
2014 Michigan Environmental Compliance Conference

# Wastewater Treatment Technology

Presenter

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Presentation prepared by Brian Jankowski, DEQ

# Wastewater Treatment Technology

Goal and objectives

1. Familiarity with basic wastewater treatment
2. Identify some advantages/disadvantages
3. Recognize the need for qualified professionals for the selection, design, and operation of treatment processes

# Wastewater - definition

Definition in DEQ's *Michigan Manufacturer's Guide - Chapter on Wastewater:*

- *"Wastewater is liquid waste that results from industrial and commercial processes and municipal operations...."*
- Also includes:
  - Sanitary sewage
  - Storm water in certain cases

# Waste Characterization

- What's in the wastewater ? (identify pollutants)

- What needs to be removed from the wastewater (and to what extent) ?

# Waste Characterization

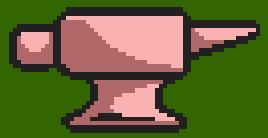
Pollutant Examples

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Solids (suspended or dissolved)
- Oils/Grease
- Temperature
- Phosphorous & Nitrogen Compounds
- pH
- Metals
- Other elements or compounds

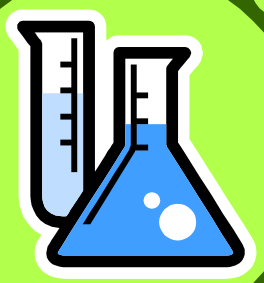
# Wastewater Treatment

- Basic process categories

**Physical**



**Chemical**



**Biological**

Some processes may consist of more than one type; combination of Physical, Chemical and/or Biological

# Physical Processes

- Clarification/Settling
- Air flotation
- Filtration (incl. activated carbon, membrane filters/bioreactors and reverse osmosis)
- Oil/water separation
- Cooling

# Clarification/Settling "sedimentation"

Circular settling tank

Rectangular settling tank

Commonly referred to as "clarifiers"

# Clarification/Settling

## Circular “upflow” clarifier

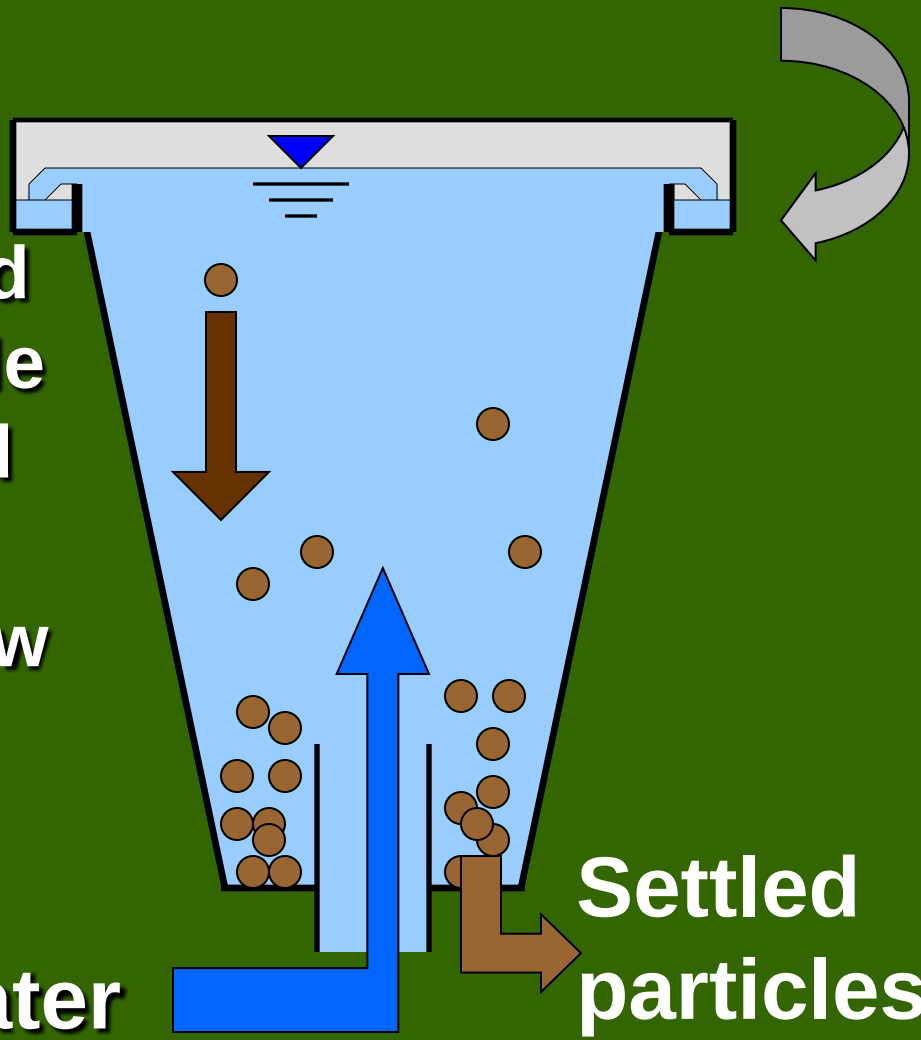
Settling velocity

vs.

Overflow velocity

**Suspended solids settle downward**

**Water flow is up**

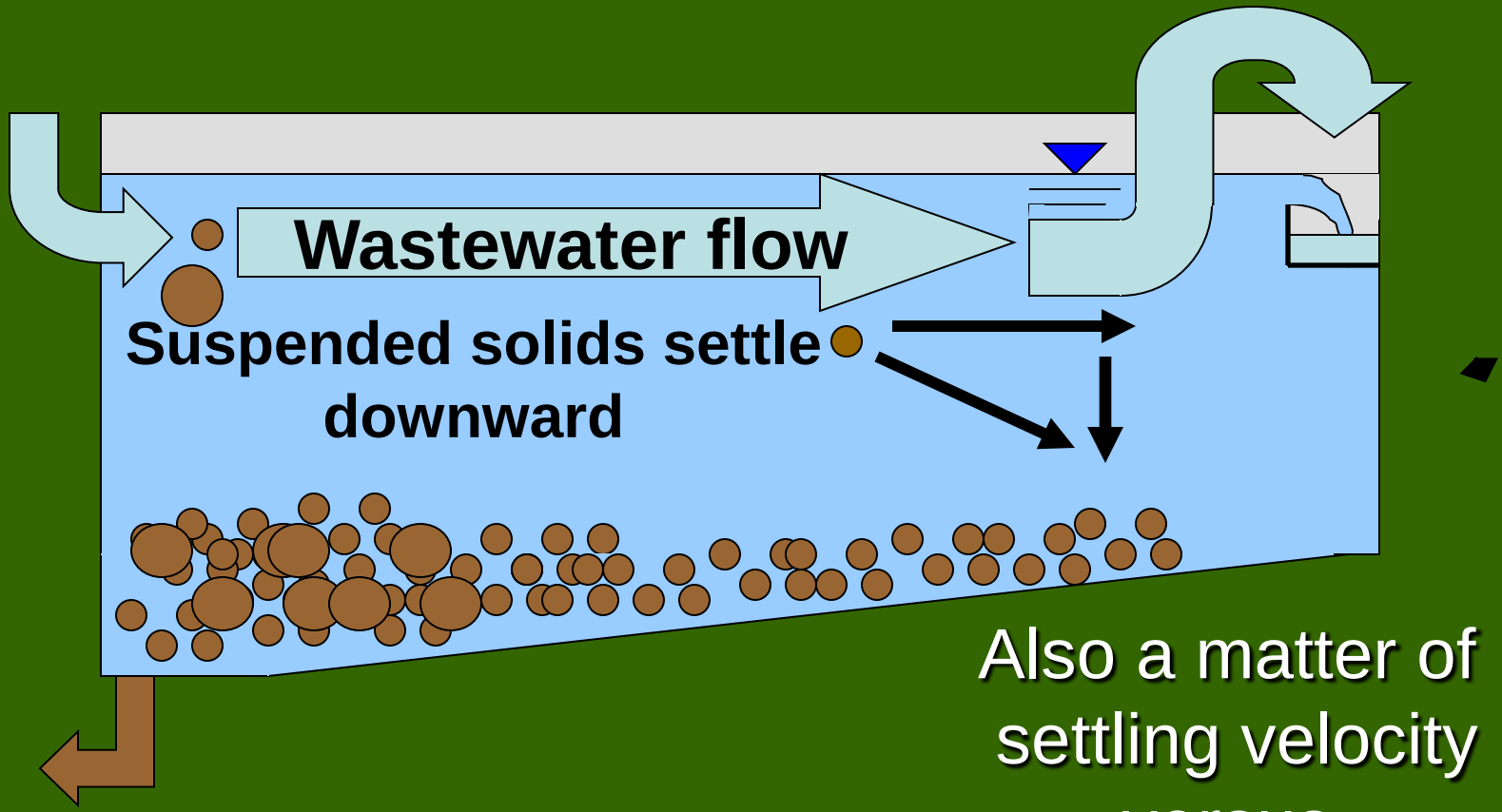


**Settled particles**

**Incoming Wastewater**

# Clarification/Settling

## Rectangular, horizontal flow clarifier




Sludge removal

Also a matter of settling velocity versus overflow velocity

# Clarification/Settling

- Settling can be enhanced by addition of certain chemicals (coagulants)
- Baffles, typical
- Inclined plates, option

# Clarification/Settling

Notable issues/concerns

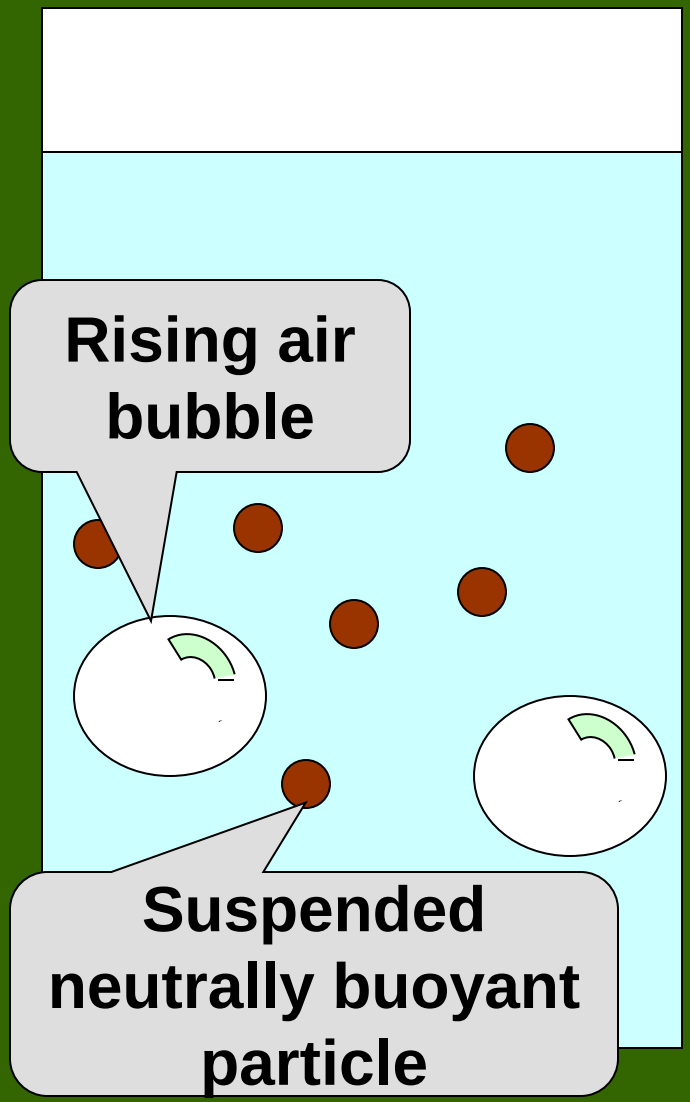
- Will only address “settleable” solids
- Impaired settling &  “bulking sludge”

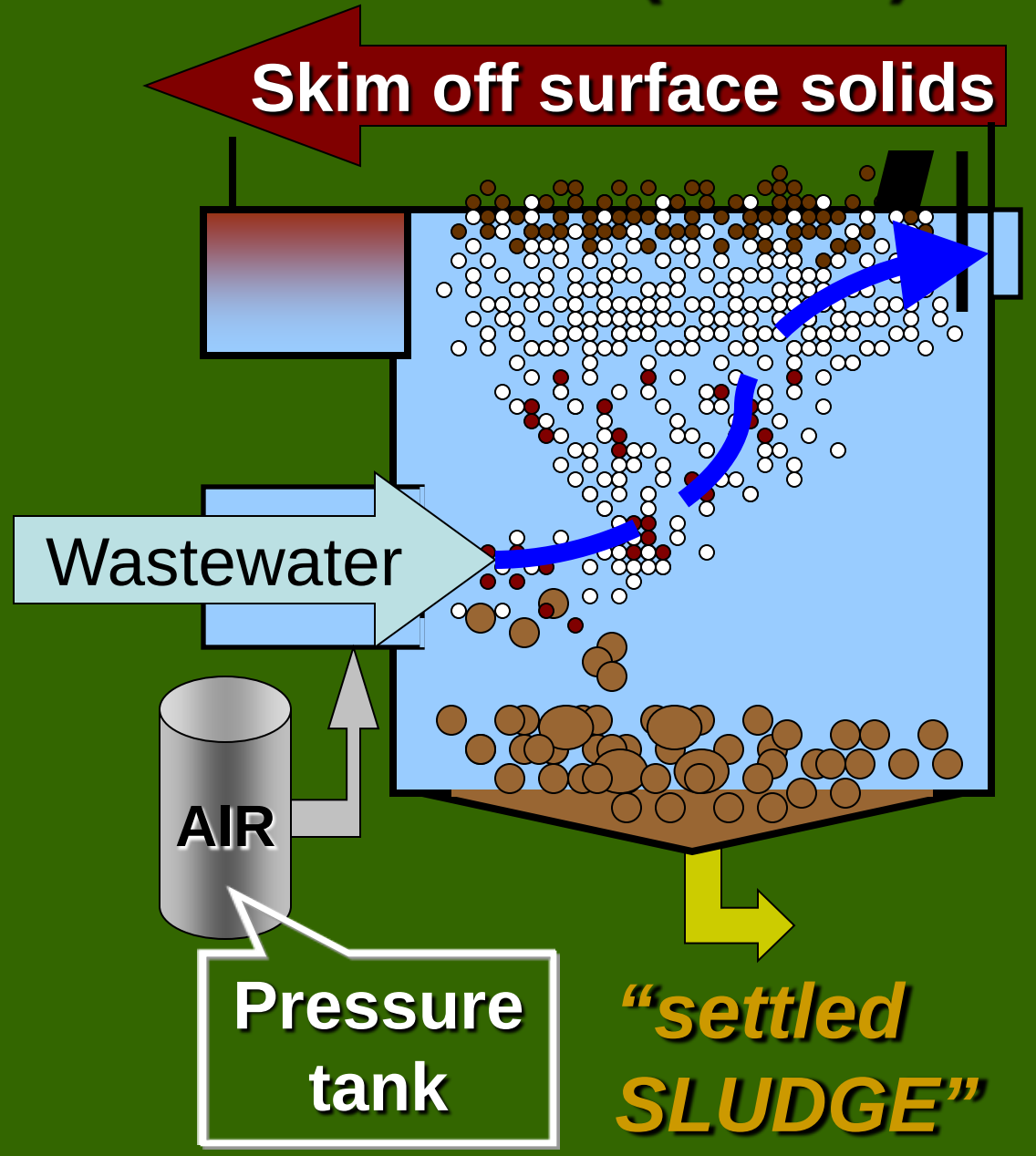
# Physical Processes

- Clarification/Settling
- Air flotation
- Filtration
- Oil/water separation
- Cooling

