# PATHOGENS : DISEASE-CAUSING ORGANISMS

**ISSUE #1 !!**

Viruses, Bacteria, Protozoa, Helminths

- WIDE RANGE OF ORGANISMS & DISEASE
- WIDE RANGE OF CHARACTERISTICS

EX: **VIRUSES**
- Hard to physically remove
- ~ Susceptible to disinfection
- Freely transported

**BACTERIA**
- Not hard to remove physically
- Easy to disinfect
  Extremely populous & stable (some)

**PROTOZOA**
- Easy to remove (if done right
- Very hard to disinfect
- Oocysts ("spores") super stable
- May be multiplied by animals (Giardia)

**Pathogens** are microbes that cause disease.

They include:

- a few types of bacteria
- viruses
- protozoa
- other organisms.

Some pathogens (*coliform bacteria)* are often found in water, frequently as a result of fecal matter from sewage discharges, leaking septic tanks, and runoff from animal feedlots into bodies of water.

Infections by water-borne pathogens also can occur through non-drinking water means such as

- recreational activities (e.g., swimming and water slides)
- person-to-person contact (diaper changing, unwashed hands)
- consumption of food.


Yards
50 0 50 100 150 200
× Pump
• Deaths from cholera
OXFORD STREET
REGENT STREET
GT. MARLBOROUGH ST.
WARDOUR STREET
BROAD STREET
KING STREET
GOLDEN SQUARE
BREWER STREET
CONDUIT STREET
SAVILLE ROW
NEW BOND STREET
REGENTS QUADRANT
PICCADILLY
Dr. John Snow's Map
LONDON: 1854

# WATERBORNE HUMAN PATHOGENS

"Fecal - Oral" Pathway

## VIRUSES:

- Multiply ONLY in living host cells
- But can survive a long time in water
- About 1/50 th the size of bacteria (20-100 nm)

**MAJOR DISEASES:**

- Polio (poliomyelitis)
- Hepatitis A
- Meningitis (viral)
- Gastroenteritis (viral)

## BACTERIA

- Single cell "plants"
- Can reproduce on their own, but...
- Many pathogens ONLY reproduce while inside a host.

SIZE: 500-5000 nm (0.5-5 μm)

**MOST are HARMLESS**

⇒ Human feces can be primarily made up of bacteria

Up to 1 BILLION CELLS PER GRAM

COLIFORM BACTERIA - "Form of" (like E. coli (Escherischia coli)

⇒ Most E. coli are harmless, but they're found ONLY in gut of warm-blooded animals.

CONVENIENT but IMPRECISE MARKER OF FECES

## PATHOGENIC BACTERIA:

- *Pathogenic strains of E. coli*
- *Salmonella typhi* [Typhoid fever]
- *Salmonella spp.* [Gastroenteritis]
- *Shigella spp.* [Bacillary Dysentery]
- *Vibrio cholerae* [Cholera]

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**PROTOZOANS** - Single-celled animals

Most harmless: HUMAN PARASITES ARE BIG CONCERN

Grow in intestine, release CYSTS via feces. CYSTS survive VERY WELL

▶ **CYSTS:**
- Much larger than bacteria (10-15 $\mu m$)
- Can survive drying, even Chlorine

▶ **ZOONOSES:** Some parasites also live and breed in non-human hosts (e.g. BEAVERS)

CYSTS: Hard to kill
~ Easy to physically remove

## Protozoan Diseases:

- *Entamoeba histolytica* [Amoebic Dysentery]
- *Giardia lamblia* [Giardiasis, "beaver fever"]
- *Cryptosporidium spp.* [Cryptosporodiosis]

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**HELMINTHS** (Intestinal worms)

Most Do NOT breed in humans

∴ Number of worms ≈ number of eggs ingested

Hookworms, roundworms, etc.

