



24. Odor Control

24.1 Background

Odors associated with wastewater, result from the release of the following:

1. compounds which are originally discharged into the sewer – chemicals, wastes, or
2. by products of biological and chemical reactions occurring in wastewater

Odors are generated from every phase of wastewater treatment. Odor characteristics, intensity, and volume of foul air generated is dictated by the treatment process and the stage of wastewater treatment.

Odors are dependent on:

- Odor causing compounds present
- Exposed process surface area
- External factors including temperature and atmospheric conditions including wind speed and direction.
- Proximity and sensitivity of odor receptors

Key wastewater properties which dictate odors include:

- pH and Temperature: These affect the rate of biological degradation and the rate at which the odorous compounds are released.
- ORP: ORP governs the rate of biodegradation activities in the wastewater. Lower (more negative) implies anaerobic conditions.
- Dissolved/bound/available oxygen: Presence of oxygen will increase the wastewater ORP.
- Conveyance time: Longer time due to longer distance and lower velocities will promote anaerobic degradation in the wastewater.

24.2 Drivers for Odor Control

1. Air Quality Regulations

In many instances, the need for odor control systems is driven by local and state air quality regulations including regulations related to prevent public nuisance.

2. Low Odor Thresholds

Many of the compounds commonly found in wastewater such as H_2S , skatoles have perceptible odors even at very low concentrations at parts per billion levels (ppb).

3. Worker Safety

Ventilation requirements to protect workers from health hazard associated with compounds such as H_2S and to comply with fire and explosion prevention related regulations including NFPA, will generate foul air requiring treatment prior to discharge.

4. Corrosion Prevention Severe corrosion potential of wastewater conveyance and treatment infrastructure due to H_2S conversion by bacteria to sulfuric acid.
5. Good Neighbor Policy The location of the treatment plants and sewage conveyance systems in urban areas necessitate treatment plants to adopt a good neighbor policy to establish expectations/limits of the treatment plant vis-a-vis odor, noise, light pollution etc. to ensure harmony with its neighbors.

24.3 Odor Causing Compounds

Hydrogen sulfide(H_2S) is the most common compound which causes odors related to wastewater treatment.

- Hydrogen sulfide is the most common wastewater origin odorous compound
- it is produced in wastewater by the activity of sulfate reducing bacteria which live in the slime layer in the sewer pipes.
- hydrogen sulfide characteristics:
 - has an offensive smell
 - it is highly toxic and has the potential to instantly kill
 - it is converted into highly corrosive sulfuric acid through microbiological activity in the wastewater systems.

Thus, the prevention or treatment of odors, in particular hydrogen sulfide provides benefits including:

- safety
- preventing public nuisance, and
- corrosion prevention.
- Other common odor pollutants include
 - organic compounds - these are typically associated with the foul air from the preliminary, primary and secondary treatment processes
 - reduced sulfur compounds including mercaptans which are typically byproducts of solids decomposition
 - ammonia - the odor causing constituent of the foul air from dewatering operations associated with anaerobic digested sludge.

24.4 Theory of Odor Control

Theory related to the control of the the main odor causing compounds is as follows:

24.4.1 Hydrogen Sulfide

H_2S is generated in the wastewater from the biological reduction of dissolved sulfates and some of the H_2S present in the wastewater will escape into the gas phase causing odors. Once formed, H_2S control is accomplished using the following principles:

1. pH Control
 - Amount of H_2S escaping into the gas phase is dictated by Henry's Law and is pH dependent.
 - H_2S being a weak acid, when present in an alkaline (>7 pH) solution, will ionize to HS^- (bisulfide) and subsequently to S^{2-} (sulfide) ions.
 - H_2S odors will not occur as long as H_2S remains in solution as HS^- or S^{2-}
 - Increasing pH (or OH^- conc.) does not destroy H_2S , but keeps it from escaping into the gas phase, as long as an alkaline pH is maintained.
 - By adding alkaline chemicals, a majority of H_2S remains in solution in the wastewater and the amount of odorous H_2S released in the gas phase is reduced.


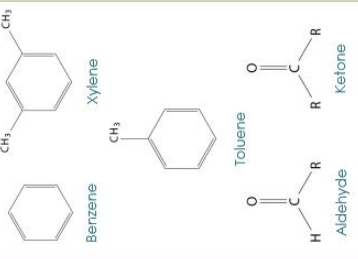
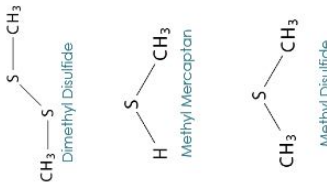

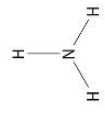
ORGANICS		INORGANICS	
Indoles & Skatoles	 Skatole	Aromatic compounds of faecal origin. Occur in very low concentrations but have a very low odor threshold. Being easily oxidizable, these compounds are effectively removed using chemical scrubbers and in biofilters.	
Aromatics, Aldehydes & Ketones	 Benzene, Toluene, Aldehyde, Ketone	Mainly originate from wastewater discharges from home and industrial sources. Contribute to odors but are not the dominant odor causing agent.	
Organic Reduced Sulfur Compounds	 Dimethyl Disulfide, Methyl Mercaptan, Methyl Disulfide	Produced from the breakdown of biological matter. Strong odor potential—rotten cabbage or garlick odors. Low odor threshold in ppt (parts per trillion) and is dominant cause of odor after hydrogen sulfide. Limited/poor water solubility and its acidic characteristics guide its control alternatives. In general, carbon adsorption and packed tower scrubbers are effective means of control.	
Hydrogen Sulfide		It is the most common wastewater odor constituent and is produced from biological reduction of sulfates. Its low odor threshold combined with its toxicity, flammability and explosion risks are the main drivers for its control requirements. It is acidic and has relatively good solubility in water. Can be effectively removed by chemical, biological and chemically enhanced carbon adsorption means.	
Ammonia		Produced from the anaerobic breakdown of nitrogenous material including uric acid and proteins. High odor threshold with a characteristic pungent odor. Water soluble and effectively treated using biological and chemical methods. Ammonia is target compound for air quality regulations because it contributes to the formation of PM10 which causes smog.	

Figure 24.1: Odor Causing Compounds in Wastewater Treatment

2. Chemical Precipitation
 H_2S can be precipitated using iron salts such as ferric or ferrous chloride.
3. Chemical Oxidation
Strong oxidants including bleach and hydrogen sulfide can oxidize H_2S to elemental sulfur.

24.4.2 Ammonia

- Ammonia (NH_3) is produced from the bio degradation of nitrogenous material in wastewater including proteins and uric acid.
- NH_3 is soluble in water and when in solution (liquid phase), some NH_3 will escape into the gas phase causing odors.
- Amount of NH_3 in the gas phase is dictated by Henry's Law and is pH dependent. NH_3 is a weak base (unlike H_2S which is a weak acid) and in the presence of H^+ , it ionizes to NH_4^+ (ammonium). Under acidic conditions, NH_3 is kept in the liquid phase of wastewater, reducing amount of odorous NH_3 released in the gas phase.
- NH_3 odors will not occur as long as NH_3 remain in solution as NH_4^+ . pH adjustment only helps to keep the ammonia in solution, it does not remove/destroy the ammonia.

