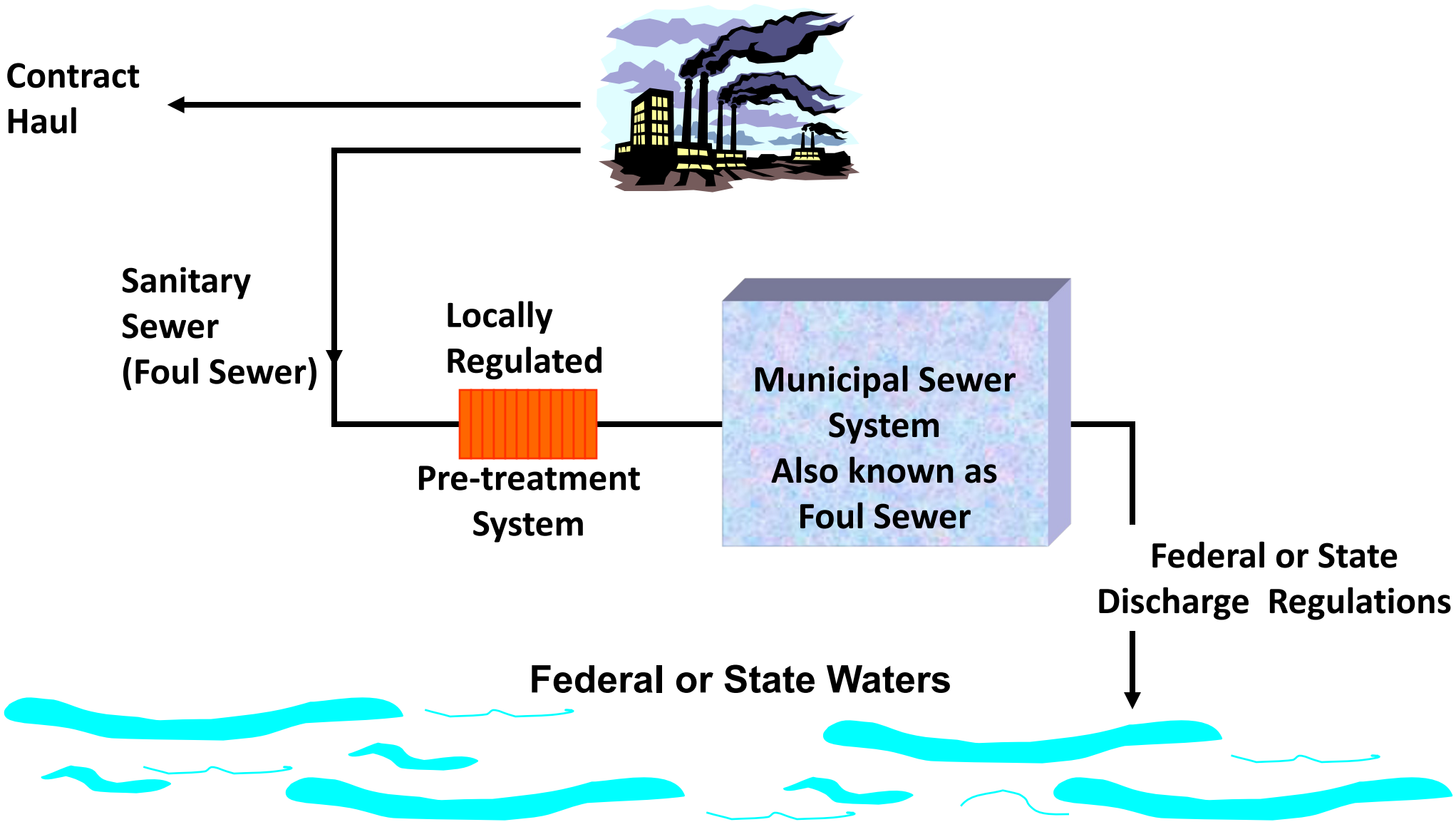
- CN Cyanide
- As Arsenic
- Se Selenium
- NO_3 Nitrate
- SO_4 Sulfate
- NH_3 Ammonia
- P Phosphorus
- N Nitrogen

Increased Regulatory Interest

Typical Pollutant Limits

- **BOD5** — **250 mg/L**
- **COD** — **500 mg/L**
- **Total Suspended Solids** — **250 mg/L**
- **Oil & Grease** — **10 to 100 mg/L**
- **Metals** — **Varies per metal and location**
- **Other Inorganics** — **Varies per organic and location**
- **pH** — **5.5 to 9.0**
- **Remember…..It Depends on Location**

Regulatory Model Example



MWF Pollutant Properties

Mixed 5% by volume

FLUID	BOD5	COD (mg/L)	O&G	pH	
A	15,000	500,000	35,000	8.7	Basic Emulsion
B	26,500	1,100,000	29,000	8.9	Premium Emulsion
C	13,500	45,000	3,500	9.3	Semi -Synthetic
D	9,500	30,000	900	9.2	Synthetic

A =	Basic Emulsified Oil	80%	oil
B =	Premium Emulsified oil	65%	oil
C =	Semi Synthetic	10%	oil
D =	True Solution Synthetic	0%	oil

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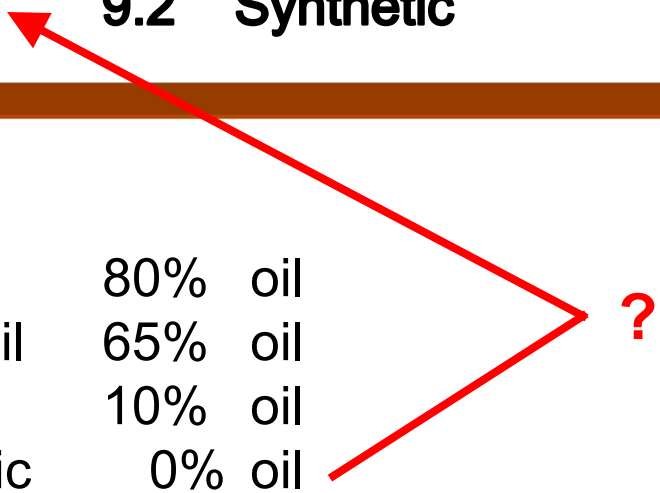

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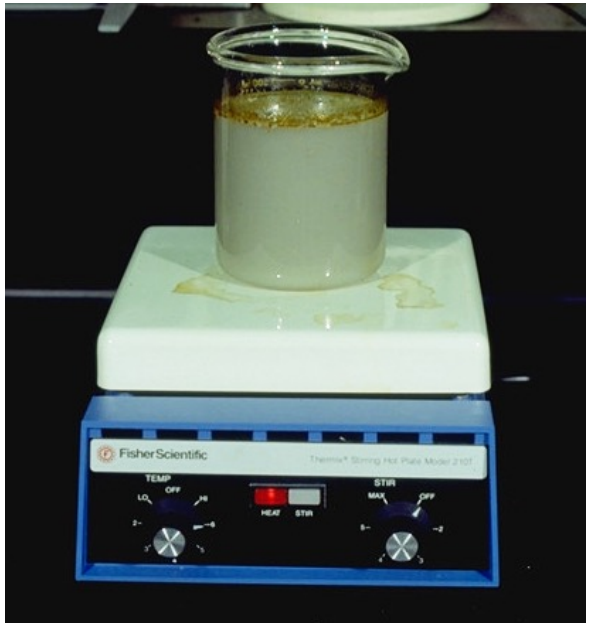
Wastewater Treatment

- **Evaporation Method**

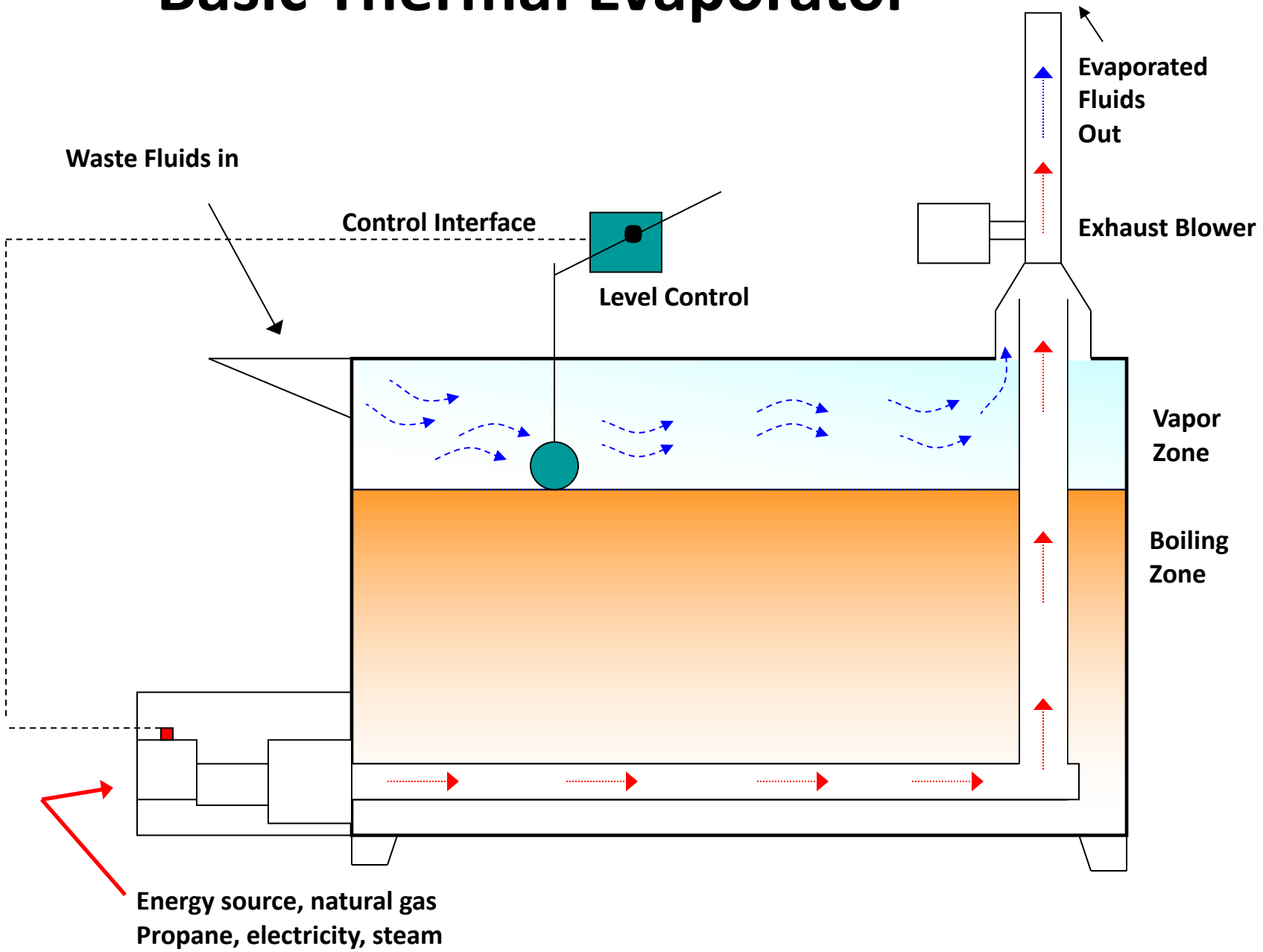
Basic Thermal Evaporation

- **Objective:**

  Concentrate waste by evaporating water phase



Basic Thermal Evaporator



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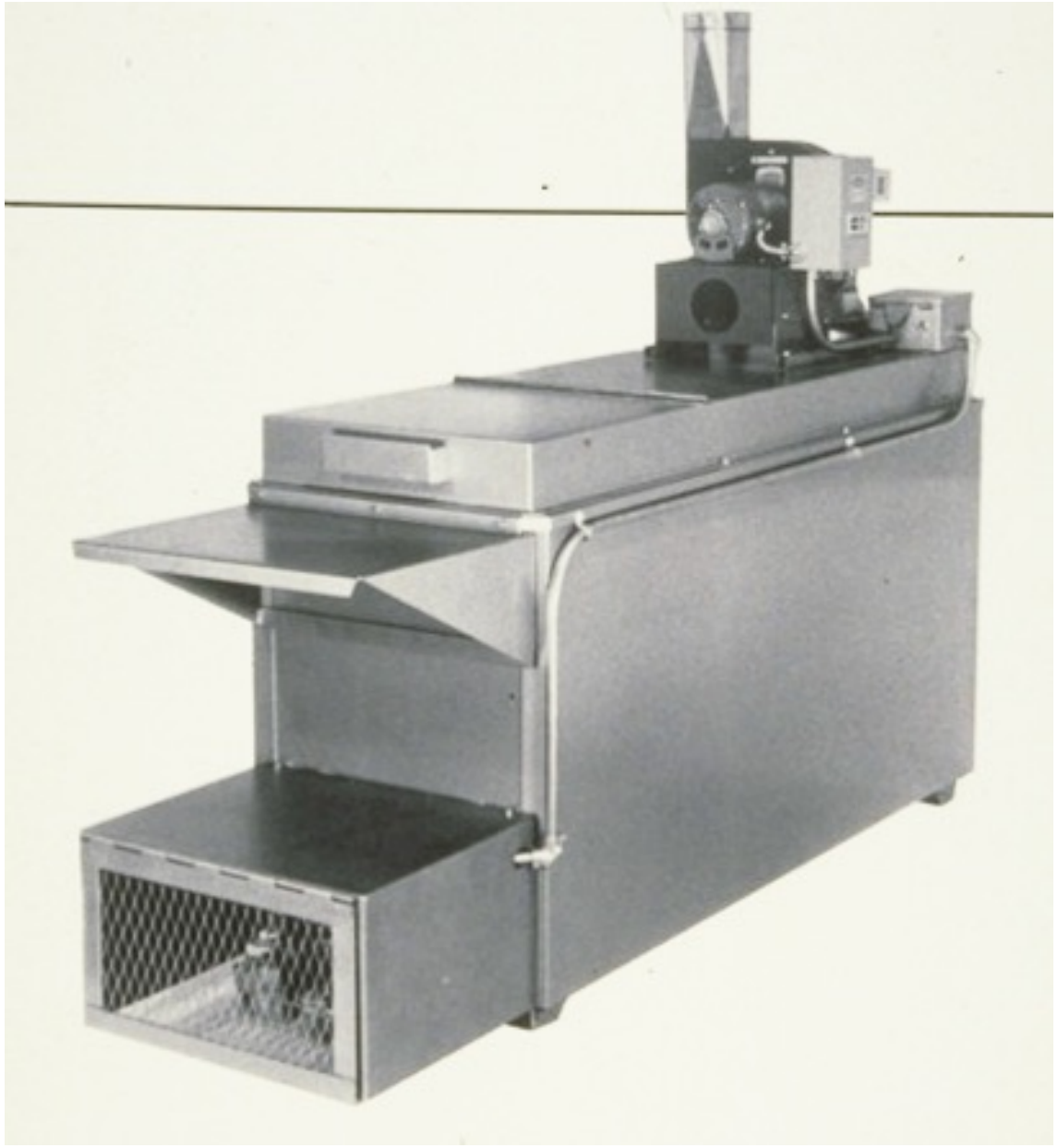


