Disinfection

Presented By

Operator Training and Certification Unit

Disinfection

- The destruction of pathogenic organisms
- Not to be confused with sterilization, which is the destruction of all organisms
- Chlorine is the most widely used disinfecting chemical
  - easily obtained & inexpensive
  - leaves a residual that can be measured
  - however, it also forms byproducts which may contribute to increased risk of cancer

Alternate Disinfectants

- Chlorine Dioxide
  - -produced on site w/sodium chlorite
  - -used to control taste and odors
  - -does not form byproducts, TTHMs

- Ozone
  - -produced on site by passing an electrical voltage through oxygen
  - -very powerful oxidant
  - -does not form byproducts, TTHMs
  - -unstable
  - -high cost
  - -lack of residual

CHLORINE

- Discovered in 1774
- First identified as an element in 1810
- Early use in water application was for deodorizing capacity.
- First use of chlorine as a continuous treatment process was in 1902, at Middlekerl, Belgium.
- First continuous use of chlorine in the US was in 1908. Sodium hypochlorite was used to disinfect a 40 MGD supply for Jersey City, New Jersey.

Properties of Chlorine

- Atomic Wt. = 35.5
  Molecular. Wt. Cl_2 = 71.0
- Depending on the temp. and pressure Chlorine can exist as a **GAS, LIQUID OR SOLID.**
- Greenish Yellow Gas
- Packed as liquefied gas in cylinders
- Not Explosive or Flammable
- Cl_2 gas is 2.5 times heavier than air
- Cl_2 liquid is 1.5 times heavier than water
- Less than 3 ppm in the air can be detected by nose
- Dry gas is not Corrosive; but is very corrosive in moist environment

Health Concerns due to Chlorine Gas

- 3.5 ppm – chlorine odor can be detected
- 4 ppm – can be inhaled up to 1 hour
- 15 ppm – produces throat irritation
- 40-60 ppm – 30 minute exposure is dangerous
- 1000 ppm – few breaths can be fatal

Chlorine Reactions

Hypochlorous + Hydrochloric Acids formed, lowering the pH.

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-$$

Hypochlorous Acid will further disassociate.