Some waterborne, many are soil borne

# WATERBORNE DISEASE INCIDENCE IN MODERN U.S.

RARE in U.S. but only because of good sanitation/treatment

1946 - 1980: 672 outbreaks
(35 yrs) 150,000 persons affected

∴ 4400 people per year on average

1 in 34,000 per year (odds of getting one)
~ About 1 fatality per year

In ~50% NO SPECIFIC CAUSE FOUND

MOST COMMON IDENTIFIED
- Salmonellosis (gastroenteritis)
- Shigellosis (bacterial dysentery)

MOST SERIOUS:
- Hepatitis A
- (Polio in 40s - 50s)

# THE "CRYPTO" SCARE

1993-94: 30 outbreaks of waterborne pathogens

405,000 people affected

↓

403,000 in one outbreak Cryptosporidium in Milwaukee, Wisconsin

>100 deaths (Mostly AIDS patients, chemotherapy patients, elderly, other immuno-compromised)

Other significant outbreaks

1987 - Carrollton, GA (13,000)

1993 - Jackson County, OR (~2000)

**Some Waterborne Diseases of Concern in the United States**

| Disease | Microbial Agent |
|---|---|
| Amebiasis | Protozoan (*Entamoeba histolytica*) |
| Campylobacteriosis | Bacterium (*Campylobacter jejuni*) |
| Cholera | Bacterium (*Vibrio cholerae*) |
| Cryptosporidiosis | Protozoan (*Cryptosporidium parvum*) |
| Giardiasis | Protozoan (*Giardia lamblia*) |
| Hepatitis | Virus (hepatitis A) |
| Shigellosis | Bacterium (*Shigella* species) |
| Typhoid Fever | Bacterium (*Salmonella typhi*) |
| Viral Gastroenteritis | Viruses (Norwalk, rotavirus, and other types) |

## Cryptosporidiosis and Giardiasis

- ❑ Severe gastointestinal diseases:
  - diarrhea
  - vomiting
  - stomach cramps
  - possibly fever and flulike symptoms
- ❑ Do not respond to antibiotics
- ❑ Few effective treatments available
- ❑ Can be fatal to the elderly and the immuno-compromised (AIDS, chemotherapy patients, organ transplant patients)

Along with *E. coli* bacteria and waterborne viruses (such as poliovirus), these are considered the greatest threat to public health via drinking water.

Much greater health risk than chemical water pollution.

# Interim Enhanced Surface Water Treatment Rule (1998)

- Maximum contaminant level goal (MCLG) of zero for *Cryptosporidium*

- 2-log *Cryptosporidium* removal requirements for systems that filter

- Strengthened combined filter effluent turbidity performance standards

- Disinfection profiling and benchmarking provisions

- Systems using ground water under the direct influence of surface water now subject to the new rules dealing with *Crypdosporidium*

- Inclusion of *Cryptosporidium* in the watershed control requirements for unfiltered public water systems

- Requirements for covers on new finished water reservoirs

- Sanitary surveys, conducted by States, for all surface water systems regardless of size

## Long Term 1 Enhanced Surface Water Treatment Rule

The above only applies to systems serving 10,000 or more people. The Long Term 1 Enhanced Surface Water Treatment Rule, due in the fall of 2000, will strengthen microbial controls for small systems i.e., those systems serving fewer than 10,000 people.

## Significant Cryptosporidium Outbreaks

| Year | Location | Reported Cases | Reported Deaths |
|---|---|---|---|
| 1984 | Braun Station, Texas | 2,000 | |
| 1987 | Carrollton, Georgia | 13,000 | |
| 1989 | Thames River area, England | 100,000 | |
| 1992 | Jackson County, Oregon | 15,000 | |
| 1993 | Milwaukee, Wisconsin | 403,000 | 100 |
| 1994 | Las Vegas, Nevada | 78 | 16 |