Basic Thermal Evaporation Process

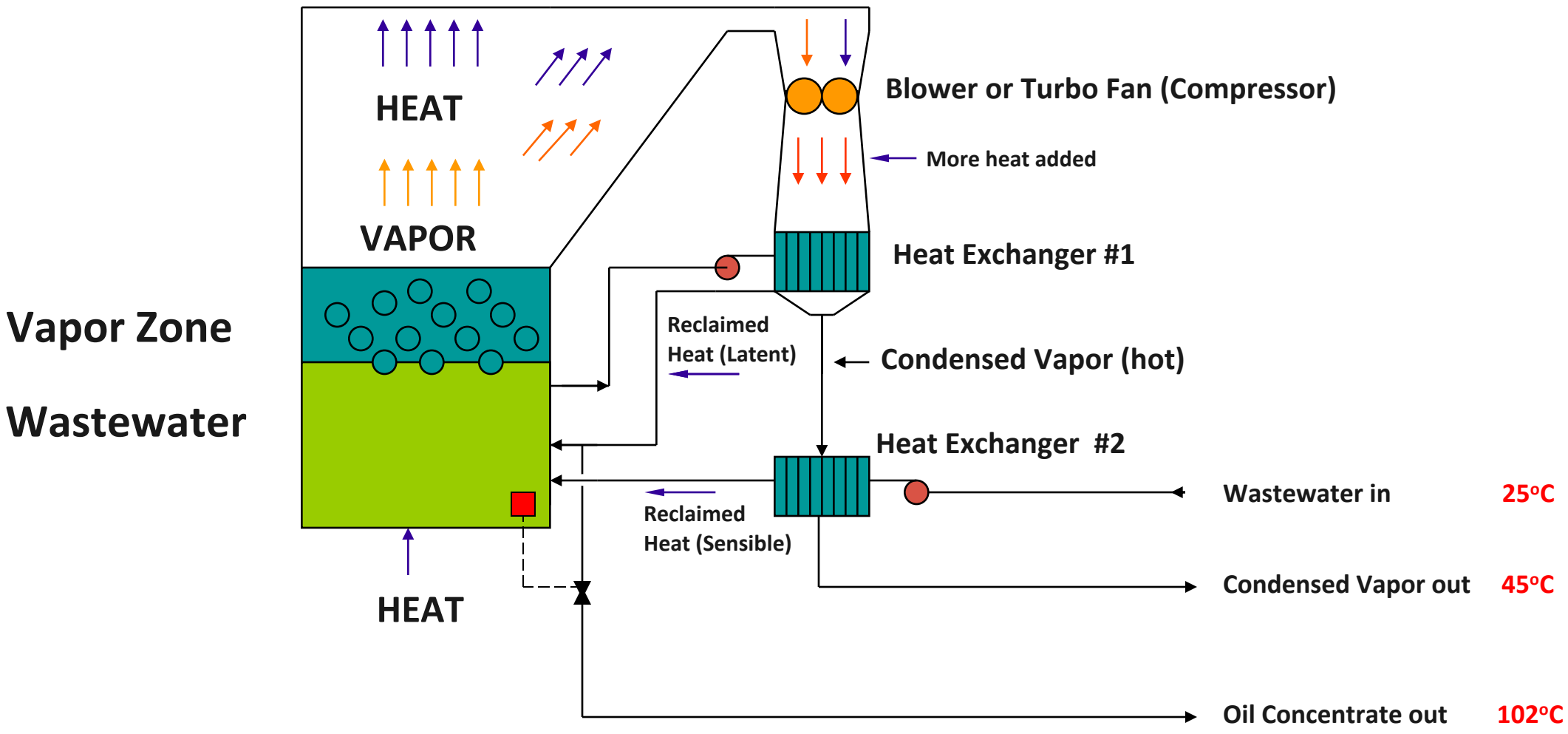
- **Advantages**
  - **Concentrates waste**
  - **Eliminate sewer discharge**
  - **Easy operation**
  - **Low capital cost**
  - **Low H_2O in sludge**
  - **Unaffected by solids**

- **Disadvantages**
  - **Fire or explosion hazard**
  - **Foam**
  - **High treatment cost**
  - **Energy intensive**
  - **Air pollution permit**
  - **Corrosion, Chlorides**
  - **Odors**
  - **Suitable for low volumes**
  - **Volatile liquids will follow distillate**

Vapor Compression Distillation

- Distillation with heat recovery (92%)
- Flows up to 400,000 liters per day
- Partial mechanical method to oil/water separation
- Extremely high oil sludge content
- (80 +%)
- Treated effluent (water phase) can be recycled to non-critical processes
- Much more energy efficient than basic thermal evaporation

Basic Vapor Compression Distillation



100,000 Liter per Day Vapor Compression System

Location
Caterpillar East Peoria, Illinois USA

100,000 Liter per Day Vapor Compression System

Location
Caterpillar East Peoria, Illinois USA

Vapor Compression Distillation

- Advantages
  - No / low metals in discharge
  - Extremely low BOD and COD in discharge
  - No oil in discharge
  - Unaffected by solids
  - Relatively compact
  - Low H_2O in sludge
  - Low cost to treat
  - Not energy intensive
  - No odors
  - No fire risk
  - No air permit
  - Concentrates waste 80%

- Disadvantages
  - Foam
  - Higher capital cost over basic evaporation processes
  - Volatile liquids will flash over

Evaporation / Distillation
Cost to Operate (US Dollar / 1000 liter)

Basic Thermal Evaporation	**$ 32.00** [1]
Vacuum Assist – Thermal Evaporation	**$ 21.00** [1]
Vapor Compression Distillation	**$ 2.60** [2]

1. **Primary energy source is natural gas / methane - CH_4**
2. **Primary energy source is electricity**

Evaporation Method

Effects on Effluent (Distillate)

FLUID	BOD_5		COD		O&G		pH
	Before	After	Before	After	Before	After	
A	15,000	50	500,000	200	35,000	15	8.7
B	26,500	150	1,100,000	400	29,000	150	8.9
C	13,500	110	45,000	320	3,500	140	9.3
D	9,500	30	30,000	190	900	<1.0	9.2

A = Basic Emulsified Oil 80% oil
B = Premium Emulsified oil 65% oil
C = Semi Synthetic 10% oil)
D = Synthetic 0% oil