24.5 Odor Control Technologies

The odor control technologies used in wastewater treatment can be classified into two categories:

1. Liquid Phase Odor Control
2. Vapor Phase Odor Control

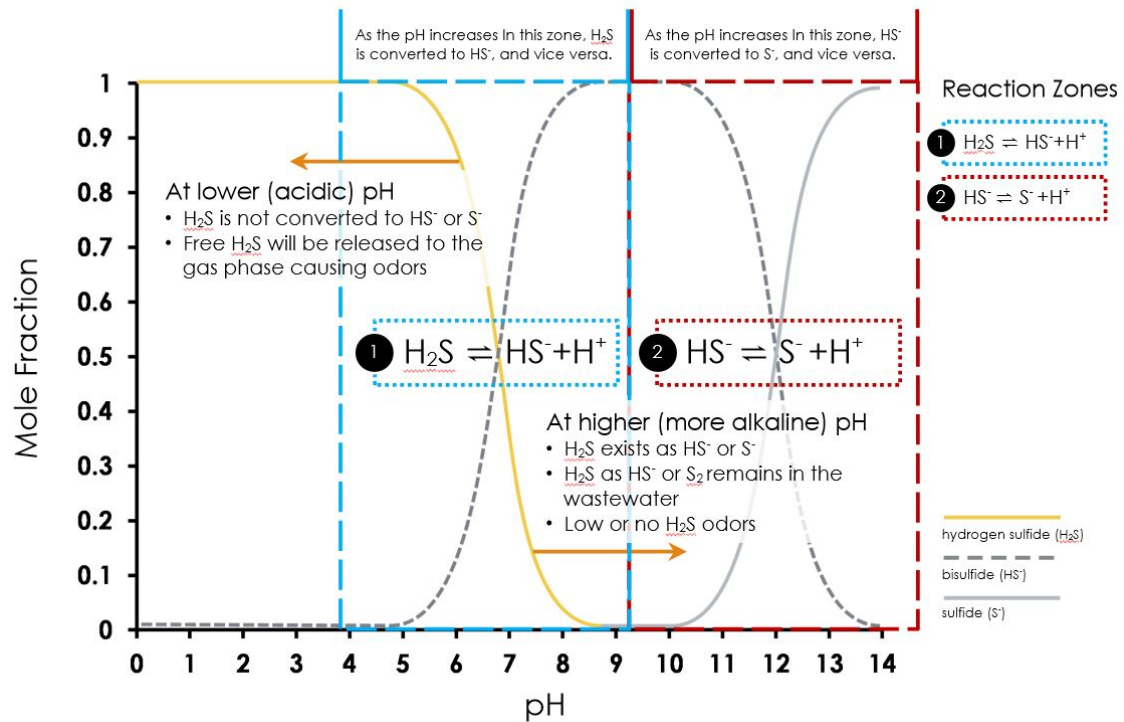
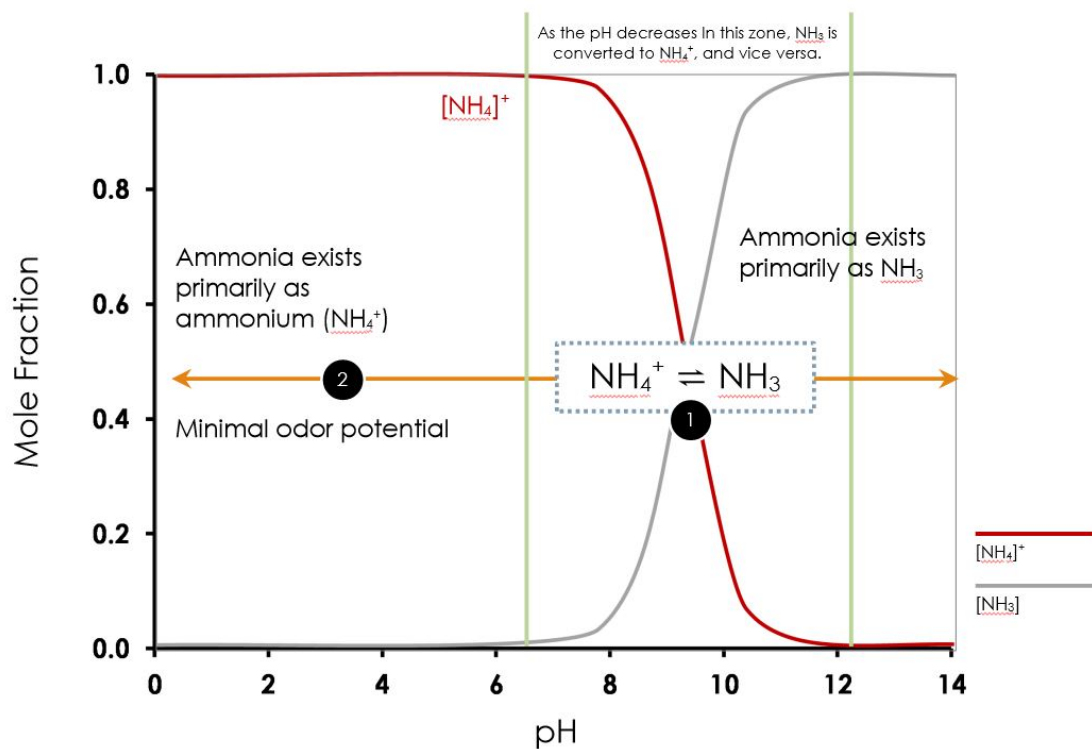
24.6 Liquid Phase Odor Control Methods

- typically applied in the collections systems
- goal for this treatment is to prevent nuisance odors associated with the production and release of hydrogen sulfide

Liquid-phase odor control strategies include:

1. **Chemical precipitation:**
Iron salts react with the hydrogen sulfide present in the wastewater to form insoluble iron sulfide precipitate
2. **Nitrate addition:**
Addition of nitrate salts promotes the activity of certain bacteria such as *Thiobacillus denitrificans*, typically present in wastewater, which oxidize reduced sulfur compounds (like H_2S) while denitrifying the nitrate. Presence of nitrate, also, increases oxidation-reduction potential, inhibiting the production of any odorous compounds such as hydrogen sulfide which are produced under anaerobic conditions.
3. **pH Control:**
Addition of alkaline chemicals including caustic soda or magnesium hydroxide increases the pH of the wastewater, preventing the escape of the hydrogen sulfide to the air phase as under alkaline condition H_2S is present as HS^- .
 - By raising the pH of wastewater through the addition of alkaline chemicals—caustic soda ($NaOH$) or magnesium hydroxide ($Mg(OH)_2$), minimizes the potential of releasing odorous H_2S to the gas phase.
 - This treatment does not destroy the H_2S but reduces its potential to return back to the gas phase as long as the alkaline pH is maintained. Caustic soda also helps remove the slime layer in the collections piping where the anaerobic bacteria responsible for the formation of hydrogen sulfide are present.
 - Magnesium hydroxide $Mg(OH)_2$ can also be used for raising the pH.
 - $Mg(OH)_2$ is used primarily because of it being environmentally safer compared to $NaOH$
 - $Mg(OH)_2$ is supplied as specially formulated slurry to improve solubility, keeping the solids in suspension and prevent solids from settling and getting deposited.

