Disinfection Processes

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Aims and Objectives

- Introduce the range of disinfection processes used in water and wastewater treatment
  - Discuss the importance of disinfection
  - Introduce use of chlorine, ozone and UV based oxidants.
  - Look at disinfectants for wastewaters
  - Raise issue of by-product formation

What is covered in this lecture?

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Microrganisms in Water

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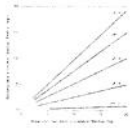
Process Science



$$\ln \frac{N}{N_0} = -k'C^n t$$

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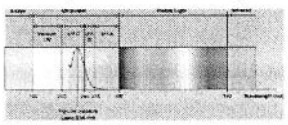
Principles of UV Technology



■ Inactivation of pathogenic microorganisms due to photooxidation of DNA

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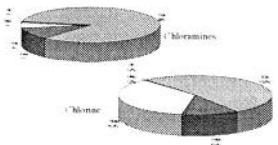
DBP Formation



Microrganisms in Water (mm)

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Pathogen	Lakes and Reservoirs	Impacted rivers and streams	Groundwater
E. coli (generic)	10000–1000000	30000–1000000	0–1000
Viruses	1–10	30–60	0–2
Cryptosporidium	4–290	2–480	0–1
Giardia	2–30	1–470	0–1

Disinfection terminology

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- ***Disinfection*** is control of levels of microorganisms
- ***Sterilisation*** is complete destruction of microorganisms (e.g. through autoclaving)
- ***Sanitisation*** is removal of bacterial fouling
- Disinfectants can also be called *biocide*s or *bacteriostats*

Disinfection

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- Disinfection is most commonly accomplished by the use of either:
  - Chemical agents (chlorine and its compounds, bromine, iodine, ozone, heavy metals and related compounds, and hydrogen peroxide) or
  - Physical agents including heat, light or physical separation by microfiltration

History

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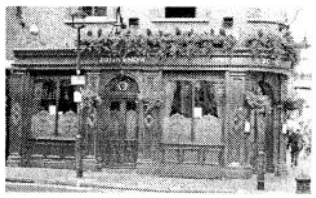
- In 1855, epidemiologist Dr. John Snow proved that cholera was a waterborne disease by linking an outbreak of illness in London to a public well that was contaminated by sewage.
- In 1897, Sims Woodhead used "bleach solution" as a temporary measure to sterilize potable water distribution mains at Maidstone, Kent (England) following a typhoid outbreak



Importance of Disinfection

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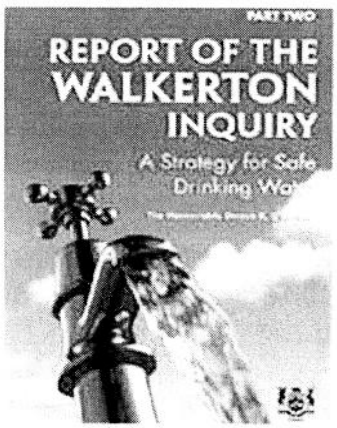
- Walkerton (Canada) E. coli Outbreak
- **Walkerton, Ontario -May, 2000**
- **Water supply contaminated with *E. coli***
- **7 deaths, 2300 illnesses, lasting effects**
- **Economic impact > $64.5 million CAD**



Chlorination

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Ubiquitous for potable water disinfection:

- Free chlorine
  - chlorine gas
  - hypochlorite salts of calcium and sodium
- "Stabilised" chlorine:
  - chloramines (or *combined* chlorine)
  - isocyanurates (small-scale processes only)

Chlorination

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- Available both as liquefied gas & hypochlorite salt
- (May also be generated in-situ electrolytically)
- Well-developed, well-understood technology
- Powerful bactericide
- Oxidises ammonia (*breakpointing*)
- Long-lasting residual, *BUT*
- Toxic and corrosive
- Poor virucide and largely ineffective for cysts
- Toxic disinfection byproducts (DBPs)

Pg 130

Process Science

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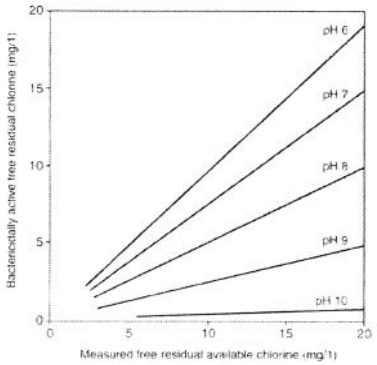

$$\ln \frac{N}{N_0} = -k'C^n t$$

4

Removal direct related with the Guerst. (C^n)

