Disinfection

The destruction or prevention of growth of microorganisms capable of causing diseases

Disinfection is achieved by altering or destroying structures or functions of essential components within the pathogens

- **proteins (structural proteins, enzymes, transport proteins, etc.)**
- **nucleic acids (genomic DNA or RNA, mRNA, tRNA, etc.)**
- **lipids (lipid bi-layer membranes, other lipids)**

Disinfectants include:

- **Heat – denatures proteins and nucleic acids**
- **Chemicals – uses a variety of mechanisms**
- **Filtration – physical removal of a pathogen**
- **Radiation – destroys nucleic acids**

Some disinfectants also control taste and odor problems, organic matter, and metals such as iron and manganese

Factors Influencing Disinfection

- **Type of disinfectant**
- **Type of microorganism**
- **Disinfectant concentration and time of contact**
- **pH**
- **Temperature**
- **Chemical and physical interference, e.g., clumping of cells or adsorption to larger particles**

Common Disinfectants in Water Treatment

- **Chlorine**
- **Ozone**
- **Ultraviolet light**

Some filtration techniques such as RO etc.

1. Disinfectants of Water by Chlorination

(a) bleaching powder

- In drinking water 1 mg/L of chlorine for 30 min is generally sufficient to reduce bacterial numbers. In wastewater with **interfering substances** up to 20-40 mg/L may be required.

  – Produces hypochlorous acid (powerful germicide)

$$CaOCl_2 + H_2O \longrightarrow Ca(OH)_2 + Cl_2$$

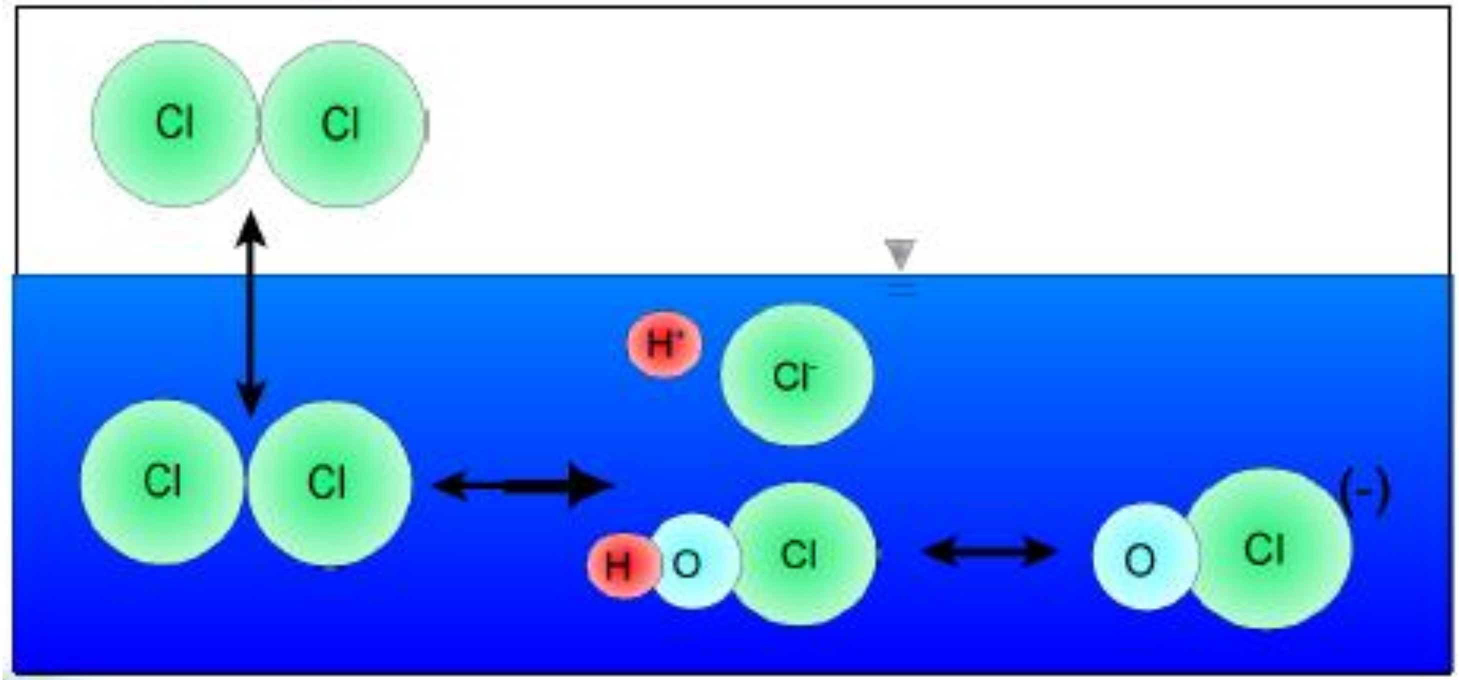
$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

