1. Waterborne and Water-Related Diseases - Role of Water Treatment and Sanitation, Syndromes

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MHP/CEE241
Tufts University School of Medicine
2007

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2. What do we mean by waterborne?

What do we mean by waterborne?

- “Waterborne” – infectious agent ingested
- “Water-washed, water-scarce” – person to person transmission because of lack of hygiene, e.g. trachoma
- “Water-based” – transmission via an intermediate host in water, e.g. schistosomiasis
- “Water-related insect vector” – insects that breed in or bite near water – malaria, yellow fever, sleeping sickness (African trypanosomiasis)
- Useful constructs; divisions may fall apart
3. Epidemic and Endemic Disease – some definitions

Epidemic and Endemic Disease – some definitions

- Endemic disease (Greek, *endemios, endemos; en, in, + demos, the people*) = The habitual presence or the usual prevalence of a disease or infectious agent within a geographic area, or the usual prevalence of a given disease within this area.
- Epidemic disease (*epidemios, epidemos; epi, upon, + demos, the people*): The occurrence in a community or region of a groups of illnesses of similar nature, *clearly in excess of normal expectancy*.

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4. Issues of Surveillance

How well do we understand the burden of waterborne diseases?...

Issues of Surveillance

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5. Why do we care about waterborne diseases?

Why do we care about waterborne diseases?
“Why do 10 Million Children die every year?”

- **UN Millennium Goal 4:** Reduce by two thirds the mortality rate among children under five
- **UN Millennium Goal 9:** Reduce by half the proportion of people without sustainable access to safe drinking water
- Pneumonia and diarrhea remain the leading causes of childhood death
- Sub-Saharan Africa, South Asia hotspots
- Malnutrition major factor
- Water: crops, safe drinking water, sanitation

6. Worldwide Distribution of Child Deaths

Worldwide Distribution of Child Deaths
(each dot represents 5000 deaths)

Image not available due to copyright restrictions.
7. Diarrhea and Pneumonia

**Diarrhea and Pneumonia**

- Acute Respiratory Infections (ARI) and Diarrheal Diseases (DD) are the two leading causes of death worldwide.
- ARI ~ 4.4 million deaths/y in children under 14y, most of these are pneumonias
- DD ~ 3.1 million deaths/y. 4 billion cases / year
- Diarrhea deaths are due to dehydration, malnutrition, or systemic invasion of the pathogens. Represent 62.5 million DALYs (4.3% total) (WHO, 2002)
- Malaria & TB important, just not the first two leading causes of death

8. Water and Hygiene

**Water and Hygiene**

Image not available due to copyright restrictions.
9. Water-related causes of child death

**Water-related causes of child death**

Image not available due to copyright restrictions.

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Where and why are 10 million children dying every year? R. Black, S. Morris.
*The Lancet*, Volume 361, Issue 9366, Pages 2224 - 2234

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10. Age-related Incidence of Diarrhea

**Age-related Incidence of Diarrhea**

<table>
<thead>
<tr>
<th>1988 Recall Survey of Diarrhea-Urban Coastal Ecuador</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE IN MONTHS</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>0 – 5</td>
</tr>
<tr>
<td>6 – 11</td>
</tr>
<tr>
<td>12 – 23</td>
</tr>
<tr>
<td>24 – 35</td>
</tr>
<tr>
<td>36 – 37</td>
</tr>
<tr>
<td>48 - 59</td>
</tr>
</tbody>
</table>

Source: UN Millennium Report 2005
13. UN Millennium Report 2005

UN Millennium Report 2005

“... a blunt reality: business as usual is taking the sector towards a potential non-achievement of the global MDG sanitation target.”

Figure 1: World population with and without access to an improved drinking water source in 1990, 2004 and 2015

Figure 2: World population with and without access to improved sanitation in 1990, 2004 and 2015

+ 450,000 per day sanitation
+ 300,000 per day drinking water
For the period 2005 - 2015

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14. “Person, Place, & Time”...