# Dissolved Air Flotation (DAF)

# Dissolved Air Flotation (DAF)

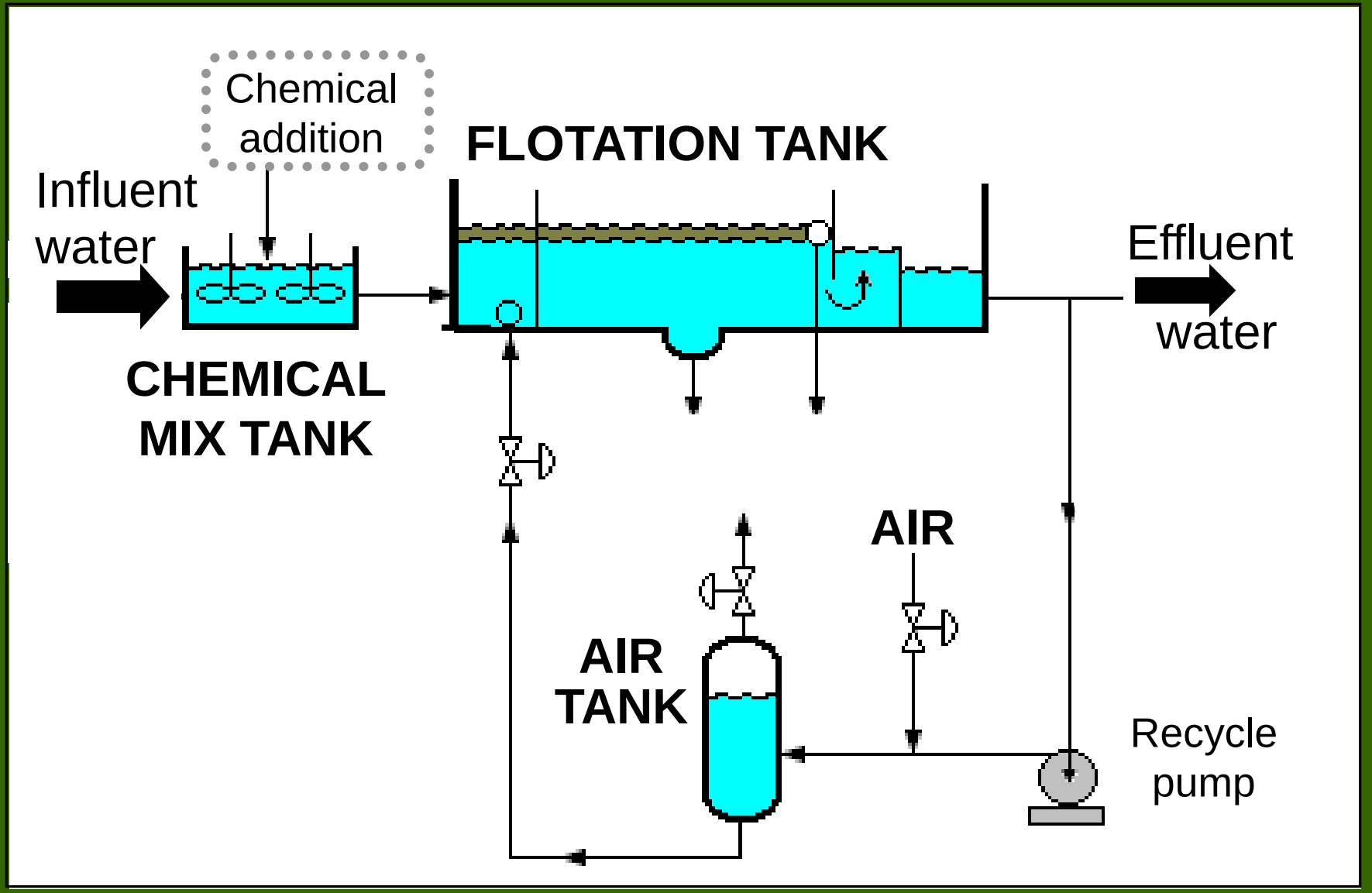


# Dissolved Air Flotation (DAF)

- Typical application in industry: refineries, chemical/petrochemical plants, paper products, food processing, and natural gas processing plants
- Typically requires addition of certain chemical “flocculating” aids or “coagulants” (mixed in waste stream ahead of DAF unit)

# Dissolved Air Flotation (DAF)




DAF Example, with recycle

# Dissolved Air Flotation (DAF)

Benefits

Lighter particles removed
Faster particle removal
More rapid startup
Thicker sludge's

} Compared to standard clarifier type settling

Issues/concerns

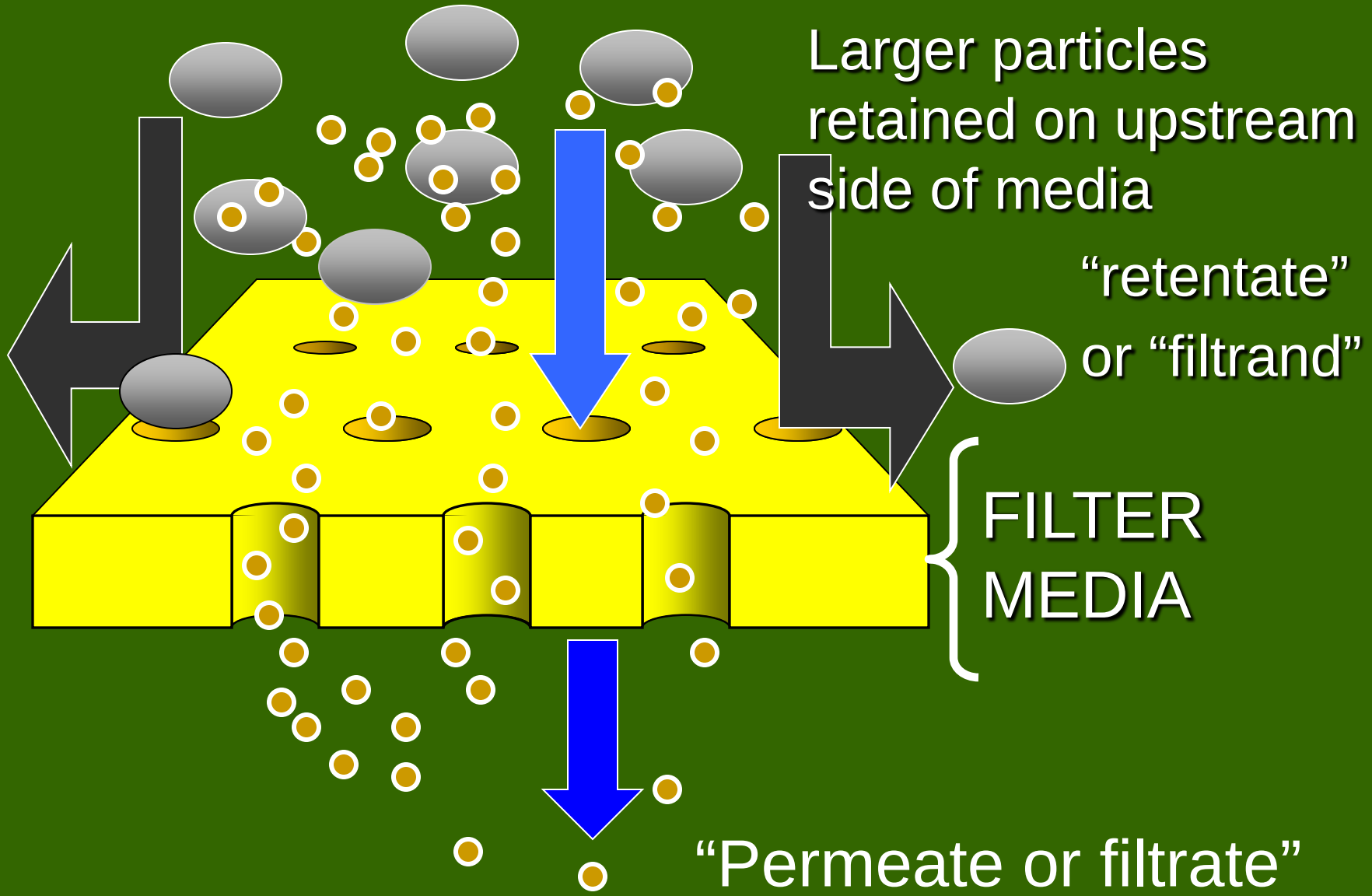
Significant mechanical equipment
More complex/more maintenance
Higher-energy consumption

# Physical Processes

- Clarification/Settling
- Air flotation
- Filtration
- Oil/water separation
- Cooling

# Filtration

porous medium separates solids from liquid

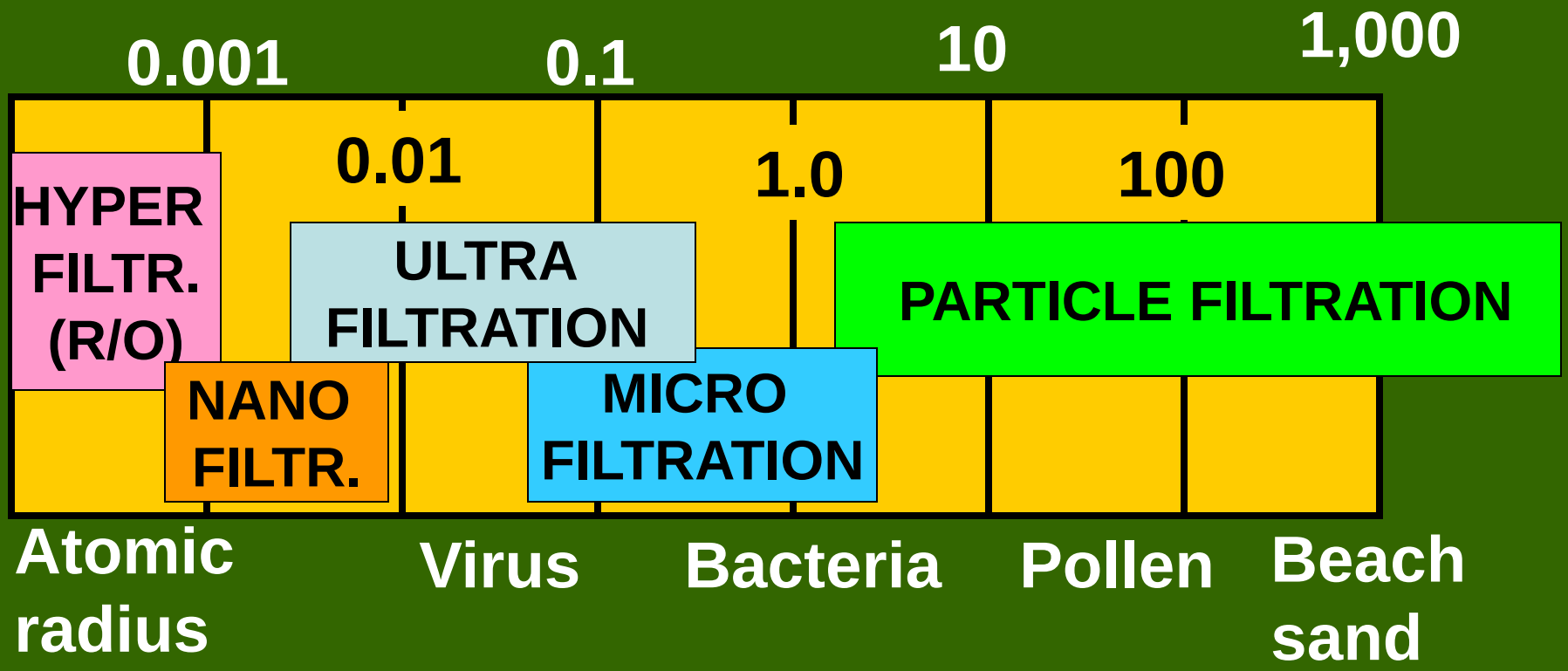


# Filtration

Size of particle removed dependent on “pore” size of media

Log scale, in microns

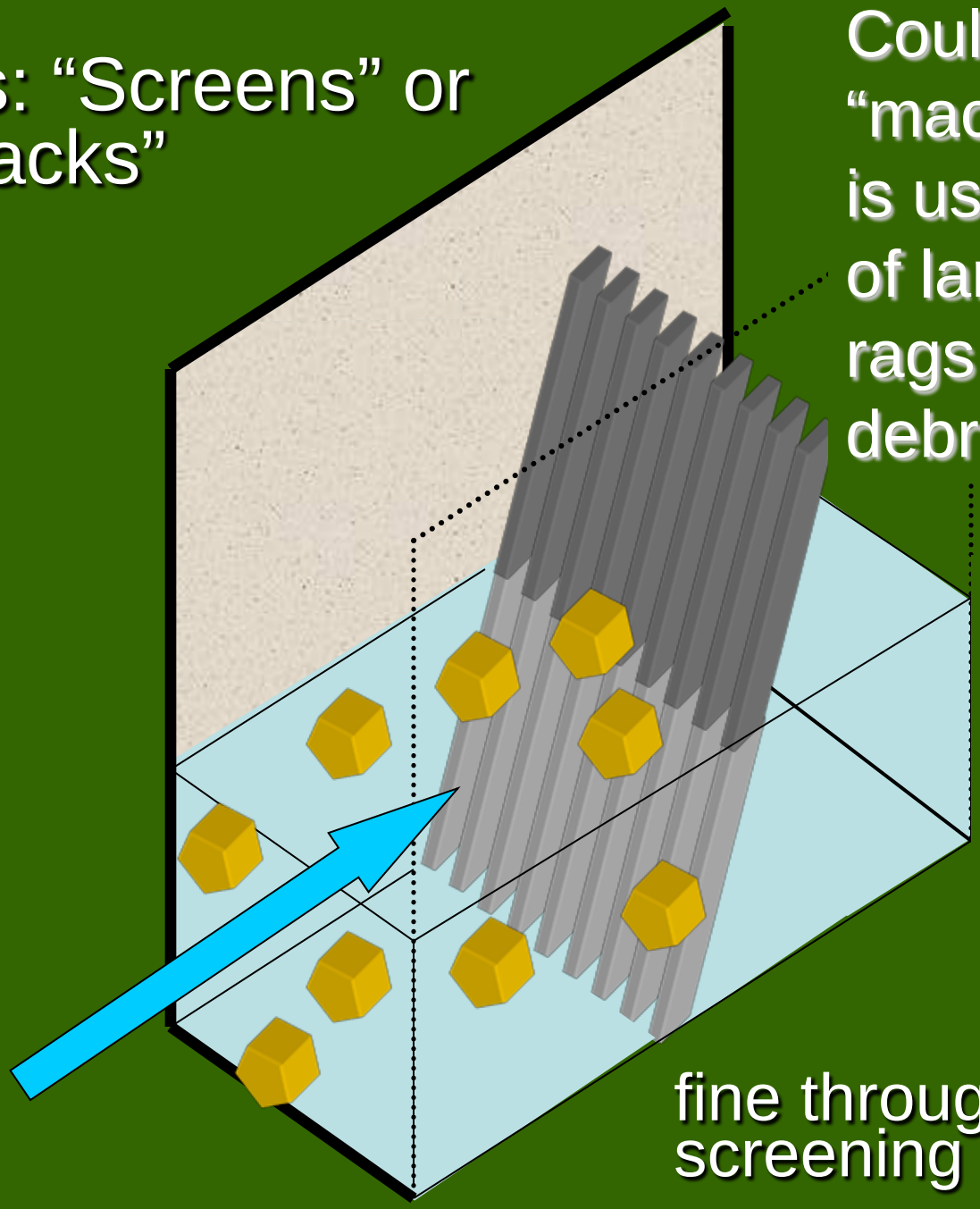
**micron** = one thousandth of a millimeter



# Filtration

- Filter Media
  - "Screens"
  - Sand
  - Diamataceous earth
  - Granular/multi- media
  - Activated carbon
  - Membrane
  - Fabric
- Filter rates
  - Rapid infiltration
  - Slow infiltration
- Filter types
  - Gravity
  - Pressure
  - Centrifugal force
  - Vacuum
- Moving or fluidized bed filters

Filters: “Screens” or “bar racks”

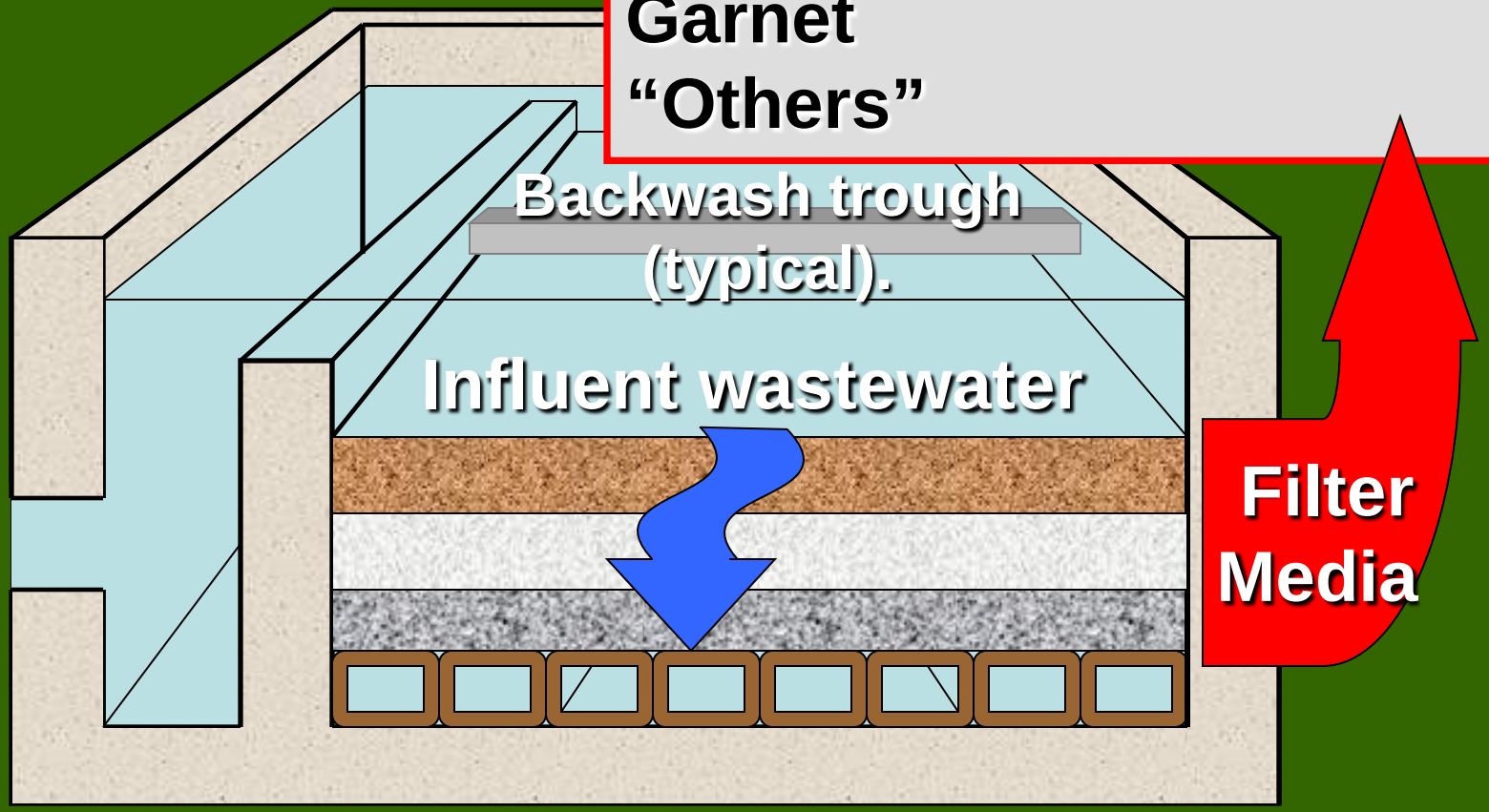


Could be called “macro” filtration, it is used for removal of larger items, rags, garbage, and debris (etc)