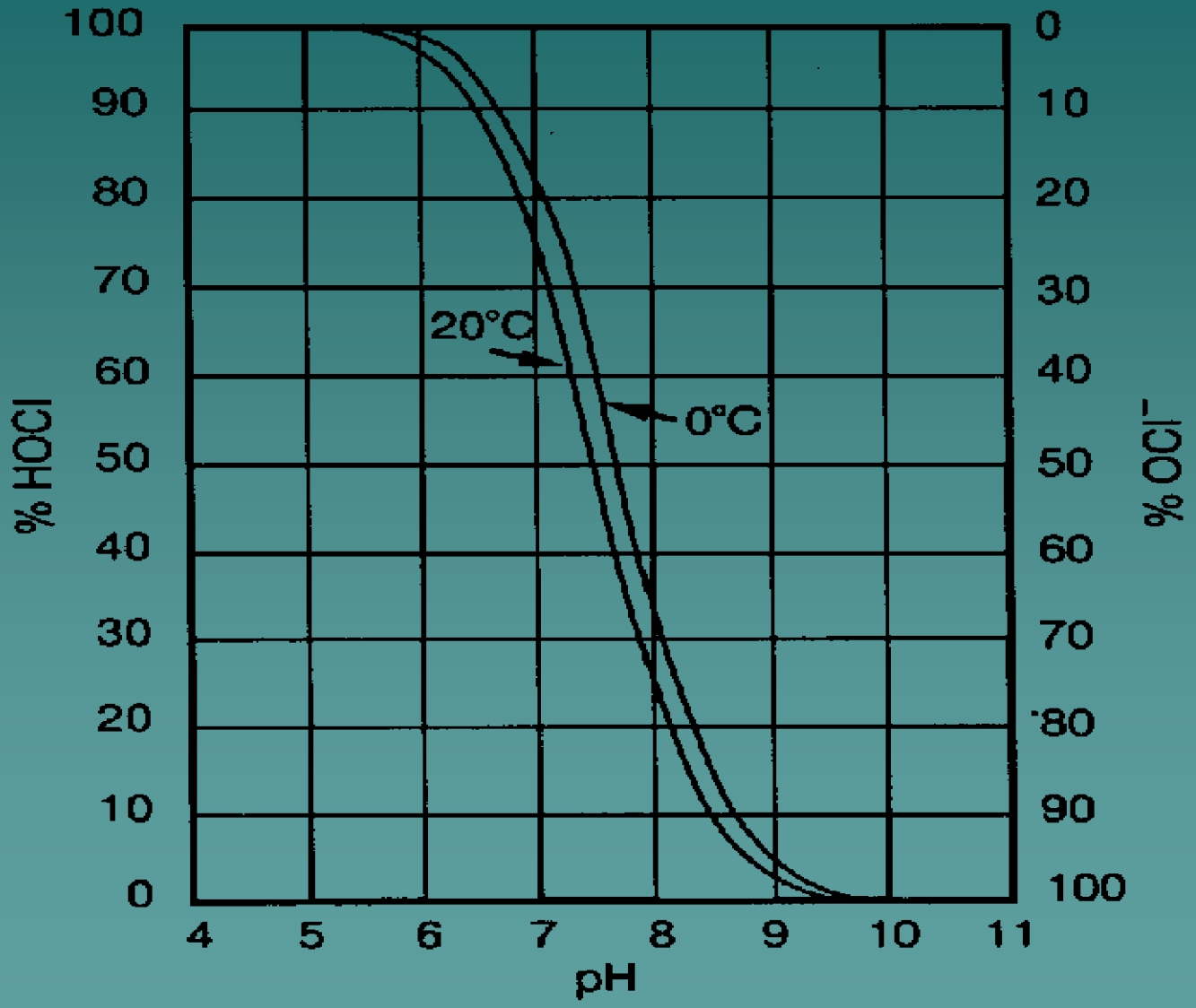
$$HOCl \rightleftharpoons H^+ + OCl^-$$

Ammonia Nitrogen compounds in the water will also react with the Cl_2, resulting in "Combined Chlorine".

Free Avail. Cl_2 + Combined Cl_2 = Total Cl_2

Hypochlorous Acid will be favored at lower pH.

This is referred to as "Free Avail. Cl_2".



Combined Chlorine

- Ammonia and/or nitrogen compounds in the water will react with the chlorine resulting in "combined chlorine"

Total residual =combined + free

Combined Chlorine

Monochloramine

$$NH_3 + HOCl \rightleftharpoons NH_2Cl + H_2O$$

Dichloramine

$$NH_2Cl + HOCl \rightleftharpoons NHCl_2 + H_2O$$

Trichloramine

$$NHCl_2 + HOCl \rightleftharpoons NCl_3\ (gas) + H_2O$$

NCl_3 is a gas, has an odor and will escape.

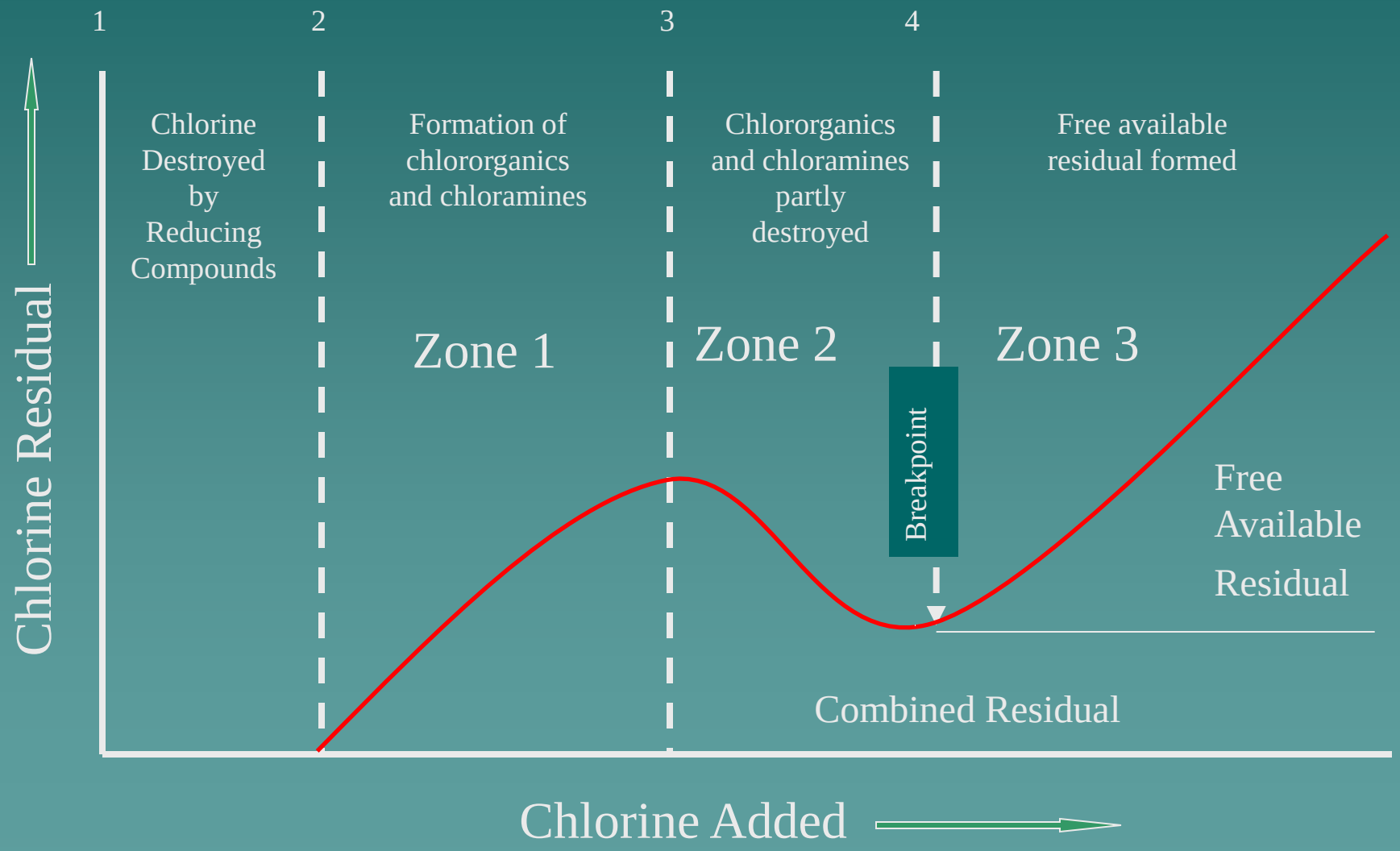
Therefore, an increase in Chlorine dose will result in a drop in Chlorine residual!

