

# Disinfectants Evaluated

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- Chlorine
- Chloramine
- Chlorine dioxide
- Ozone
- Iodine



# Disinfectants and Disinfectant by-products

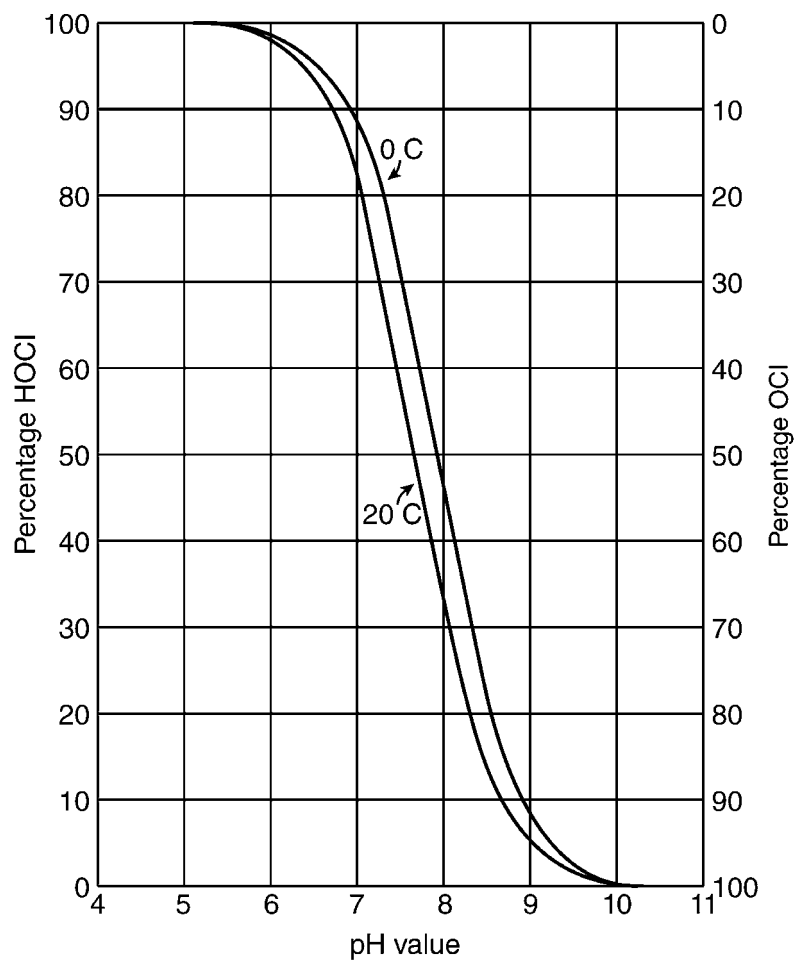
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- Overall ozone is the most effective disinfectant, although chlorine is effective and efficient
- All disinfectants have advantages and disadvantages and all produce by-products
- A number of disinfectant by-products were evaluated in the Guidelines

*Microbiological quality of water should never be compromised by concerns about disinfection by-products*