Wastewater Treatment

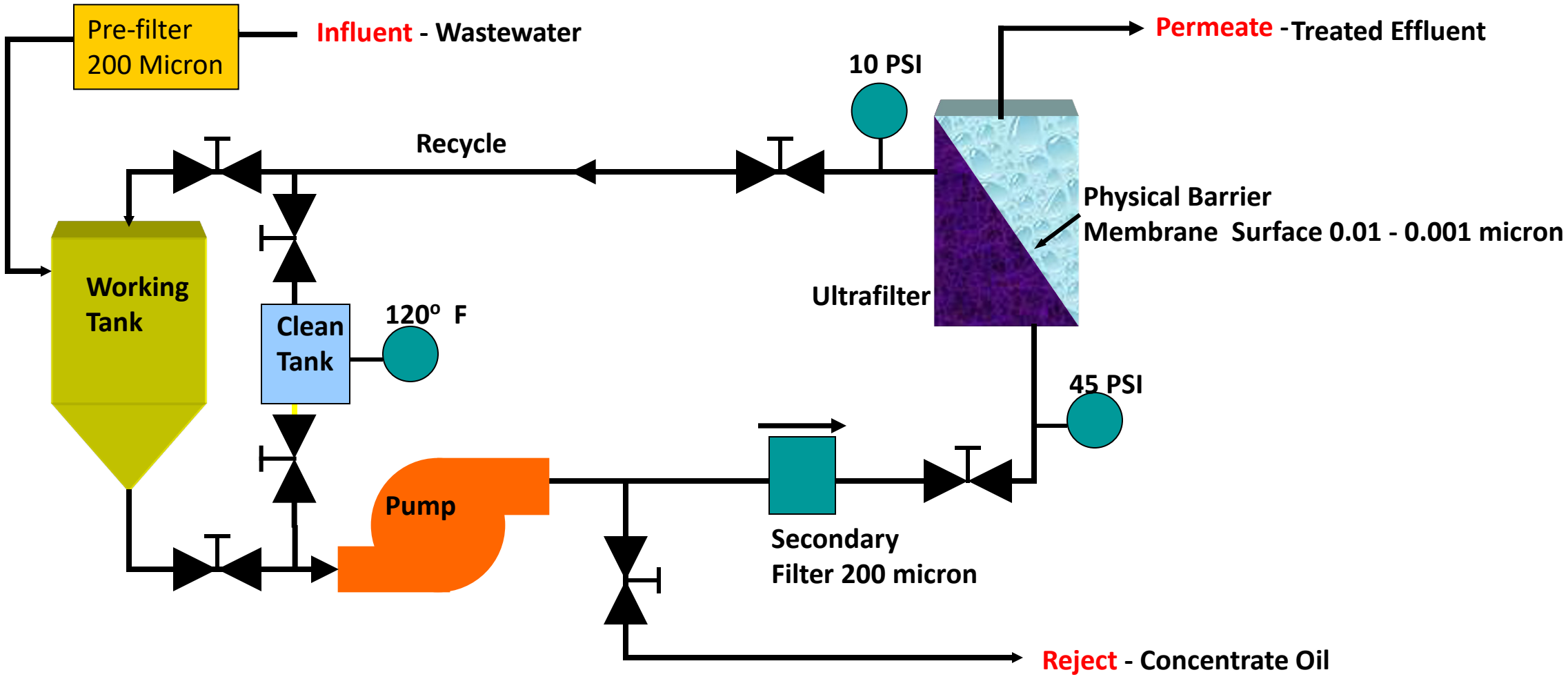
- **Ultrafiltration**

Ultrafiltration

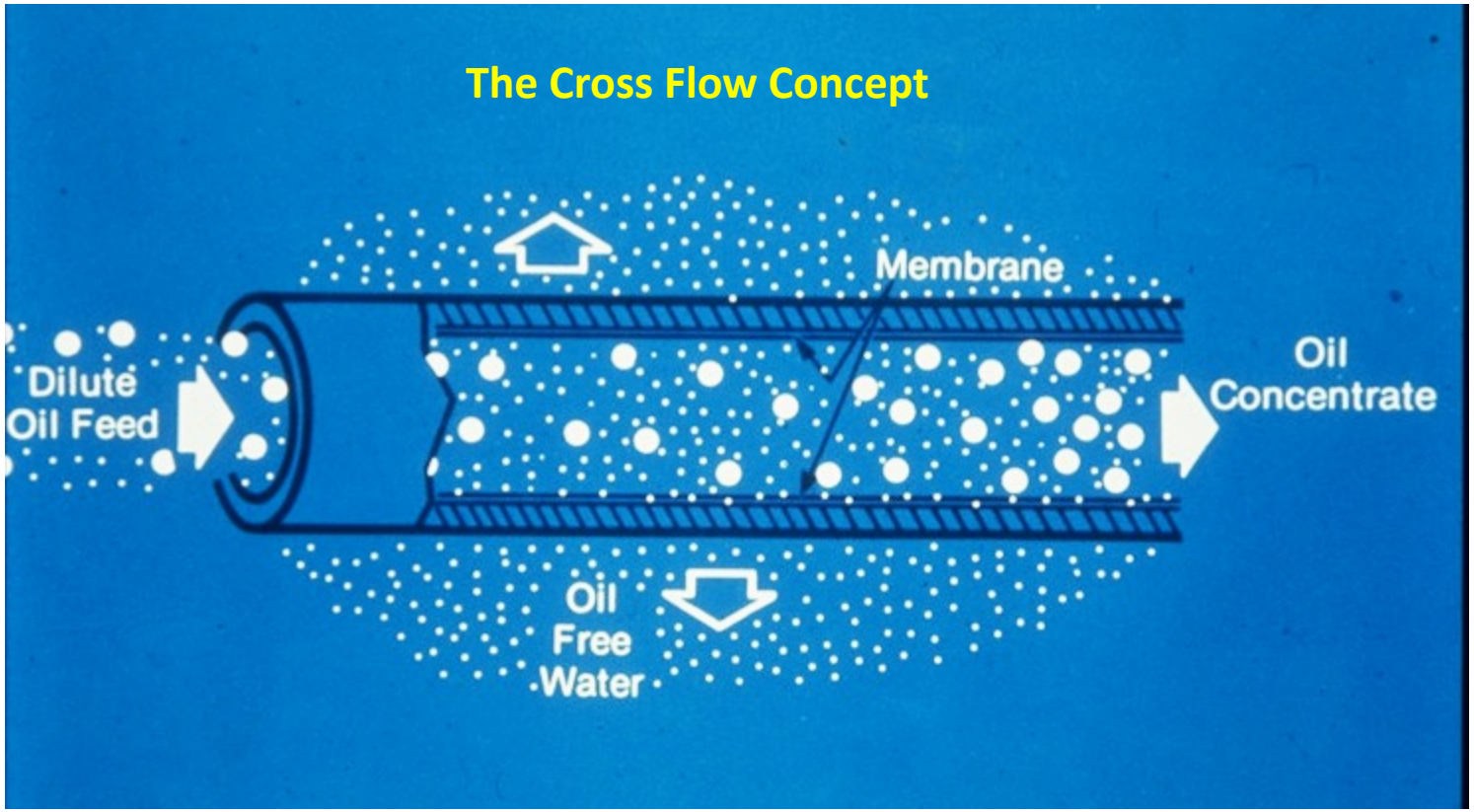
- **Method:**

  Separate oil and suspended solids from water using a physical barrier

Basic Ultrafilter Flow Schematic



Ultrafiltration



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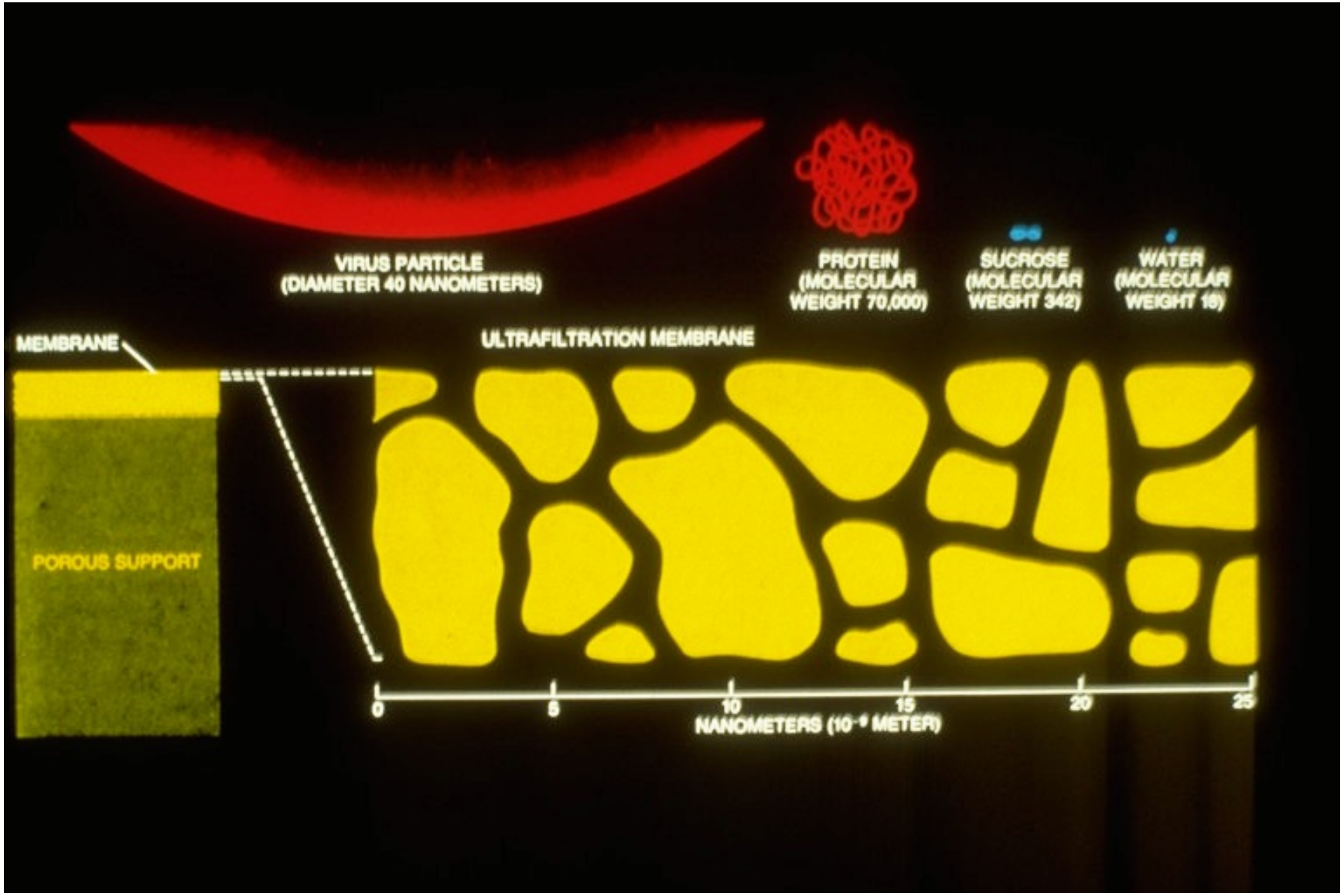
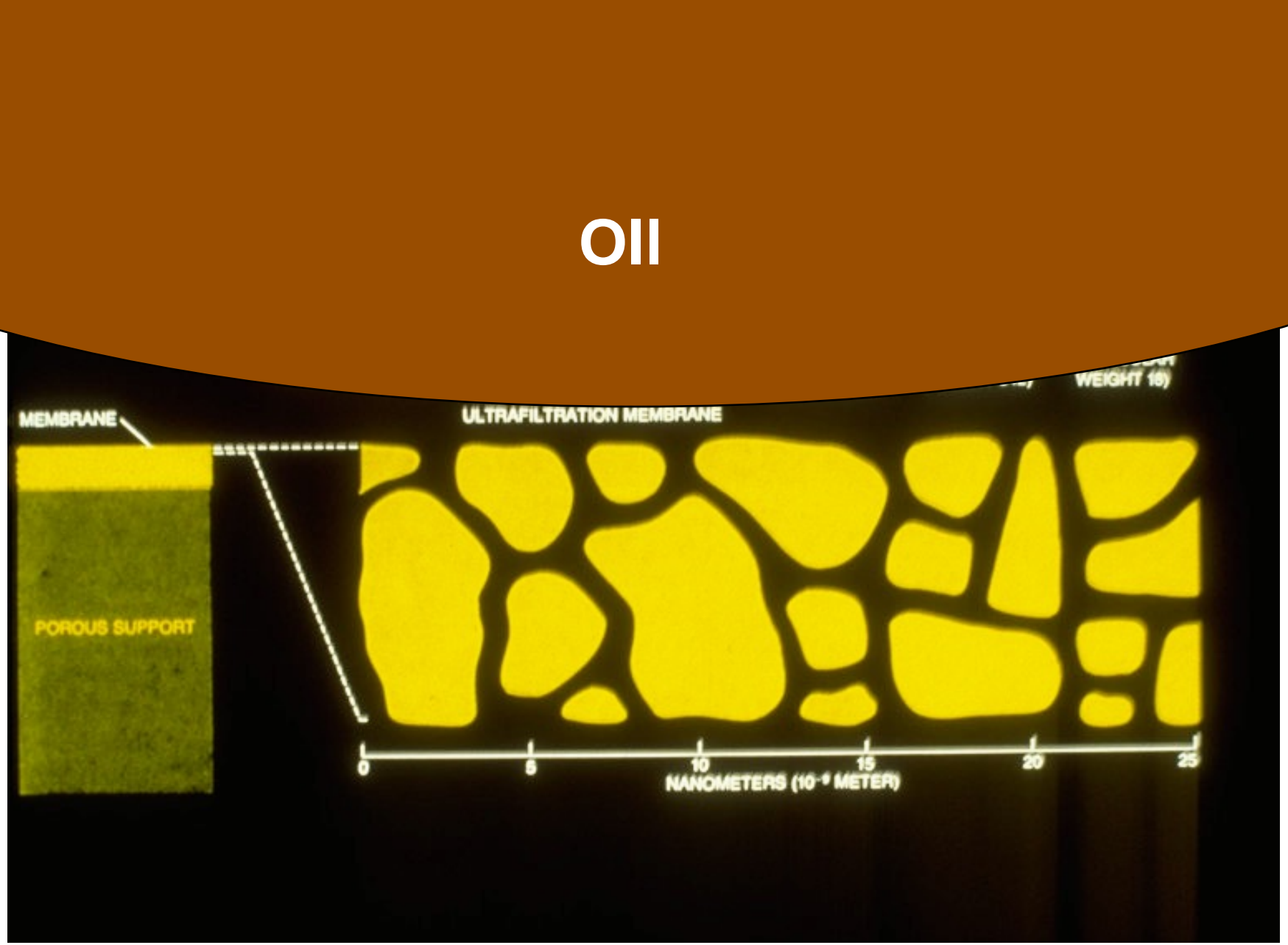


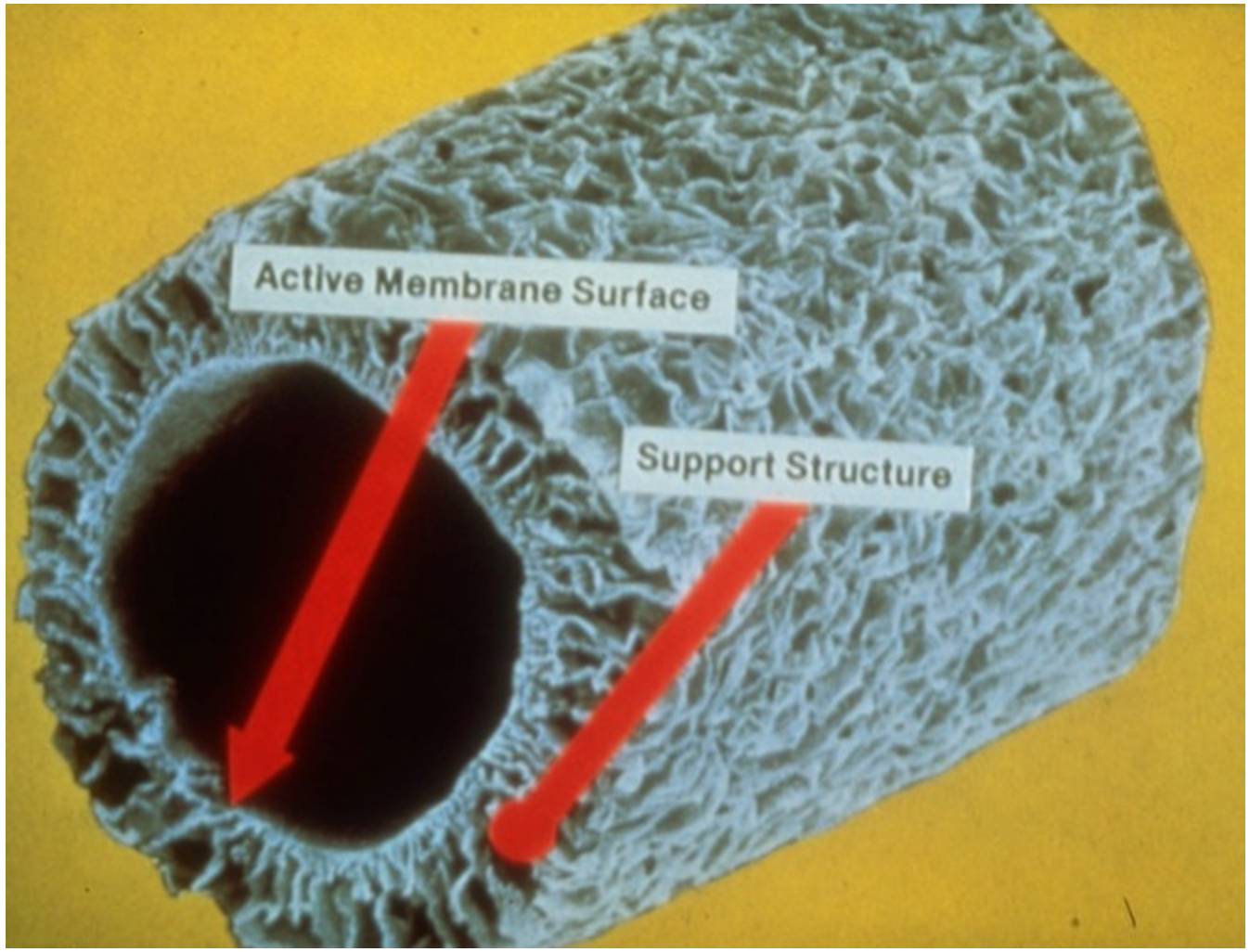
Oil

Oil
Droplet
Relative size



Ultrafiltration - 1 Inch Tube -

- Wide Channel -



Ultrafiltration - 1 Inch Tube -

- Wide Channel -

Ultrafiltration 1 Inch Tube Installation

3,000 liters / day

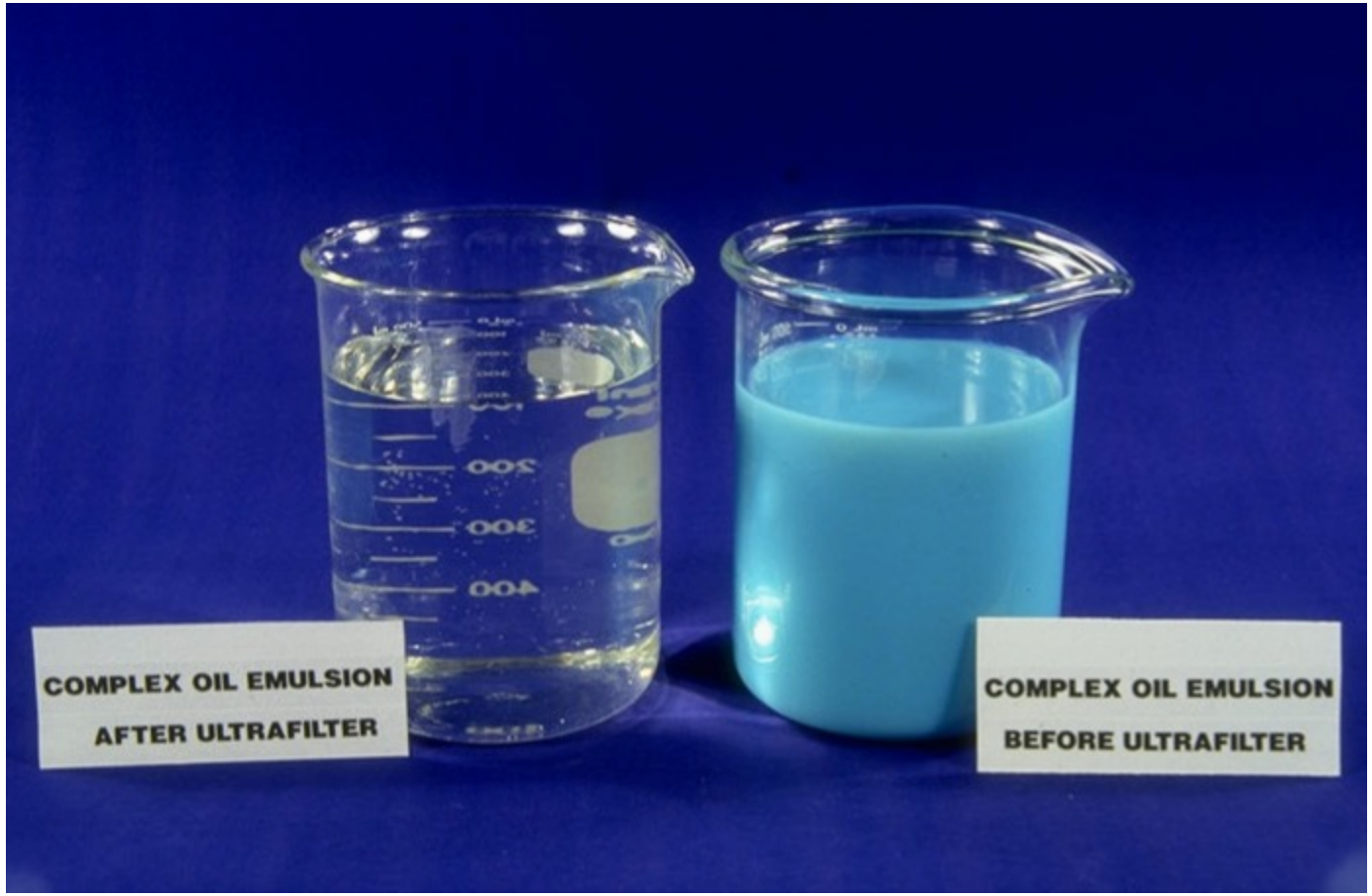
Ultrafiltration - Spiral – Narrow Channel Installation