Combined Chlorine will decrease as NCl_3 is formed, until eventually Free Chlorine predominates.

Chloramines

- CL_2 + ammonia = chloramines
- 4 parts CL_2 to 1 part NH_3
- About 1/25 powerful as HOCL
- Used in large distribution systems, more persistent
- Reduces TTHM formation
- Attacks biofilms
- Di and Tri chloramines may cause disagreeable taste and odors

Breakpoint chlorination



Factors Affecting Disinfection with Chlorine

- pH – the higher the pH, the more hypochlorite ion is present – a much less effective disinfectant

- Ammonia Nitrogen Compounds – the more ammonia nitrogen compounds that are present the more combined chlorine is formed – a much less effective disinfectant.

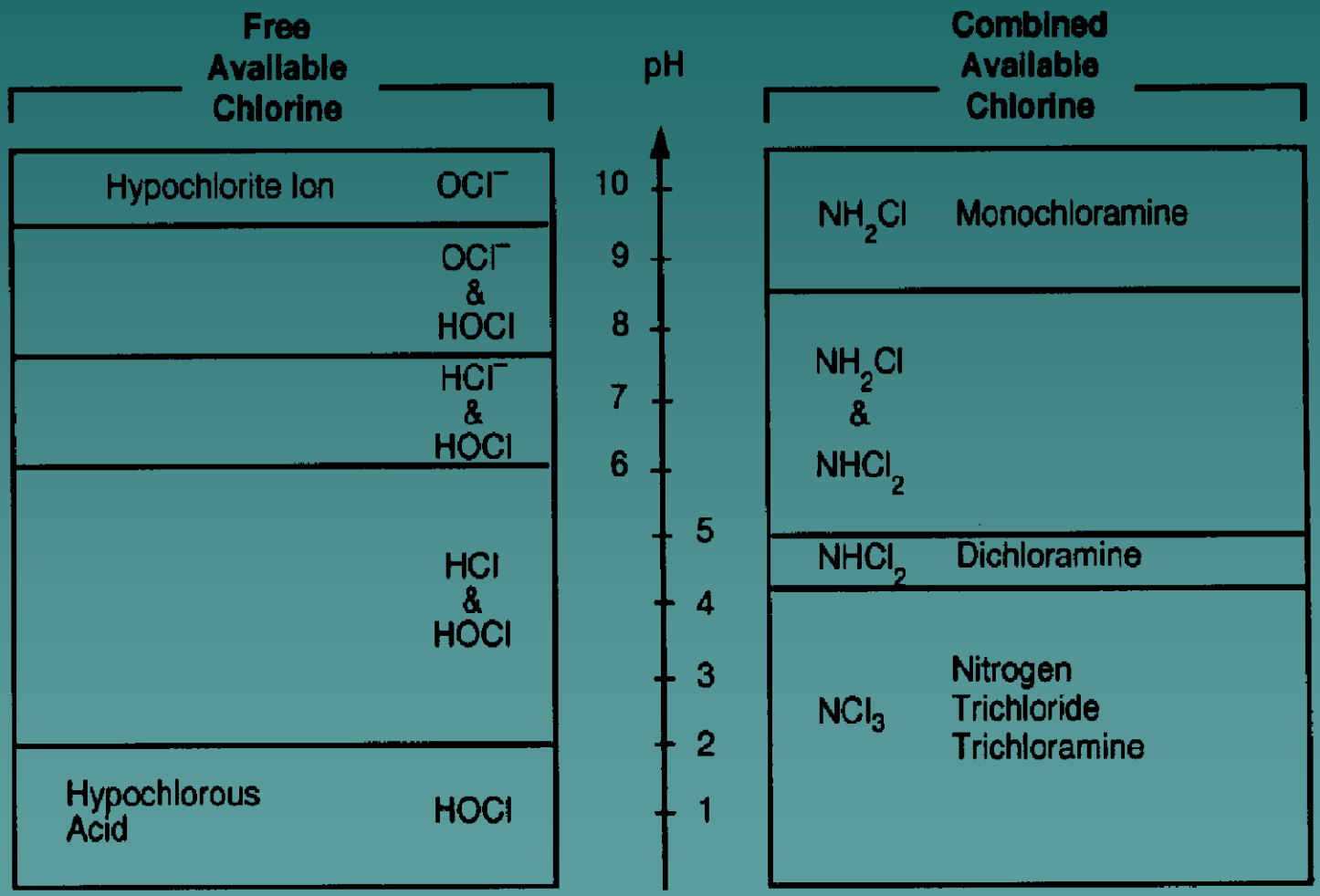
Factors Affecting Disinfection with Chlorine

