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 Treatment (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 Dechlorination	Breakpoint Chlorination Disinfection	Chlrorine Sodium Hypochlorite 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 formalydehyde 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:

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

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

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

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

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

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:

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

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

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

$$1Hp = 0.746kW$$

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

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

$$1psi = 2.31ft$$

$$Water\ \ Hp\ \ =\ \ Flow\ * \ Head$$

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

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

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

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

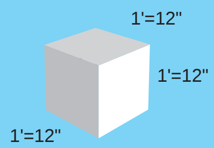
Force needs to be exerted by the pump to overcome the resistance

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

Force = Mass x Acceleration
(lb_f) (lb_m)

$lb_f = lb_m$
(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

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

1Hp = 0.746 kW

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

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

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

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

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

1Hp = 3,960 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 <u>7500 ft-lb of work (energy)</u>

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 Hp

2) Power requirement for climbing this in 1 minute

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

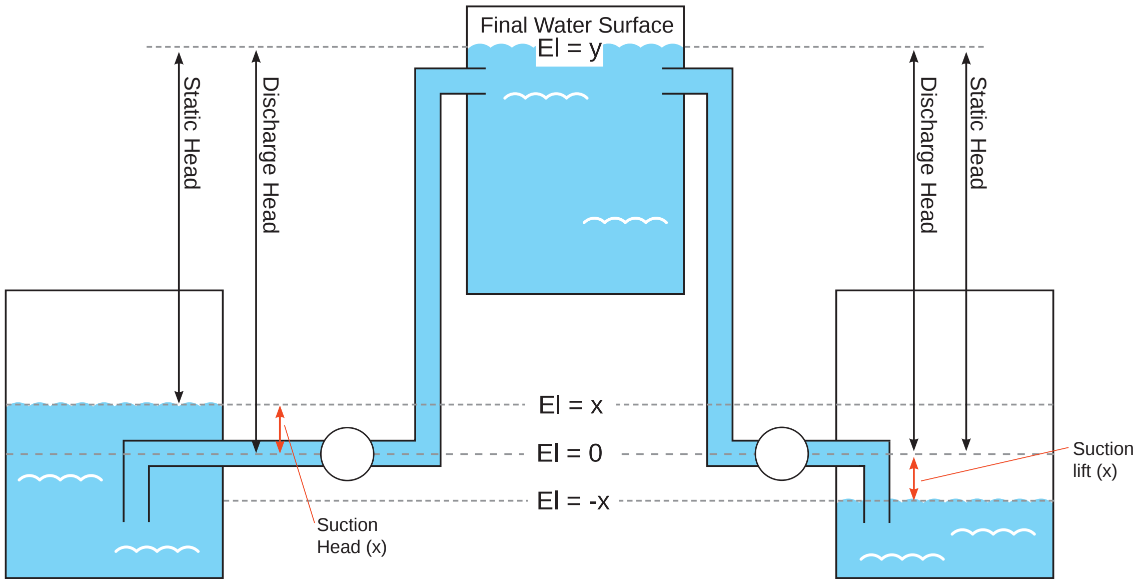
Head

Total Dynamic Head

Total equivalent height of water column needed to pump

- **Friction Head** — Head associated with energy losses due energy losses due to friction
- **Static Head** — Head associated with the height the water has to be raised

Calculating Static Head

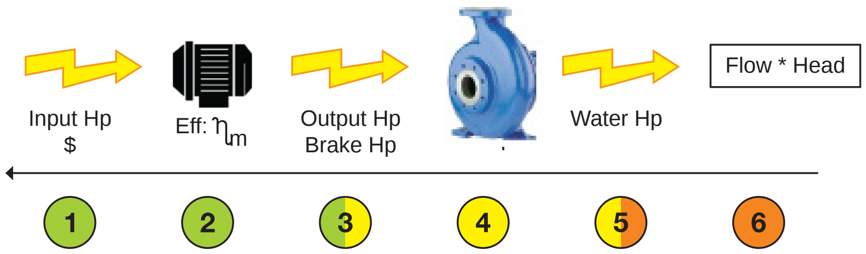


Case A:
Initial water level above pump

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:

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

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.