150,000 liters / day

Location
Dana Corporation
Glasgow, Kentucky, USA

Ultrafiltration Process

Ultrafiltration Process



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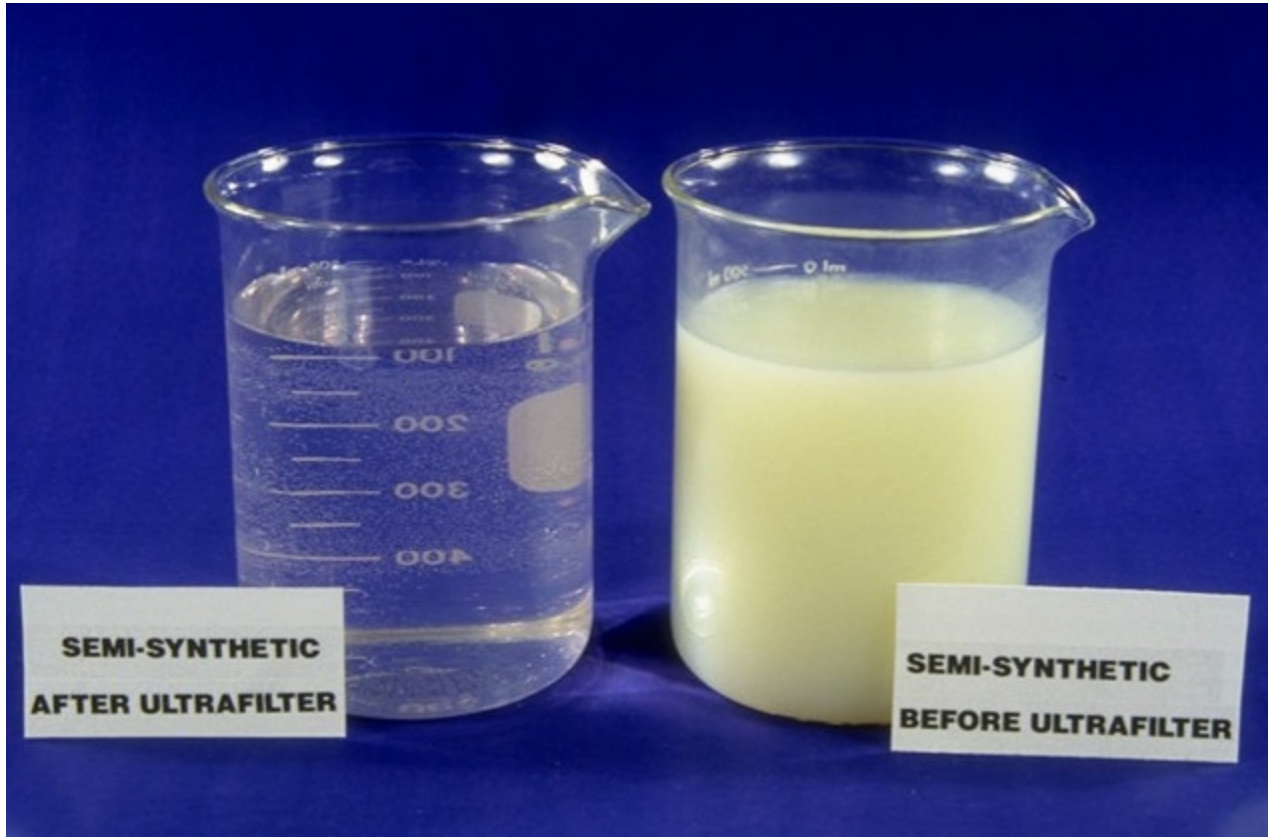

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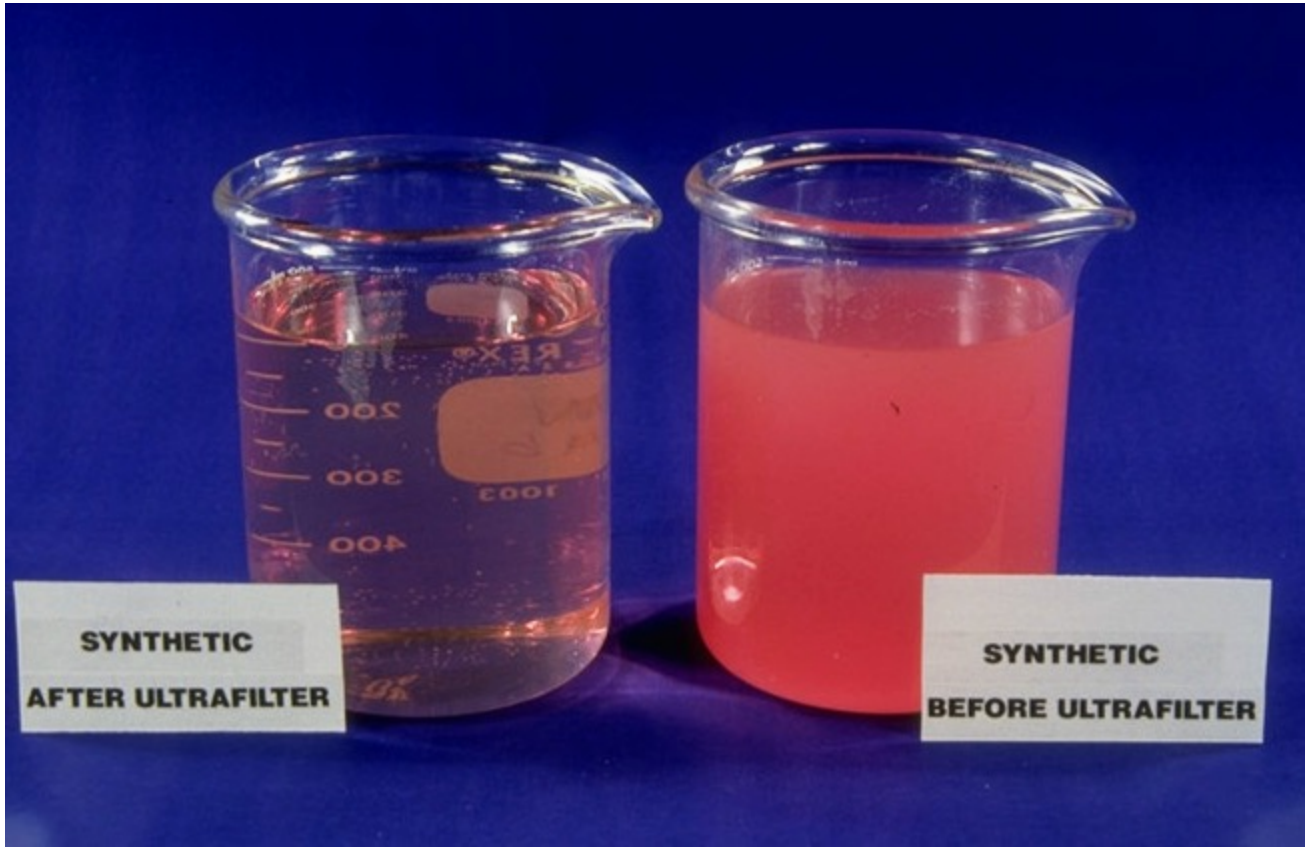


Ultrafiltration Process

- Advantages
  - Low treatment cost
  - Easy installation
  - Can Be Automated
  - Easy operation
  - Maintain discharge quality during upsets
  - Won't pass oil
  - Small footprint
  - High capacity
    - (>1,000,000 LPD)

Disadvantages

- Solids problematic
- Can't treat true solution synthetics
- Free oil problematic
- Dissolved metals pass
- pH adjustment
- Dilute waste stream better
- Silicone somewhat problematic
- Silicate is very problematic

Key Points

Ultrafiltration Method

Effects on Effluent

FLUID	BOD_5		COD		O&G		pH
	Before	After	Before	After	Before	After	
A	15,000	200	500,000	600	35,000	55	8.7
B	26,500	600	1,100,000	1,200	29,000	150	8.9
C	13,500	450	45,000	5,500	3,500	140	9.3
D	9,500	700	30,000	25,000	900	80	9.2

A = Basic Emulsified Oil 80% oil
B = Premium Emulsified oil 65% oil
C = Semi Synthetic 10% oil)
D = Synthetic 0% oil

Ultrafiltration

- **Cost to Treat**

  Assumptions:

  1” tube- wide channel - 3-year membrane life

  Process 20,000 liters per day – 5 days per week

  Cost = $1.30 USD / 1000 liters

Wastewater Treatment

- **Chemical Treatment**

Chemical Treatment

- **Method:**

  Separate oil from water through chemical additions to achieve

  a. Emulsion destabilization

  b. Precipitation

  c. Flocculation

  d. Then settling or flotation of oil and oil-like containing wastes

Commonly Used Chemicals

- **Mineral acids**
  - **Sulfuric (most common, least expensive, non-fuming)**

Commonly Used Chemicals

Polyvalent Metastable Salts

- Poly Aluminum Chloride
- Aluminum Sulfate
- Calcium Chloride
- Magnesium Chloride
- Magnesium Sulfate
- Ferric Sulfate
- Ferrous Sulfate

Typical cations used in wastewater treatment

to destabilize emulsions

Calcium	Ca^{++}
Magnesium	Mg^{++}
Iron Ferrous	Fe^{++}
Iron Ferric	Fe^{+++}
Aluminum	Al^{+++}

Aluminum is most common cation, as either: Aluminum Sulfate or Poly Aluminum Chloride

Commonly Used Chemicals

- **Reactive bases**
  - **Sodium Hydroxide**
  - **Calcium Hydroxide**

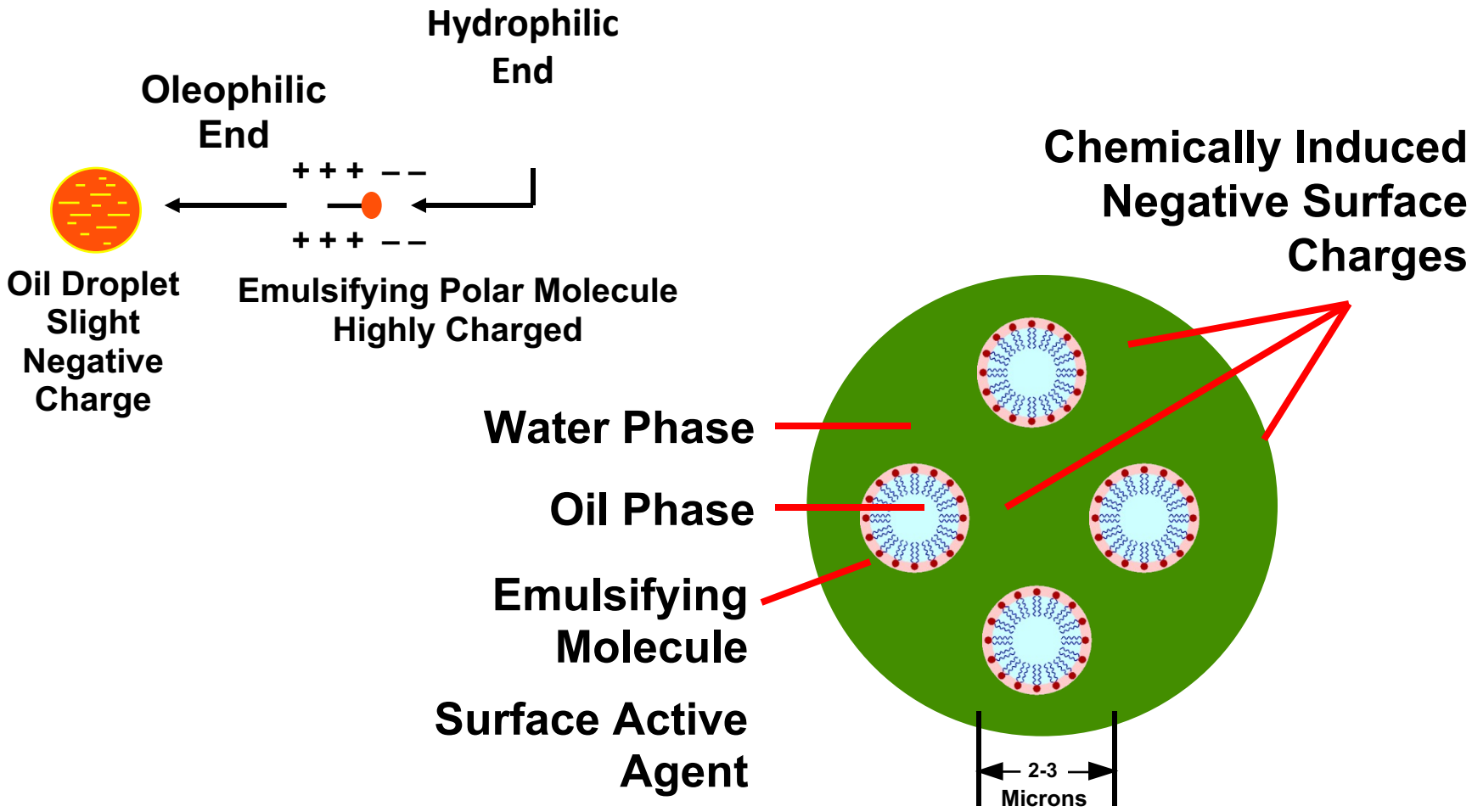
Acid - Alum - Split

- **Sulfuric Acid Cationic**
- **Aluminum Sulfate Cationic**
- **Sodium Hydroxide Base / Neutralizer**