Advantage of using $Mg(OH)_2$

(a) $\text{H}_2\text{S} - \text{H}_2\text{S}^-$ pH Equilibrium Curve(b) $\text{NH}_3 - \text{NH}_4^+$ pH Equilibrium Curve

- Poses less environmental risk than NaOH due to an accidental release because of its lower pH and corrosivity.

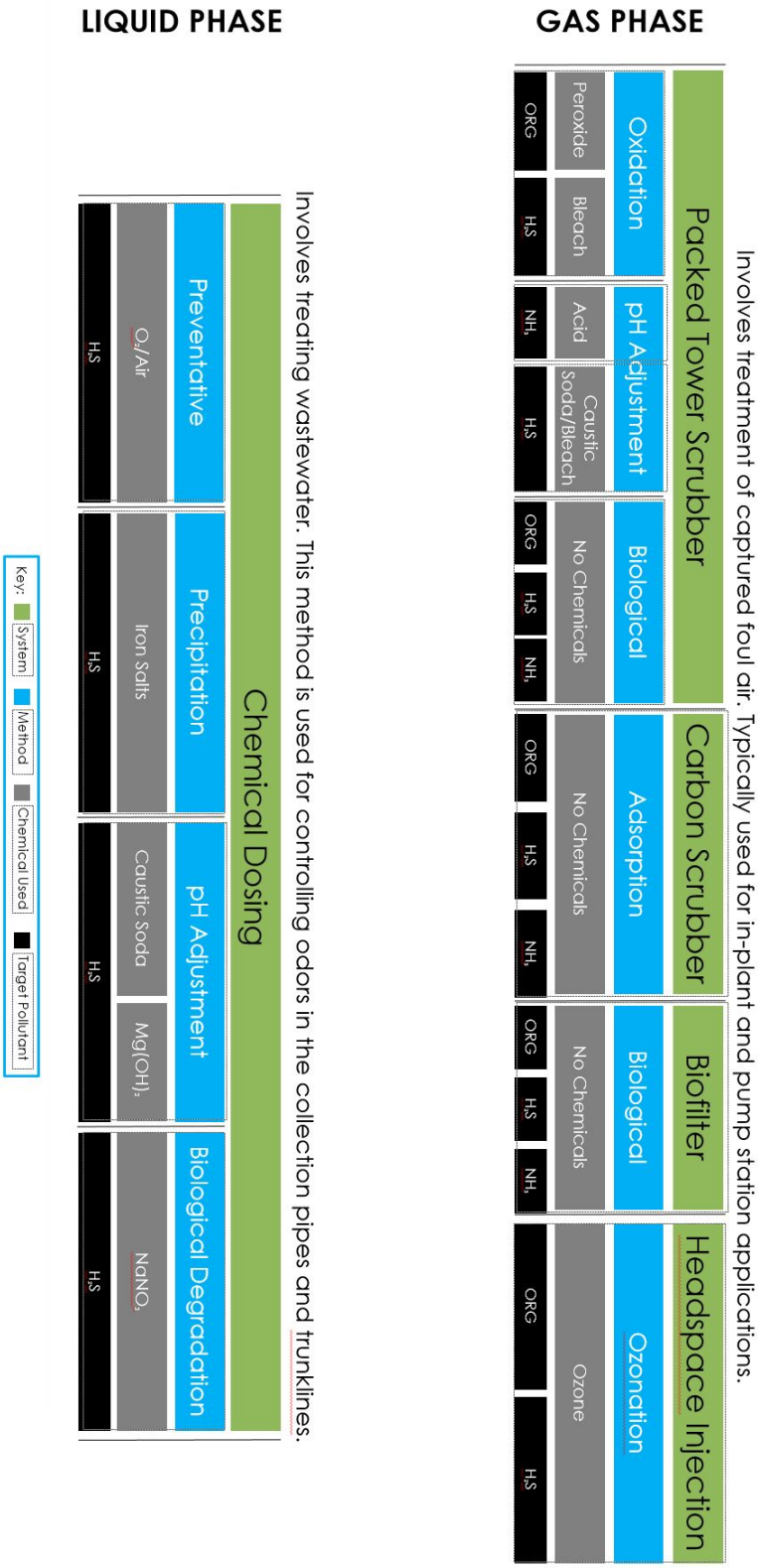


Figure 24.3: Odor Control Options

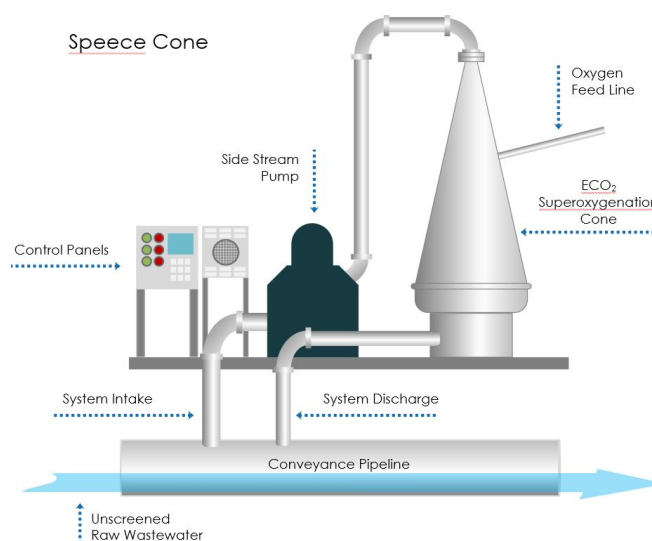


Figure 24.4: Speece Cone

Disadvantages of using $Mg(OH)_2$

- Lower effectiveness range
 - Not effective for higher H_2S concentrations
 - Higher cost
4. **Air/oxygen injection** The injection of air or oxygen in the sewer conveyance systems prevents developing anaerobic condition and thus formation of hydrogen sulfide. A Speece Cone allows for the injection of pure oxygen into the sewage.

24.7 Vapor Phase Odor Control Methods

- is typically applied inside the plant
- foul air from the treatment processes is captured and scrubbed using either a packed tower scrubber, a carbon scrubber or a biofilter.

