Disinfection and Solids Handling

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Overview

Disinfection
- Chlorination and Dechlorination
- Ultraviolet disinfection
- Ozone

Solids Handling
- Dewatering
- Digestion

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What is Disinfection?

Disinfection is the destruction of all pathogenic microorganisms

The goal of disinfection is to remove all disease causing pathogens before effluent is discharged into receiving waters
- Protects- Public water supplies, irrigation, receiving waters for recreational uses and shellfish growing areas

Sterilization- is the destruction of all microorganisms, but is impractical

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Disinfection Processes

- Chlorination- Uses chlorine gas, powder or liquid solution to disinfect
- UV systems- Uses ultraviolet light to inactivate microorganisms stopping them from reproducing
- Ozone- Uses ozone gas to disinfect

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Chlorination

- Most common form of disinfection
- Can be applied in various ways
- Chlorine is very reactive and acts as a strong oxidizing agent
- Chlorine is readily available and cost effective compared to other disinfection processes
- Long track record of efficient disinfection and can remove odors

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Chlorine Gas Hazards

Extremely hazardous
- Very toxic
  - Fatal if inhaled
- Corrosive
- Forms hydrochloric acid when exposed to moisture
- Skin, eyes and lung irritant
- Explosive

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Physiological Response to Chlorine Gas

Chlorine Gas Concentration (ppm)	Effects
.1-3	Detectable odor
1-3	Mucus membrane irritation
30	Chest pain, shortness of breath, coughing
40-60	Toxic pneumonitis/ acute pulmonary
400	Fatal over 30-minutes
1000	Fatal within minutes

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Chlorine Requirements

- Chlorine Dosage- Amount of Chlorine added to water. Calculated by dividing the chlorine feed by the flow
- Chlorine Demand- Amount of Chlorine required to act with all reactive substances in the flow
- Chlorine residual- Remaining Chlorine in the water after demand has been satisfiied

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Chlorine Requirements

- Chlorine Residual= Dosage - Demand
- Ex. Dosage - Demand = Demand
  - 3.6 mg/L- 2.2 mg/L = 1.4 mg/L
- Residual composed of free Chlorine and combined Chlorine
  - Free Chlorine- unreacted Chlorine reacts with H2O to form hypochlorous and hydrochloric acid
  - Combined Chlorine- In the presence of ammonia, hypochlorous acid forms chloramines

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Hypochlorous vs Chloramines

- Hypochlorous is a strong disinfectant, but degrades easily
- Chloramines are a weaker disinfectant, but…
  - They don't degrade as fast and stay in the system longer
  - Need longer contact time than Hypochlorous

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Chloramines

- Chloramines are created when when Ammonia (NH3) is present and reacts with hypochlorous acid.
- Chloramines are often created intentionally due to their enduring properties.
- At the SWRP flow dosed with hypochlorous is also dosed with Ammonium Sulfate [(NH4)2SO4] to create chloramines that will increase the contact time of the flow with the disinfectant

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Chloramines

Consist of mono, di and trichloramines, and the pH of the wastewater determines the concentration of the different types

- Below pH = 4.0 trichloramines exist by themselves
- At pH= 5.5 down to 4.0 dichloramine is the only compound present.
- Both monochloramines and dichloramines exist at thel pH of 6.5-7.5 of typical wastewater flows

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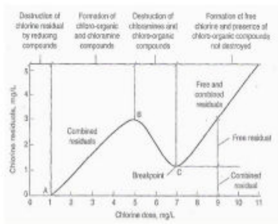
Breakpoint Chlorination



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Testing For Chlorine Residuals

- Most common field test for Chlorine residual is DPD test
- Must be tested within 15 minutes of sampling
- Very simple, a reagent is added and compared to the blank with a color wheel or a spectrometer