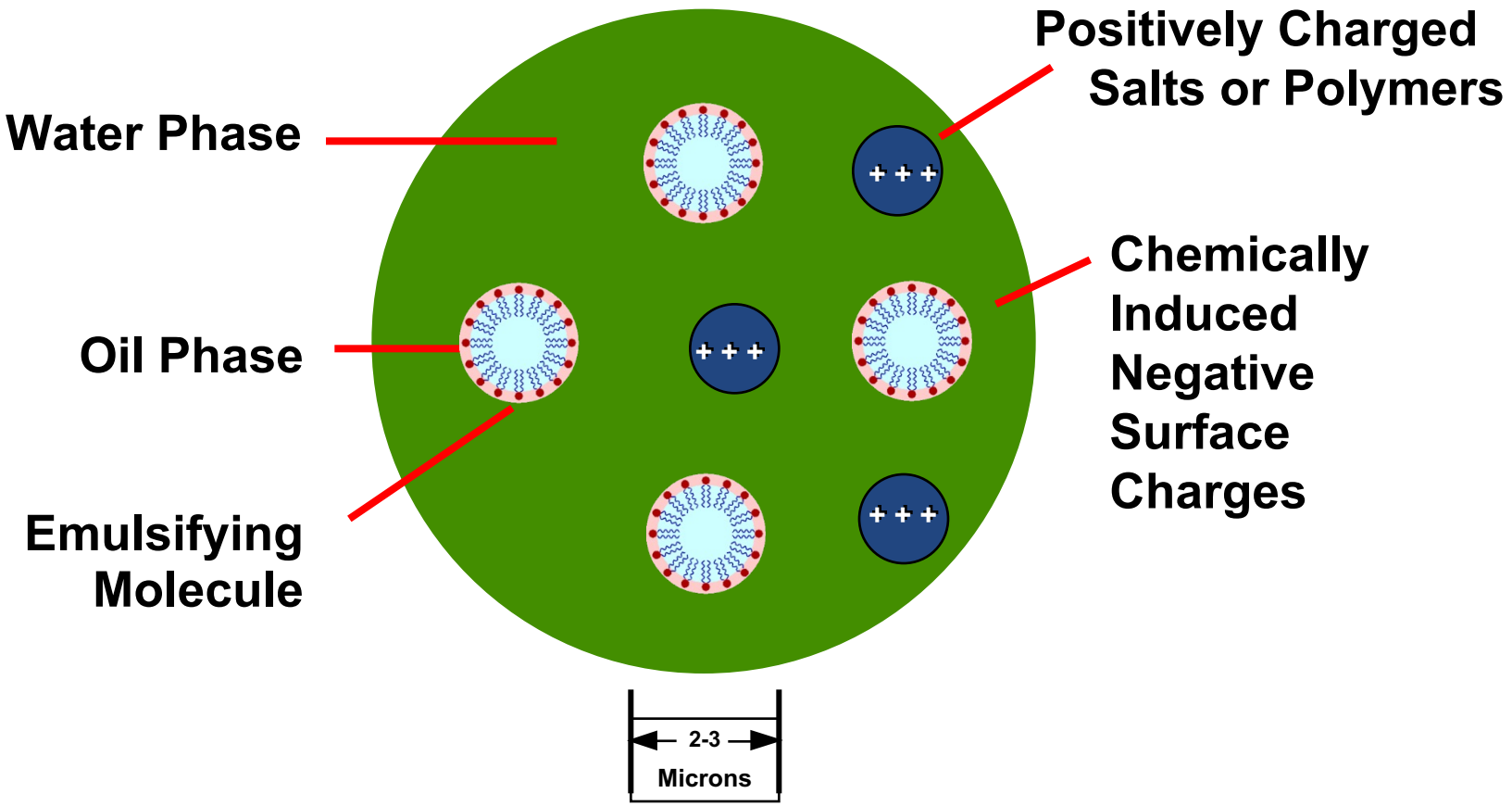
or

- **Calcium chloride – instead of Aluminum Sulfate**
  - **Referred to as the Ford Windsor Process**

Typical Emulsified Oil Schematic



Basic Theory of Chemical Separation



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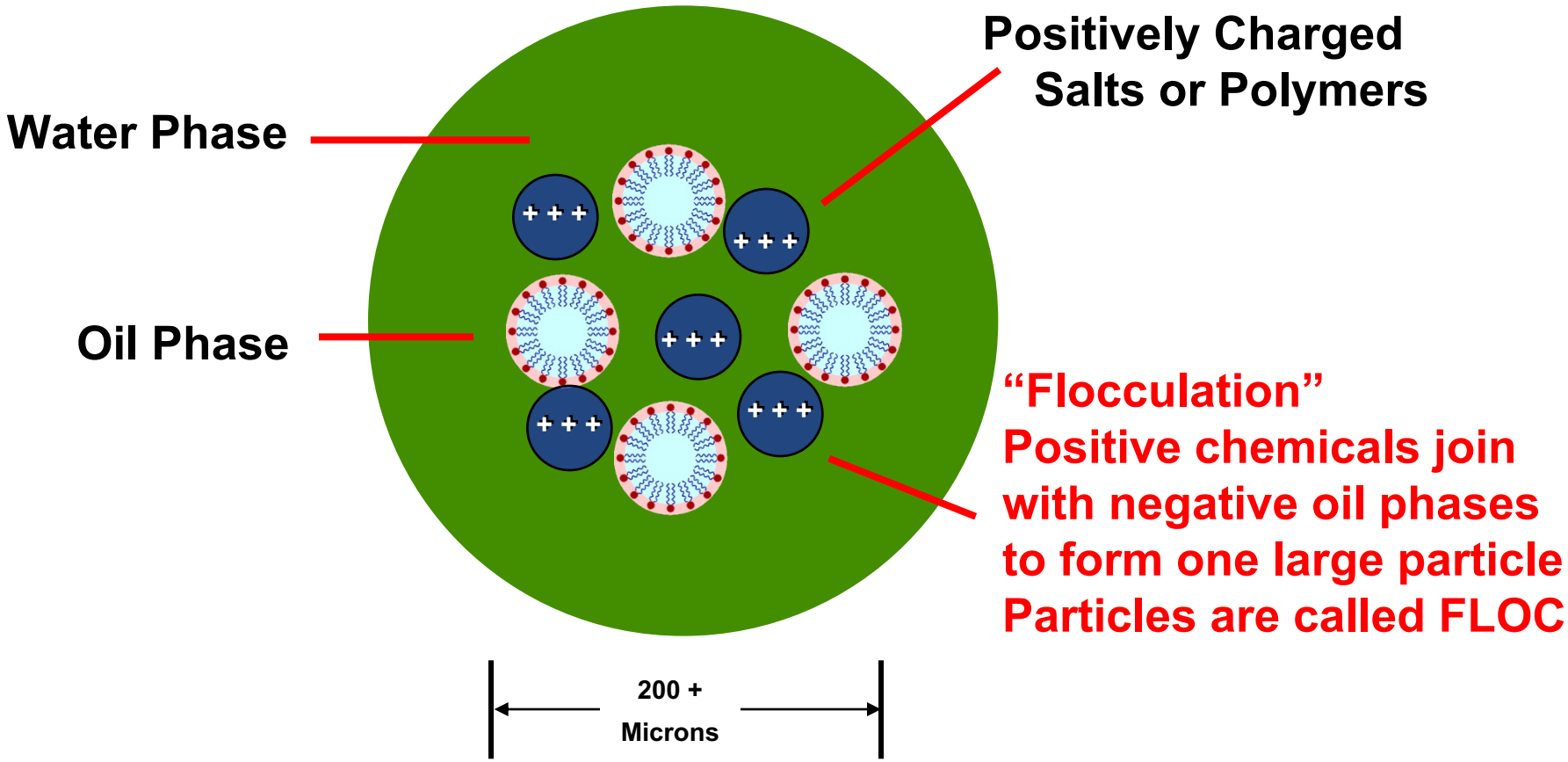
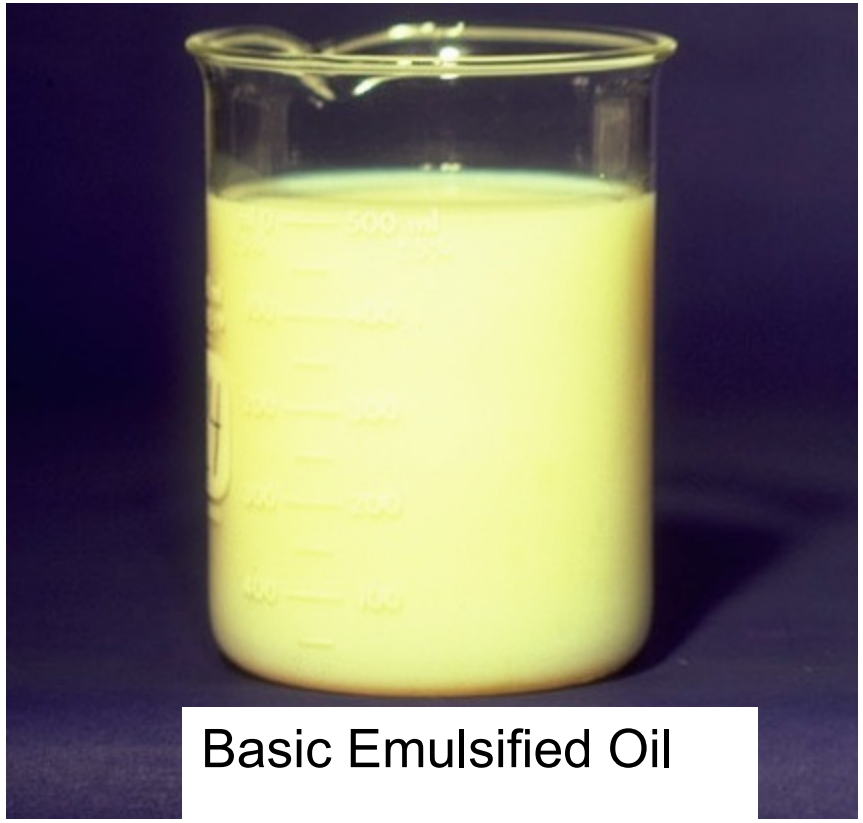
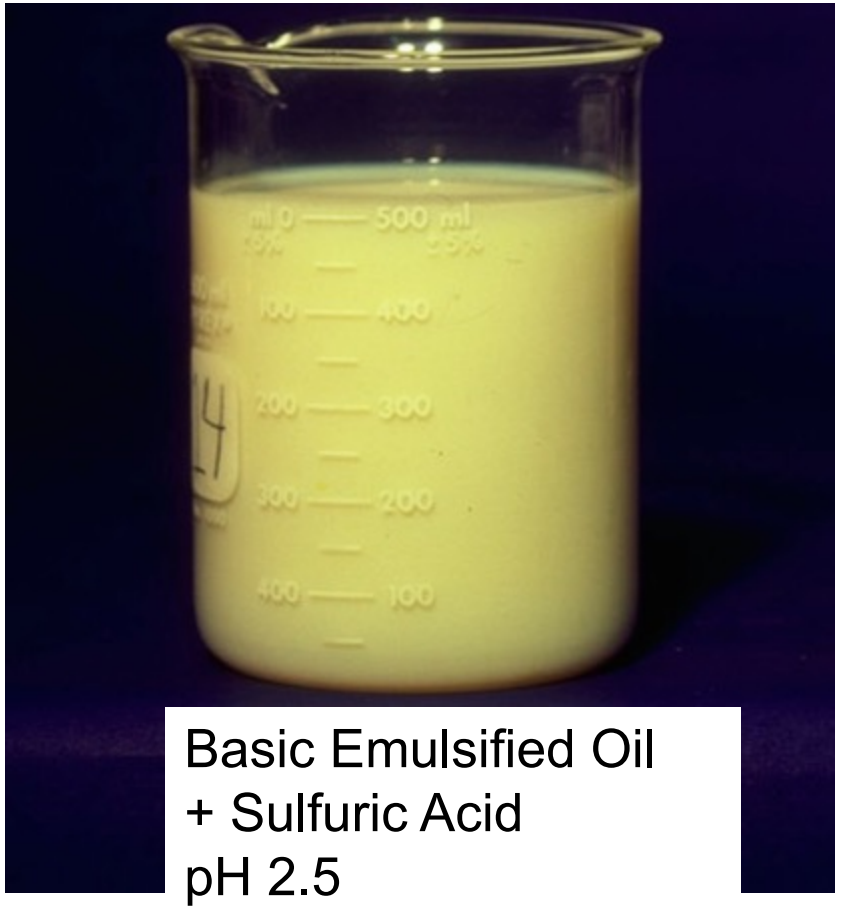


Chemical Treatment



Basic Emulsified Oil

Chemical Treatment

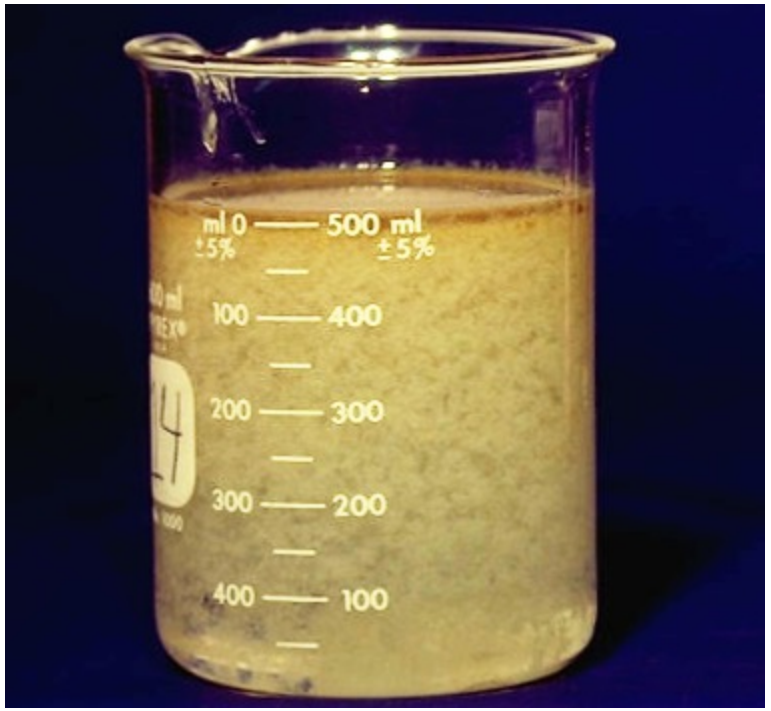


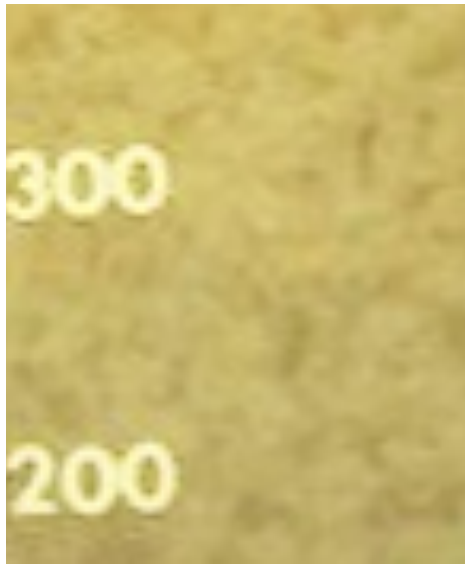
Basic Emulsified Oil
+ Sulfuric Acid
pH 2.5