24.7.1 Common Vapor Phase Odor Control Methods

1. **Packed Tower Scrubbers** Packed tower scrubbers are usually rectangular or cylindrical shaped.
 - Foul air is injected from the bottom
 - Chemicals are added to the recirculating water
 - Recirculated liquor from the sump is sprayed from the top
 - Plastic packing media provides the surface to facilitate the transfer of pollutants from the gas phase to the liquid phase.
 - The pollutants transferred to the liquid phase are chemically or biologically removed or stabilized so it does not return back to the gas phase.
 - Recirculation water is wasted periodically by adding make-up water to prevent build-up of the pollutant in the recirculation liquor.
 - Demister prevents the carryover of water with the air leaving the scrubber at top.
 - Chemical oxidants such as hydrogen peroxide (H_2O_2) and bleach ($NaOCl$), added to the recirculation water in the packed tower scrubber, removes the odor causing pollutants chemically.
 - Soluble organics are oxidized to less odorous compounds and reduced sulfur compounds are converted to elemental sulfur.
 - Solubility is the key! Only those pollutants which are soluble in water and transferred from the gas phase to liquid phase in the packed tower scrubber will be oxidized.

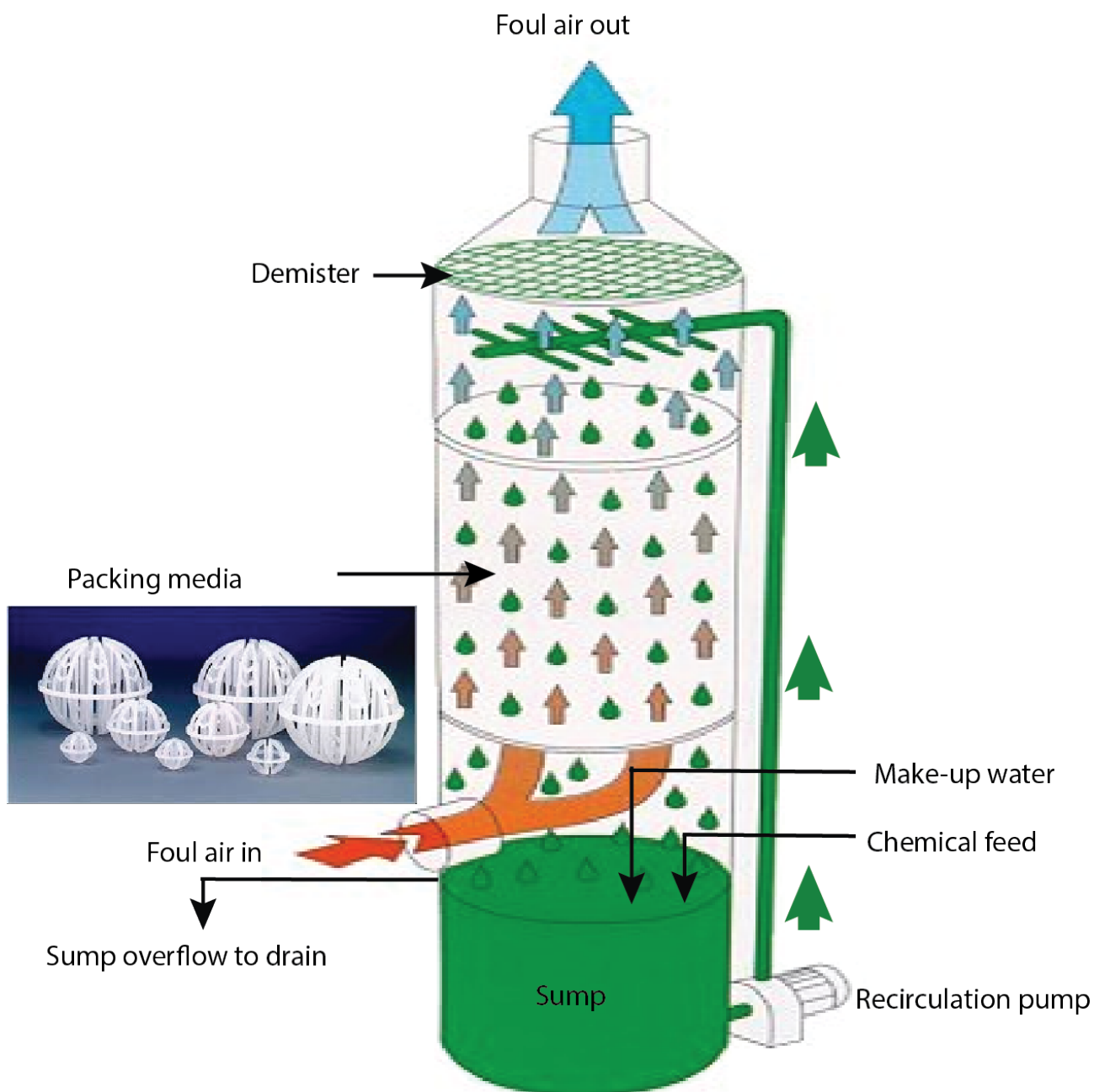


Figure 24.5: Packed Tower Scrubber

Applications of Packed Tower Scrubber

- **For controlling organics using oxidants:**
 - An oxidant such as hydrogen peroxide or bleach is added to recirculation water.
 - Organics control is typically exercised for foul air from the preliminary and secondary treatment processes.
 - Only organics soluble in water will be removed
- **For controlling hydrogen sulfide using chemicals:**

Hydrogen sulfide control in a packed tower scrubber using chemicals is accomplished using either oxidants such as hydrogen peroxide and bleach (which is a solution of sodium hypochlorite in caustic soda) or alkaline chemicals such as caustic soda or bleach can be added

to recirculation water. Note: Bleach is both - oxidant and alkaline.

- H_2S transferred from the gas phase to the liquid phase in the packed tower scrubber is kept in the liquid phase by addition of alkaline chemicals—typically bleach (NaOCl) or caustic soda (NaOH).
- This treatment does not destroy the H_2S but reduces its potential to return back to the gas phase.
- Bleach solution used is typically supplied as a solution contains 12.5% active chlorine and has a pH of about 11.5.
- Caustic soda has a pH of 14
- Bleach is advantageous over caustic for the following reasons:
 - * Use of a lower pH bleach reduces the hardness precipitation potential thereby leading to less media blockage and therefore less acid washing need.
 - * Oxidizes odorous organics
- **For controlling ammonia using chemicals:**
 - NH_3 is produced from the bio degradation of nitrogenous material in wastewater including proteins and uric acid.
 - NH_3 is soluble in water and when in solution (liquid phase), some NH_3 will escape into the gas phase causing odors.
 - Amount of NH_3 in the gas phase is dictated by Henry's Law and is pH dependent NH_3 is a weak base (unlike H_2S which is a weak acid) and in the presence of H^+ , it ionizes to NH_4^+ (ammonium). Under acidic conditions, NH_3 is kept in the liquid phase of wastewater, reducing amount of odorous NH_3 released in the gas phase.
 - NH_3 odors will not occur as long as NH_3 remain in solution as NH_4^+ . pH adjustment only helps to keep the ammonia in solution, it does not remove/destroy the ammonia.
 - An acid like sulfuric acid, can be used for lowering the pH of the packed tower recirculation water to convert NH_3 to NH_4^+ .
 - In typical wastewater odor control applications, the foul air ammonia concentration does not warrant use of an acid.
 - Solubility of ammonia in water itself is sufficient to provide the control of ammonia.
- **As a biotrickling filter for controlling H_2S and organics:**
 - Packed tower scrubbers can be operated as bioscrubbers, also known as biotrickling filters.
 - Bacteria in the slime layer on the packing and in the recirculation water consume the pollutants.
 - Aerobic process promotes growth of sulfur oxidizing bacteria when treating foul air with H_2S
 - When used for controlling H_2S , the pH of the recirculation water drops because of the biological conversion of H_2S to sulfuric acid.