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

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

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

"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.

26.2 Practice Problems

1. 1 MGD is pumped against a 14' head. What is the water Hp? The pump mechanical efficiency is 85%. What is the brake horsepower?

   water Hp = flow * head

   $$\frac{1,000,000\ gal}{day} * \frac{day}{1440\ min} * 14\ ft * \frac{Hp}{3,960\ GPM - ft} = \boxed{Water\ Hp = 2.46\ Hp}$$

   pump Hp = brake Hp * pump efficiency

   $$Brake\ Hp = \frac{2.46}{0.85} = \boxed{Brake\ Hp = 2.89Hp}$$

2. A 8 ft diameter cylindrical wetwell receives an average incoming flow if 135 gpm and is pumped down with a pump that delivers 450 gpm again a total dynamic head of 120 ft. The pump is controlled using two floats; a stop float located at 2.5 ft and a start float located at 16 ft. If the pump motor is rated at 88% and the pump at 77%, what is the monthly (30 days/month) for running this pump if power costs are $0.11/Kwh?

   When the pump is on, the volume of wetwell that will be pumped down with the 450 gpm pump and a 135 gpm flow to the wetwell:

   $$\frac{450\ gal}{min} - \frac{135\ gal}{min} = \frac{315\ gal}{min}$$

   Minutes required to pump down the wetwell :

   $$0.785 * 8^2 * (16 - 2.5)ft^3 * \frac{7.48\ gal}{ft^3} * \frac{min}{315\ gal} = 16.1\ min$$

   Time to fill wetwell with pump off @135gal/min influent flow:

   $$[0.785 * 8^2 * (16 - 2.5)]ft^3 * \frac{7.48\ gal}{ft^3} * \frac{min}{135\ gal} = 37.6min$$

   # of cycles per day:

   $$\frac{cycle}{(16.1 + 37.6)\ min} * \frac{1440\ min}{day} = \frac{26.8\ cycles}{day}$$

   # of hrs pump operational:

   $$\frac{16.1\ min}{cycle} * \frac{26.8\ cycles}{day} * \frac{hrs}{60\ min} = \frac{7.19\ hours}{day}$$

   Monthly electrical cost:

   $$\frac{450\ gpm * 120\ ft}{0.88 * 0.77} * \frac{Hp}{3,960\ gpm - ft} * \frac{0.746\ kW}{Hp} * \frac{7.19hrs}{day} * \frac{30\ days}{month} * \frac{\$0.11}{kWh} = \boxed{\frac{\$356}{month}}$$

3. A 6-year old pump motor is to be replaced at a net cost of $15,800. The new motor, just like the old one, would run 65% of the time. Both existing and replacement motors would operate at 125 output Hp. The existing motor efficiency is 86% while the replacement motor would be guaranteed at 94% efficiency. Electricity currently averages $0.088 per kWh.

   (a) Calculate the energy cost savings per year (to the nearest dollar) if the existing motor is replaced with the new motor (neglect any consideration of impact upon demand charges or interest on capital).

(b) What is payback period to the nearest tenth of a year.

Solution:

Calculate energy cost savings per year:

Input Hp for old motor: $\frac{125}{0.86} = 145.35Hp$

Input Hp for old motor: $\frac{125}{0.94} = 132.98Hp$

Energy cost savings:

$$(145.35 - 132.98)Hp * \frac{0.746 \ \ kW}{Hp} * \frac{(365 * 24 * 0.65)hrs}{yr} * \frac{\$0.088}{kWh} = \boxed{\frac{\$4,624}{yr}}$$

Calculate payback:

$$\$15,800 * \frac{yr}{\$4,623.94} = \boxed{3.4yr}$$