Chemical Treatment

Basic Emulsified Oil
+ Sulfuric Acid
pH 2.5 + aluminum sulfate

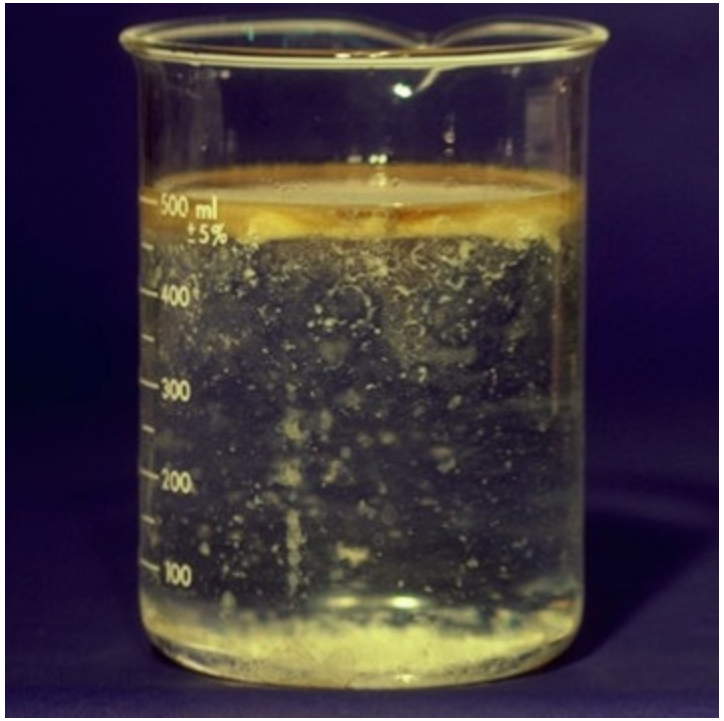
Chemical Treatment





Basic Emulsified Oil
+ Sulfuric Acid
pH 2.5 + aluminum sulfate
+ Sodium hydroxide

Chemical Treatment



After Flotation

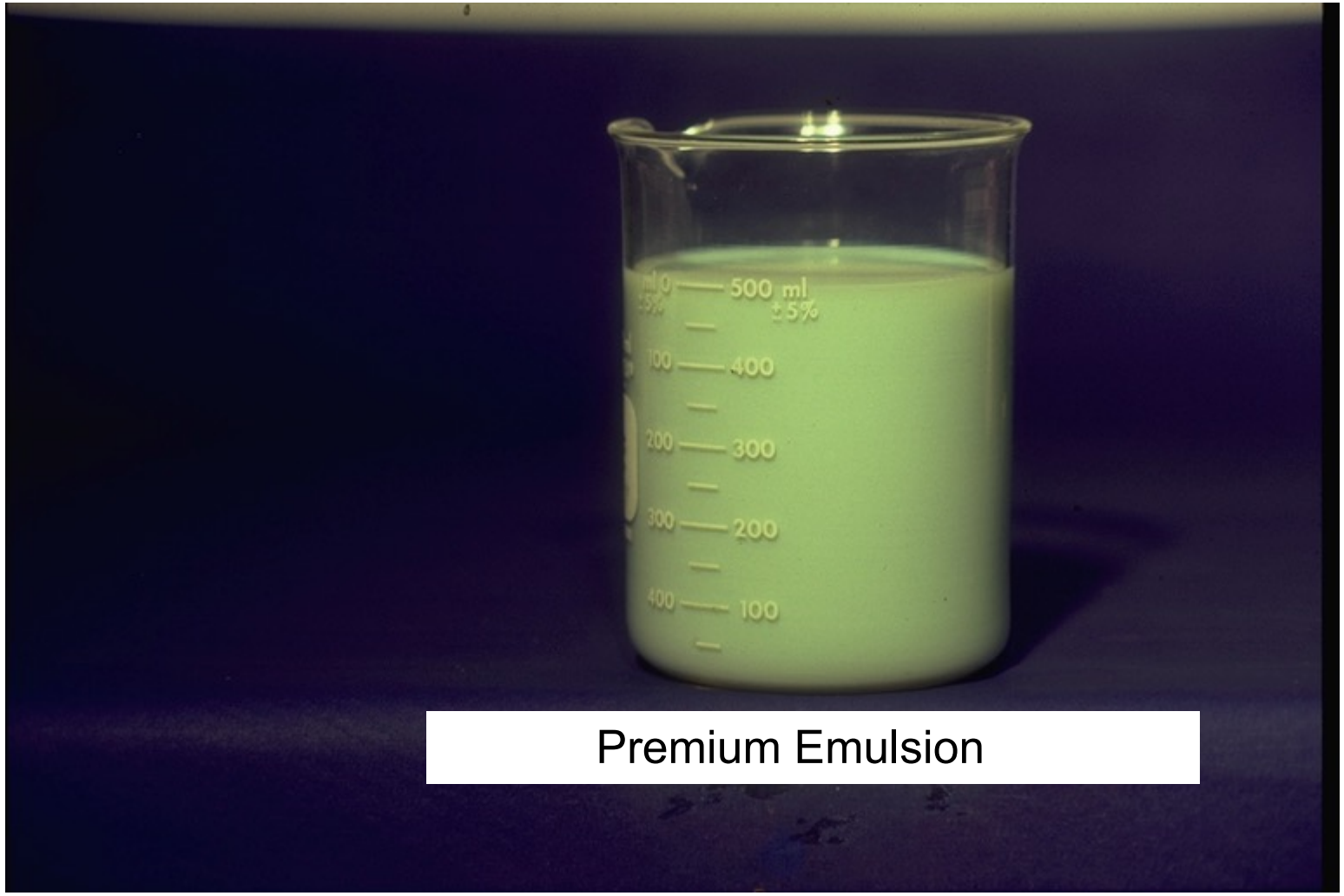
Chemical Treatment

Semi - Synthetic

Chemical Treatment

Semi – Synthetic
+ Sulfuric Acid pH 2.5
+ Aluminum Sulfate
+ Sodium Hydroxide
+ Flotation

Chemical Treatment



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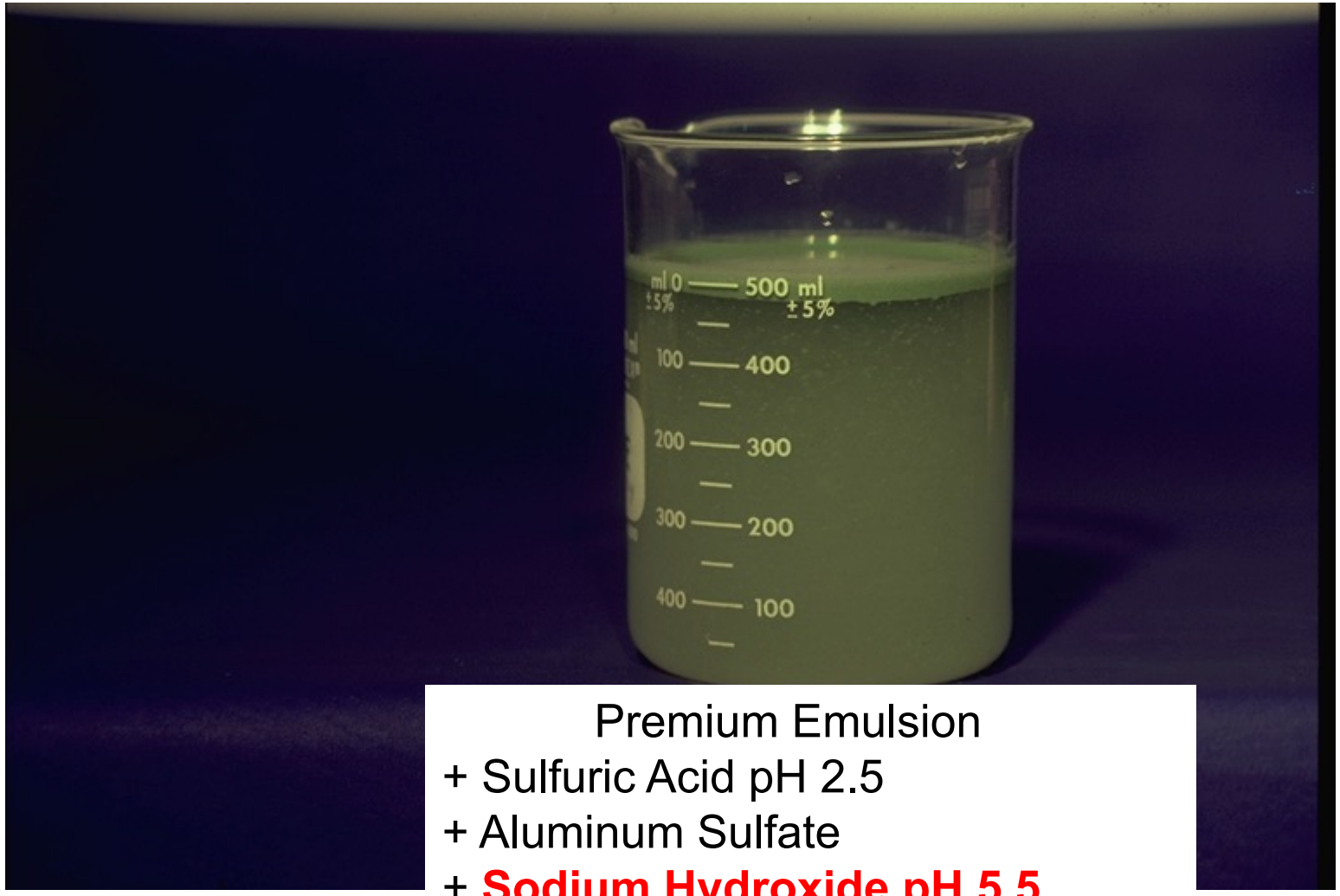
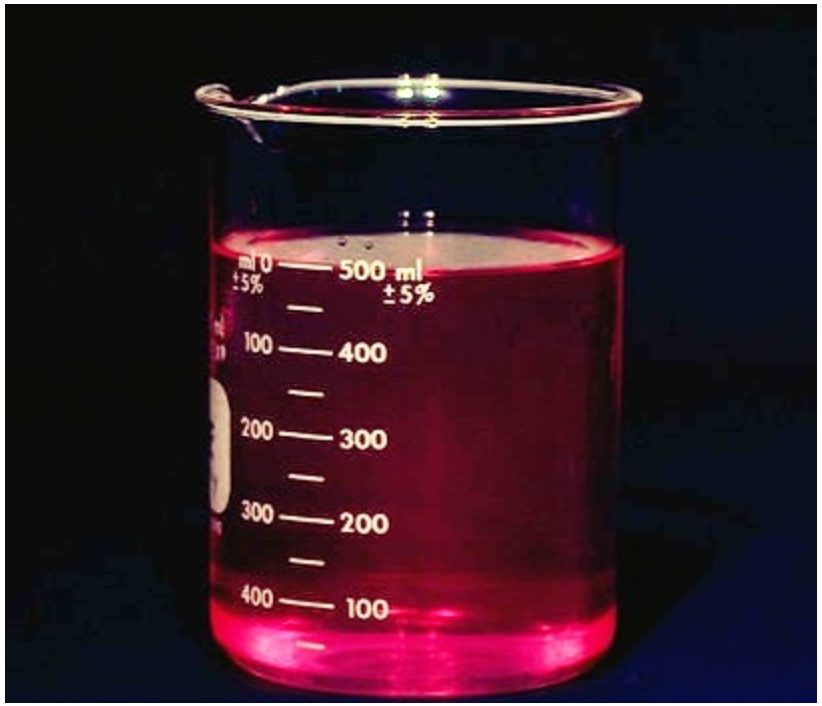


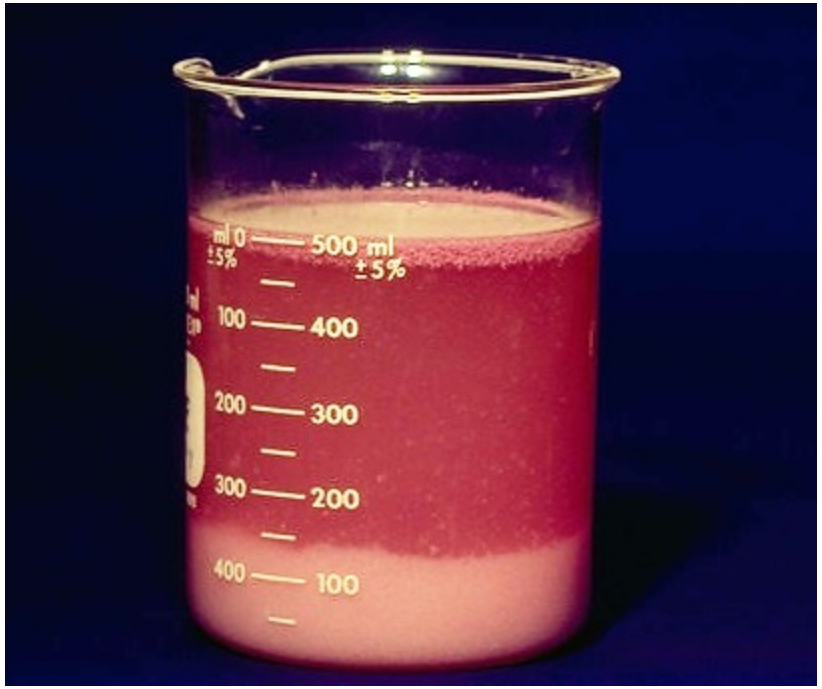
Premium Emulsion
+ Sulfuric Acid pH 2.5
+ Aluminum Sulfate
+ **Sodium Hydroxide pH 5.5**