“Person, Place, & Time”...
Being at the Wrong Place at the Wrong Time

- Rotavirus
- Entero-toxigenic
  *Escherichia coli*
- Shigella
- *Campylobacter jejuni*
- *Vibrio cholerae* 01
- Salmonella
- Cryptosporidium

- *Giardia lamblia*
- *Entamoeba coli*
- *Isospora belli*
- > 100 enteroviruses
- Other *E. coli* (EA, EI, EH)
- Norwalk and other caliciviruses

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Behaviors – Higher Risk Diarrhea

- Lack of exclusive breast-feeding
- Lack of prolonged breast feeding
- Use of feeding bottles
- Storing cooked food at room temperature
- Using drinking water contaminated by feces
- Inability or failing to wash hands before eating, after defecation, after handling feces
- Failure of disposal of feces
- But this list is incomplete for Water Related Diseases...

Fetching Water

- Fetching water is related to water contact – Schistosomiasis, dracunculiasis, ingesting water with feces in it...
17. Pipe Filters

Guinea Worm / Pipe Filters

2-year-old girl filters to protect herself from contracting Guinea worm disease, a parasitic waterborne disease that breeds in stagnant pools of water (Wau, southern Sudan, March 2002). The Carter Center

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18. Overview

Overview

- Water Quantity Needs – the basics
- Historical data (some presented last week)
- More current information, including data from outbreaks
- A bit of immunology
- Syndromes, why we are seeing new diseases, and a few key diseases to review

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19. Water Needs (Quantity) and Water Risk

Water Needs (Quantity) and Water Risk

20. Drought

- Human Needs
- Crop Failures
- Death of cattle

Communities that are resilient in the face of disasters usually have diversified forms of livelihood... and water usually underlies all of them.

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(c) 2008, Jeffrey Griffiths, MD, MPH
21. Summary of requirement for water service level to promote health

Summary of requirement for water service level to promote health

<table>
<thead>
<tr>
<th>Service Level</th>
<th>Access Measure</th>
<th>Needs Met</th>
<th>Health Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>No access - &lt; 5 L/c/day</td>
<td>&gt; 1 km, 30 minutes</td>
<td>consumption not assured; hygiene not possible</td>
<td>very high</td>
</tr>
<tr>
<td>basic - often &lt; 20 L/c/day</td>
<td>100-1000 meters; 5-20 minutes</td>
<td>consumption should be assured; hand-washing &amp; basic food hygiene; laundry/bathing no</td>
<td>high</td>
</tr>
<tr>
<td>intermediate ~ 50 L/c/day</td>
<td>with 100m, 5 minutes, or by single tap</td>
<td>consumption, ditto basic personal and food hygiene, laundry/bathing</td>
<td>low</td>
</tr>
<tr>
<td>optimal &gt; 100 L/c/day</td>
<td>supplied by multiple taps</td>
<td>consumption &amp; hygiene - all needs met</td>
<td>very low</td>
</tr>
</tbody>
</table>

http://www.who.int/water_sanitation_health/diseases/wsh0302/en/

22. Minimal Water Needs

Minimal Water Needs

<table>
<thead>
<tr>
<th>Group</th>
<th>Daily fluid intake (IPCS, 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>1.2-4.4L, average 1.9 including breast milk (bm), 1.4 excluding bm; 2.8-3.4L @ 32 C; 3.7L with moderate activity</td>
</tr>
<tr>
<td>Adult male</td>
<td>2L (70 kg male)</td>
</tr>
<tr>
<td>Adult female</td>
<td>1.4L (64 kg female)</td>
</tr>
<tr>
<td>Child (10 years)</td>
<td>1L</td>
</tr>
</tbody>
</table>

23. **Sub-populations Needed Water**

**Sub-populations Needed Water**

- “Usual” loss = 4% adult, 15% young child — so demands much higher in children
- Pregnant women, lactating women
- Elderly may have decreased thirst sensation, decreased ability to concentrate urine (and hold onto water)
- Exercising

24. **Need Water....**

**Need Water....**

- For hydration
- For cooking
- For hygiene
- For washing clothes
- To carry away our feces
- For irrigation (decreases poverty)
- For industry (e.g. chip manufacture)
- For combating fires
- Lawns....
Historical Information...

US was once a developing country:
death from diarrhea was common
> 10% died before 1 year old
27. It was Cleanliness against Cholera and Yellow Fever

28. Water Tunnels
29. Typhoid rates in Chicago deaths per 10,000 persons

Typhoid rates in Chicago deaths per 10,000 persons

Image not available due to copyright restrictions.

30. ‘Multiple Barriers’ Concept

‘Multiple Barriers’ Concept

Source Waters can vary from pristine to diluted sewage

Watershed protection

Filtration

Disinfection

Distribution system integrity - no cross-connections to sewer

No Sewage in Water!