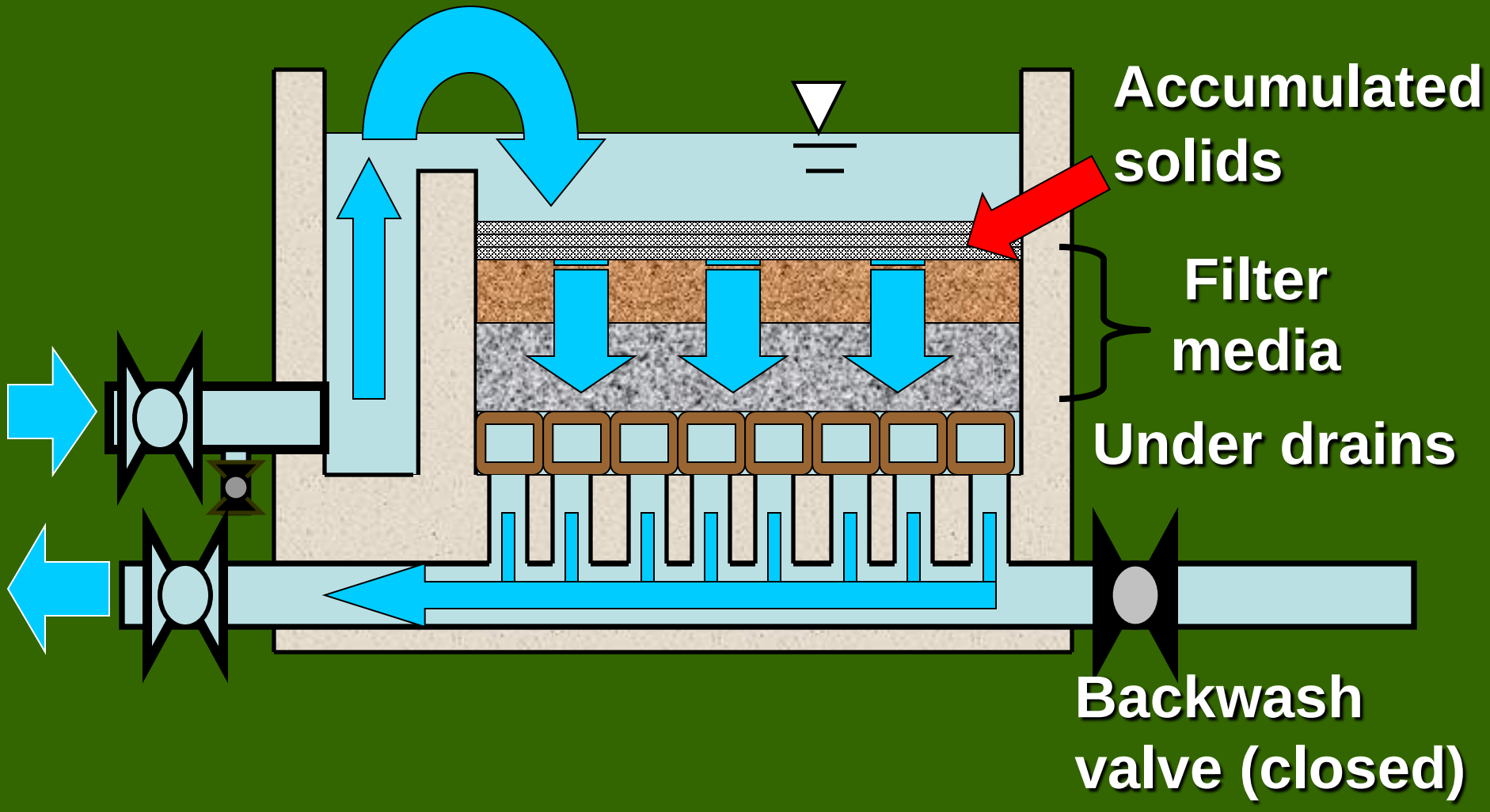
fine through coarse screening options available

- **Filter Media**
  - "Sand" or
  - Granular/multi-media

**Anthracite Coal,**
**Intermediate Sand,**
**High Density Sand,**
**High Density Support Gravel**
**Silica Sand or Gravel**
**Garnet**
**"Others"**



# Filtration, rapid-gravity type

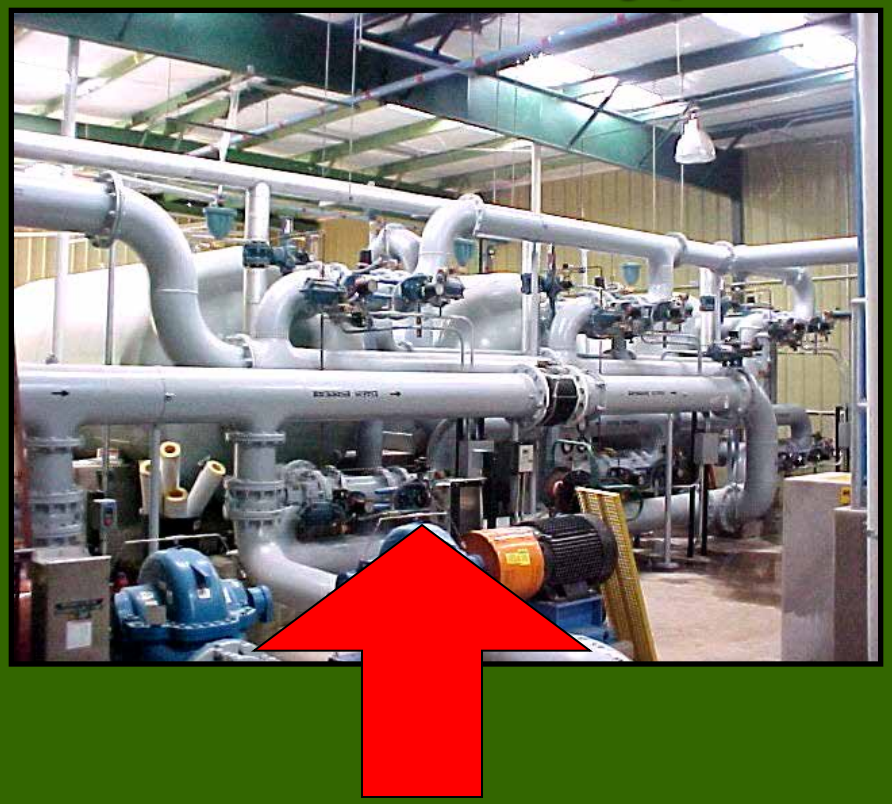


# Filtration
## Issues and concerns

- Subject to routine plugging & bio-fouling, so influent water characteristics are critical
- Require frequent cleaning or “backwashing”
- Cleaning & operation are typically mechanized & dependent on automated and/or computer controls
- Secondary cleaning methods,  chemicals or air scour
- Periodic replacement of filter media

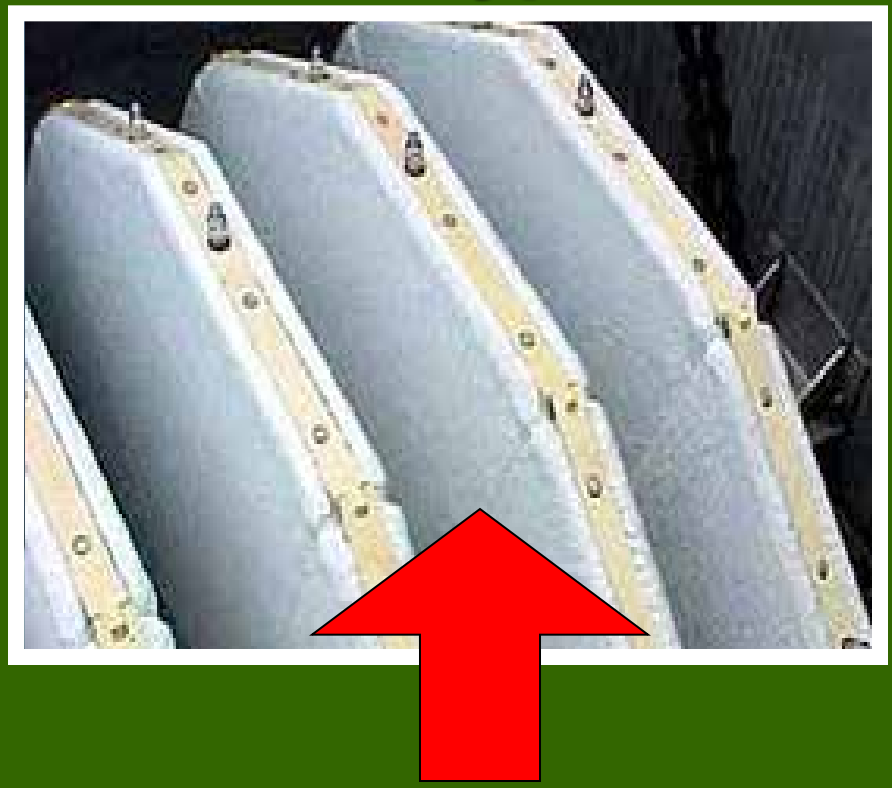
# Filtration

**Pressure type**



**Filter media in pressure vessel**

**“Fabric” type**

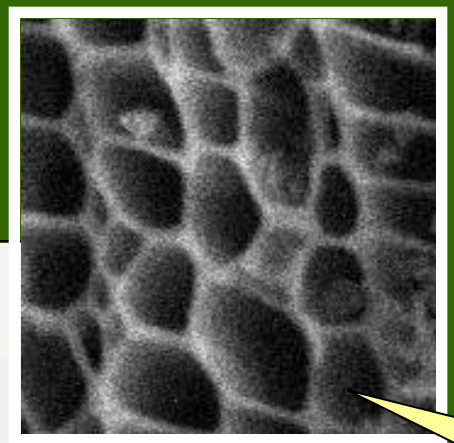


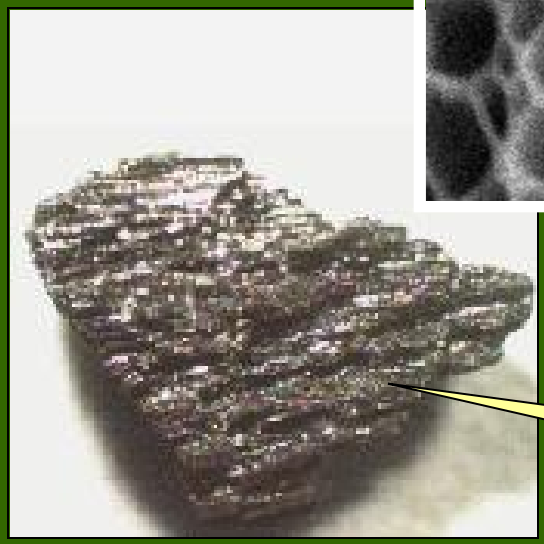
**Gravity flow through submerged cloth filter disk**

# Filtration: Activated carbon filter media

## Granular Activated Carbon (GAC)

uses "**adsorption**" - a type of attractive force between molecules






Magnified GAC particle surface

Granular Activated Carbon particle

# Filtration: Membrane biological reactors (MBR)

- Combine biological treatment with a membrane liquid-solid separation process
- Low pressure micro-filtration or ultra-filtration
- Uses synthetic membranes
- Can be immersed in an aeration tank

Benefits:

- Eliminates need for clarification & “tertiary” filtration
- Needs small land area, small “footprint”

Issues/concerns

- Higher building & operating costs than conventional wastewater treatment
- Highly dependent on computer control technology

# Membrane bio-reactors

# Filtration : Reverse osmosis (RO)

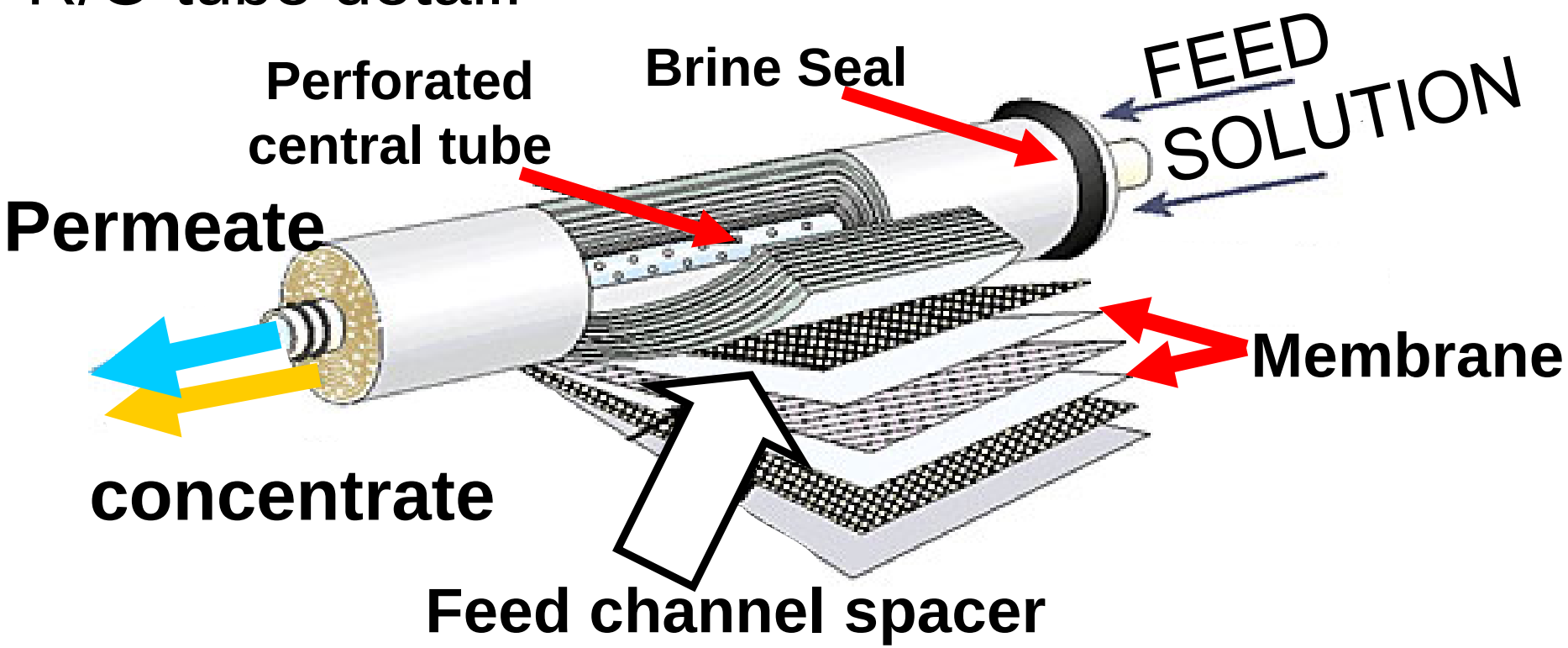
- A filter separation process using pressure to force a solution through a semi-permeable membrane

- RO process requires high pressure be exerted on the membrane

- Process is best known for removing salt from water

# Reverse Osmosis
# “detail”

R/O tube detail:




R/O “sorts” at the molecular level

# Reverse Osmosis

Benefits

- Removes  wide range of pollutants

Issues/concerns

- Pretreatment . Feed water needs pretreatment to remove particulates, influent turbidity
- Scaling, fouling, and degradation of membranes
- Ineffective in removal of some lighter, low molecular weight volatile organics (such as THM's, TCE, vinyl chloride, carbon tetrachloride).
- Disposal of reject water

# Physical Processes

- Clarification/Settling
- Air flotation
- Filtration
- Oil/water separation
- Cooling