## Parasite in Pool Infects 51 People at Summer Party

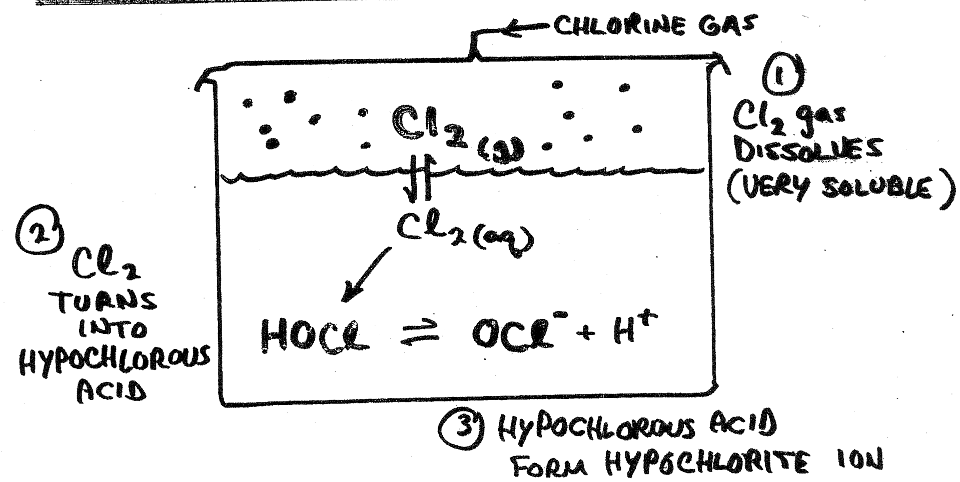
An outbreak of cryptosporidiosis in Sellwood continues to affect a number of children and adults

Friday, September 25 1998

By David Austin of the *Oregonian* staff

## CHLORINATION

Why?
- Removes objectionable compounds
- Disinfection (kills bacteria, viruses, protozoa, cysts)




$$Cl_{2(aq)} + H_2O \rightleftharpoons HOCl + Cl^- + H^+$$

HOCl: HYPOCHLOROUS ACID "ACTIVE"; $Cl^-$: CHLORIDE "INACTIVE"

HOCl forms by a **REDOX** RXN

**REDUCTION - OXIDATION**

REDUCTION: Compound **picks up** an electron ($e^-$)

OXIDATION: Compound **loses** an electron

OBVIOUSLY NEED A "REDOX PAIR" OF CMPDs.

- **One** gives its electron to the **other**
  - One ← **REDUCTANT**
  - other ← **OXIDANT**

Ex: Mix "Ox1" with "Red1"

$$\text{Ox1} + \text{Red1} \rightarrow \text{Red2} + \text{Ox2}$$

$\text{Red1} \rightarrow e^- + \text{Ox2}$ (Red1 gives up an $e^-$)

$\text{Ox1} + e^- \rightarrow \text{Red2}$ (Ox1 picks it up)

A real example:

$\frac{1}{2}Cl_2 + Fe^{2+} \rightarrow Cl^- + Fe^{3+}$ TOTAL RXN

$Fe^{2+} \rightarrow Fe^{3+} + e^-$

$\frac{1}{2}Cl_2 + e^- \rightarrow Cl^-$

} "HALF REACTIONS" (or "HALF CELLS")

# DISPROPORTIONATION

Sometimes a cmpd. gives an $e^-$ to itself...

$\frac{1}{2}Cl_2 + H_2O \rightarrow e^- + HOCl + H^+$

$\frac{1}{2}Cl_2 + e^- \rightarrow Cl^-$

Chlorine is a good oxidant, so it can "oxidize itself"

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

OXIDATION STATE → $Cl_2$: [0], HOCl: [+I], $Cl^-$: [-I]

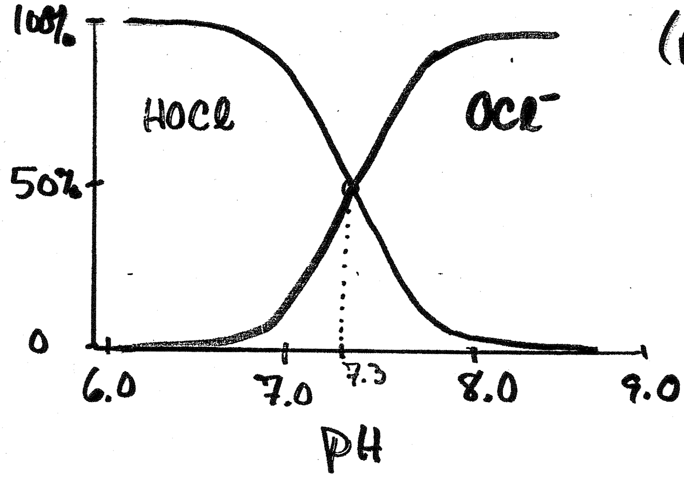
[0] → [+I], [-I]   $Cl_2$ "DISPROPORTIONATES"