$$\text{Germs} + HOCl \longrightarrow \text{Germs are killed}$$

Disadvantage

- **Introduces Calcium in water, thereby making it more hard**
- **excess of it gives a bad taste and smell to treated water**
- **Chlorinated organic compounds (some of them are carcinogenic)**

Disinfection by HOCl



Produces hypochlorous acid (powerful germicide)

Hypochlorous acid weak acid

- Neutral or weak acidic pH HOCl (stable)
- Basic pH it forms OCl^- not a powerful germicide

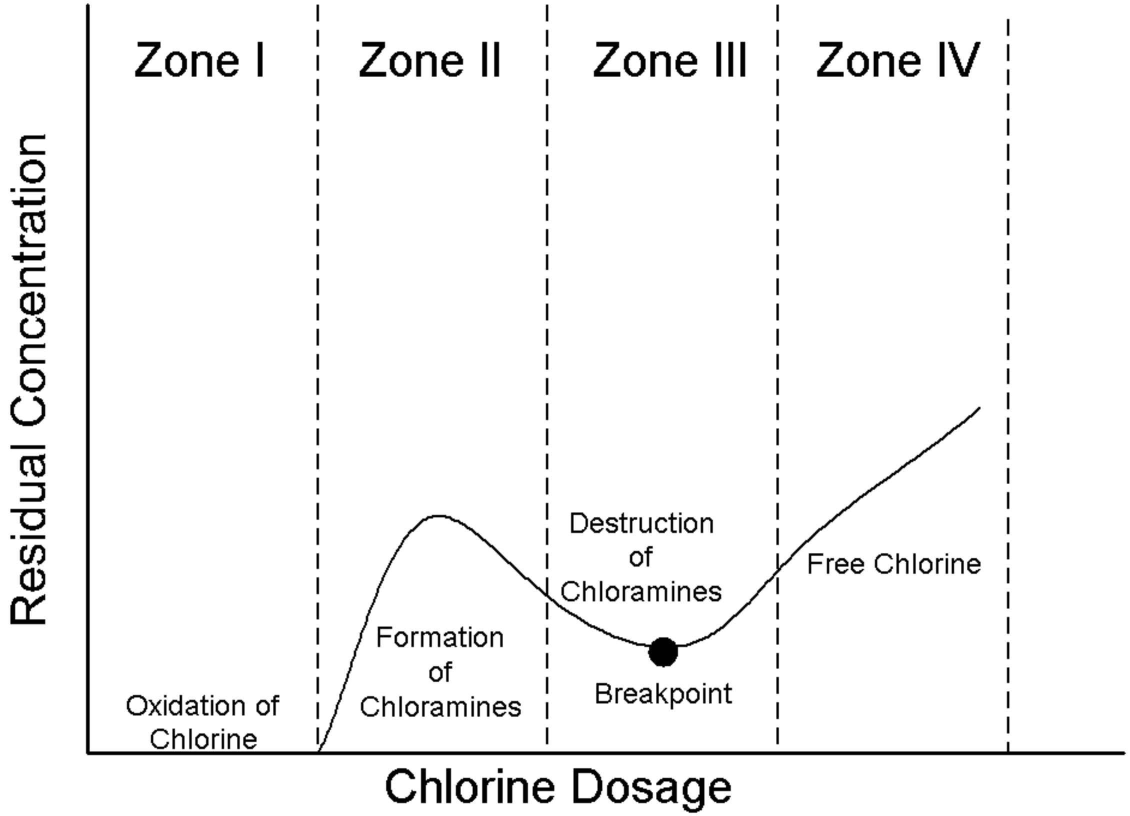
1. Disinfectants of Water by Chlorination

