

Disinfection

(Nazaroff & Alvarez-Cohen, Section 6.D.1)

Purpose:

To reduce risk of disease transmission associated with either drinking or wastewater.

Objective:

To kill or inactivate microorganisms

Methods:

Boiling of water	Very effective	Very energy intensive
Irradiation with UV light	Limited efficacy	Cheap and convenient Requires clear water
Chemical disinfection by chlorine or chlorinated compound	Very effective Leaves lasting residuals	Cheap to expensive May create harmful by-products
Chemical disinfection by ozone	Very effective	Quite expensive No residual left

Disinfection by chlorine

The active ingredient that kills microorganisms is hypochlorous acid, HOCl.

HOCl must be made in the water from a chlorinated precursor. The most common method is the injection of pure chlorine gas, Cl₂.

More expensive but safer than handling chlorine gas is the use of sodium hypochlorite (NaOCl – commonly called bleach) or calcium hypochlorite (Ca(OCl)₂), a solid.

U.S. standards for drinking water:

- minimum contact of 45 minutes
- minimum residual chlorine concentration of 1.1 mg/L
(from initial dose of 2 to 5 mg/L)

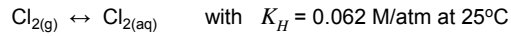
U.S. practice for end of wastewater treatment:

- injection of 40 to 60 mg/L.

Chlorine chemistry in pure water

Let us consider the use of chlorine gas as the disinfection method.

First, Cl_2 in gas (from compressed bottle, handled with care!) penetrates the water, following Henry's Law:



Aqueous Cl_2 reacts rapidly with water to form hypochlorous acid:

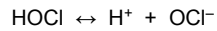


with constant

$$K = \frac{[\text{HOCl}][\text{H}^+][\text{Cl}^-]}{[\text{Cl}_2]} = 5 \times 10^{-4} \text{ M}^2$$

The preceding two reactions are highly tilted to the right, meaning that chlorine gas most easily goes into hypochlorous acid in the water.

However, hypochlorous acid HOCl is not just consumed in killing microorganisms; it also decays spontaneously into:



with constant

$$K_2 = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]} = 2.6 \times 10^{-8} \text{ M}$$

The hypochlorite ion OCl^- is much less potent as a disinfectant than HOCl.

To keep the previous reaction tilted to the left (in favor of HOCl and against OCl^-), the pH must be controlled.

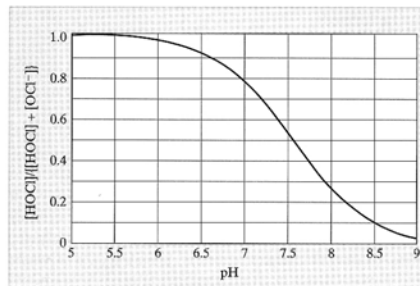


Figure 6.D.1 The fraction of hypochlorous species ($\text{HOCl} + \text{OCl}^-$) that is present as undissociated hypochlorous acid (HOCl), versus pH.