Adding Chlorine, We change the Ph

Performance

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Micro-organism	Ct for 2 log reduction, pH 6-7
E. coli.	**0.034 - 0.05** 50 µg chlor. x min
Polio 1	**1.1 - 2.5**
Rota Virus	**0.01 - 0.05**
Phage f2	**0.08 - 0.18**
G.lamblia cysts	**47 - >150**
G.muris cysts	**30 – 630**
C. parvum oocysts	**7200**

Ozone is more ~~Effective~~ efficient than chlorine

UK Ct Values

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Source	Quality	Ct (mg.min/L)
Groundwater	**No E Coli**	**5**
Groundwater	**E Coli**	**15**
Surface Water	**Lowland**	**20**
Surface Water	**Moorland**	**30**

Chloramination

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- Chlorine combined with ammonia to produce *chloramines*:
  - NH_2Cl (monochloramine)
  - $NHCl_2$ (dichloramine),
- Chloramines generally have lower bactericidal potency than chlorine but chemically more stable.
- Becoming more widely used in potable water treatment

Chloramines

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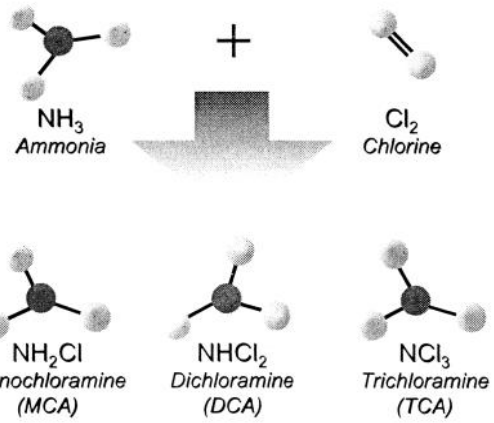

Ozonation

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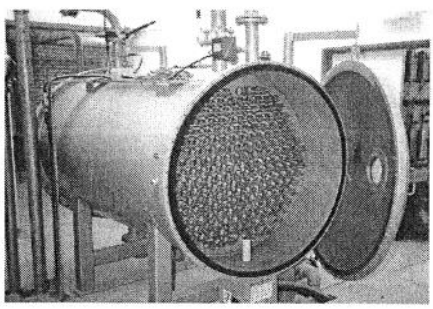
More powerfull desinfectan

- Relatively short contact time required
- Leaves no long-lived residual
- Effective against viruses and, to some extent, cysts
- Fewer halogenated DBPs *BUT*
- Highly toxic material of limited solubility
- Complicated technology with high costs
- Can lead to bromate formation



UV

No kill cells (like O_3 and chlor.), UV ~~changes~~ causes chemical in living cells, changing the DNA

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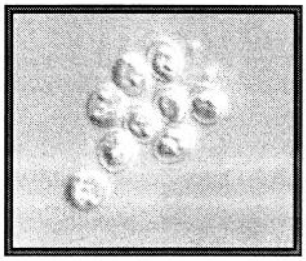
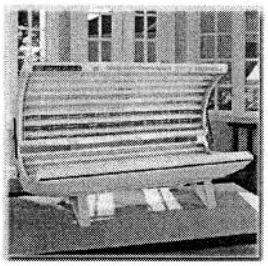
- Tanning - causes chemical changes in living cells





- Disinfection - causes chemical changes in living cells

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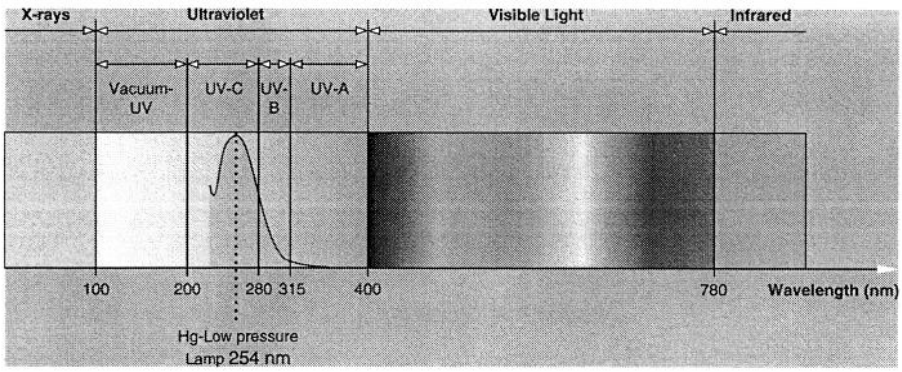
Principles of UV Technology