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Gas Chlorination

- Greenish-Yellow Gas
- 2.5 times heavier than air
- Chlorine gas is compressed into a liquid for storage in 150 or 2000 lb cylinders which are attached to a chlorinator for dosing. Gas Chlorinators consist of pressure regulating valve, a feed rate indicator, a flow regulating device (needle valve or V- notch plug) and an injector or ejector.
- Chlorine Pressure Regulating Valve- Maintains a constant negative pressure inside the chlorinator
- Feed rate controlled by needle valve or V-notch plug and read in pounds per day

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Gas Chlorination Feed Rate

- Maximum feed rate for 150 lb cylinder is 40 lbs/day
- Maximum feed rate for 2000lb/ 1 ton tank is 400lbs/day
- If these rates are exceeded tank will frost over which can cause ruptures in the tank

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Gas Chlorination Safety

- Gas masks should be available to allow operators to escape when a leak occurs. Self-contained breathing apparatus (SCBA) must be available when work is being done in a chlorine gas atmosphere. Should hold 30 minutes of air and alarm when the pressure shows that the air tank has five minutes remaining
- Every chlorine cylinder is equipped with a fusible plug that melts at 157° F to prevent the cylinders from rupturing at this temperature.
- Chlorine evaporators are hot water heaters surrounding tanks that act as a means to evenly distribute heat throughout the chlorine cylinder or tubes with warm water that surround the chlorine line

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Chlorine Powder

- Chlorine in its dry form is known as HTH or Ca(OCl)2. The powder is 65-70% Chlorine and is 2-3 times more expensive than chlorine gas, but much safer to use.
- Dosage is accomplished by diluting with water and pumping into the flow
- Care must be taken to avoid skin contact and inhalation of HTH. It needs to be stored in a cool dry place. Contact with petroleum products or organic solvents will result in a violent explosions

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Hypochlorination Systems

- Can be used to pump bleach solution or diluted HTH.
- Bleach solutions typically have a 3-12% concentration and are sometimes produced on site.
- Ex. SWRP uses water, salt and electrical cells to produce Sodium Hypochlorite or NaOCl

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Dechlorination

- Due to the reactive nature of Chlorine it must be removed before being discharged into most receiving waters.
- Dechlorination is accomplished by
  - Long detention times
  - Aeration- Bubbling air at the end of long narrow chlorine contact basins
  - Sunlight- Spreading chlorinated effluent in a thin layer and exposing it to sunlight
  - Activated Carbon- activated carbon can absorb chlorine
  - Chemical reactions- Typically SO2 is used because it reacts on a 1:1 ratio with chlorine

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Sulfur Dioxide (SO2)

- Sulfur Dioxide is preferable, because it is safe and uses the same equipment as chlorination. It's density is similar to chlorine and it is neither flammable nor explosive. It is however toxic in large quantities. When combined with moisture it forms sulfuric acid, which is highly corrosive.
- When reacted with chlorine the chlorine becomes inactive.
- Excessive sulfur dioxide can result in dissolved oxygen reduction, increased BOD and a decrease in the pH

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Ultraviolet or UV systems

- Ultraviolet light is used to damage the genetic material (DNA) of microorganisms so they are unable to reproduce. If they are unable to reproduce they can no longer increase in numbers and act as pathogens.
- UV has gained in popularity due to it's safety advatages over chlorine and recent advatages in technological efficiency.

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UV systems

- UV light is produced my low pressure mercury lamps which are immersed in the flow exposing microorgasims. Lamps are arranged in a rack configurage to allow all of the flow to be exposed.
- The wavelength of the UV light is 254nm, which has been identified as the most efficient wavelength for disinfection.
- Never look directly into UV light bulbls and take special precaution when handling mercury lamps, mercury is hazardous.