So hypochlorous acid is even STRONGER OXIDANT than $Cl_2$ gas.

HOCl is a weak acid, so...

$$HOCl \rightleftharpoons H^+ + OCl^- \; ; \; \log K_a = -7.3$$

$(pK_a = +7.3)$




HOCl is a better disinfectant than $OCl^-$
So want to keep pH a bit low

**CAN ALSO BUY HYPOCHLORITE ITSELF**

- Sodium hypochlorite NaOCl (5% = BLEACH)
- Ca Hypochlorite $Ca(OCl)_2$

↑ DRY POWDER, GRANULES, TABLETS
"HTH" = high-test hypochlorite (70% active)

## FREE RESIDUAL vs. COMBINED CHLORINE

Free available residual chlorine:

$= [HOCl] + [OCl^-]$

COMBINED AVAIL. RESIDUAL chlorine:

Rxn with AMMONIA ($NH_3$)

$$HOCl + NH_3 \rightarrow H_2O + NH_2Cl$$
MONO-CHLORAMINE

$$HOCl + NH_2Cl \rightarrow H_2O + NHCl_2$$
DICHLORAMINE

$$HOCl + NHCl_2 \rightarrow H_2O + NCl_2$$
TRICHLORAMINE

**Chloramines are weaker disinfectants but more stable than HOCl/OCl⁻**

## If excess HOCl :

HOCl will oxidize chloramines to $N_2$ or other forms ($N_2O$, etc)

$$HOCl + 2NH_2Cl \rightarrow N_2 + 3Cl^- + 3H^+ + H_2O$$

↑ ONE ADDED ACTIVE Cl

↑ DESTROYS TWO ACTIVE Cl's

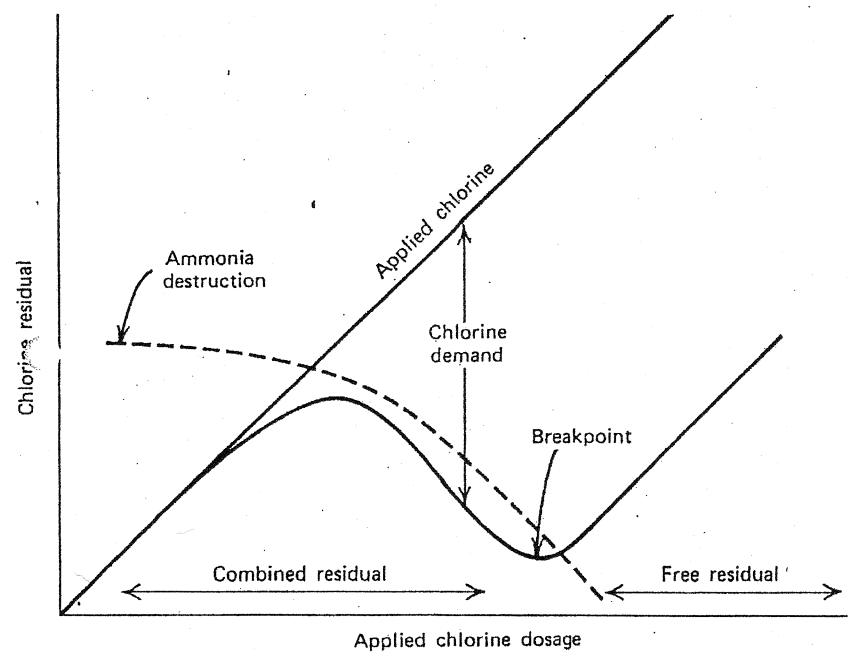
↑ ($N_2$) Nitrogen gas

⟹ Hence NET LOSS OF ONE Cl FOR EVERY x.s. Cl (HOCl) ADDED.
(Add 1, lose 2)