Consumption

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31. Overview of Waterborne and Water-Related Diseases: Slide 31...

Overall mortality and diarrhea mortality among children aged younger than 2 years Stockholm 1878-1925.

Image not available due to copyright restrictions.

32. Overview of Waterborne and Water-Related Diseases: Slide 32...

Diarrhea mortality rate in relation to daily average water consumption per person and cumulative number of new water pipe connections, Stockholm 1878-1925.

Image not available due to copyright restrictions.
33. Overview of Waterborne and Water-Related Diseases: Slide 33...

Diarrhea mortality rates among children aged younger than two.

Image not available due to copyright restrictions.

34. Overview of Waterborne and Water-Related Diseases: Slide 34...

Overall mortality rates among children aged younger than two years.

Image not available due to copyright restrictions.
35. Overview of Waterborne and Water-Related Diseases: Slide 35...


Image not available due to copyright restrictions.

36. Sanitation / Cholera

Sanitation / Cholera

1. Sanitation, combined with water provision, led to marked decreases in waterborne diseases especially once the majority of the population was serviced.

2. Cholera still occurs in epidemics when drought occurs and contaminated water is used – lots of secondary transmission.

Image not available due to copyright restrictions.
37. Things are better – 1870s on

**Things are better – 1870s on**

- Life expectancy has increased by 30+ years over the last 100 years.
- Water treatment, sewers, safe food - 2/3 of this increase. Some benefit from vaccines and antibiotics.
- New medicines, intensive care, etc - little or no impact on overall lifespan.

38. We developed guidelines

**We developed guidelines**

- Rule #1. Keep poop out of your drinking water.

- Rule #2. If you can’t keep poop out of your water, kill the bacteria in the water.

- **Rule #3. Never, ever stop killing the bacteria in the water.**
39. What did chlorination accomplish 1910-1925?

What did chlorination accomplish 1910-1925?

- Decreased US cholera by 90%
- Decreased US typhoid by 80%
- Decreased US leptospirosis by 80% (urine of infected rodents)
- Began chronic exposure to low levels of halogenated chemicals in DW

40. Nutrition/Cognition

A Couple of Other Benefits:
41. Water and Sanitation associated with improved child growth...

- 25,483 children aged 6-72 months, rural Sudan enrolled in an 18-month study of vitamin A in 1988
- In normally nourished children, the risk of stunting (HAZ < -2) was lowest in homes with both water and sanitation (RR = 0.79)
- In stunted children, those from homes with water and sanitation had a 17% greater chance of reversing stunting vs homes with neither.

Image not available due to copyright restrictions.

Water and Sanitation associated with improved child growth

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42. Effect of Water and Sanitation

Effect of Water and Sanitation

Image not available due to copyright restrictions.

Connell et al Effect of water and sanitation on childhood poor health in a Peruvian peri-urban community Lancet 363:112-118 2004

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43. Effects of Stunting, Diarrheal Disease, and Parasitic Infection...

Effects of Stunting, Diarrheal Disease, and Parasitic Infection

Image not available due to copyright restrictions.

44. Epidemics... what happens when water treatment lapses

Epidemics... what happens when water treatment lapses

- Rwandan refugees in Congo
- Walkerton (Ontario, Canada)
- Dushanbe, Tajikistan
- Milwaukee & Las Vegas (USA)
45. Morbidity, Rwandan Refugees, '94 (UNHCR)

Morbidity, Rwandan refugees, '94
(UNHCR)

Image not available due to copyright restrictions.

46. Walkerton

- E. coli found in town’s well water 5-7 times/yr
- Shallow wells, downhill from cattle farms
- Identified by consulting engineer as problem (78); ignored by regional gvt.
- Cycle of excess chlorine followed by use of less disinfectant when taste bad, and faked tests
- Rare inspections
- April 2000 – chlorinator breaks down
47. Walkerton Deaths and Illness

Walkerton Deaths and Illness

*E. coli* O157:H7, Campylobacter

- 7 deaths, 27 HUS, *65 hospitalized*
- 2,321 people sick
- 42% of the cases were unreported
- $155 million cost

Hemolytic-uremic syndrome: renal failure, bleeding

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48. Animal Manure to Human Disease

Animal Manure to Human Disease

- Probably recognized in ancient times
- First law passed in El Paso, Texas when settled: can’t water cattle in drinking water

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49. Contaminated Wells

Contaminated Wells

Wells in Walkerton are downhill from a farm – wells were contaminated during heavy rains.