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Ozone

- Ozone (O3)is creating by adding energy to atmospheric oxygen (O2). Ozone is a strong oxidant, which makes it an effective disinfectant and virus killer. Ozone must be generated on site due to its unstable nature.
- Water is exposed directly to ozone in a plug-flow type contactor.
- Due to ozones unstable nature there are no harmful residuals

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Ozone

Advantages
- More effective than chlorine in destroying bacteria and viruses
- Short contact time
- No harmful residuals
- No shipping hazards due to onsite production
- Bacteria will not grow back unless shielded by molecules

Disadvatages
- Low doses may not be effective enough
- Technology is very complex and can be dangerous

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Sludge Handling

- The solids (sludge) must be stabilized and reduced in volume before it can be reused or disposed of safely and economically
- The solids handling processes stabilize the sludge and reduce its volume
- There are four common process
  - Thickening
  - Digestion
  - Dewatering
  - Sludge disposal and re-use

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Digestion

- Digestion stabilizes sludge by breaking down sludge into simpler components
  - CO_2, CH_4, H_2O
- Stabilization is done to prevent odors, human exposure to pathogens, and attracting vectors
- Primary sludge is unstable and secondary sludge has been partially stabilized
- Anaerobic and aerobic
- Chemical stabilization is possible, but uncommon

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Anaerobic Digestion

- Converts sludge from primary and secondary clarifiers into stabilized sludge that is relatively odor free and more easily dewatered
- Volatile content reduction: 30-60%
- Fats, sugars, and proteins are converted to short chain fatty acids, which are broken down further to gases
  - Acid Formers (Saprophytic bacteria)
  - Methane producers (Archae-Bacteria)
    - Require pH of 6.6-7.6
- Sludge is pumped to dewatering process after digestion

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Anaerobic Digestion Cont'd

Anerobic digestion occurs in three temperature ranges

- Psychrophilic: 10-20°C (50-68°F)
- Mesophilic: 20-45°C (68-113°F); ideal range is 95°-98°F medium temperature loving bacteria; most common range; produces a high level of CH4 in a short digestion time usually 25-30 days
  - Utilizes primary and secondary digestion
- Thermophilic: 49-57°C (120-135°F); hot temperature loving bacteria; very difficult to maintain these hot temperatures and sensitivity of the organisms to temperature changes; produces poor liquid/solids separation; not common
- Temperature is maintained w/ heat exchangers

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Anaerobic Digestion Operation

- Detention time is 25-30 days
- Feeding should be slow and steady
  - Typically a rotation should be established
- Sludge temp should be monitored and heat exchange flow adjusted as needed
  - Desired for mesophilic: 95° F
  - Temperature changes should not exceed 1° F / day
- Mixing should be constant

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Aerobic Digestion

- Considered an extension of secondary biological treatment
- Used in small to medium sized plants that utilize extended aeration activated sludge and SBR's
- Solids held in a tank are provided air and mixing with no additional heating
- Endogenous respiration: There is no external food source provided so microorganisms devour each other
  - This results in the release of CO_2 and H_2O
- Volatile solids reduction is 20-40% and detention times are 20-30 days

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Aerobic Digestion Operation

- Aeration provided by floating surface aerators, fixed bridge aerators or blowers : maintain at 1.0mg/L DO
  - DO: 1 mg/L, never < .5 mg/L
- Supernatant tubes: Decanted liquid removed and returned to headworks
  - Can be source of filamentous bacteria
- Should be taken offline and cleaned at least every 3 years to remove sediment buildup and to inspect equipment inside digester
- pH: > 7.0
- Total Solids (TS): 1.5-4%

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Sludge Thickening

- Sludge with high water content is difficult to transport or store
  - "Thick" sludge is 5-6% and still 90% water
- Utilized before and/or after digestion
  - Waste activated sludge (WAS)
  - Digested sludge
- Thickening methods focus on separating solids from water (dewatering)
  - Water is returned to treatment process
  - Dewatered solids can be digested, disposed of, or used for land application
  - Polymer utilized to enhance thickening

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Sludge Thickening Methods

- Gravity thickeners
- Diffused air flotations units (DAF)
- Belt presses
- Centrifuges
- Sludge drying beds