EVENTUALLY, NO CHLORAMINES LEFT

"BREAKPOINT"

## CHLORINE DEMAND CURVE

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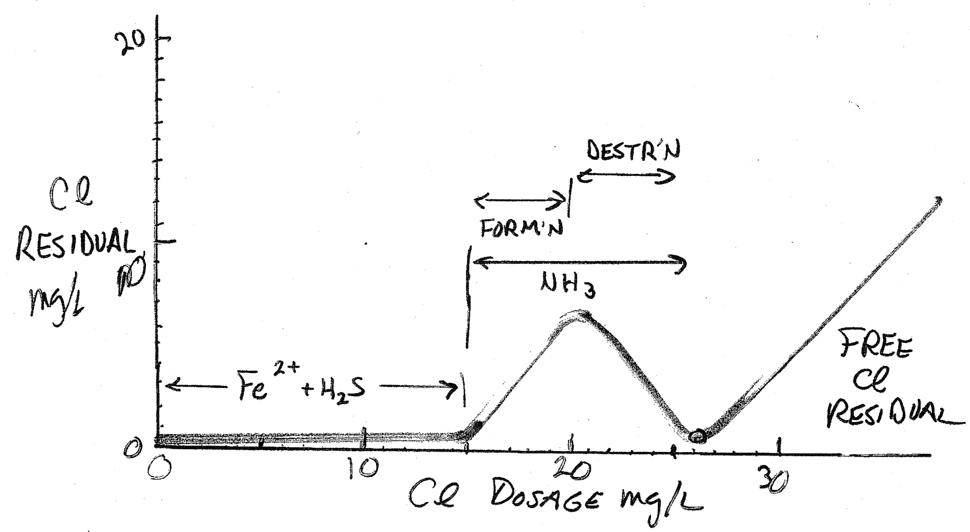
# CHLORINE DEMAND & BREAKPOINT CHLORINATION




WATER ANALYSIS:

$Fe^{II}_{TOTAL} = 0.05$ mmol/L

$H_2S_{TOTAL} = 0.10$ mmol/L (mM)

$NH_{3\,TOTAL} = 0.20$ mM

REACTIONS:

$HOCl + H^+ + 2e^- \rightarrow Cl^- + H_2O$

$Fe^{2+} \rightarrow Fe^{3+} + e^-$

$H_2S + 4H_2O \rightarrow SO_4^{2-} + 10H^+ + 8e^-$

SO 1 $Fe^{2+}$ CONSUMES ½ HOCl

1 $H_2S$ CONSUMES 4 HOCl

AND $NH_3$ CONSUMES HOCl TWICE

$HOCl + NH_3 \rightarrow H_2O + NH_2Cl$

$2NH_2Cl + HOCl \rightarrow N_2 + Cl^- + 3H^+ + H_2O$

OR $1\,NH_2Cl + \frac{1}{2}HOCl \rightarrow \ldots$

1st is 1:1 $NH_3$:HOCl

2nd is 2:1 "$NH_3$":HOCl

∴ EACH $NH_3$ CONSUMES

1 + ½ HOCl's = **1.5 HOCl**

SO:

| ANALYSIS | | | | HOCl CONSUMED |
|---|---|---|---|---|
| $Fe^{2+}$ | 0.05 mM | × | 0.5 = | 0.025 |
| $H_2S$ | 0.10 mM | × | 4.0 = | 0.40 |
| $NH_3$ | 0.20 mM | × | 1.5 = | 0.30 |

0.725 mM HOCl CONSUMED ⇒ "CHLORINE DEMAND"

0.725 mM × 35.5 mg-Cl/mM

= 25.7 mg/L as Cl

BREAKPOINT DOSE (THEORETICAL)