2. Carbon Scrubbers

- This odor scrubber utilizes activated carbon's natural adsorptive property wherein odor causing compounds are attracted and held to its surface.
- The carbon adsorbs pollutants from the foul air passing through the scrubber. Carbon scrubbers can be designed to remove specific target pollutants.
- Suitable for non-polar organic and inorganic compounds including H_2S
- The carbon may be impregnated with an oxidant such as potassium permanganate or an alkaline substrate to enhance its effectiveness in treating foul air with organics and hydrogen sulfide respectively..
- When the capacity of the carbon bed is exhausted, the carbon can be cleaned/regenerated or replaced.

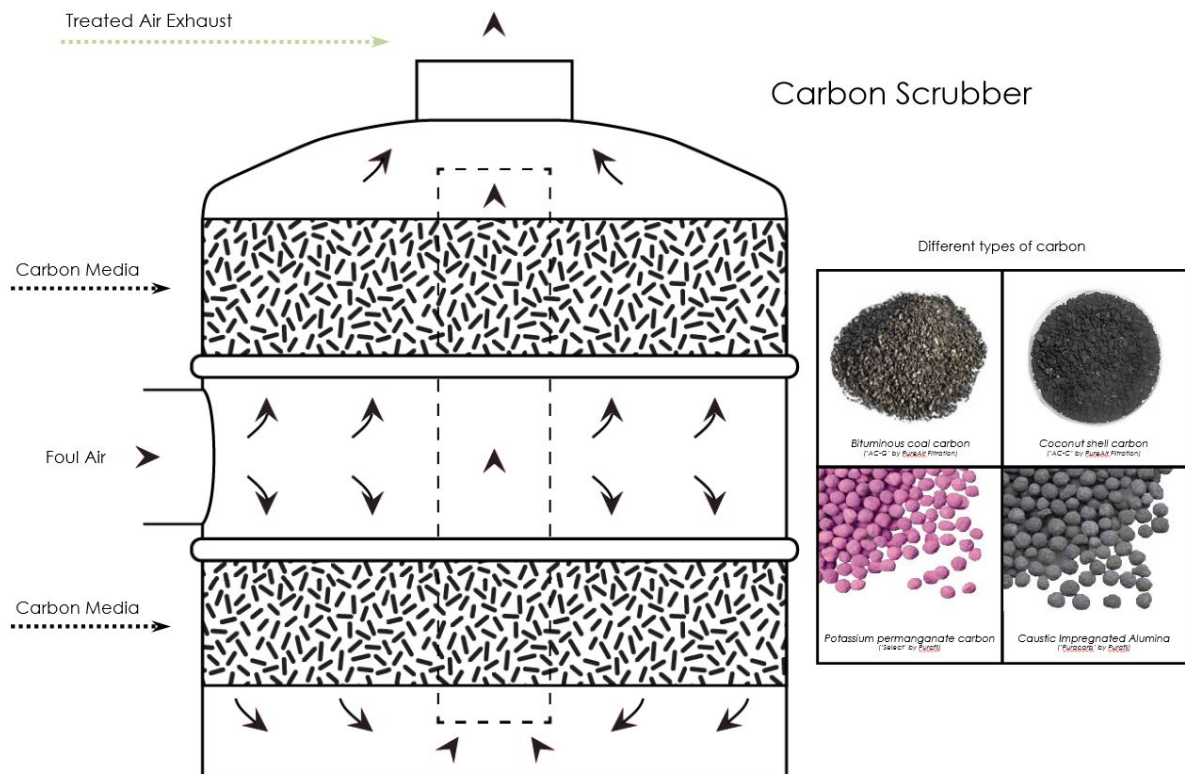


Figure 24.6: Carbon Scrubber

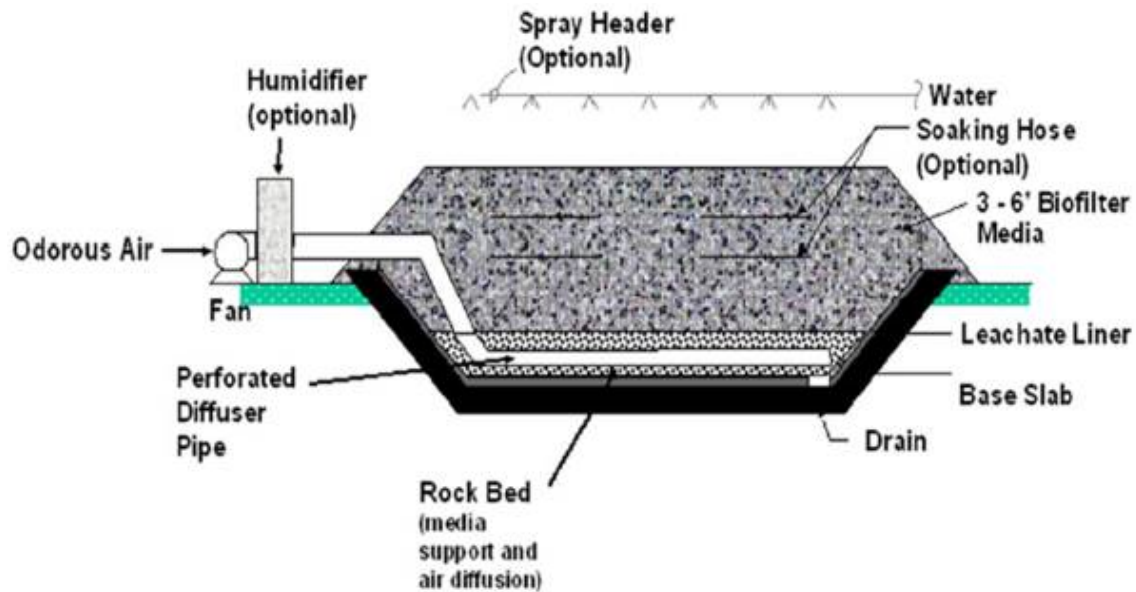


Figure 24.7: Biofilter

3. Biofilters

- Biofilters utilize biological processes wherein microorganisms growing on a slime layer on a packed substrate - biofilter media, consume the odor causing compounds from the foul air which dissolve in the slime layer as it passes through the biofilter
- Biofilters can remove hydrogen sulfide, organics and ammonia
- Typical biofilter media includes organic or inert material such as compost or activated carbon.
- Foul air is passed through the bed from the bottom
- Irrigation water is provided on the surface and/or the foul air stream is humidified to sustain the biological growth