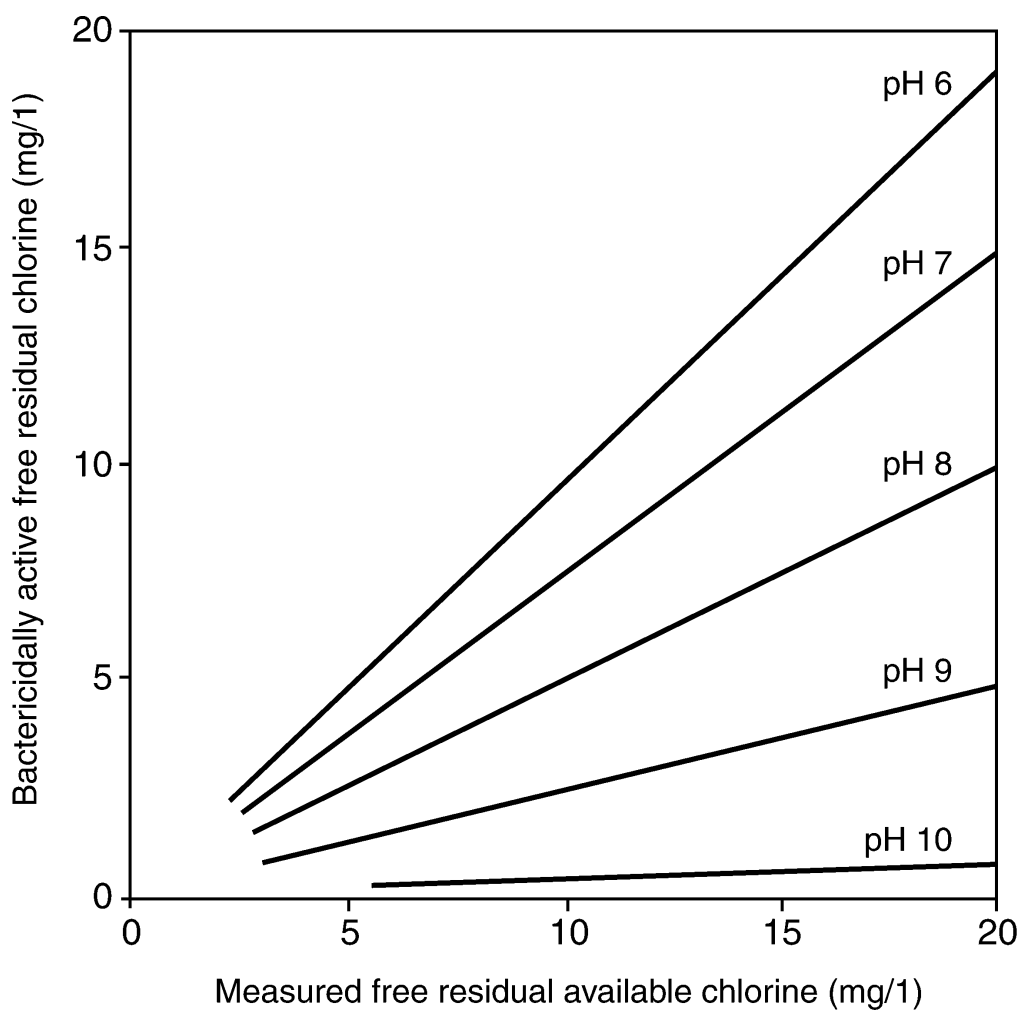
# Distribution of Hypochlorous Acid and Hypochlorite Ion in Water at Different pH Values and Temperatures



(Morris, 1951)



# Relationship between Measured Free Residual Available Chlorine ( $\text{HOCl}^+$ , $\text{OCl}^-$ ) and Bactericidally Active ( $\text{HOCl}$ )



# Chlorine

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- Chlorine is the most common disinfectant
- Chlorine by-products
  - » Free chlorine
  - » Trihalomethanes (THMs)
  - » Chlorinated acetics acids
  - » Halogenated acetonitriles
  - » Chloral hydrate (trichloroacetaldehyde)
  - » Chlorophenols
  - » MX  
(3-chloro-dichlormethyl-5-hydroxy-2(5H)-furanone)

May not need to set standards for all by-products included in the Guidelines, it is better to concentrate on the major groups (e.g. THMs)



# Trihalomethanes

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- The principal by-product of chlorination
- Formed by the aqueous chlorination of humic substances
- More likely to occur in chlorinated surface water than groundwater
- Concentrations of THMs tend to increase with increasing temperature, pH and chlorine dosage
- THMs consist primarily of:
  - » Chloroform
  - » Bromodichloromethane
  - » Dibromochloromethane
  - » Bromoform
- Formation of THMs can be minimised by avoiding prechlorination and optimising treatment



# Chloramine and its By-products

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- Chloramines formed by reaction of chlorine and ammonia or organic amines
- Mono-, di- and trichloramines may be formed depending upon pH and temperature
- Chloramine by-products similar to free chlorine with the exception of cyanogen chloride
- Mono-chloramine is a less effective disinfectant than free chlorine and cannot be relied upon as a primary disinfectant; though useful for maintaining a residual.