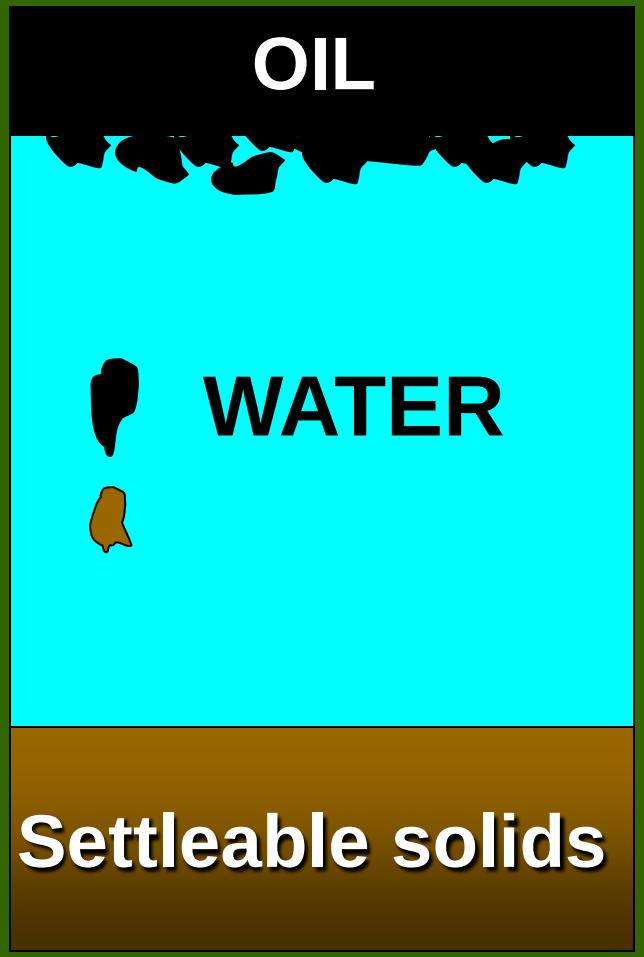
# Oil/water separators

Gravity separation device

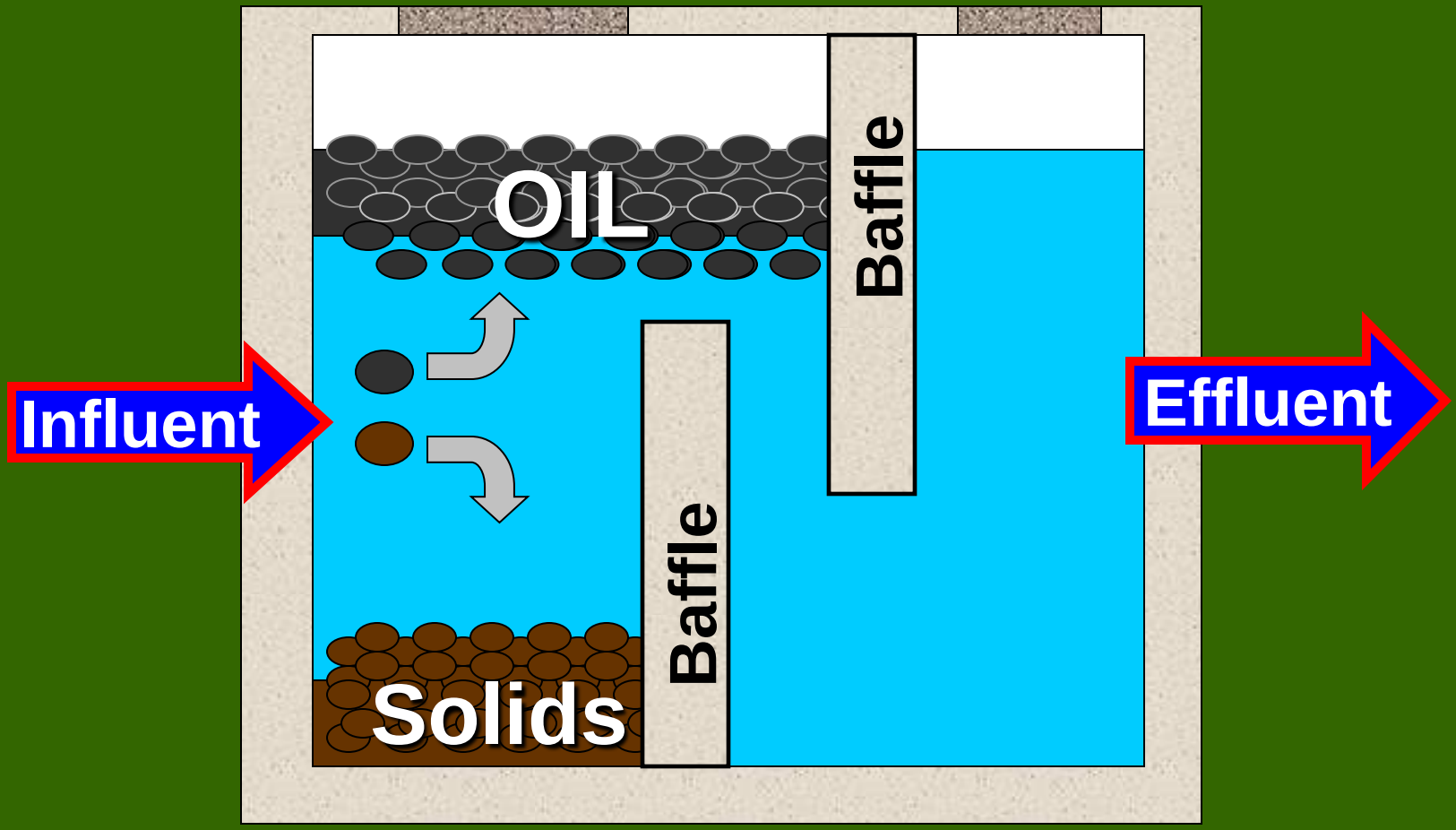
Oil droplets rise (density and size dependent).

Design based on differences in specific gravity between oil and water.

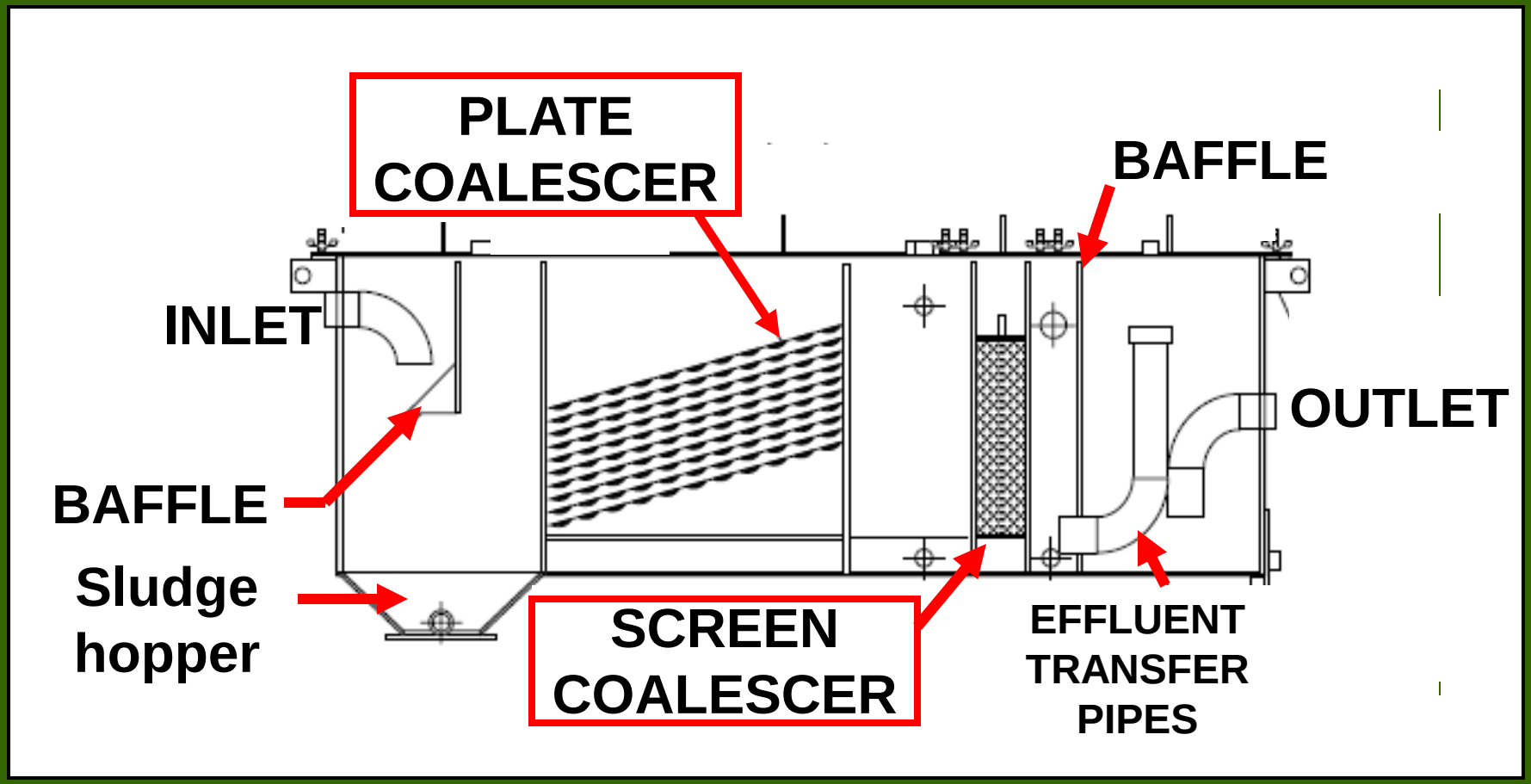
Standardized Criteria by the American Petroleum Institute (API)



# Oil/water separators
# “simplified example”



# Oil/water separators
# “Additional Features”




“COALESCERS” often added to enhance separation

# Oil/water separators

## Common limitations

Both emulsified and dissolved oils cannot be removed in physical oil/water separators

Emulsions: fine oil droplets which cannot be separated from water physically because of other chemicals in the water, such as soap.

***Routine maintainance!*** Solids and oils must be removed & properly disposed. This must occur frequently or pollutants will pass through.

# Oil/water separator

Relatively simple to operate…

…but the effluent water must often be sent on for further treatment (dissolved air flotation unit for example) to remove any residual oil, followed by biological treatment unit for removal of dissolved compounds

# Physical Processes

- Clarification/Settling
- Air flotation
- Filtration
- Oil/water separation
- Cooling

# Cooling

- Many industries generate heat in their processes and often need cooling water systems

- If need to discharge to natural waters or public sewer system may be required to cool that water first

NON CONTACT COOLING WATER is water used for cooling which does **not** come into direct contact with any raw material, product, byproduct, or waste

# Cooling

- Evaporative cooling systems include
  - cooling towers,
  - evaporative condensers
  - spray ponds
  - cooling ponds.

- Reduce temperature of wastewater by transfer of heat from the wastewater to another fluid or to the atmosphere

# Cooling: issues/considerations

Ponds

- Large land area required
- Algae/bacteria growth

Towers

- Power and maintenance requirements
- Impurities in process water can cause scale, corrosion, and fouling
- Water Treatment Additives (WTAs)
  - May be needed to address scale, corrosion, and fouling
  - May complicate suitability for discharge; WTAs require special approvals from DEQ.

# Chemical Processes

- Air Stripping
- Precipitation
- Ion exchange
- Chemical neutralization

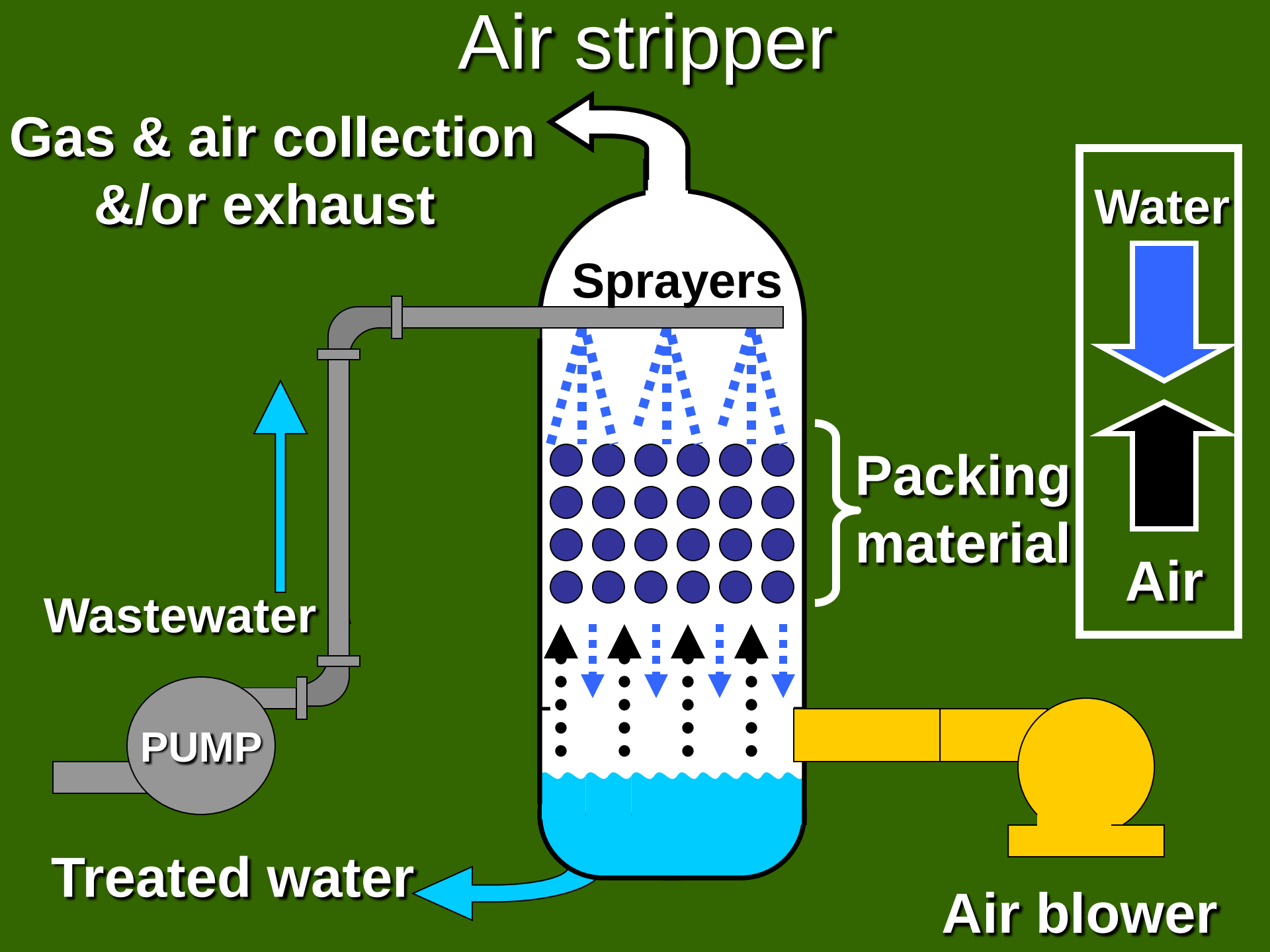
# Air stripping

- Air stripping is the transfer of volatile components of a liquid into an air stream.

- Volatile compounds with certain properties can be economically stripped from water.
  - Includes BTEX compounds and certain solvents
  - Ammonia can also be removed by air strippers, typically enhanced by adjustment of pH & temperature of the waste stream

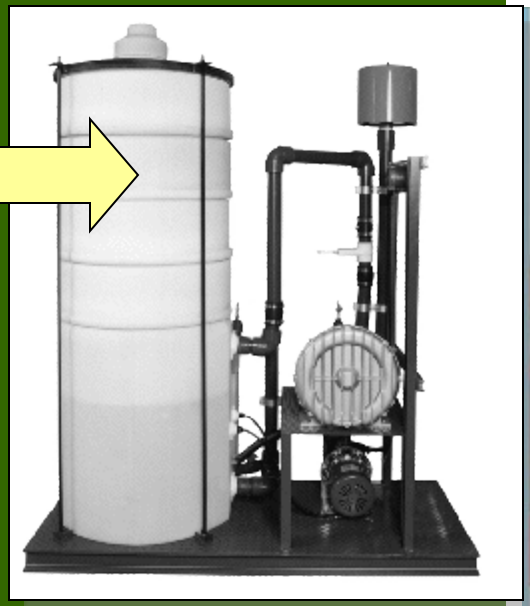
- Air strippers are usually towers
  - “Packed” or “tray” towers of packing media

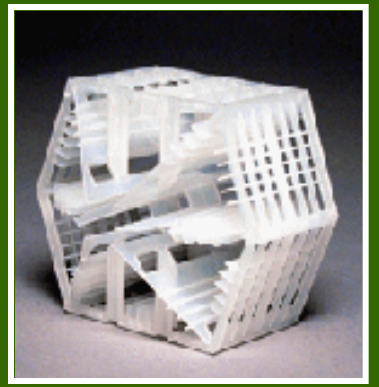
# Air stripper

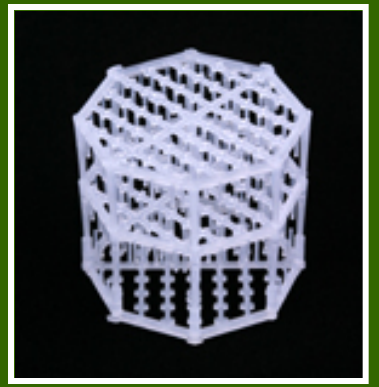


# Air Stripping

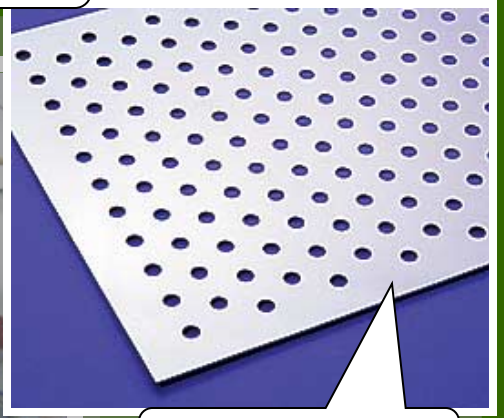
- Packed towers
  - Engineered or random plastic packings