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Gravity Thickeners

- Similar concept to clarifiers
- Gravity creates separation of solids and liquid
  - Solids pumped out similar to sludge
  - Liquid water decanted
- Ideal sludge based on detention time and sludge age
- Solids concentration of 2-4% or 6% with polymer

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DAF

- Secondary sludge is mixed with polymer and air to separate solids that float to the top of the basin
- Scrapers scrape solids into a hopper
- Separated water returns to the treatment process
- Secondary sludge is preferable to primary sludge
  - Organics have been partially broken down during biological treatment
  - Primary sludge can deposit sediment
  - Young sludge thickens better than old sludge

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DAF Operations

- Blanket depth: 6-8 inches
  - Controlled by adjusting speed of the scraper
- Thickened sludge:
  - 2-4% w/o polymer
  - 3-5% w/ polymer
- Air pressures determines amount of air available for flotation
  - Air/solids ratio: .01-.1
- Effluent should have a TSS < 100 mg/L

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Belt Presses

- Consists of 2 endless belts traveling over a series of rollers assembled on a steel frame
- Polymer is injected into sludge and dewatered in a drainage area before entering between the belts
- Sludge traveling between belts is pressed between perforated and non-perforated rollers where water is forced out of the sludge
- The liquid effluent is returned to treatment plant process and the sludge cake is scraped off the belts, carried off by a conveyor
- Belts are washed off to prevent plugging

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Belt Presses

- Primary and digested sludge are better suited for belt filter presses
  - Requires smaller amounts of polymer
  - Total Solids:
    - Primary sludge= 25-35%
    - Primary digested sludge- 25-30%
    - Secondary and digested secondary sludge= 17-20%
- Sludge conditioning: Consistent sludge feed and proper polymer are very important
- The belt tension pressure determines cake concentration
- Belt speed depends on sludge flow rate and the concentration of influent sludge
  - Speed must be fast enough so washout doesn't occur, but slow enough to maintain effluent quality
- Belts are made of nylon or polypropylene
  - High porosity can result in poor effluent quality and lower porosity can result in binding and plugging

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Centrifuges

- Feed sludge is fed into the rotating bowl encased in the centrifuge
  - Solids and liquids are separated by centrifugal force
  - Solids are concentrated to the outside of the bowl and an internal scroll moves the solids to a hopper located at the same end of the centrifuge as the feed port
  - The separated liquid (centrate) discharges to the opposite side of the centrifuge
- Requires secondary sludge to mitigate sediment deposit and off gasing
- Increasing bowl speed = increased cake thickness
- The differential scroll speed also effect cake thickness and centrate quality. As cake concentration increases, solids removal efficiencies decrease
- Liquid depth: liquid level in centrifuge can be changed by adjusting effluent weirs
- Polymer added to improves cake thickness and solids recovery
- Feed solids: 4% solids, Thickened sludge: 5-30%, Solids recovery: 90-99%

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Polymer

- Large repeating molecules that disassociate to positively charged cations and negatively charged anions in water
  - Positively charged cations used in dewatering process
  - Sludge and biosolids are typically negatively charged
- Polymers are typically proprietary materials
  - Can come in liquid or powdered form
  - Require bench testing to determine applicability
  - Vary based on technology being used

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Sludge Drying Beds

- Utilized by small to medium sized plants w/ less than 5 MGD
- Land intensive and require warm climate
- 3 types
  - Sand
  - Asphalt or concrete
  - Vacuum filter beds
- Requires draining system

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Sludge Reuse and Disposal

- Disposal regulated by Title 40 of the Code of Federal Regulations part 503
- Composting and land application
  - Contain high levels of nutrients
  - Regulates for contaminants including pathogens and heavy metals
  - May require thermal composting depending on usage
- Surface disposal
  - Injected below 1-3 ft below surface and mixed with soil
  - Typically required ground water permit
- Landfilling
  - Land intensive and requires special hauling permit
  - Practiced due to economic viability or poor sludge quality

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