Advantages of biofilters include:

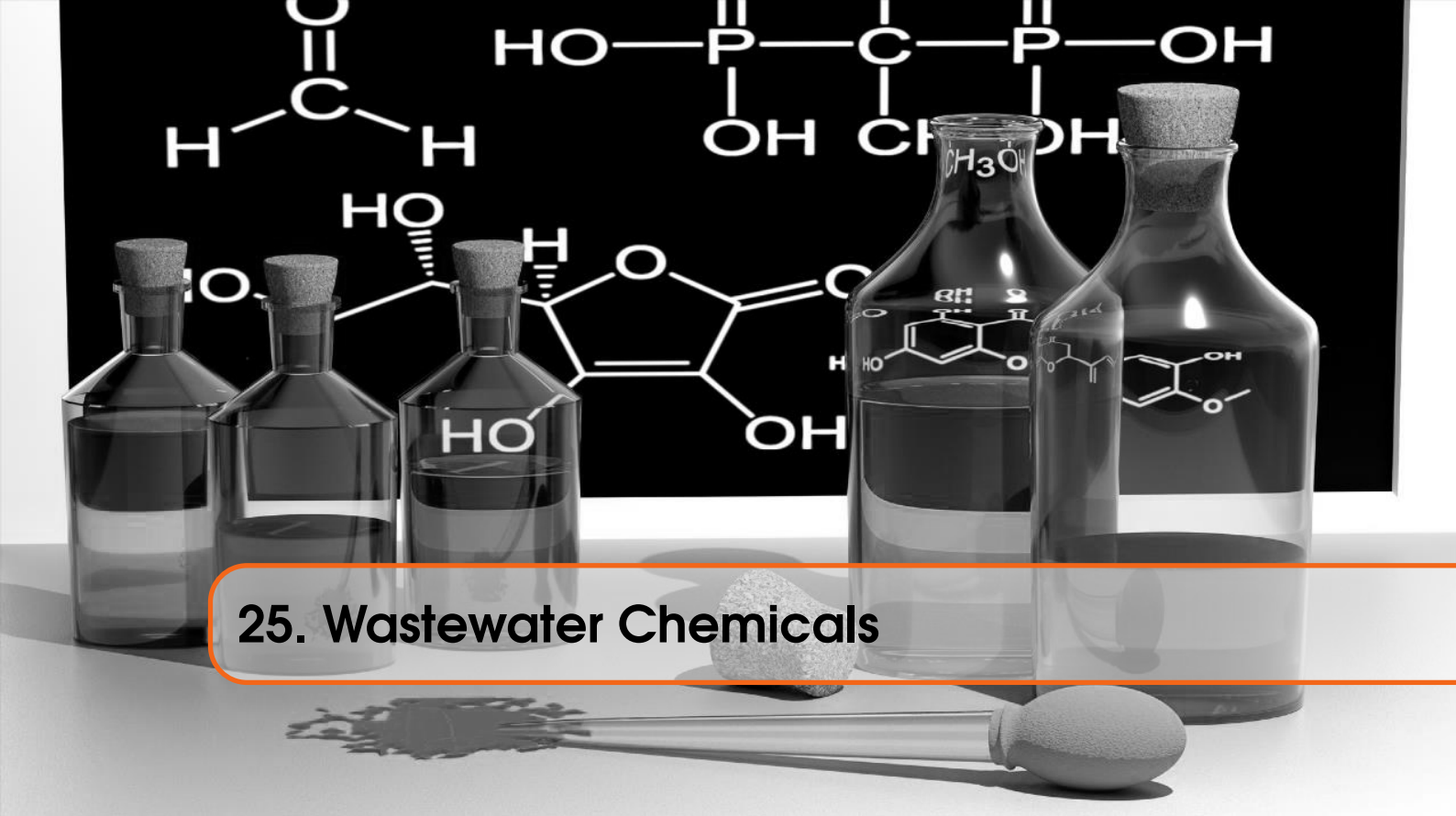
- Simplicity of design and operation
- Minimal maintenance requirements

4. Ozonation

- Ozone, a strong oxidizing agent, is injected in conjunction with water in the headspace to control odors.
- Application involves the use of an on-site ozone generator for controlling odors at locations such as a pump station wet well.
- Effective method to control odors in sensitive environments near residential neighborhoods.
- The ozone based oxidation of compounds including H_2S and organics requires a very short contact time.



Figure 24.8: Ozone Injection Unit



25. Wastewater Chemicals

25.1 Wastewater treatment chemicals - by use/category

USE/CATEGORY	PROCESS	CHEMICALS USED
pH Control/ Alkalinity Supplement	Odor Control Secondary Treatment Digestion	Caustic soda Magnesium hydroxide Calcium oxide Ammonia Sodium carbonate Muriatic acid
Oxidant	Odor Control Disinfection	Chlorine Sodium hypochlorite (NaOCl) Calcium hypochlorite (HTH) Hydrogen Peroxide
Advance Primary Treatment/ Chemically Enhanced Primary Treat- ment (CEPT)/Phys-Chem	Primary Treatment	Ferric Chloride Anionic Polymer
Filament Control	Secondary	Bleach Cationic Polymer
Phosphorous Removal	Primary Treatment Secondary Treatment	Iron Salts Alum (Precipitant)
Nitrogen Removal	Breakpoint Chlorination	Chlorine Sodium Hypochlorite
Dechlorination	Disinfection	Sodium bisulfite Sulfur dioxide
Flocculation/Solids Separation	Sludge Dewatering Sludge Thickening	Cationic Polymer
Descaling	Odor Control Scrubber	Muriatic Acid

25.2 Wastewater treatment chemicals - by use/category

PROCESS	ACTION	CHEMICAL USED (ROLE)
Collections	Odor Control	Caustic Soda (pH control) Magnesium Hydroxide (pH control) Hydrogen Peroxide (Oxidant) Sodium Nitrate (Biological Degradation) Iron Salts (Precipitant)
Primary	CEPT	Ferric Chloride (Coagulant) Anionic Polymer (Flocculant)
Secondary	Filament Control WAS Thickening	Bleach Cationic Polymer Cationic Polymer (Flocculant)
Nutrient Removal	Phosphorous Removal Alkalinity Supplementation	Iron Salts (Precipitant) Alum (Precipitant) Calcium Oxide Ammonia Sodium Carbonate
Tertiary Treatment	Disinfection Dechlorination	Chlorine/Bleach Sodium Bisulfite Sulfur Dioxide
Dewatering	Flocculation	Cationic Polymer
Plant Odor Control	Foul Air Scrubbing	Hydrogen Peroxide (Oxidant) Bleach (Oxidant) Caustic Soda (pH Control) Muriatic Acid (pH Control & Scrubber Descaling)
Anaerobic Digestion	Hydrogen Sulfide Control Alkalinity Supplementation	Iron Salts (Precipitant) Calcium Oxide Ammonia Sodium Carbonate