Low profile unit



tray

# Air Stripping

Benefits

- Simple. Generally easily built, operated, & maintained

Issues/concerns

- Noise, very loud
- Cannot remove metals, PCBs, or other chemicals that do not evaporate
- Air stripping transfers pollutants to the air
  - the air exiting the stripper may require emissions control and air quality permits
- Fouling, deposits of minerals, solids, biological films

# Chemical Processes

- Air Stripping
- Precipitation
- Ion exchange
- Chemical neutralization

# Chemical Precipitation

- For removal of:
  - metals, other inorganic, suspended solids, fats, oils, greases, and some other organic substances from wastewater
- Dissolved or suspended contaminants in a solution settle out of the solution as a solid *precipitate*
- *Precipitate* is then separated from the liquid by clarifiers, filters or centrifuging etc.
- Assisted through the use of coagulants and polymers

# Chemical precipitation

- Coagulants
  - Cause smaller particles suspended in solution to gather into larger aggregates
- Polymers
  - Contain electrically charged molecules which allow the polymers to act as connecters between particles suspended in solution, or to neutralize particles in solution

# Chemical precipitation

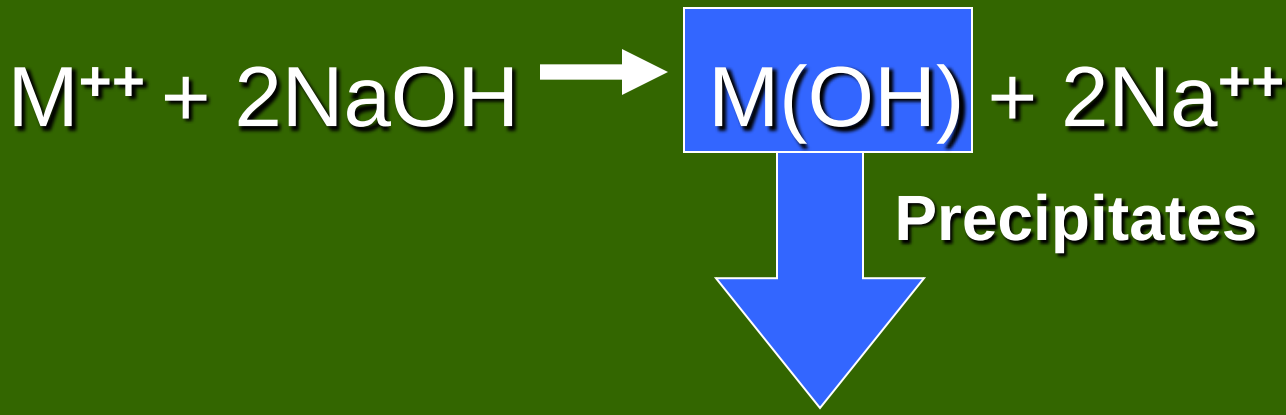
Common uses

- Water softening
- Heavy metal removal (metal plating wastes)
- Oil & grease removal from emulsified solutions
- Phosphate removal from wash-waters and other wastewater

# Chemical precipitation

Converts metals to an insoluble hydroxide
(the hydroxides of most metals are insoluble)

Example reaction mechanism for a divalent metal

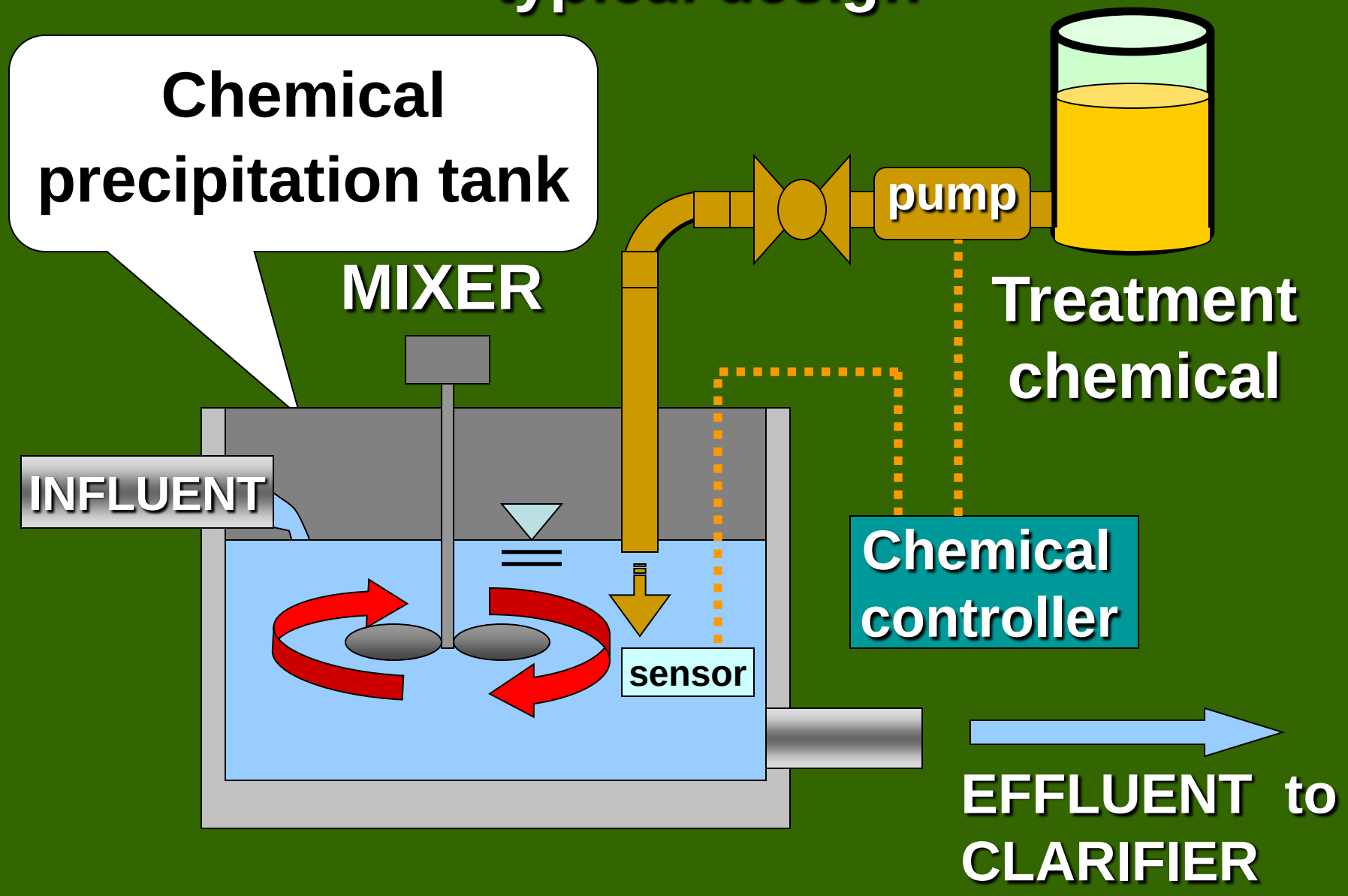



Note:

- Metal precipitation, solubility is pH dependent, need to optimize pH for each metal

# Chemical Precipitation,

## typical design



# Chemical precipitation

Benefits

- Well-established technology, readily available
- Some systems can be self-operating with low maintenance

Issues/concerns

- Competing reactions, pH, alkalinity, temperature, mixing effects, and other factors can make precipitation delicate and frustrating
- Some chemicals are hazardous and corrosive,
- Transport / handling / storage of large amounts of chemicals may needed

# Chemical Processes

- Air Stripping
- Precipitation
- Ion exchange
- Chemical neutralization

# Ion Exchange

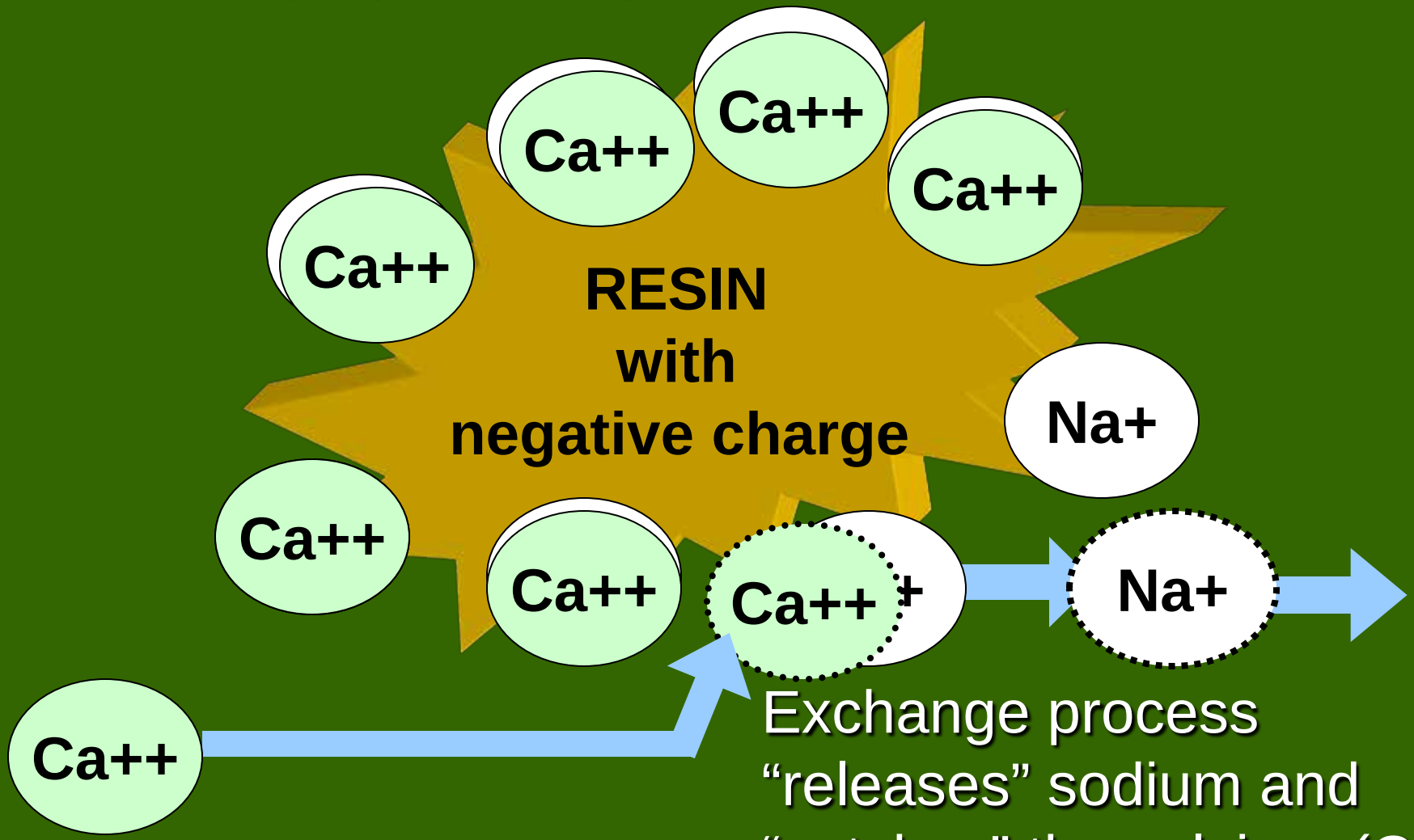
- Used to remove heavy metals from low–concentration waste streams

  **Ion:** an atom or molecule that has lost or gained one or more valance electrons, making it positively or negatively charged

- Pass wastewater through a bed of resin
- Resin has groups of ionic charge on its surface

# Ion Exchange Example

Sodium (Na) is initially attached to resin



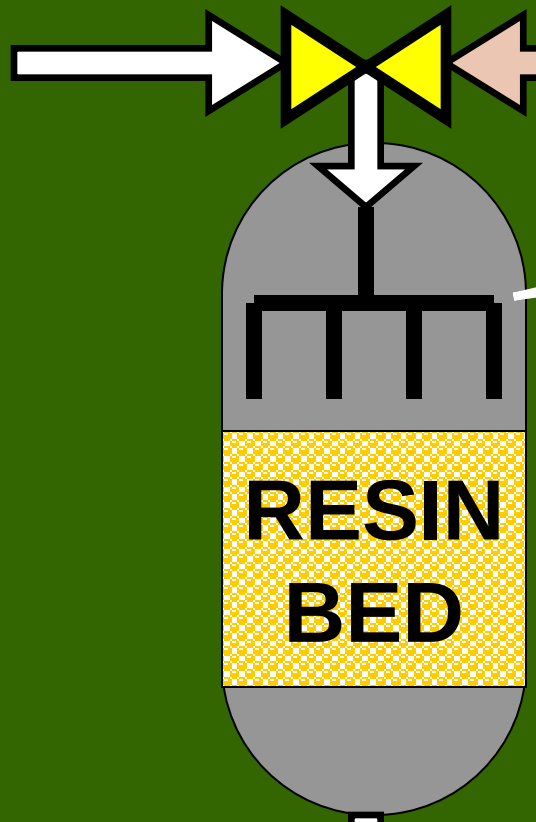

Exchange process "releases" sodium and "catches" the calcium (Ca)

# Ion Exchange

**Wastewater influent**

**Regenerant Solution**

**Distributor**




Process steps

- Treatment
- Backwash
- Regeneration
- Rinse

**Used regenerant**

**Treated effluent**

# Ion Exchange

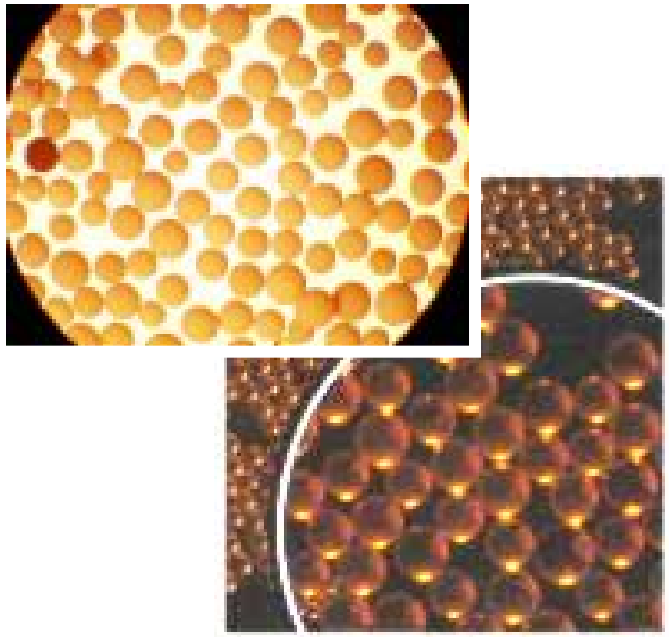
Benefits

- Metal contaminants can be recovered and reused
- Selective, may be designed to remove certain metals only

Issues/concerns

- Resins may be fouled by some organic substances, oils, & polymers.
- Wash water disposal

**Sample resin beads**



Bead material has a structure of pores on the surface which accommodate easily trapped and released ions