Image not available due to copyright restrictions.

50. Socio-Economic Analysis of Walkerton

Socio-Economic Analysis of Walkerton

- Structural causes and rural, agroeconomic economy... upstream causes relate to the source of the outbreak, downstream ones permit the outbreak to occur
- Emergence of E. coli O157:H7 ecologically
- “Factory” farming in a poor town, promotion of feedlot feeding to consume excess grain, few resources, collapsing family farming,
- Reduced funding for public health in Canada – ‘voluntary compliance’ and ‘streamlining’...
- Rural health penalty: emerging diseases, pesticides and herbicides, lack of infrastructure... urban health penalty is air pollution, unemployment, violence, lack of housing....

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51. Overview of Waterborne and Water-Related Diseases: Slide 51...

<table>
<thead>
<tr>
<th>DOWNSTREAM</th>
<th>MESO LEVEL</th>
<th>UPSTREAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICRO LEVEL</td>
<td>Meso level</td>
<td>Macro level</td>
</tr>
<tr>
<td>ECOLOGICAL</td>
<td>Individual water</td>
<td>Regionalized factory farms</td>
</tr>
<tr>
<td>DIMENSION</td>
<td>well: extreme</td>
<td>setting</td>
</tr>
<tr>
<td>SOCIAL</td>
<td>Operator failure:</td>
<td>Public utilities: company:</td>
</tr>
<tr>
<td>DIMENSION</td>
<td>individual farmer</td>
<td>government agencies (municipal, public health, private labs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>International political economy (agribusiness)</td>
</tr>
</tbody>
</table>


52. Concentrated Animal Feedlot Operations (CAFO)

Concentrated Animal Feedlot Operations (CAFO)

Concentrated Animal Feedlot Operations are upstream of many cities that have to use the contaminated water, manure pathogens.

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53. Typhoid in Tajikistan

Typhoid in Tajikistan

FIGURE 1. Location of Tajikistan

Source: CDC

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54. Typhoid Fever

Typhoid Fever


Source: CDC

(c) 2008, Jeffrey Griffiths, MD, MPH
55. Case-control Dushanbe, Tajikistan

Case-control
Dushanbe, Tajikistan

- 43 cases and 123 age-matched neighborhood controls
- Drinking unboiled water: OR 9.6
- Drink from tap outside home 16.7
- Drinking boiled water significantly protective (OR = 0.2)

56. Overview of Waterborne and Water-Related Diseases: Slide 56...
57. Overview of Waterborne and Water-Related Diseases: Slide 57...

Countries by per capita GNP and by Non-Typhi Serotypes as a Percent of Total Salmonellosis

Non-Typhi serotypes as a % of total

Gross national product per capita (1975 dollars)

Source: CDC

58. Cryptosporidium

- Resistant to chlorination
- Present in 95% of surface waters (LeChevalier et al)

1993 Milwaukee outbreak:
- 403,000 people sick,
- > 100 deaths, mostly people with AIDS, children with cancer

Milwaukee Sentinel headlines, April/8/1993

Boil Water, mayor says...
Safety of drinking supply probed in wake of mystery epidemic
Bottled water buyers deluge stores...

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59. Geographic Pattern to Diarrhea

Geographic Pattern to Diarrhea

No pattern before outbreak. Clear gradient of increased diarrhea in south Milwaukee.

Source: Emerging Infectious Diseases, CDC.

Naumova et al 2005

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60. ‘Multiple Barriers’ Concept

‘Multiple Barriers’ Concept

Source Waters can vary from pristine to diluted sewage.

Watershed protection

Filtration

Disinfection

No Sewage in Water!

Distribution system integrity - no cross-connections to sewer

Consumption

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61. The epidemiological iceberg...

Cholera: one quarter of all cases easily detected with bacteriology.
Cryptosporidium: only one in 20,000 cases detected.

62. Las Vegas 1994

1992: 2 cases
1993: 23 cases
1994: 78 in 3 months

Chlorination system, and filtration, that are state-of-the-art and “the best in the USA.” No oocysts detected.
Range of syndromes I

- Acute dehydrating diarrhea (cholera), fever with abdominal symptoms (typhoid fever), acute blood diarrhea (dysentery), chronic diarrhea (opportunistic pathogens in people with HIV, recurrent infections)
- Hepatitis (A, E)
- Encephalitis e.g. Polio (enteroviruses)
- Non-intestinal syndromes... next slide...