Chemical Treatment



Synthetic

Chemical Treatment

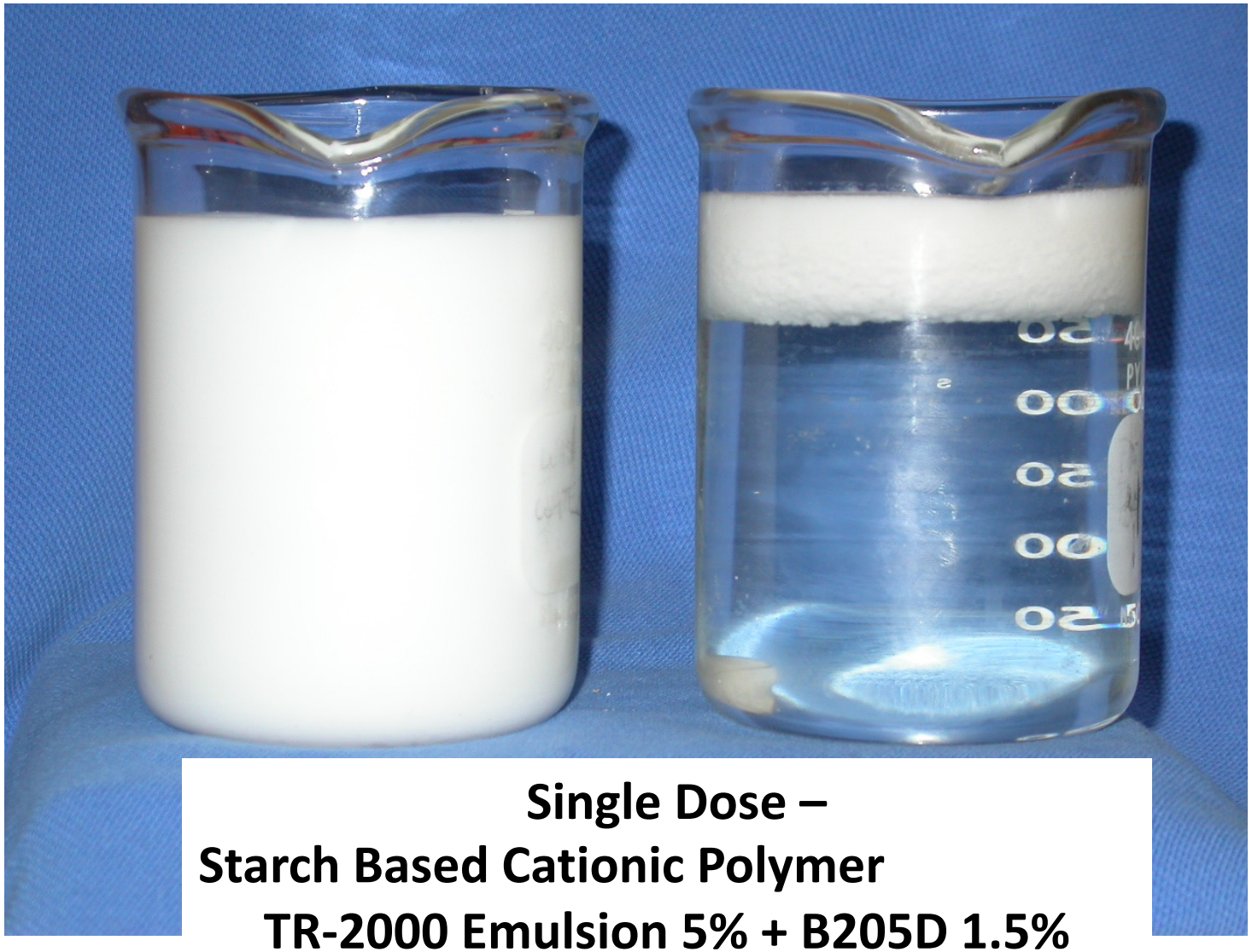


Synthetic
+ Sulfuric Acid
+ Aluminum Sulfate
Sodium Hydroxide + Flotation

Chemical Treatment

Waste Treatment Polymers

Chemical Treatment – Starch Polymer

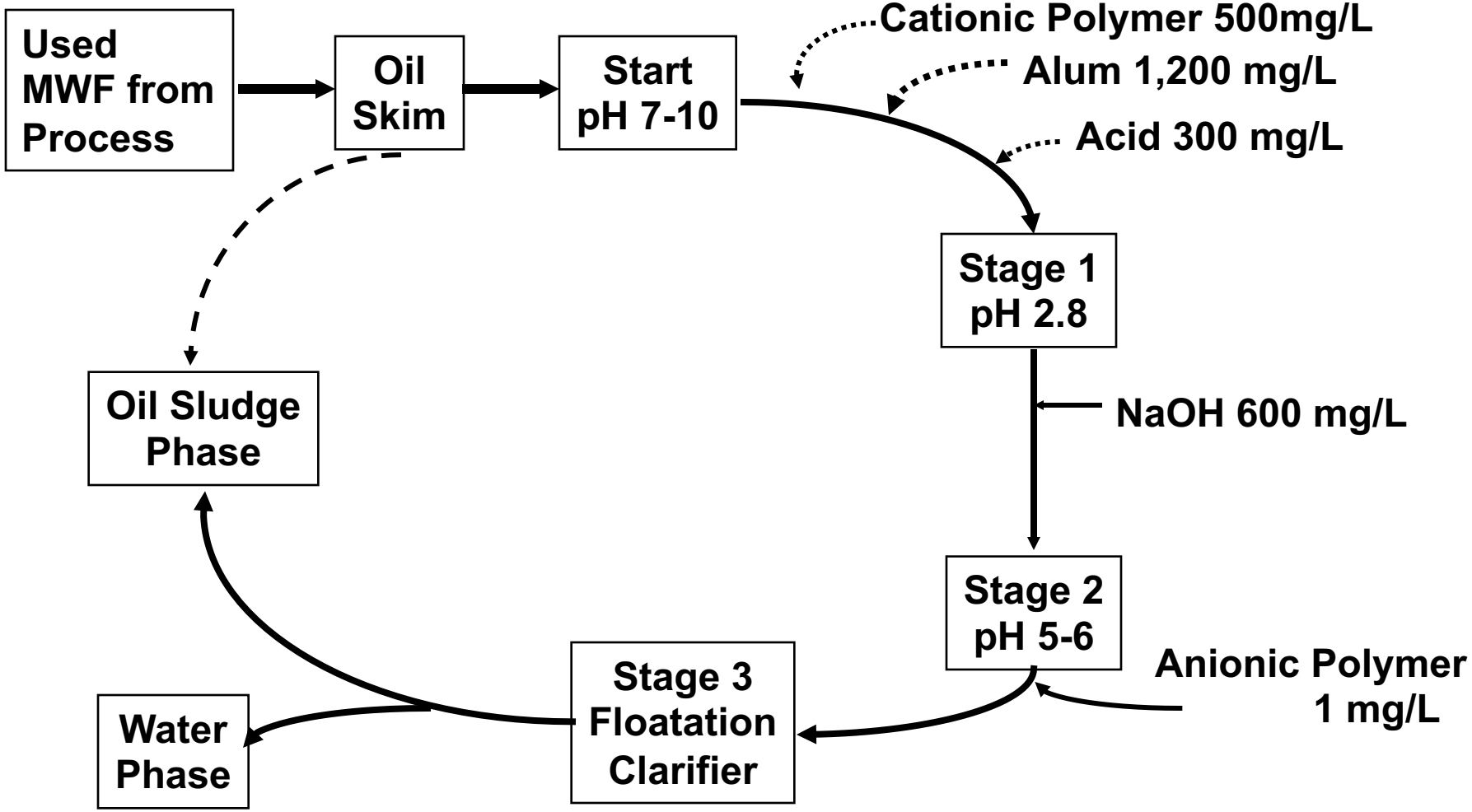


Single Dose –
Starch Based Cationic Polymer
TR-2000 Emulsion 5% + B205D 1.5%

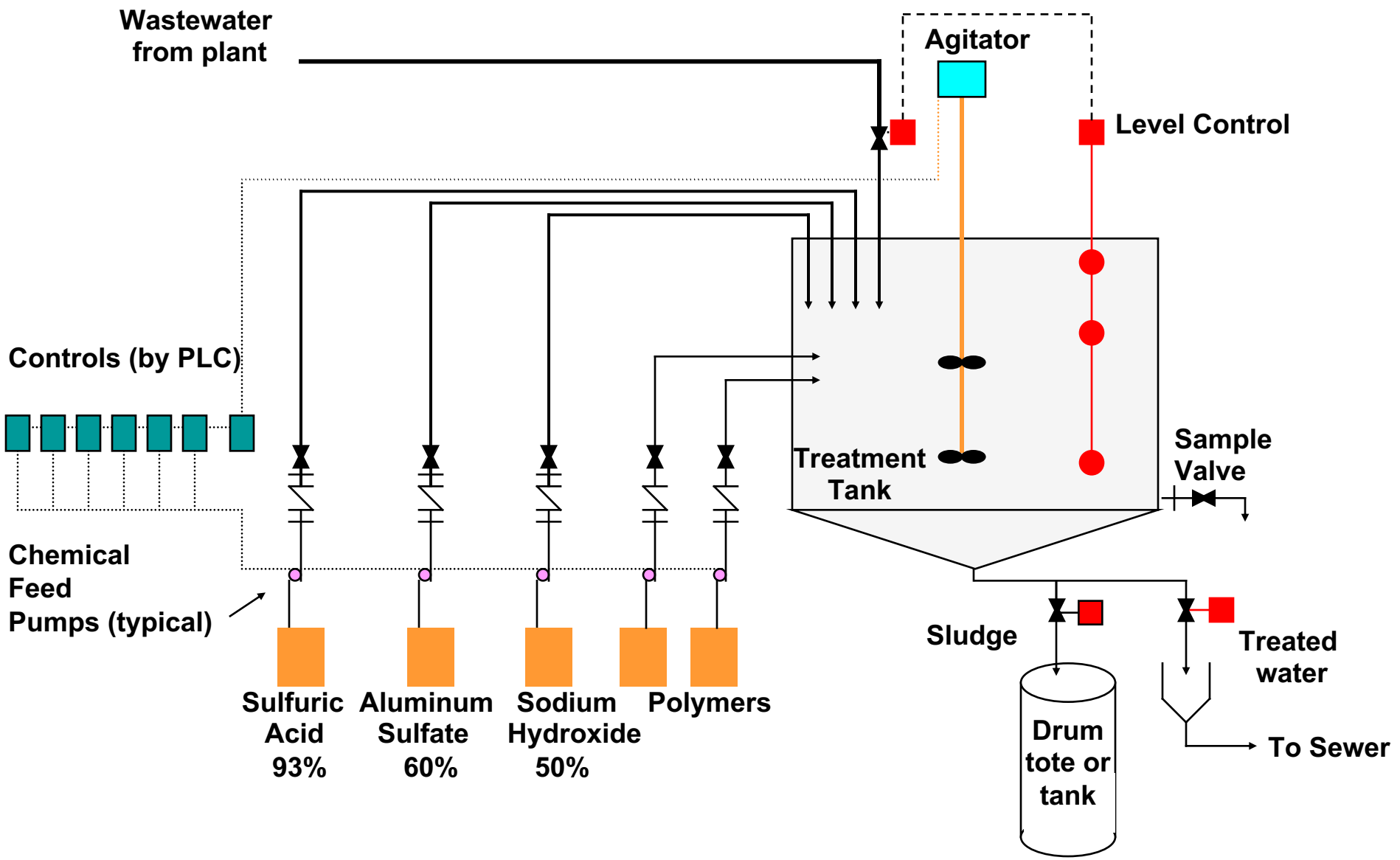
Polymer Treatment Advantages

- Lower Dosage Levels
- Wider Application Range
- Reduced Sludge Volumes
- Potentially Better Water Quality
- Potentially Easier to Recover Oil from Sludge Phase

Chemical Treatability Sequence for MWF



Wastewater Treatment - Batch Method



Daily Bench Testing is Required

Chemical Treatment Method Results

Additions of:
- Sulfuric Acid
- Aluminum Sulfate
- Sodium Hydroxide

FLUID	BOD_5		COD		O&G		pH
	Before	After	Before	After	Before	After	
A	15,000	500	500,000	200	35,000	10	8.7
B	26,500	2,000	1,100,000	400	29,000	400	8.9
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D = Synthetic 0% oil

Chemical Treatment

- **Advantages**
  - Handle very dilute fluids
  - Handle excess free oil
  - Can be varied in output
  - Low cost to treat (basic emulsions)
  - Easier oil recovery
  - Tolerates high solids
  - Low equipment / capital cost

- **Disadvantages**
  - Technically intensive
  - Difficult with synthetics or semi-synthetics
  - Difficult with “hard water stable” emulsions
  - May require complex instrumentation
  - May fail with out warning
  - Hazardous chemical handling
  - Maintenance intensive (corrosive chemicals)