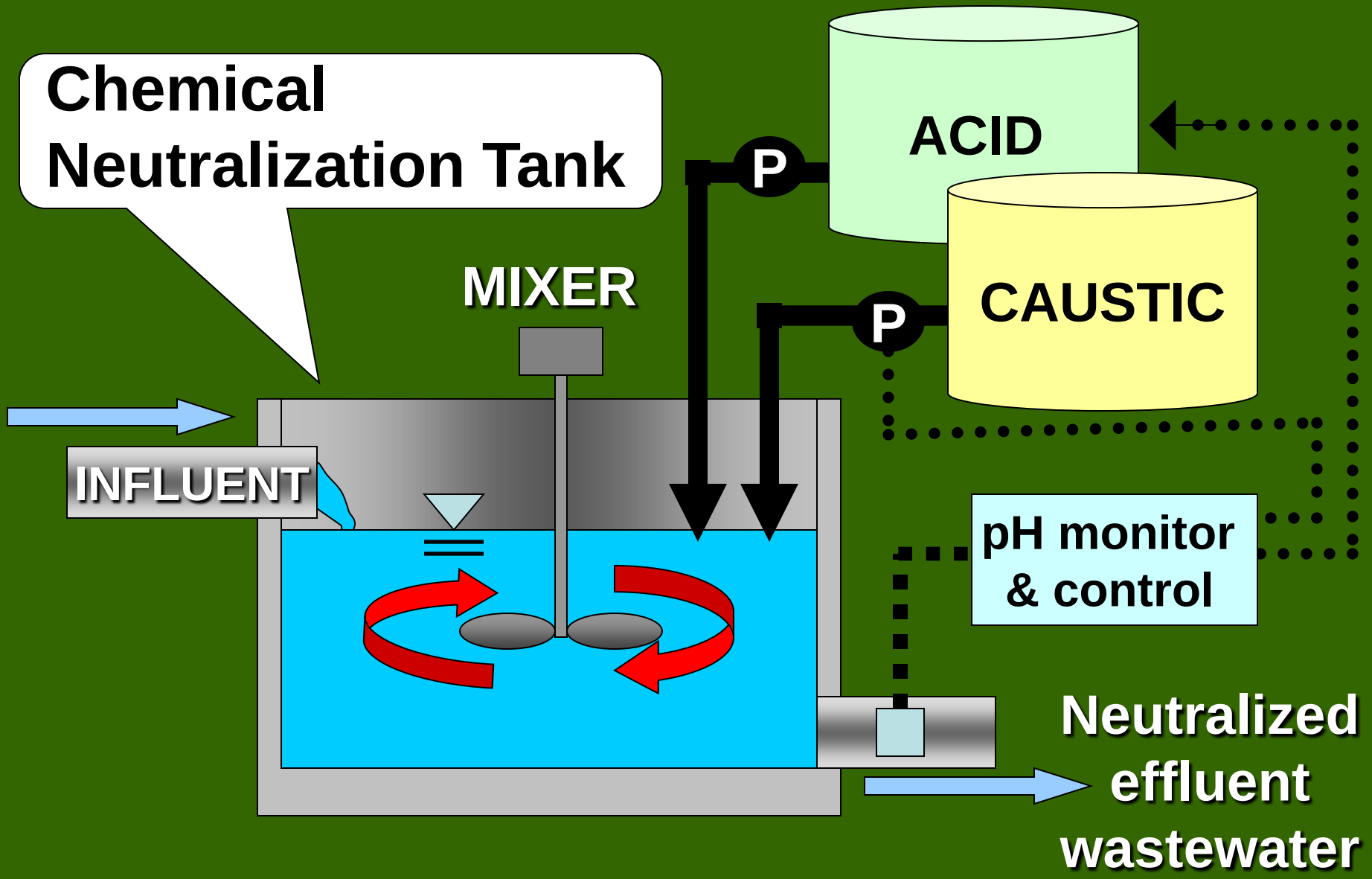
# Chemical Processes

- Air Stripping
- Precipitation
- Ion exchange
- Chemical neutralization

# Chemical Neutralization

- Eliminate either high or low pH values
  - to meet discharge limits
  - or prior to other treatment processes that require pH adjustment
- Add acids, such as sulfuric or hydrochloric acid, to reduce pH
- Add  alkalies, such as sodium hydroxides, to raise pH values
- Typically performed in a holding tank, rapid mix tank, or an equalization tank

# Chemical Neutralization



# Chemical Neutralization

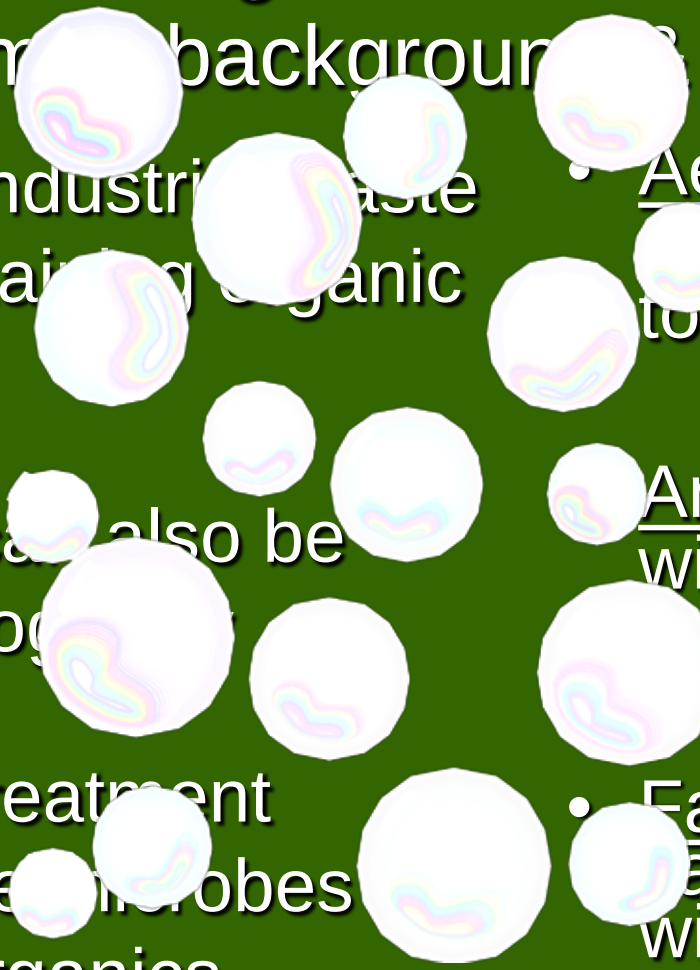
- Control pH between 6 and 9 in order to meet typical discharge limitations
- Relatively simple, but typically involves handling hazardous chemicals

## Typical chemicals

| ACIDS | BASES |
| --- | --- |
| Sulfuric Acid ($H_2SO_4$) | Caustic (NaOH) |
| Carbonic Acid ($H_2CO_3$) | Calcium Hydroxide ($CaOH_2$) |
| Hydrochloric Acid (HCl) | Calcium Carbonate |
| Phosphoric Acid ($H_3PO_4$) | ($CaCO_3$)-Lime |
| Nitric Acid ($HNO_3$) | Ammonium Hydroxide ($NH_4OH$) |

# Biological Processes
## Comm[illegible] backgroun[illegible] definitions

- Applies to industri[illegible]aste waters contai[illegible]g organic pollutants
- Some oils ca[illegible] also be treated biolog[illegible]
- Biological treatment systems use microbes consume organics



- Aerobic microbes require oxygen ($O_2$) to grow
- Anaerobic microbes will grow only in the absence of $O_2$
- Facultative microbes can grow with or without $O_2$

Aeration is the process by which air (or oxygen) is added to, dissolved in, circulated and/or mixed in wastewater

# Biological Processes

*The microorganisms used are commonly referred to as the "bugs"*

<u>These organisms:</u>

- Use organic compounds or matter as food and/or energy
- Degrade (break down) these materials in metabolic processes
- Produce carbon dioxide, water and other "smaller" compounds as a result of metabolic processes

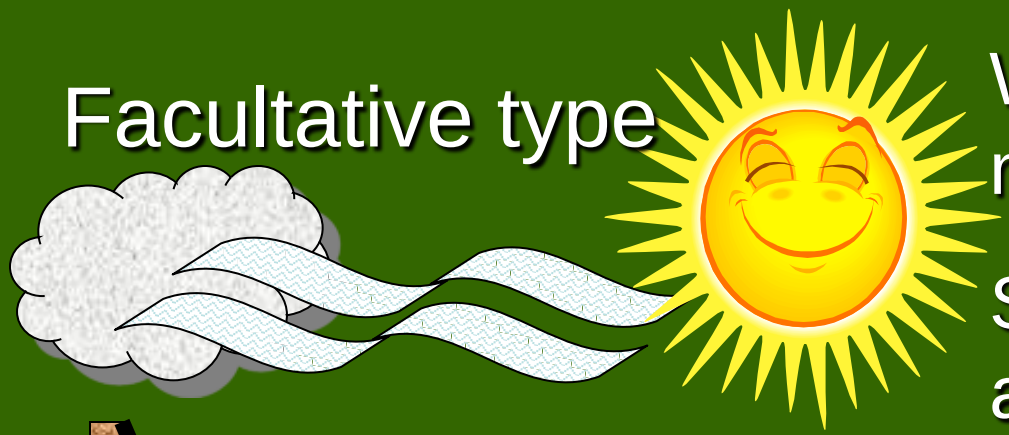
# Biological Processes

- Lagoons/Stabilization Ponds
  - Facultative
  - Aerated
  - Anaerobic
- Suspended growth
  - Activated Sludge
  - Sequencing batch reactors (SBRs)
  - Oxidation ditch
- Attached growth
  - Trickling Filters
  - RBCs
- Anaerobic digestion

# Lagoons/Stabilization Ponds

# Lagoons/Stabilization Ponds

## Facultative type



Wind provides surface mixing and aeration

Sun provides energy to algae

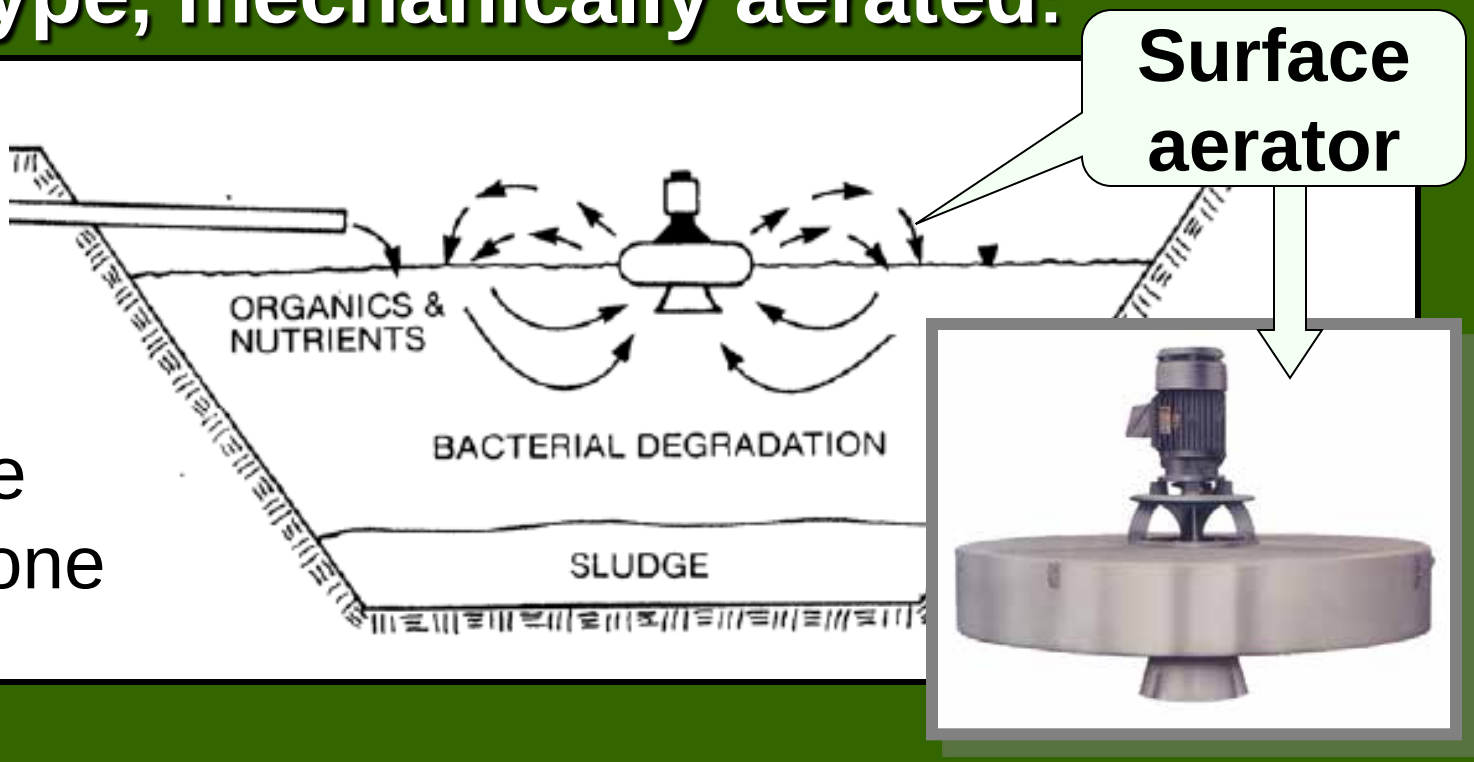

Bacteria & algae in the pond consume organics and modify chemical byproducts

{ Anaerobic zone (bottom sludge)

# Lagoons/Stabilization Ponds

## Aerobic type, mechanically aerated:

Add air to increase biological activity, & extend the aerobic zone

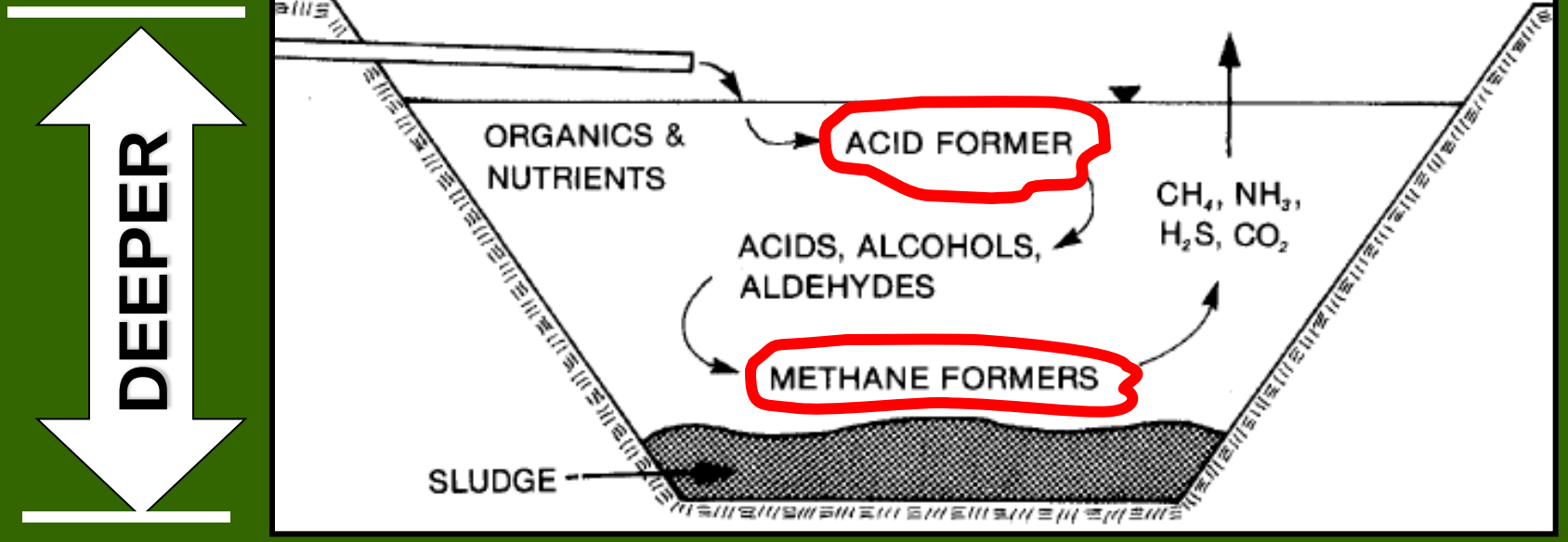



Bacteria + $O_2$ = BOD reduction & nitrogenous compound conversion

Organic carbon is oxidized & sulfur compounds are converted also.

# Lagoons/Stabilization Ponds

Anaerobic type: Anaerobic "bugs" convert organic materials into stable products such as carbon dioxide & methane in a 2 phase process:



# Lagoons/Stabilization Ponds

## "general comments"

- Simple treatment systems, but the biology and biochemistry involved are very complex
- Different types of lagoons often combined to achieve the best treatment
- Operated at ambient temperature, only function well in mild or warm climates

# Issues and Concerns common to all lagoon types

- Removal of settled sludge's & grit
- Sludge reduction limited in cold climates
- Emergent vegetation, insects & burrowing animals
- Need for composite liners (expensive)

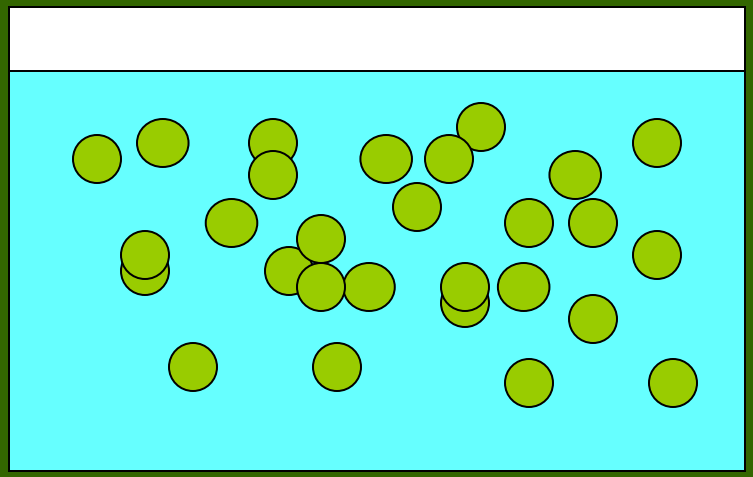
# Conventional biological treatment

## Two main categories

### Suspended growth

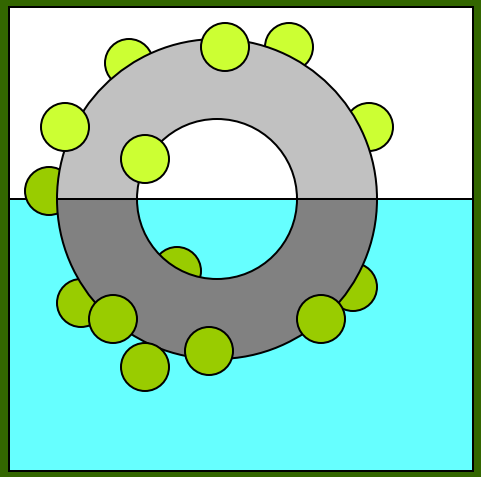
Microbes mixed and suspended in wastewater