Range of syndromes II

[Water as environmental reservoir for]:

- Schistosomes (S. mansoni, japonicum, haematobium; ‘bird’ schisto or cercarial dermatitits) – broad range of symptoms
- Guinea Worm (Dracunculus medinensis) – painful eruptions and infection
- Parasitic and invasive amoebae (diarrhea to hepatitis to systemic syndromes)
A review of immunology and a few words on clinical syndromes...

The Gut Surface

The gut surface is vast and flat, the surface upon which bacterial pathogens play...

- Serves as a barrier to macromolecules, microorganisms, and toxins in the lumen of the gut.
- Enteric pathogens express surface adhesions, enzymes, and other specialized mechanisms to assist in colonization and invasion of the mucosa.
Lumen

- Lumen of the gut is heavily populated with cells of the immune system. The intestine is the largest immunological organ in the body in terms of lymphoid cells and antibody production.
- Secretory IgA is the major antibody produced at this site.
- Antigens in the lumen are separated from the immunologically competent cells by the mucosa, and thus must be transported across the mucosa - thought to be via the M cells, specialized cells found over the organized mucosal lymphoid tissues.
Idiot’s Guide to Pathogens

• Develop antibody to a virus – it resolves, cannot be infected again (HIV exceptional)
• Bacteria: develop antibody and cell-mediated responses, repeated infection
• Protozoans: develop all forms of immunity, they don’t care very much
• Helminths, amoebas, etc – you’re toast

MALT: the Mucosa-associated Lymphoid Tissues

• Antigen sampling and generation of lymphocytes, including specific IgA effector B cells, memory B cells, and T cells
• Active lymphocyte proliferation and continuous cellular trafficking; cytokine production; generation of killer T cells
• Exist both in organized form (Peyer’s patches) and diffuse form
71. M Cell Internal Topology

M Cell Internal Topology

72. Some pathogens get inside...Shigella

Some pathogens get inside...Shigella
73. Some pathogens get inside....Shigella

Some pathogens get inside....Shigella

74. Shigella zooming around inside of cell by polymerizing actin...

Shigella zooming around inside of cell by polymerizing actin

Source: Emerging Infectious Diseases, CDC

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75. Syndromes and a Few Specific Diseases

76. The Big Picture...

The Big Picture...

1960s – 7 to 10 million deaths a year from diarrhea
Most deaths from acute watery dehydrating diarrhea

Oral Rehydration Therapy developed
Pennies per packet of ORS

2005 – 2 million deaths a year from diarrhea
Most deaths from invasive or persistent diarrhea

Invasive diarrhea requires $$$
Diagnosis, Treatment with Abx...

Persistent requires nutritional support, Abx's...

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What is dehydration? How is it classified?

- ‘Reduction of water content’
- NIH, 2002: mild = 3-5% loss; moderate 6-10%, severe (medical emergency) = 9-15%.
- Mild dehydration – reverse with ingestion
- Severe – may require iv RX to reverse shock, address salt loss in all but mild disease

Cholera

- Causative organism = *Vibrio cholerae* serogroup O1 or O139 makes cholera toxin
- Up to 50% mortality (case fatality rate) in epidemics if untreated; ~ 1/1000 if hydrated
- Natural reservoir = warm brackish coastal waters
- 2,728 deaths in 184,311 cases reported 01; CFR 1.48% (was 3.8% in 2000)
Cholera: In the New World, and a New Serotype

1991: classic cholera explodes in a new epidemic in South America, with Peru as the center of the epidemic. Cholera had been eradicated from Latin America, and the only remaining focus in the hemisphere had been Louisiana. Spreads to most of South and Central America. Now endemic.

Thought to have been introduced by ships emptying their water ballast tanks, allowing *V. cholerae* bacteria (an halophile) to enter the food supply (seafood).

New serotype (O139) arises in South and Southeast Asia, causing new epidemics in groups immune to the old serotype.

Points: **global transfer** and **microbial adaptation**

Cholera continues to plague communities around the world where clean drinking water is in short supply.