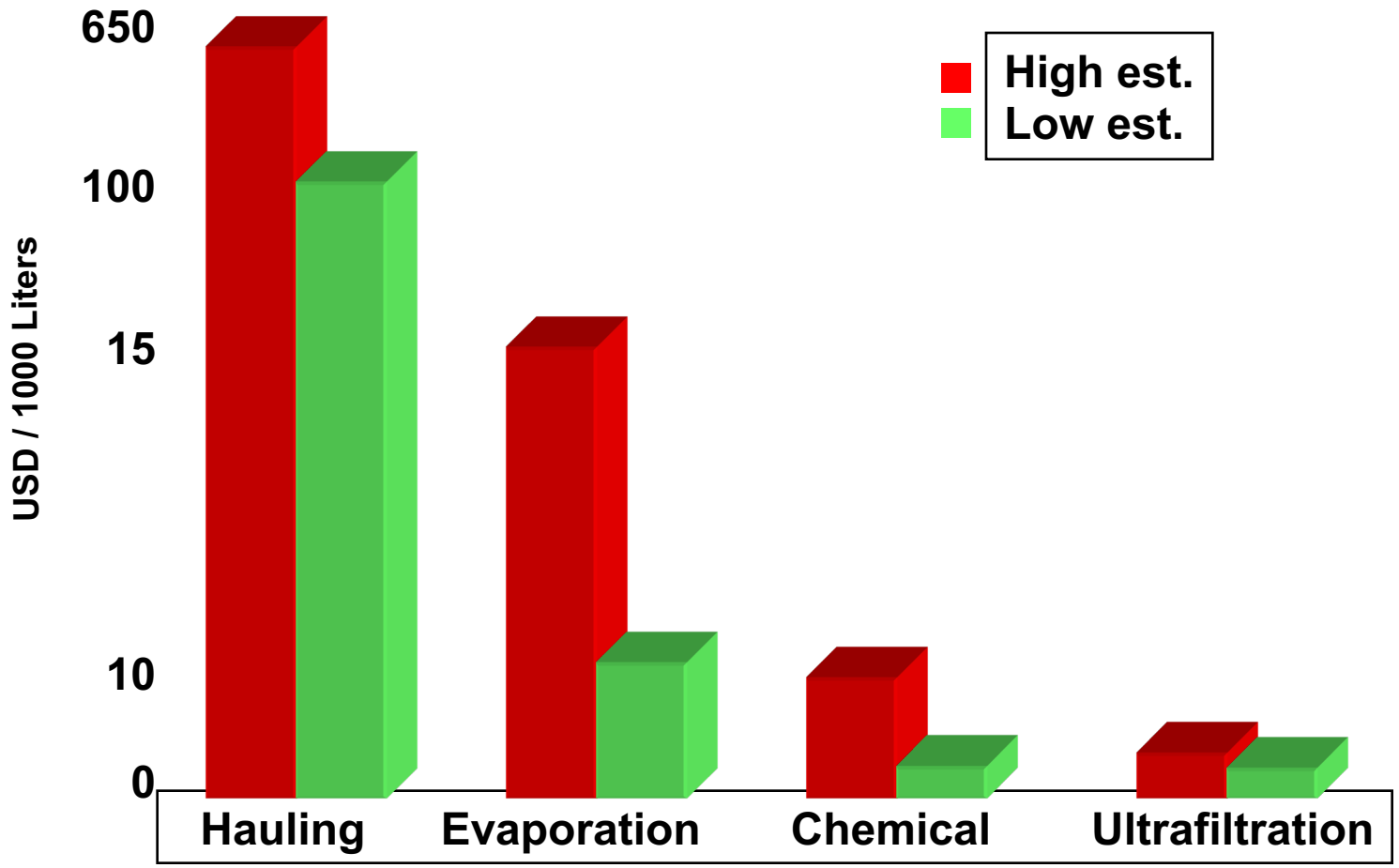
← Key Point

Chemical Treatment

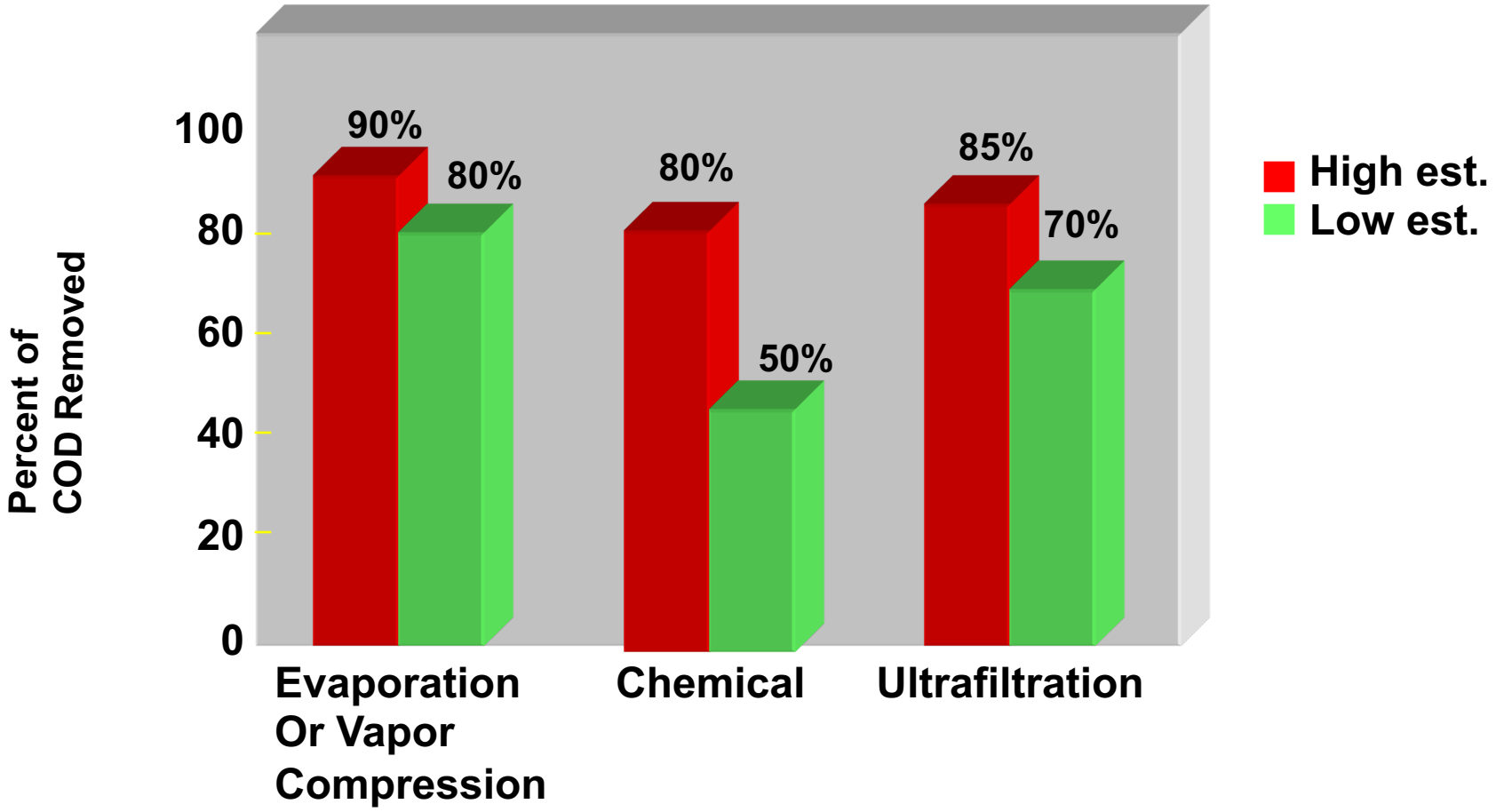
- **Cost to Treat:**

Basic Oil Emulsion	**$ 0.25 USD / 1000 Liters**
Premium Emulsion	**$ 2.25 USD / 1000 Liters**
Semisynthetic	**$ 2.20 USD / 1000 Liters**
Synthetic	**$ 0.75 USD / 1000 Liters**

Cost Comparisons



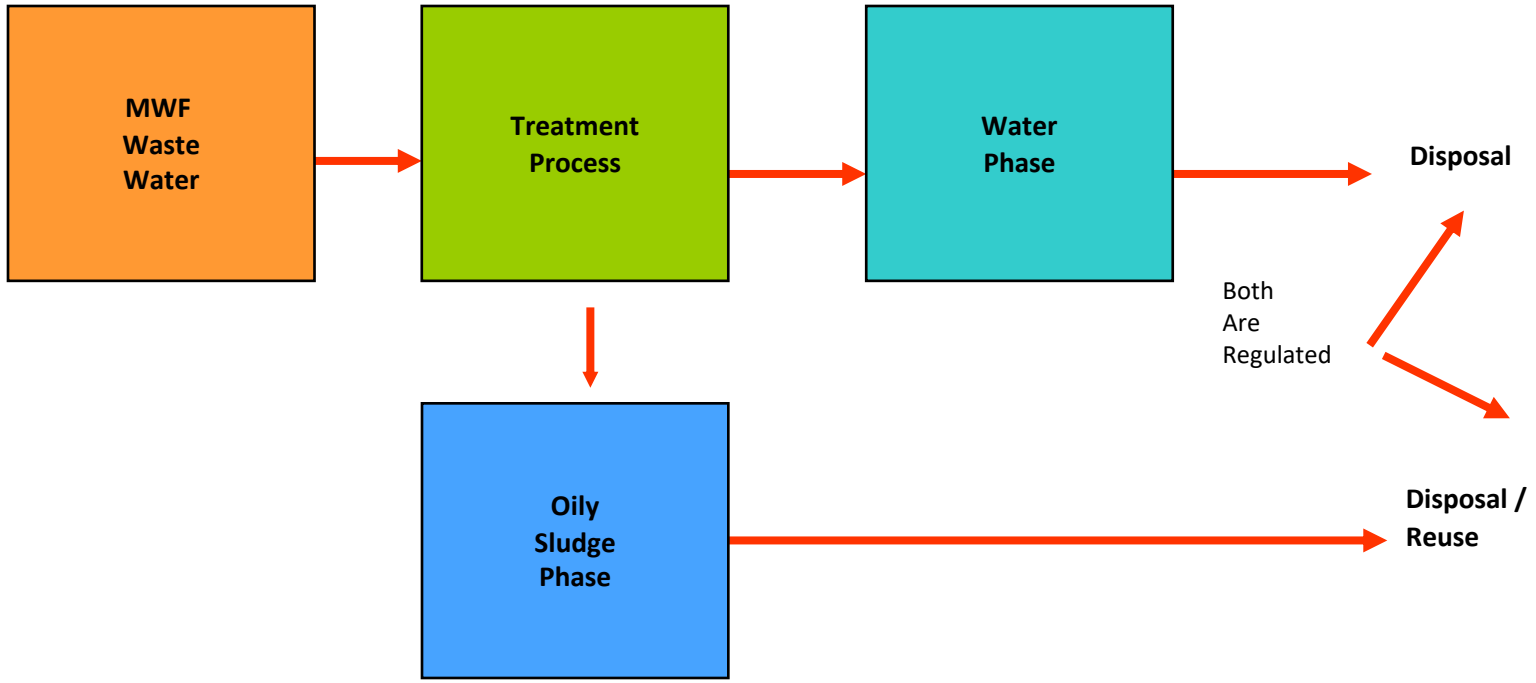
Performance Comparison



Oil Recovery

The Long-Term Challenge

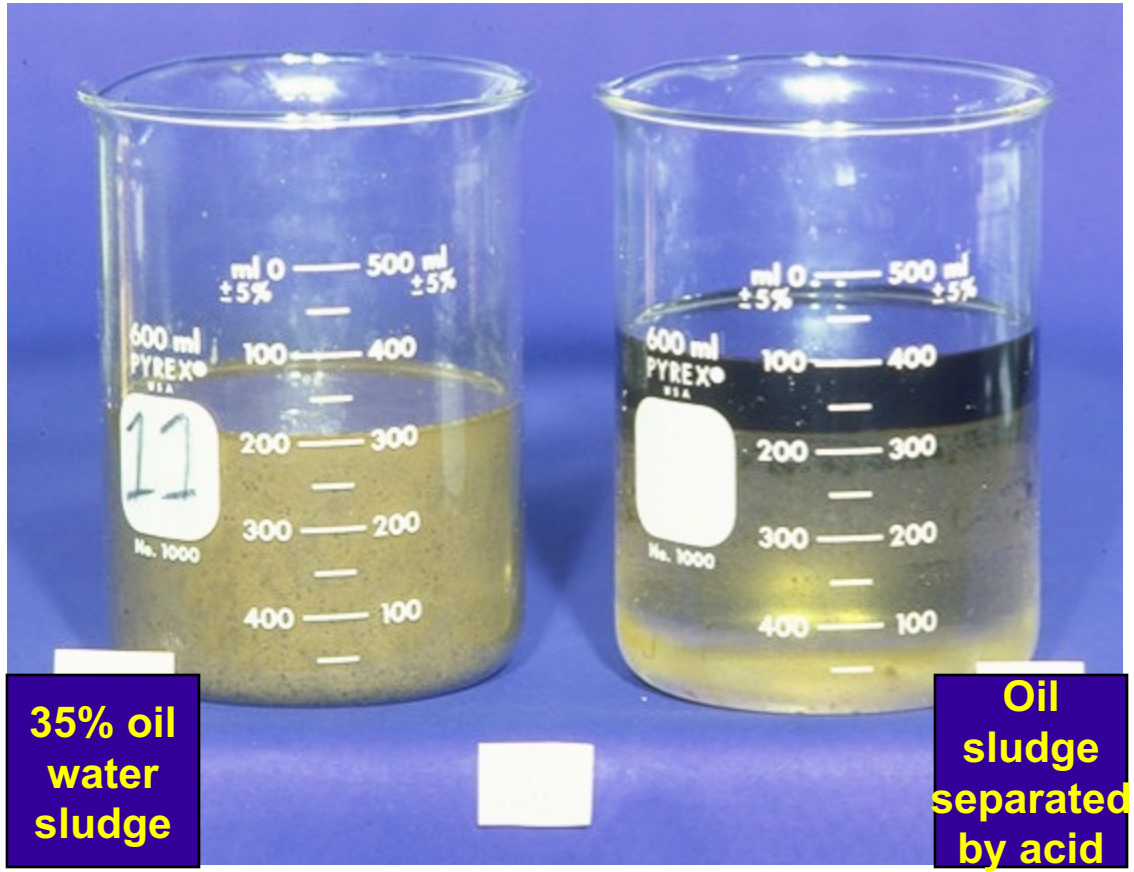
Only solved one-half of the problem with wastewater treatment



Oil Recovery after Conventional Treatment

- **Objective**
  - **Minimize waste hauling**
  - **Possibly add value to hauled oil**

Oil recovery/recycling



Oil Sludge Separation Options

- **Heat** — **140 - 180°**
- **Acid** — **Sulfuric acid**
- **Polymers** — **Usually cationic**
- **Solvent** — **Xylene (not water soluble)**

- **Or Any Combination Above**

- **Cost - approximately $22 / 1000 liters (chemical + heat only)**
- **May still have to add up to 10% water in the oil phase**

Waste Treatment Management Summary

- Advantages & disadvantages to each strategy /process / method
- Fluid selection is very important
- No universal treatment method exists

- **WARNING!**
- **THAT PERFECT METALWORKING FLUID CAN BE REJECTED BY THE CUSTOMER IF IT CANNOT BE WASTE TREATED ON SITE OR IS TOO EXPENSIVE TO HAUL**

Thank You

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