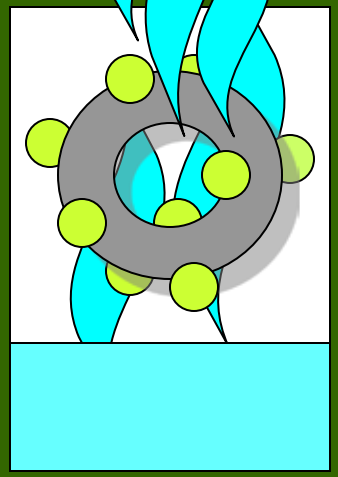
**Enlarged “microbe”**



### Attached growth

A media is immersed in wastewater, or wastewater poured over media. Microbes attached to media





# Biological Processes

- Lagoons/Stabilization Ponds
  - Facultative
  - Aerated
  - Anaerobic
- Suspended growth
  - Activated Sludge
  - Sequencing batch reactors (SBRs)
  - Oxidation ditch
- Attached growth
  - Trickling Filters
  - RBCs
- Anaerobic digestion

# Suspended growth

## Biological processes

Suspended growth process variations:

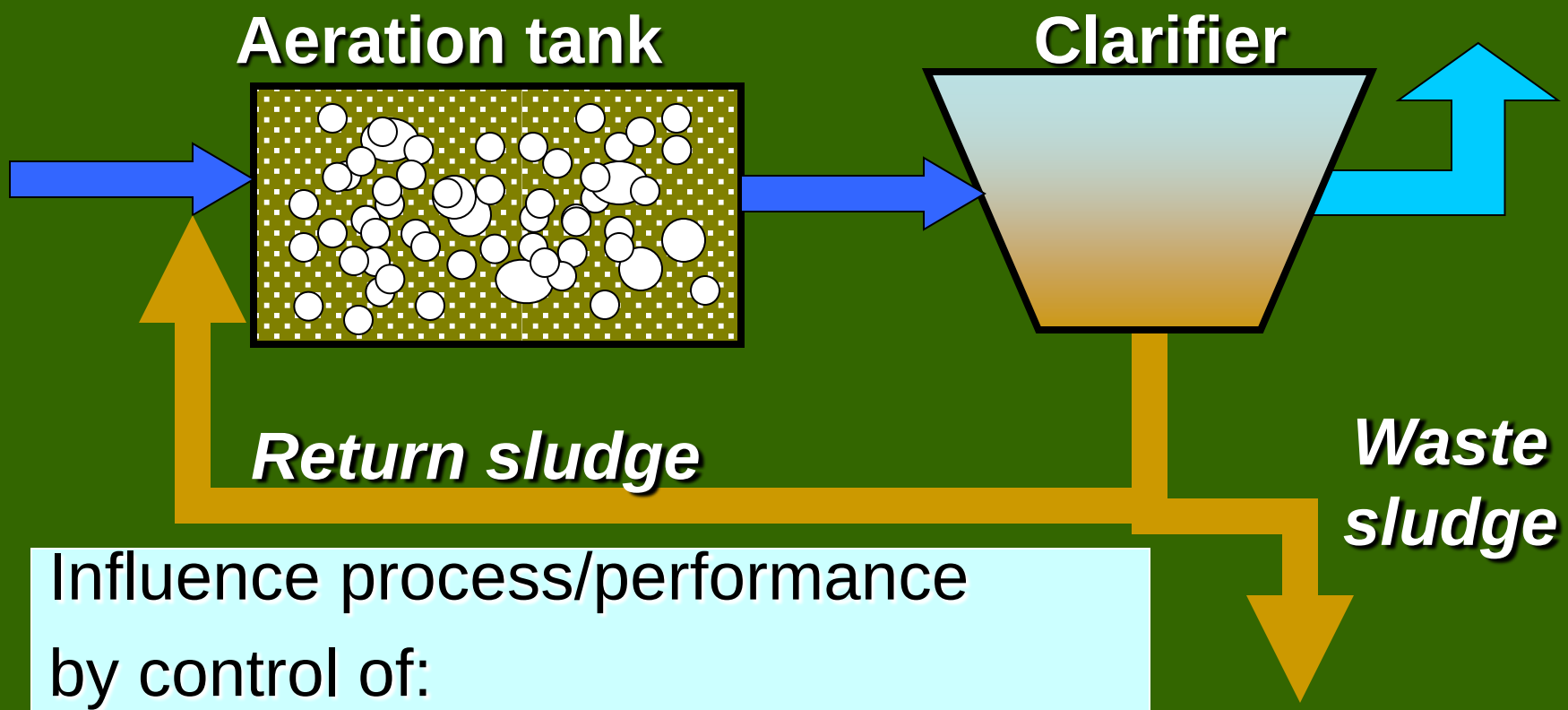
- Activated sludge,
- Oxidation ditches
- Sequencing batch reactors (SBRs)

Speed up the work of aerobic bacteria & other organisms by providing a highly aerobic environment to increase their efficiency

Removes or breaks down bio-degradable organic material & converts organic nitrogen-compounds

Air is added to the water, provides oxygen to the suspended microbial growth

# Activated sludge (typical)

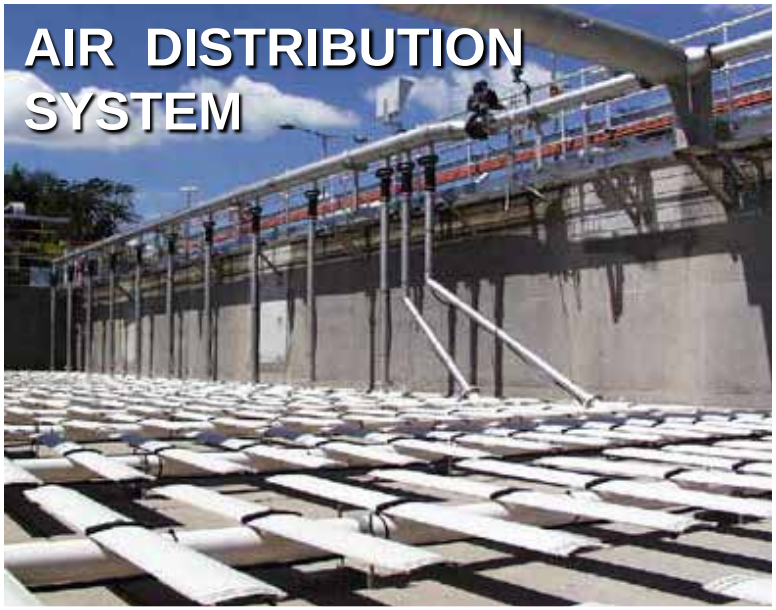



Influence process/performance

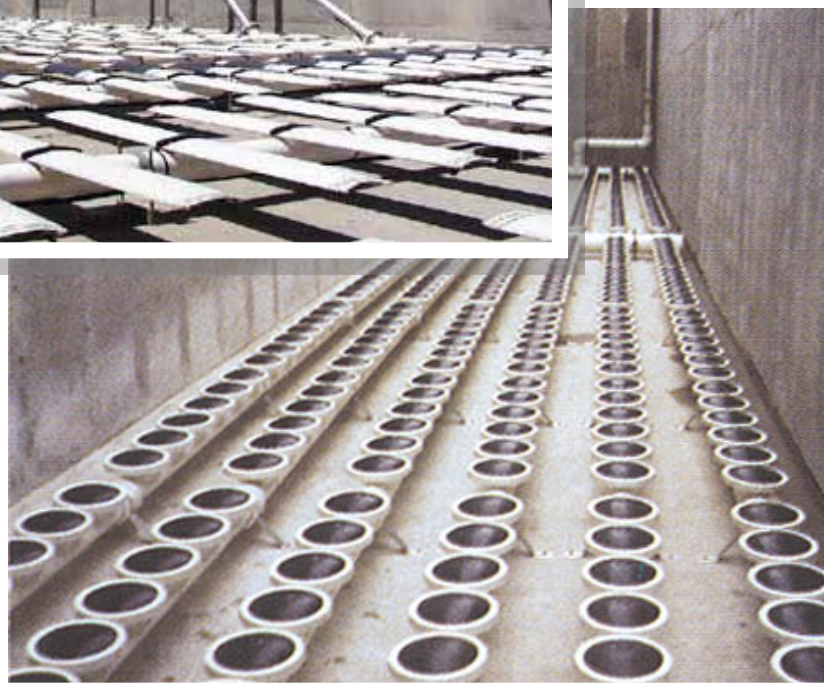
by control of:

- sludge recycle vs. waste
- micro-organisms' residence time,
- sludge density

# Activated sludge







AIR DIFFUSER HEADS

# Activated sludge

Benefits

- Treatment units are relatively small, requiring less space than attached growth processes
- Good process control features and options
- Process is generally free of odors
- Process flexibility, has many variants

Issues/concerns

- Can be costly to operate compared to attached growth units, higher energy use for aeration system
- Process can be impacted by elevated levels of toxic compounds in the wastewater

# Biological Processes

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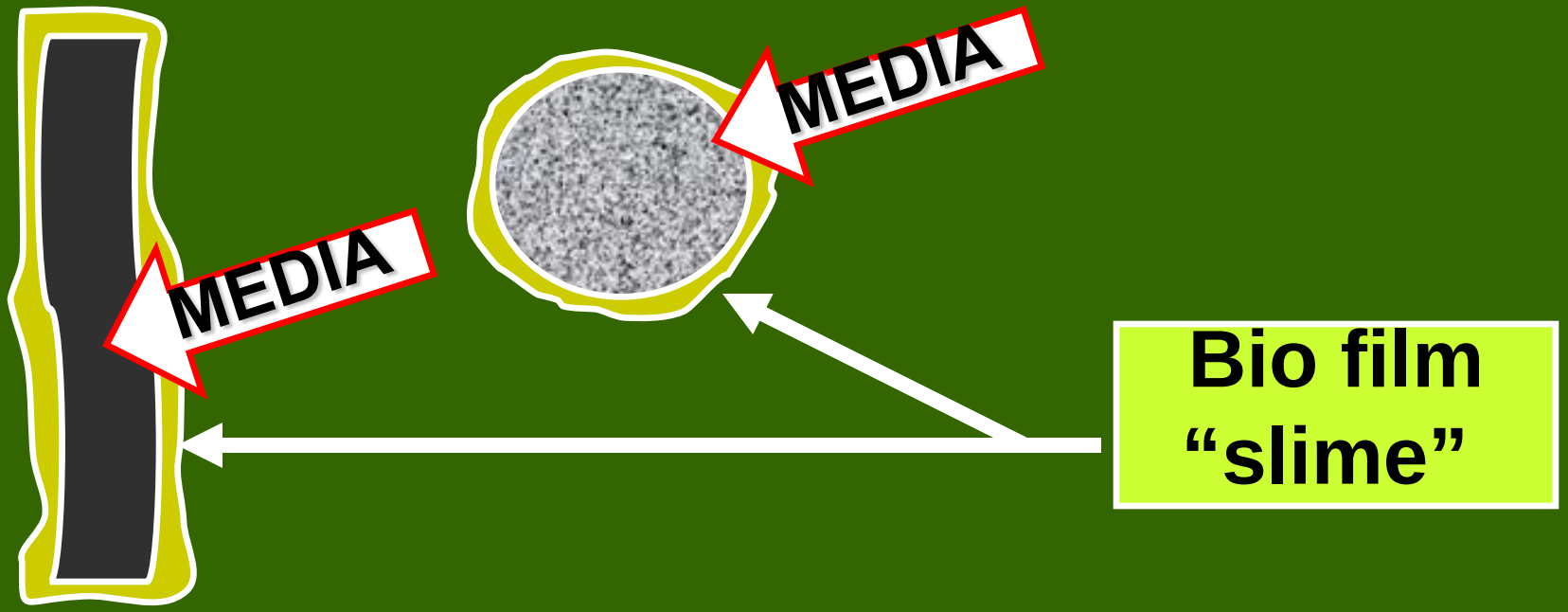
# Attached Growth biological processes

Attached growth

Microbial growth is on the surface of media, a “film” of microbes




Media: typically made of plastic or stone

# Attached Growth biological processes

Attached growth variations:

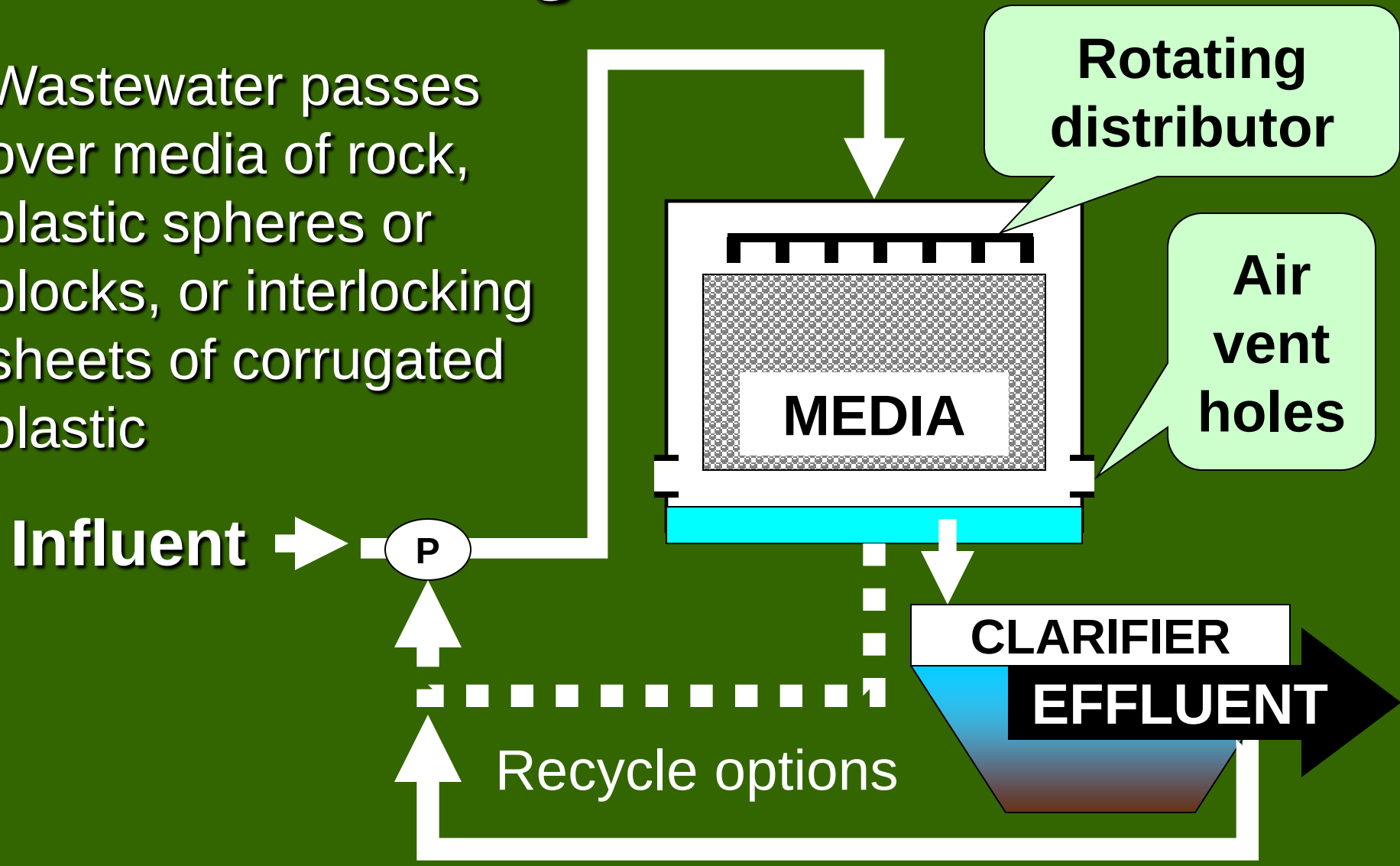
- Trickling filters or towers
- Rotating biological contactors (RBCs)