## Chlorine dioxide and its By-products

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- Chlorine dioxide made at point of use because of its explosive hazard
- Reactions with humic substances do not form significant levels of THMs or chloramines
- Main by-products are:
  - » chlorite
  - » chlorate
  - » chloride
- More effective than free chlorine in inactivation of *Giardia* cysts but less effective against *E.coli* and rotaviruses
- No GV for chlorine dioxide in water as it dissociates rapidly. GVs set for chlorite but not chlorate





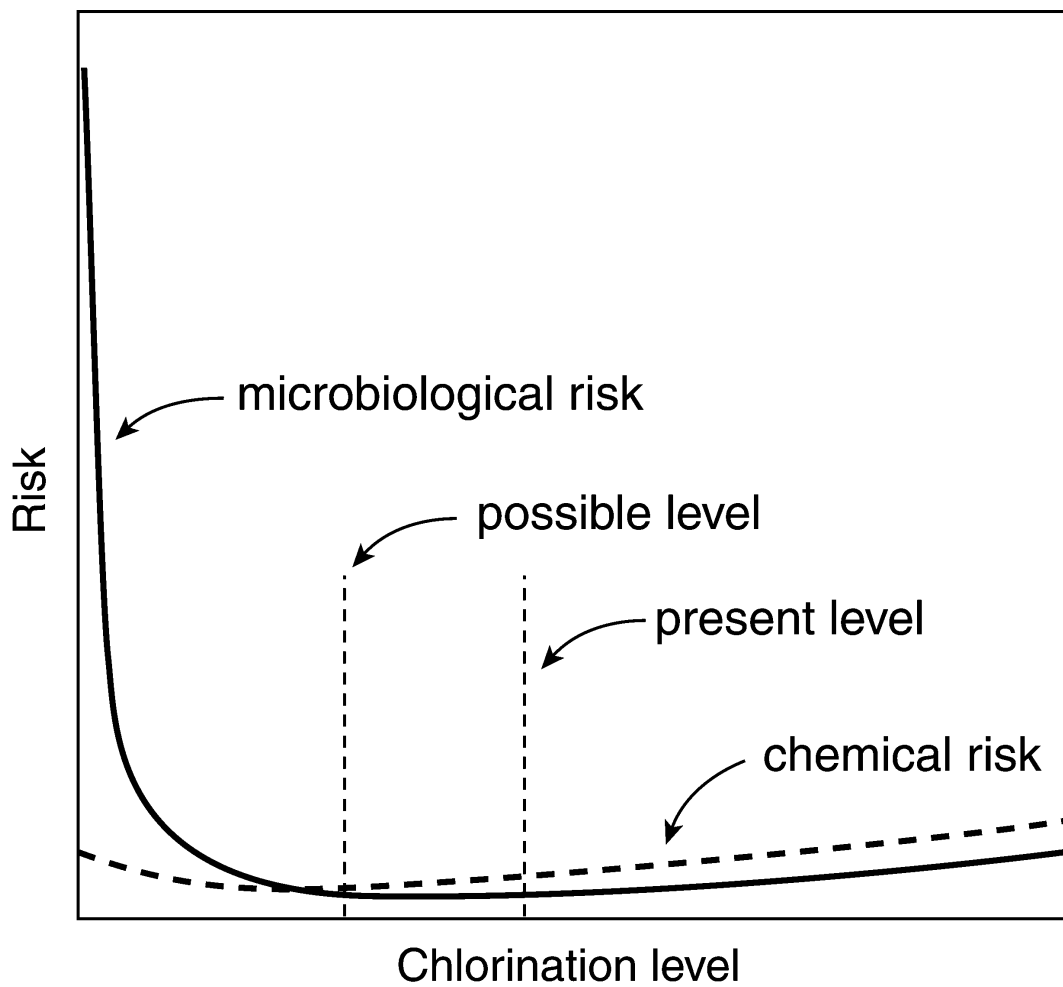
# Ozone and its By-products

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- Most efficient disinfectant for all types of micro-organisms
- Decomposes rapidly following application thus no GV has been proposed for ozone
- By-products include:
  - » formaldehyde
  - » aldehydes
  - » hydrogen peroxide
  - » bromomethanes
- Disadvantages include:
  - » lack of residual
  - » biological regrowth in distribution systems
  - » high cost
  - » limited information on toxicity of its by-products



# Balancing chemical and microbiological risks



(Morris, 1978)