(b) Chlorine gas

– Chlorine either gas or in concentrated solution form produces hypochlorous acid, which is a powerful germicide

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$
$$\text{Germs} + HOCl \longrightarrow \text{Germs are killed}$$

Break point chlorination or free-residual chlorination



Involves addition of sufficient amount of chlorine to oxidize organic matters, reducing substances, free ammonia leaving behind free chlorine to kill bacteria.

The addition of chlorine at the dip or break is called break-point chlorination

Break point chlorination

The point at which near complete oxidation of nitrogen compounds are reached. Any point beyond breakpoint is mostly free chlorine (HOCl and OCl^-)

(i) Amount of chlorine required

- **Theory:** 7.6 to 15 times the ammonia nitrogen content of the water
- **Practical:** up to 25 times the ammonia nitrogen content

(ii) Beyond breakpoint

- 90% free residual chlorine (HOCl and OCl^-)
- 10% combined chlorine

(iii) Why much breakpoint chlorination be reached

- Necessary for the production of free residual chlorination (HOCl and OCl^-)
- Reduces taste and odours
- Reduces chloramines

Chlorination (advantages and disadvantages)

Advantages

- Effective against all types of microbes
- Relatively simple maintenance and operation
- Inexpensive

Disadvantages

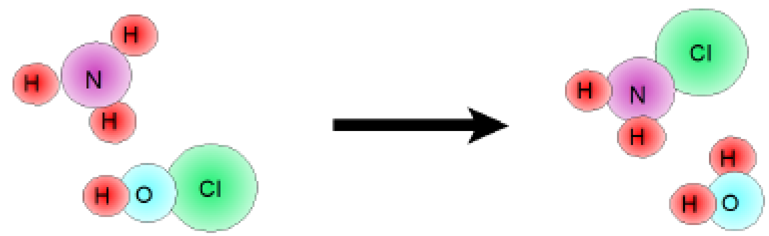
- Corrosive
- High toxicity
- High chemical hazard
- Highly sensitive to inorganic and organic loads
- less effective in higher pH values
- excess chlorine produces unpleasant taste and odour
- Formation of harmful disinfection by-products (DBP's)

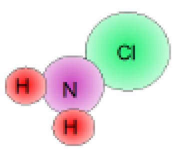
1. Disinfectants of Water by Chlorination

- First used in 1905 in London, in Bubbly Creek in Chicago (in USA) in 1908

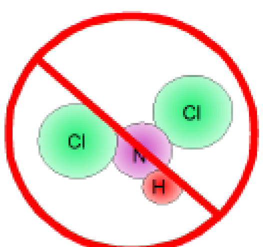
- Chlorine being replaced by alternative disinfectants after the discovery of its disinfection by-products (trihalomethanes and other chlorinated organics) during the 1970's

If ammonia present in the raw water, these reactions occur:

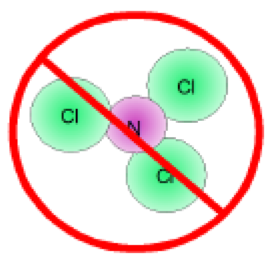




Monochloramine



Dichloramine



Trichloramine

Formation is dependent on the pH and chlorine to ammonia ratio

2. Disinfection of water by Ozone (O_3)

$$3O_2 \longrightarrow 2O_3$$

$$O_3 \longrightarrow O_2 + [O]$$

Nascent oxygen

- Very strong oxidant but has no residual disinfection power
- Generated by passing high voltage through the air between two electrodes
- More expensive than chlorination but does not produce trihalomethanes which are suspected carcinogens
- Widely used in Europe, limited use in U.S.