Wastewater passes over/through the media along with air to provide oxygen

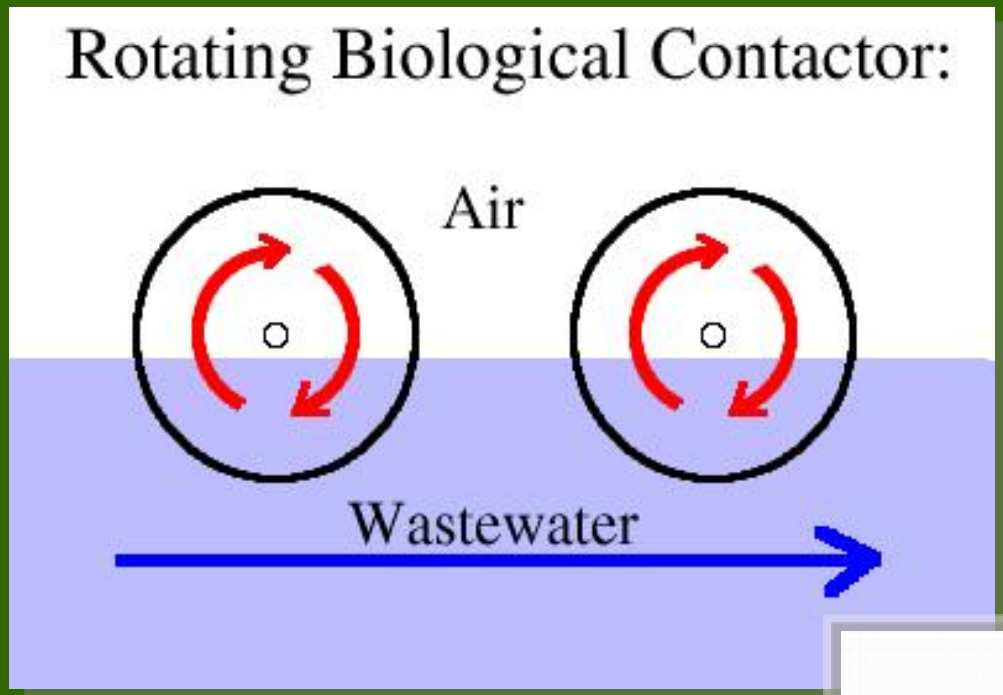

The media is rotated in and out of the wastewater to provide oxygen

# Trickling filter or tower

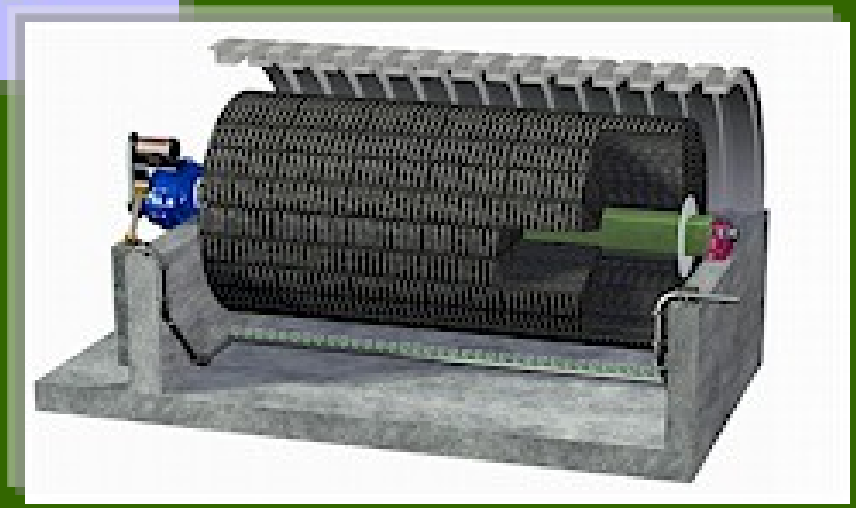
Wastewater passes over media of rock, plastic spheres or blocks, or interlocking sheets of corrugated plastic



# Attached growth: RBC




Air is provided by rotation of disk out of the water



# Attached growth

**Benefits**

- **Efficient at nitrification**
- **Low power requirements**

**Issues/concerns**

- **Additional treatment often needed**
- **Accumulation of excess biomass can impair performance**
- **Flexibility & control are limited (compared to activated-sludge processes)**

# Biological Processes
# common issues and concerns

Supplemental nutrients or carbon may be needed in order for the process to work properly if the waste stream is deficient in carbon or nutrients

Inconsistent waste type and loading can reduce effectiveness (of some types more than others)

Toxics can kill the biomass

# Biological Processes

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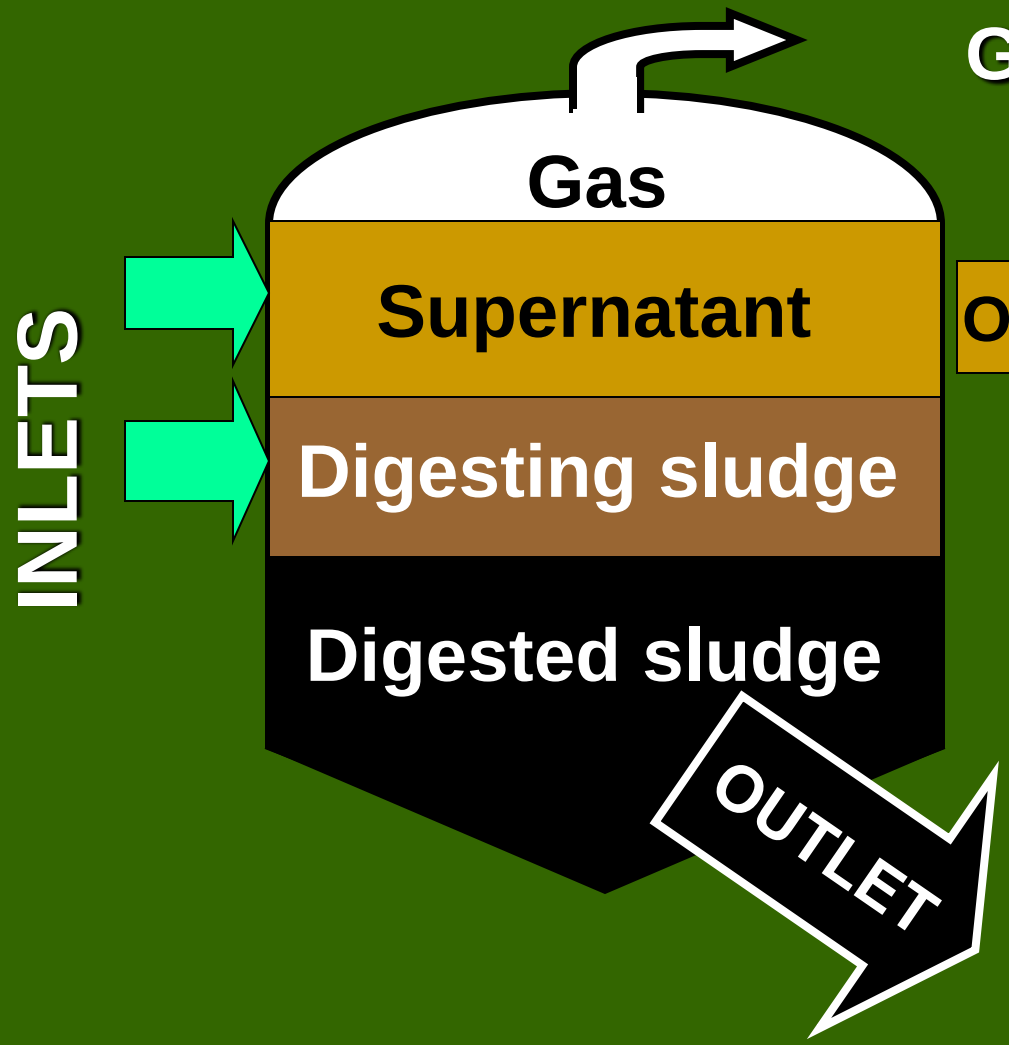
# Anaerobic Digestion

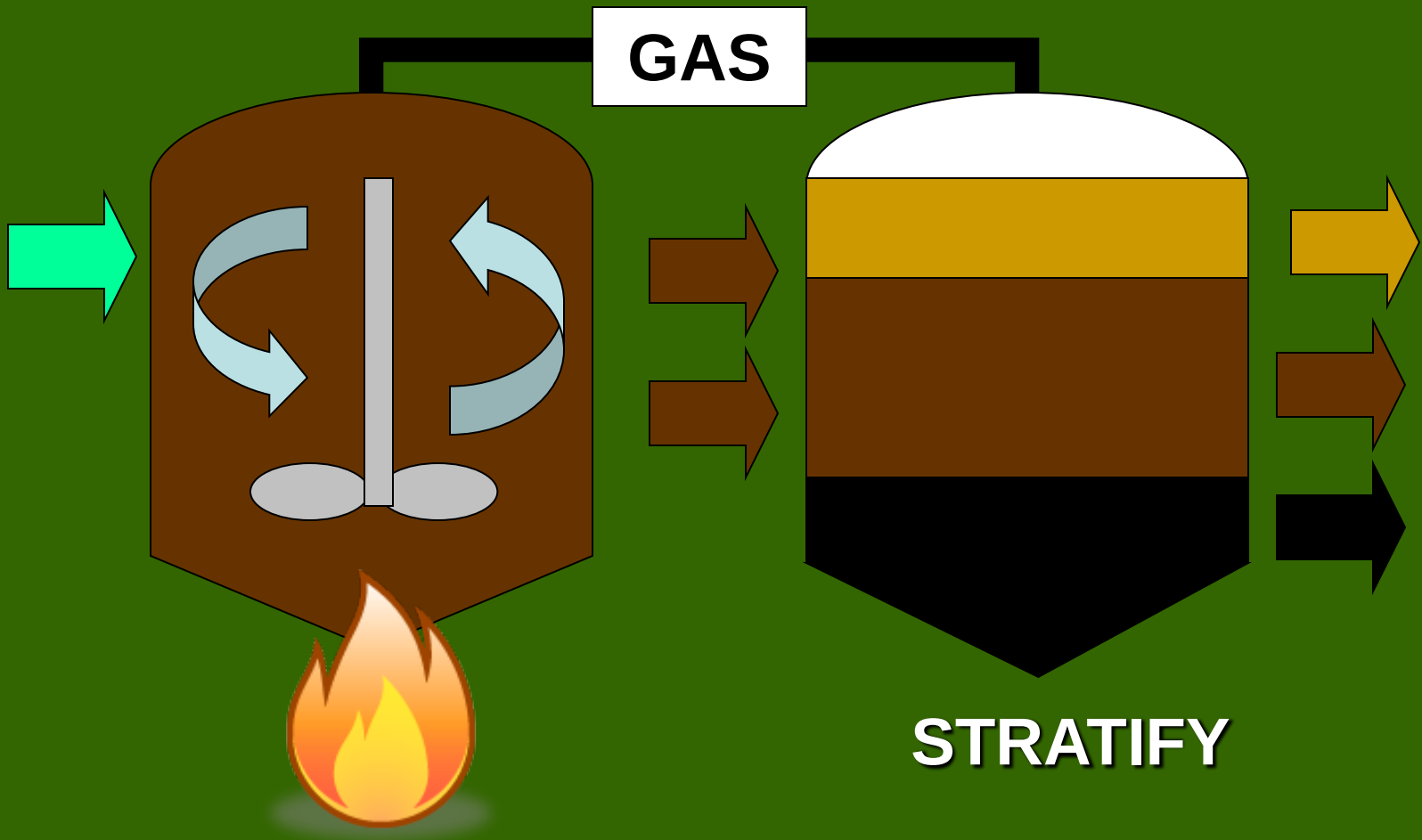
Used for stabilizing sludge's and industrial wastes




Anaerobic bacteria produce methane & carbon dioxide, reducing high strength organic waste

# Anaerobic Digestion

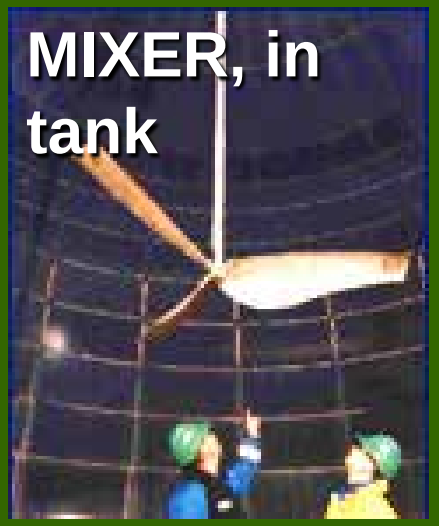
## Two Stage “High Rate” Version



# Anaerobic Digestion

Benefits

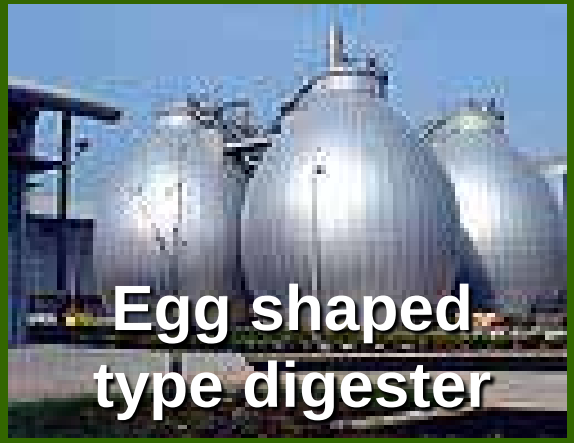
- Low energy required compared to aerobic versions
- Less biological sludge produced
- End product can be saleable or useable products such as biogas (methane production), soil conditioners, and fertilizer
- Suitable for high-strength industrial wastes



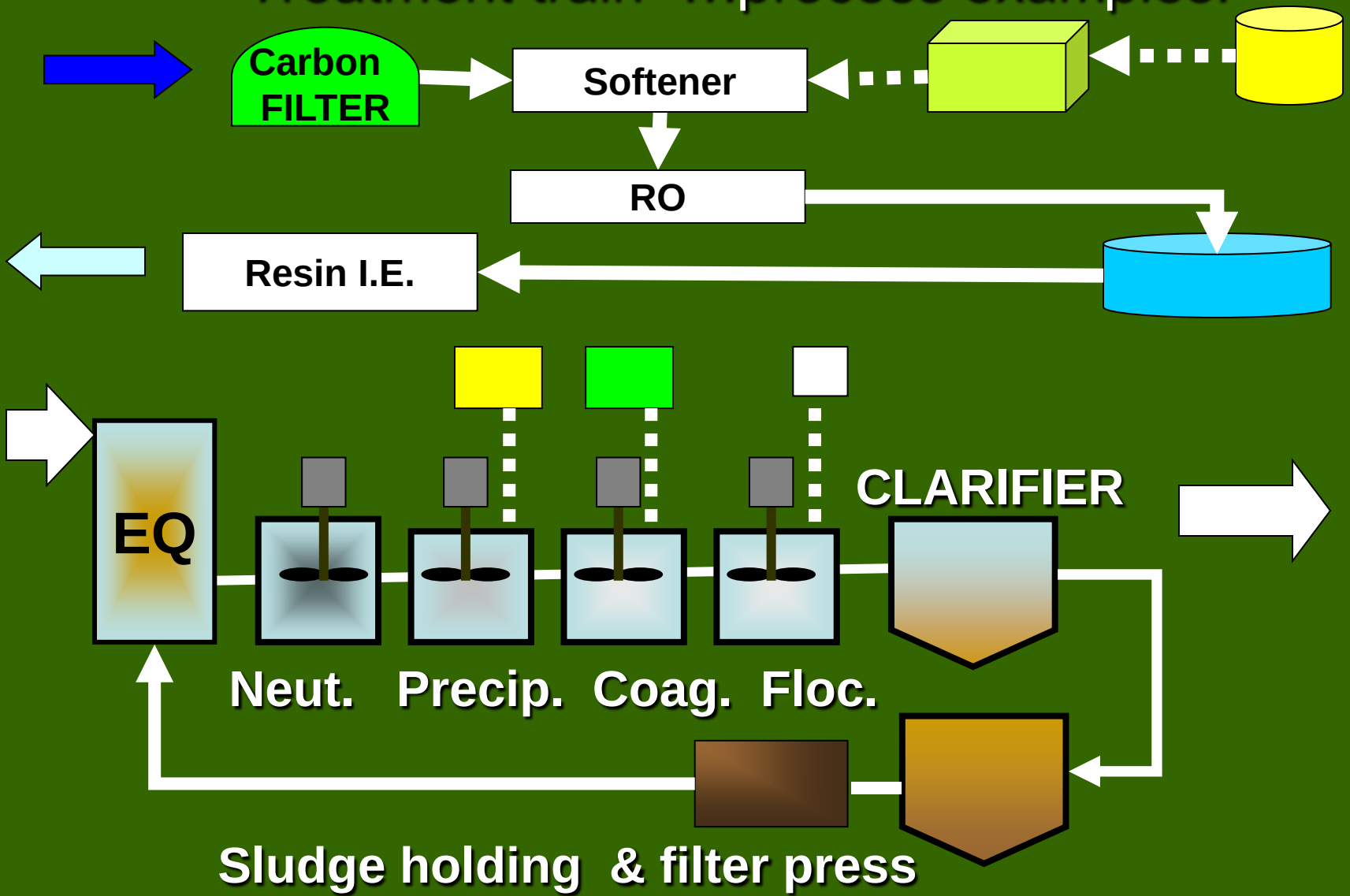

# Anaerobic Digestion

Issues/concerns

- Longer start-up time to develop necessary biomass inventory
- May require further treatment with an aerobic treatment process
- Reaction rates are sensitive to lower temperatures; heating used to achieve adequate reaction rates
- Increased potential for production of odors and hazardous and corrosive gases.




# Likely need more than one process typically a "Treatment train" …process examples:



# Design Process, Selection of technologies

- Use a qualified consultant
- Consult with DEQ staff
- Consider capital & operation costs
- Consider complexity of testing & reporting requirements
- Consider complexity of operation, and the qualifications needed for operators
- Operator training requirements

# Other info and resources

- DEQ's "**Michigan Manufacturer's Guide…"** contains a discussion of Wastewater Treatment Technology

- The ***Michigan Fruit and Vegetable Processor's Guide to Environmental Regulations, Chapter 3, Wastewater*** contains a detailed discussion of Wastewater Treatment Technology

It would likely be useful for sectors that manage wastewater with similar pollutants and can be found online at: www.michigan.gov/deq, more specific website location details provided in your handout

# The end


# Thank you !