- Temperature – higher temperature the faster the rate of reaction (better disinfection). Chlorine is also used up quicker.
- Time – longer contact time means that better disinfection is more likely.
- Impurities – the more impurities in the water , the greater the chlorine demand and the less effective disinfection is likely to be.

Common Chlorine Compounds

- **Chlorine Gas**
  - 100% available Chlorine.
  - 150 lb Cylinders
  - 1 ton Cylinders
- **Calcium Hypochlorite**
  - 65% available Chlorine
  - Must be Dissolved in Water
  - Used in Construction Projects
- **Sodium Hypochlorite**
  - Liquid (Bleach)
  - 3 to 19% (10 -15% typ.) available Chlorine
  - Used in Low Volume or Low Rate Applications

pH Effects on Chlorine Residual



Definitions

- **Available Chlorine:**
  Refers to the oxidizing power of a chlorine compound.

- **Free Available Chlorine:**
  The concentration of HOCl and OCl^- ions in the water.

- **Chlorine Applied:**
  The amount of chlorine added to the water.

- **Total Chlorine Residual:**
  The amount of chlorine remaining in the free and combined form after a certain contact time.

Definitions

- Free Chlorine Residual:

  The amount of chlorine that has not reacted with other compounds found in the water.

- Combined Chlorine Residual:

  The amount of chlorine that has reacted with the natural ammonia or organic nitrogen compounds in the water to form chloramines.

- Chlorine Demand:

  The difference between the chlorine applied and the chlorine residual. Usually the amount of the chlorine that has reacted with or is lost to other substances in residual.

chlorine applied – chlorine demand = chlorine residual

Chlorine Residual Measurements

DPD (diethyl-p-pheneylene diamine)

- **Titrimetric**
  - Pink color is removed slowly by adding FAS.
  - Chlorine Residual Conc. is calculated by the amount of FAS used to remove all color.
- **Colorimetric**
  - Relies on color development after DPD is added to the Chlorinated water sample.
  - Pink/Red color develops
    - More chlorine; darker color

Chlorination ByProducts

- CL2 combines with organic matter in water to form:
  - -Trihalomethanes (TTHMs)
  - -Haloacetic acids (HAA5s)

- MCL's
  - - TTHMS – 80 ppb
  - - HAA5s – 60 ppb

  - New Rules (Stage 2) require MCL to be met at each location a TTHM/HAA5 sample is collected. This called a Locational Running Annual Average (LRAA)

STAGE 2 Rules

- CWS system using chlorine must meet Individual Distribution System Evaluation (IDSE) requirements using one of the following methods
  - Small system waiver
  - 40/30 waiver
  - Standard Monitoring Plan
  - System Specific Study
- Current sampling continues
- New sampling begins in 2012 or later based on IDSE results

PPM Formula

- ppm = mg/l when talking about a chemical in water

- ppm = $\frac{\text{\# pure chemical}}{\text{M \# water}}$
- ppm x M # water = # pure chemical
- ppm x M gal water x 8.34#/gal = # pure chemical

- M = one million

Conversion factors

- $\frac{8.34\ \#}{\text{gallon}}$ or $\frac{\text{gallon}}{8.34\ \#}$

- $\frac{7.48\ \text{gal}}{\text{ft}^3}$ or $\frac{\text{ft}^3}{7.48\ \text{gal}}$