Ozone - History and Background

- First used in 1893 at Oudshoon, Netherlands and at Jerome Park Reservoir in NY (in USA) in 1906
- Used in more than 1000 WTPs in European countries, but was not so popular in USA
- Increased interest due to the discovery of chlorination disinfection by-products during the 1970's
  - an alternative primary disinfectant to free chlorine
  - strong oxidant, strong microbiocidal activity, perhaps less toxic DBPs

Ozone - Chemistry

Ozone

- colorless gas
- relatively unstable
- highly reactive
    - reacts with itself and with OH^- in water

The method of application

- generated by passing dry air (or oxygen) through high voltage electrodes (Ozone generator)
- bubbled into the water to be treated.

Ozone (advantages and disadvantages)

Advantages

- Highly effective against all type of microbes

Disadvantages

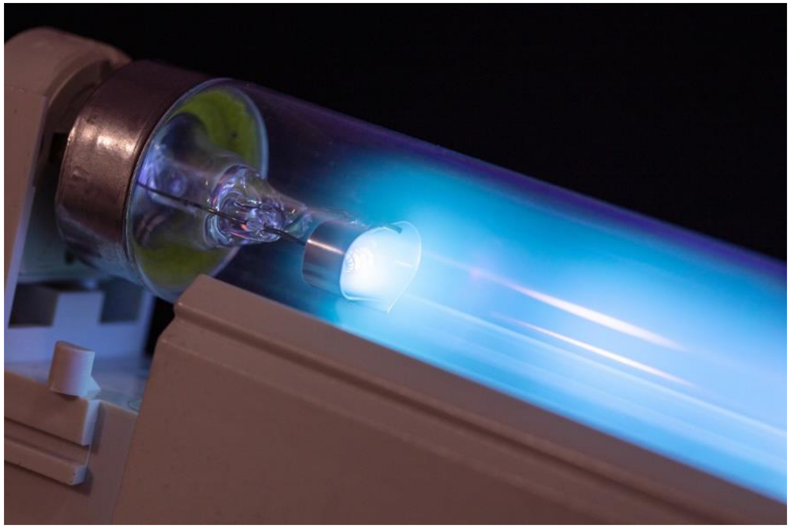
- Expensive
- Unstable (must produced on-site)
- High toxicity
- High chemical hazards
- Highly sensitive to inorganic and organic loads
- Formation of harmful disinfection by-products (DBP’s)
- Highly complicated maintenance and operation

3. Water disinfection by UV

- Optimum ultraviolet light wavelength range for germicidal effect: 250 nm - 270 nm
- Low pressure mercury lamps emit 253.7 nm
- Damages microbial/viral DNA and viral RNA by causing dimerization, blocking nucleic acid replication
- **Does not produce toxic by-products**
- Higher costs than chemical disinfection, no residual disinfection