25.2.1 Polymers in wastewater treatment

- Polymer use in wastewater treatment includes:
 - For enhancing primary removal efficiencies
 - For sludge thickening - to increase the solids content of the sludge feed to the digester
 - For solids dewatering - to reduce the digested solids hauling cost and to make the final solids product more manageable
 - For filament control in activated sludge treatment

Both anionic and cationic polymers used in wastewater treatment are available in the following forms:

1. Dry Polymers: These are available in granular, flake or bead form and have an active polymer as high as 95%. Prior to use, the dry polymers have to be dissolved in water using specialized mixing units
2. Emulsion Polymer: This water soluble version consists of water droplets dispersed in oil. They have 25% to 50% active polymer content and require a specialized system to disperse it in water prior to use.
3. Solution polymers: These are water soluble polymers in water. These polymers are relatively easy to put into dilute solution. However, the lower active polymer content increases the shipping cost of this type of polymer.
4. Cationic polymer is also available as a low cost solution type polymer - Mannich Polymer (mannich is a type of chemical reaction involving formaldehyde which is used for making this polymer). However, it has certain drawbacks which include:

- (a) Presence of formaldehyde which lends its offensive odor
- (b) Higher viscosity which imposes operational challenges related to its use, and
- (c) High pH which leads to formation of hardness deposits in the associated piping and equipment.

The polymers use is primarily a function of the process stream. Each system is different and there are no hard and fast rules regarding which products will work and therefore jar tests and pilot tests are conducted as part of the product selection process.

25.3 Chemical dosing math problems

25.3.1 lbs chemicals needed given flow and dosing rate

- Use lbs formula to calculate the lbs of chemicals required
- Using the calculated lbs chemical required value, calculate the amount of that chemical at the concentration available

So for example, if asked how much many gallons per day of bleach solution (SG 1.2) containing 12.5% available chlorine is required to disinfect a 10 MGD flow of water given the required chlorine dosage of 7 mg/l.

1. calculate the lbs of chlorine required using the lbs formula:

$$= 10 \text{MGD} * 7 \frac{\text{mg}}{\text{l}} * 8.34 = 583.8 \text{ lbs chlorine per day}$$

2. calculate the gallons of bleach which will provide the 583.3 lbs chlorine

Applying the lbs formula - note that $8.34 * \text{SG}$ will give the actual lbs/gal of bleach. If SG is not provided, use only 8.34 lbs per gallon:

$$583.3 \frac{\text{lbs bleach}}{\text{day}} = x \frac{\text{gal}}{\text{day}} * 8.34 * 1.2 \frac{\text{lbs bleach}}{\text{gal}} * 0.0125 \frac{\text{lbs chlorine}}{\text{lb bleach}}$$

$$\Rightarrow x \frac{\text{gal}}{\text{day}} = \frac{583.3}{8.34 * 1.2 * 0.125} = \boxed{466 \frac{\text{gal}}{\text{day}}}$$

25.3.2 Chemical batching and dilution

These problems include questions such as: *How much initial volume of a 4% polymer solution is needed to make 3500 gallons of polymer at 0.25% concentration?*

- These type of problems are solved using $C*V$ relationship where C is the concentration and V is the volume.
- As C is expressed in weight/volume, $C*V$ will equal to weight. The weight of the chemical will be same before and after the dilution
- If C_1 is the concentration of the chemical before dilution and V_1 is the volume of that initial concentration that is needed and C_2 is the final concentration that you want to make and V_2 is the volume that you are making of the final concentration, $C_1 * V_1 = C_2 * V_2$.
- Knowing C_1 , C_2 and V_2 , we can calculate V_1 as:

$$V_1 = \frac{C_2 * V_2}{C_1}$$

$$V_{4\%} = \frac{C_{.25\%} * V_{.25\%}}{C_{4\%}} = \frac{0.25 * 3500}{4} = 219 \text{gal}$$

Take 219 gallons of the 4% polymer and dilute to 3,500 gallons to give a 0.25% polymer solution.

26. Pumping Efficiencies and Costs

26.1 Important conversions and formulas

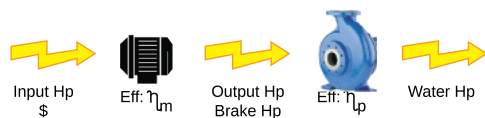
Total dynamic head = Friction head + Static head

$$1Hp = 0.746kW$$

$$1Hp = \frac{33,000 \text{ ft} - lb}{min}$$

$$1Hp = 3,960 \text{ GPM} - ft$$

$$1psi = 2.31ft$$



$$Water \ Hp = Flow * Head$$

$$Brake \ Hp = Input \ Hp * Motor \ efficiency$$

$$Water \ Hp = Brake \ Hp * Pump \ efficiency, \ and$$

$$\Rightarrow Water \ Hp = Input \ Hp * Motor \ efficiency * Pump \ efficiency$$

PUMPS & PUMPING

1

Pump is a device for raising
or moving water or any other fluid.

2

To move water, need to overcome
resistance due its density,
gravitational force & friction.

3

This resistance is dependent on:

- Height the water needs to be raised
- Quantity of water involved

4

Force needs to be exerted
by the pump to overcome
the resistance

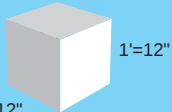
Force is the head which is measured in terms
of the height of water - inches or feet

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$(\text{lb}_f) \quad (\text{lb}_m)$$

$$\text{lb}_f = \text{lb}_m$$

(per definition)

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$


$$\text{Pressure exerted by a 1ft column of water} = \frac{62.4 \text{ lb}}{12 \text{ in} \times 12 \text{ in}} = 0.43 \text{ psi}$$

so 0.43 psi = 1ft (water column)
or 1 psi = 2.3ft

5

Pump will need to
provided energy to raise
the water

Energy = resistance force

Energy = Force x Distance

Energy units

ft-lb
KWh
Calories
Hp-h

6

Power needs to be delivered to the pump so it can provide energy. Power = Energy per time

Power Units

$\frac{\text{ft-lb}}{\text{min}}$
KW
Hp

$$1\text{Hp} = 0.746 \text{ kW}$$

Watt determined that one horse on an
average could lift 330lbs 100ft in one minute

$$1\text{Hp} = \frac{33,000 \text{ ft-lb}}{\text{min}}$$

$$\text{As 1 GPM (Water)} = \frac{8.34\text{lb}}{\text{min}}$$

$$\frac{\text{lb}}{\text{min}} = \frac{\text{GPM}}{8.34}$$

$$1\text{Hp} = \frac{33000 \text{ ft-lb}}{\text{min}} = \frac{33000 \text{ ft} \times \text{GPM}}{8.34 \text{ min}}$$

$$1\text{Hp} = 3,960 \text{ GPM-ft}$$

1Hp is needed to raise one gallon of water 3,960
ft in one minute

Understanding the concept of power:

A 150lb person climbing 50ft will expend
7500 ft-lb of work (energy)

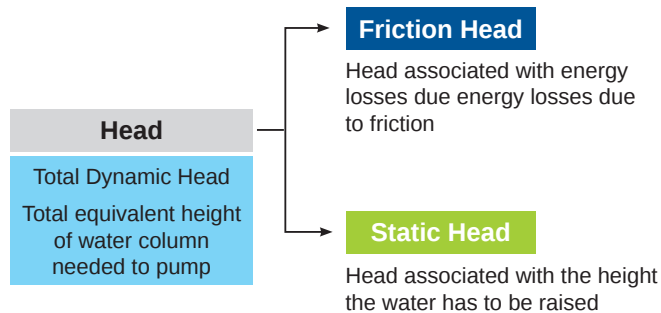
1) Power requirement for climbing this in 5 minutes

$$\frac{7500}{5} \frac{\text{ft-lb}}{\text{min}} = 1500 \frac{\text{ft-lb}}{\text{min}}$$

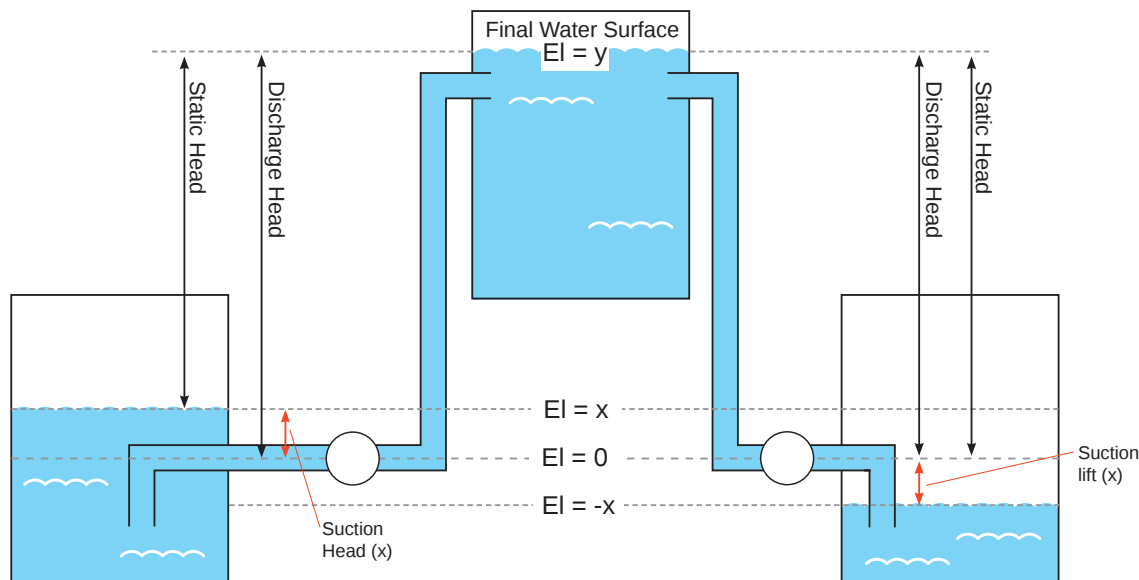
$$= 0.045 \text{ Hp}$$

2) Power requirement for climbing this in 1 minute

$$\frac{7500}{1} \frac{\text{ft-lb}}{\text{min}} = 0.23 \text{ Hp}$$



Calculating Static Head

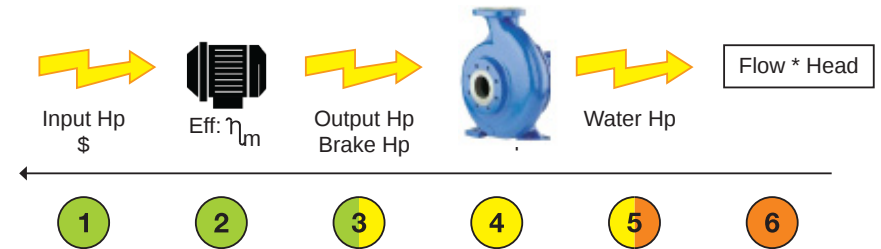


Case A:
Initial water level above pump

Static Head = $y - x$

Case B:
Initial water level below pump

Static Head = $y - (-x)$
= $y + x$



Given 6 **Calculate** 5

What is the required water horsepower to pump 300 GPM if the suction head and discharge heads are constant at 20 ft and 120 ft respectively and the system head losses are 5 ft.

Solution:

$$\frac{300 \text{ GPM} \times (120 - 20 + 5 \text{ ft})}{3960 \left(\frac{\text{GPM-ft}}{\text{Hp}} \right)} = \boxed{7.95 \text{ Hp}}$$

Given 2 4 5 **Calculate** 1

Find the input Hp Given the water Hp equals 8Hp and the pump and motor efficiencies are 80% and 50% respectively.

Solution:

Step 1: Find 3 knowing 4 & 5

$$0.5 = \frac{8 \text{ Hp}}{\text{Brake Hp}} = \text{Brake Hp} = 16 \text{ Hp}$$

Step 2: Find 1 knowing 2 & 3

$$0.8 = \frac{\text{Brake Hp}}{\text{Input Hp}} = \frac{16}{\text{Input Hp}}$$

$$\text{Input Hp} = \frac{16}{0.8} = \boxed{20 \text{ Hp}}$$

Given 3 and existing 2 & replacement 2 **Calculate** 1 savings

An older motor which is 82% efficient is to be replaced by a new, 94% efficient motor. Calculate the annual savings for the new motor given the output horsepower from both motors is 180Hp and the electricity cost is \$0.075/kWh & the motor operates 24 hours per day throughout the year.

$$\text{Hp input to new motor} = \frac{180}{0.94} = 191.5 \text{ Hp}$$

$$\text{Hp input to old motor} = \frac{180}{0.82} = 218.5 \text{ Hp}$$

Annual Savings $\gg (218.5 - 191.5) \text{ Hp} \times \frac{0.746 \text{ Kw}}{\text{Hp}} \times \frac{365 \times 24 \text{ hrs}}{\text{Year}} \times \frac{\$0.075}{\text{Kwh}} = \boxed{\$23,779 \text{ Year}}$

“Demand Charge” (\$/kw) is imposed on consumer by the utility company to compensate it for the design & upkeep of equipment to meet the peak power draw by the consumer. The demand charge is in addition to the regular energy consumption charge (\$/kw). The demand charge is based upon highest power consumption over any 15 minute period during the billing cycle. Oversized and inefficient equipment (motors & pumps) would mean higher demand charges.