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81. **Cholera Cot**

Cholera Cot

- Cholera cot has space for buttocks – bucket underneath
- Allows measurement of fluid losses
- Knowing losses, then fluid replacement can be matched to the losses, preventing dehydration

Source: CDC

MPH 2-41 Tufts University

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82. **Extreme Dehydration from Cholera**

Extreme Dehydration from Cholera

Source: http://phil.cdc.gov/phil

MPH 2-41 Tufts University

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Cholera in Chad (WHO website)

1 September 2004:
A total of 2,046 cases and 98 deaths (case fatality rate, 4.8%) have been reported from 14 June to 22 August 2004 in Western Chad, some distance from the refugee camps in the east of the country. The outbreak started in Massaguet (Hadjar Lamine) North of N'Djamena, from there it spread to Lok and Kanem provinces as well as to the capital city N'Djamena. The previous week a total of 453 new cases occurred in N'Djamena.

No cases have been reported from the Eastern part of Chad where the refugees from Darfur are gathering, though they are seen to be at high risk. They have only limited access to water and proper sanitation is scarce, with the rainy season ongoing.

In N'Djamena, the city council together with the Ministry of Health and other partners are working to improve sanitation and access to safe water.

Cholera in Chad update (WHO website)

27 September 2004:
A total of 3910 cases and 164 deaths (case fatality rate, 4.2%) have been reported from 14 June to 19 August 2004. The outbreak is declining in the western part of the country except for Bousso where there are new outbreaks. The outbreak started in Massaguet (Hadjar Lamine) north of N'Djamena, the capital city, and from there it spread to Lok and Kanem provinces as well as to N'Djamena. Cases have now been reported in Mongo and Aïr, two areas between N'Djamena and Abeché.

A team from the Global Task Force on Cholera Control composed of a public health specialist and 3 sanitation engineers will work with the Ministry of Health in assessing and supporting preparedness activities, which are being organized by international aid agencies and nongovernmental organizations in eastern Chad, in the areas where refugees from Darfur are present.
85. Cholera in Iraq (WHO website)

**Cholera in Iraq (WHO website)**

**14 September 2007:**
Between 23 August and 10 September 2007, the cumulative number of cases of acute watery diarrhoea reported from Sulaymaniya province stands at 6,142 including 9 deaths (case fatality rate, CFR: 0.14%). Of these reported cases, *Vibrio cholerae* has been laboratory confirmed in 392 stool specimens.

From 29 July to 12 September 2007, the health authorities of Kirkuk province reported a total of 6,749 cases of acute diarrhoeal disease including 1 death (CFR: 0.01%). The first index case of cholera, confirmed by laboratory test, was reported on 14 August 2007. The outbreak continues to spread into Erbil province, where, between 1 and 10 September 2007, 11,641 cases of diarrhoeal disease with no deaths were reported. Among samples tested, 33 were identified as positive for *V. cholerae*.

Until now, there is no confirmed information that cholera has spread to other parts of Iraq. A stool sample collected from a suspect case in Baghdad has tested negative for *V. cholerae*. Another suspect case detected in Mosul is currently being investigated.

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86. Invasive Diarrhea = Dysentery = Diarrhea containing blood

**Invasive Diarrhea = Dysentery = Diarrhea containing blood**

- Major causes: Shigella, Campylobacter, Salmonella. *Shigella dysenteriae* 1 is only cause of epidemic dysentery. 5-15% fatal
- Can cause both diarrhea as well as bleeding & hemorrhage; bacteria can then spread throughout the body
- Oddly, these organisms, especially Shebelle, have a much lower infectious dose than cholera

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87. Invasion of the Colon

Invasion of the Colon

Source: Slice of Life and Suzanne S. Stensaa. Restricted use.

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88. Death of the Colon due to Dysentery

Death of the Colon due to Dysentery

Source: http://phil.cdc.gov/phil

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89. Increasing Antibiotic Resistance

Increasing Antibiotic Resistance

![Graph showing increasing antibiotic resistance](image)

Source: CDC

89

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90. Pathogens

Pathogens

Table 1. Pathogens with a steadily increasing prevalence of acquired antibiotic resistance in developing tropical countries

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Drug(s)</th>
<th>Country (years)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Shigella flexneri</em></td>
<td>ampicillin, tetracycline, sulfonamides</td>
<td>Bangladesh (1983-1990)</td>
<td>(6)</td>
</tr>
<tr>
<td><em>S. dysenteriae</em></td>
<td>(alone or with trimethoprim)</td>
<td>Brazil (1988-1993)</td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td>ceftiraxone, nalidixic acid, ampicillin</td>
<td>Guinea-Bissau (1987-1989)</td>
<td>(9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Salmonella typhi</em></td>
<td>nalidixic acid, chloramphenicol, ceftriaxone</td>
<td>Bangladesh (1989-1995)</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Address for correspondence: Robert Edelman, Center for Vaccine Development, 615 West Baltimore St., Room 480, Baltimore, MD 21201, USA; fax: 410-706-6295; e-mail: edelman@umaryland.edu.