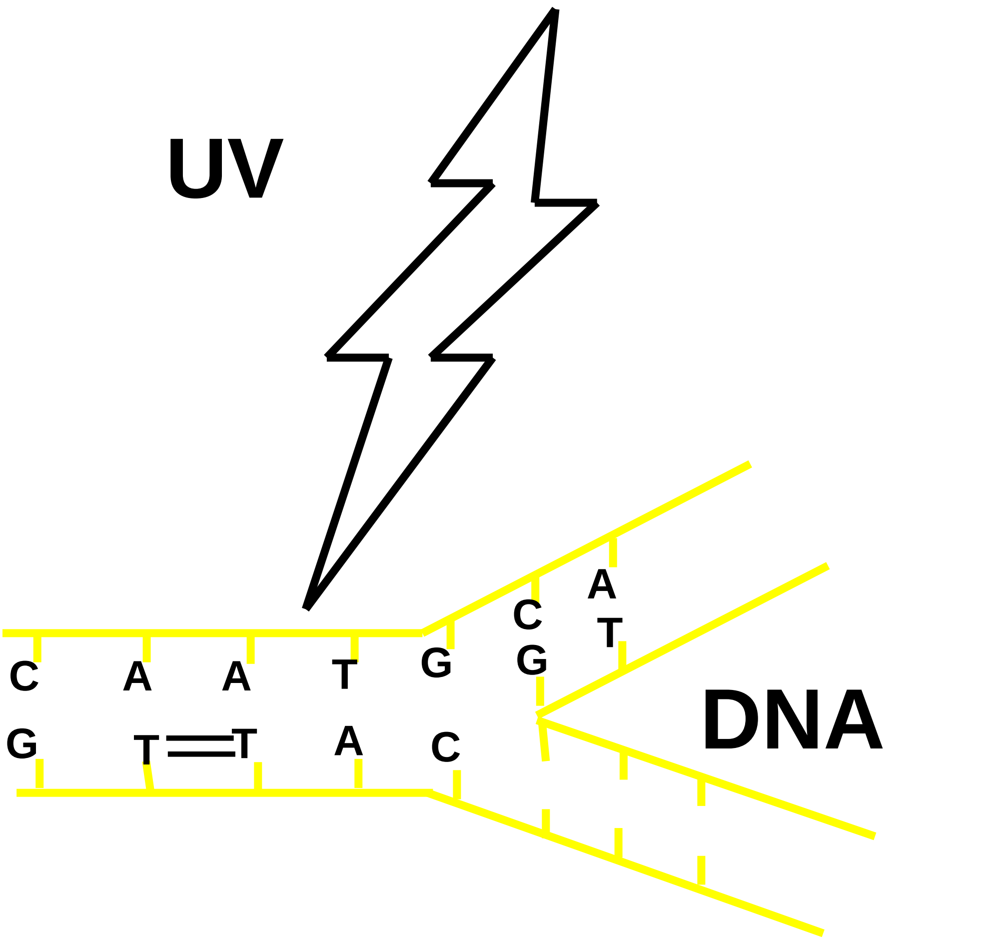
Ultraviolet irradiation

- Has been used in wastewater disinfection for more than 50 years
- Increased interest after the discovery of its remarkable effectiveness against *Cryptosporidium parvum* (diarrhea) and *Giardia lamblia* in late 1990's



Ultraviolet irradiation

- physical process
- energy absorbed by DNA
  - pyrimidine dimers, strand breaks, other damages
  - **inhibits replication**



Ultraviolet irradiation

The advantages of using UV, rather than chemical disinfection, include:

- Has no known toxic or significant nontoxic by-products
- Has no danger of overdosing
- Removes some organic contaminants
- Has no volatile organic compound (VOC) emissions or toxic air missions
- Has no onsite smell and no smell in the final water product
- Requires very little contact time (seconds versus minutes for chemical disinfection)
- Does not require storage of hazardous material
- Requires minimal space for equipment and contact chamber
- Improves the taste of water because of some organic contaminants and nuisance microorganisms are destroyed

Disadvantages of UV disinfection include

- No technical database exists on how well UV systems perform for various water quality conditions
- No standardized mechanism measures, calibrates, or certifies how well equipment works before or after installation

Purification of Municipal water supply

- **Screening**
  - Water passes through screens with larger holes
- **Sedimentation**
  - Allow water to stand undisturbed in big tanks
- **Coagulation and/or flocculation**
  - Alum, Sodium aluminate, copper or Ferrous sulphate
- **Filtration**
  - Sand filtration – (Coarse & Fine sand bed)
  - Activated carbon filtration – (Adsorption)
  - Candle filtration – (Ceramic materials)
- **Disinfection –** Factors influencing disinfection process
  - Chlorination
    - Bleach or gaseous chlorine <u>(break-point of chlorination)</u>
  - Ozonation <u>(Oxidation using [O])</u>
  - Ultraviolet light irradiation <u>(Higher energy – DNA strand breaks)</u>
- **Supplementary treatment**