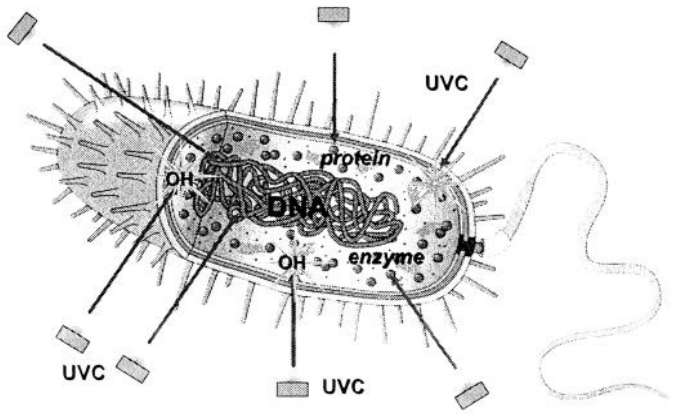
(100 - 400)



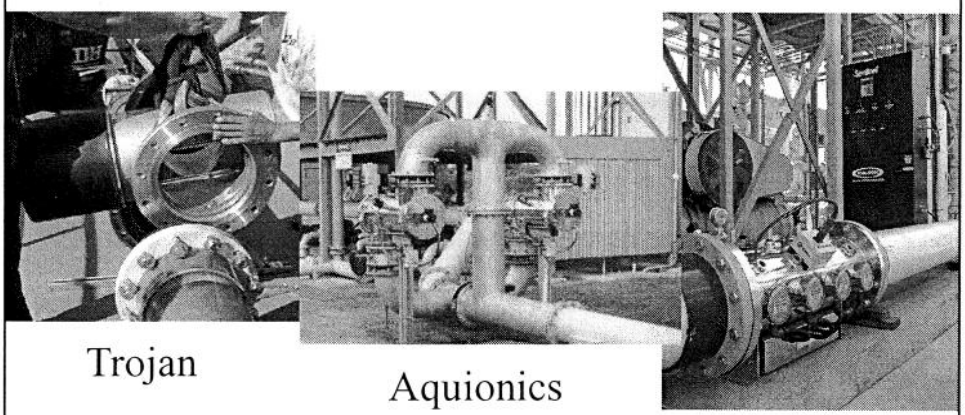
- Inactivation of pathogenic microorganisms due to photooxidation of DNA

UV - Mechanism

Avoid replicant
Very effective for cryptosporium



Enclosed UV Reactors (MP)



Trojan

Aquionics

Calgon

Physical disinfection: filtration

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Membrane filtration removes micro-organisms:

- Microfiltration
  - 0.1-2 bar, 50-500 LMH
- Ultrafiltration
  - 1-5 bar, 20-100 LMH
- Nanofiltration, reverse osmosis
  - 5-25 bar (inland waters), 15-30 LMH

Physical disinfection

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- **UV** employed for **municipal wastewater** disinfection for sea discharge
- **UV** now used for **Cryptosporidium**
- **UF/MF** employed for **Cryptosporidium** removal (e.g. Clay Lane, Three Valleys W)
- **Chlorine still required for UK potable water supply** for disinfection residual in network

Disinfection By-products (Pag 138)

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Disinfectant	Inorganic byproduct or disinfectant residual formed
Chlorine	trihalomethanes, haloacetic acids, haloacetonitriles, haloketones, chlorophenols, MX
Chlorine Dioxide	chlorine dioxide, chlorite, chlorate, bromate
Ozone	bromate, iodate, hydrogen peroxide
Chloramines	monochloramine, dichloramine, trichloramine, ammonia, cyanogen chloride

Goslan *et al.*, 2009; Water Research, doi:10.1016/j.watres.2009.07.029

Disinfection byproducts (DBPs)

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DBP	USEPA classification and 10^{-6} cancer risk	Carcinogenicity
Chloroform (THM)	B2 10^{-6} = 6 ug L^{-1}	Live (mice); kidney (rats)
Bromodichloro-methane (THM)	B2 10^{-6} = 0.6 ug L^{-1}	Live (male mice, rats); liver (female mice)
Dichloroacetic acid (HAA)	B2 ND	Liver (mice, male, rats)
Trichloroacetic acid (HAA)	C	Liver (mice, male, rats)
Bromate	B2 10^{-6} = 0.05 ug L^{-1}	Kidney (rats)

Children's Health Article

Relation of Trihalomethane Concentrations in Public Water Supplies to Stillbirth and Birth Weight in Three Water Regions in England

Summary

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- A range of chemical and physical disinfection process are available.
- Chlorine most widely used and most suited for potable water supply
  - Effective for wide range or organisms
  - Provides residual in distribution system
- UV 'emerging' for potable water

Further Reading

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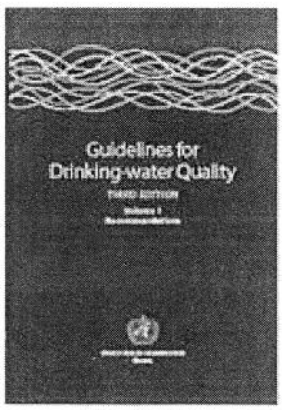

www.who.int/water_sanitation_health/en/

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