Emerging Infectious Diseases Source: CDC

Vol. 5, No. 1, January-February 1999

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Persistent Diarrhea

By definition, diarrhea > 14 days
...unusually resistant bacteria...
...malnutrition...
...protozoa...

Hospital del Nino ‘Francisco Icaza’ with Persist...
93. E. Bieneusi and E. Intestinalis sporesi

94. Why new waterborne disease agents?

Why new waterborne disease agents?

- Aging (changing) population
- More immunosuppression
- Changing water treatment
- More exposure to animals (zoonoses)
- Evolution of new pathogens
- Exposure to old/new pathogens
95. Demographics – Population Density and Aging

Demographics – Population Density and Aging

- **1900**: 76 million in the USA
- **2000**: 275 million (US Census)
- **1800**: 98% of the world rural
- **2000**: 75% of US is urban (crowding)
- **2000**: 6.1 billion people in the world
- **2050**: 8 to 12 billion people

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96. Overview of Waterborne and Water-Related Diseases: Slide 96...
99. 2000 Superimposed on 2050

![Graph showing population distribution between 2000 and 2050]

Source: U.S. Census Bureau, International Database.

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100. Modern View of Risk

![Diagram illustrating modern view of risk with risk levels over age]

Source: J. Griffiths.

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Ill people are living longer

A few important waterborne diseases to know about:

- Salmonella
- Rotavirus
- Polio
- Hepatitis A
- Cryptosporidium
- *Entamoeba histolytica* (amoebas!)
- *Giardia*
- Schistosomiasis
103. Salmonella Infections

Salmonella Infections

- Salmonella bacteria cause 5 major syndromes:
  - Gastroenteritis (75%)
  - Bacteremia (10%)
  - Localized infection (≤5%)
  - Chronic asymptomatic carrier state (0.2-0.6% nontyphoidal strains, 1-3% of typhoidal strains)
  - Enteric fever, or typhoid

- At least 1700 serotypes are known to cause disease in humans
- Salmonella bacteria display somatic O antigens and flagellar H antigens; an additional somatic virulence antigen, Vi, is found on some strains especially S. typhi.
- Widespread throughout the animal world, infecting whales, ticks, lizards, birds, eggs.

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104. Overview of Waterborne and Water-Related Diseases: Slide 104...

Typhoid Fever

- Differs from non-typhoidal salmonellosis being a systemic disease and not primarily an intestinal illness
- Characterized by hectic fevers, delirium, persistent bacteremia, abdominal pain, splenic enlargement, and perforation and hemorrhage from the gut, leading to anemia and death
- Only adapted to the human host

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105. Overview of Waterborne and Water-Related Diseases: Slide 105...

![Graph showing countries by per capita GNP and by Non-Typhi Serotypes as a Percent of Total Salmonellosis.](source:CDC)

106. Overview of Waterborne and Water-Related Diseases: Slide 106...

**Ty-21a, Live Oral Typhoid Vaccine**

- Produced by chemical mutagenesis of a pathogenic *S. typhi* strain during the early 1970s. It is unclear what mutations account for this stable attenuation.

- Controlled field trials (1982-1991) emphasize that formulation, number of doses given, and spacing of the doses markedly effects the level of protection.

- Egypt: 30,000 schoolchildren aged 6-7; 1 gram bicarbonate followed by a liquid dose of vaccine (M, W, F one week) - 96% protection over the following 3 years (Wahdan et al, 1982)
107. Overview of Waterborne and Water-Related Diseases: Slide 107...

*Ty21a Vaccine....*

- Chile: lyophilized bacteria in enteric coated, acid resistant capsules; 3 doses gave 67% protection over 3 years.
- Ferreccio et al (1989) show that 4 doses gives much more protection than either 2 or 3 doses. Liquid vaccine proven superior in trials in Indonesia and Chile (Simanjuntak et al 1991, Levine et al 1990).
- Current US vaccine is 4 doses of lyophilized bacteria in enteric capsules. Duration of efficacy is quoted as 7 years. A new liquid formulation should be available soon.

108. Overview of Waterborne and Water-Related Diseases: Slide 108...

*Purified Vi Polysaccharide Parenteral Vaccine*

- Vi is a polysaccharide capsule antigen on *S. typhi* and is a virulence factor.
- 25 micrograms of purified Vi conferred ~ 65% protection against typhoid fever for at least 2 years in trials in Nepal and South Africa (Acharya et al 1987, Klugman et al 1987).
- Safe in school age children and adults, moderate protection after a single dose and does not require a cold chain.
109. **Rotavirus: Diarrheal Pathogen**

Rotavirus: Diarrheal Pathogen

- 130 million infants and children infected per year
- 18 million cases of moderate to severe disease
- > 870,000 deaths
- USA: 3 million, 50-100,000 hospitalizations, 20-100 deaths

Source: CDC

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110. **Rotavirus: Washington DC**

Rotavirus: Washington DC

![Graph showing number of rotavirus cases](source)

Source: MMWR CDC

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Rotavirus, cont’d.

- Most important cause of severe diarrhea in children under the age of 2
- 4 serotypes with partial cross-immunity
- First infection usually the most severe
- 2 recently licensed vaccines

Global Distribution of Deaths from Rotavirus

[Map showing the global distribution of deaths from rotavirus]

Source: CDC

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113.

Polio

- Leading cause of a limp worldwide.
- Causes diarrhea in young children, paralysis in adults.

Source: CDC

114.

Poliovirus

- Enterovirus, Picornaviridae, small RNA viruses, 3 serotypes, minimal cross immunity
- Primary replication in pharynx, GI tract
- Blood spread to central nervous system
- Destroys motor neurons in spinal cord
- 95% inapparent; ~ 1:200 paralytic; 4-8% nonspecific illness; asymptomatic meningitis in 1-2%

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Polio Outbreaks: How to Stop Them

- Remove the source of the pathogen: Polio is an enteric virus of children, so keep drinking water supplies and sewage well separated.
- Block transmission: Quarantine cases of polio, and boil water used for cooking to denature the virus.
- Eliminate susceptibility: Vaccinate everyone.
- There is now no endemic polio in the Western Hemisphere.

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Wild Poliovirus*, 12 Aug 2002 to 11 Aug 2003

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117. Wild Poliovirus, 2003

**NIGERIA**

Wild Poliovirus, 2003

1 new virus reported to HQ since last week.

- Nb of type 1: 39
- Nb of type 3: 52
- Nb of type 1&3: 1 under investigation
- Nb of infected districts: 53
- Pending lab result
- Primary isolation: 138
- ITD result: 11

Data in WHO HQ as of 12 Aug 2003

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118. Wild Poliovirus, 2006-2007

**Wild Poliovirus, 2006-2007**

**New infections:**
- Saudi Arabia
- Indonesia
- Ghana
- Benin
- Togo
- Guinea
- Botswana
- Sudan
- Ivory Coast
- Yemen
- Ethiopia
- Angola
- Mali
- Cameroon
- Chad
- Eritrea

Data in WHO HQ as of 06 Feb 2007

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119. Wild Poliovirus, 2003

Wild Poliovirus, 2003

INDIA

4 new viruses and 1 new district reported to HQ since last week.

Nb of type 1: 89
Nb of type 3: 10
Nb of infected districts: 55

New districts:

Wild virus monthly distribution

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120. Wild Poliovirus, 2003

Wild Poliovirus, 2003

Egypt

No new wild virus.
No new environmental virus.

Nb of type 1: 1
Nb of type 3: 0
Nb of infected districts: 1
Nb of environ. type 1: 5

Pending lab result:
primary isolation: 36
ITD result: 1

Wild virus monthly distribution 2001 - 03

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121. Overview of Waterborne and Water-Related Diseases: Slide 121...

Hepatitis A Virus

Source: http://phil.cdc.gov/phil

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122. Geographic Distribution of Hepatitis A Virus Infection

Geographic Distribution of Hepatitis A Virus Infection

Source: CDC

(c) 2008, Jeffrey Griffiths, MD, MPH
123. Overview of Waterborne and Water-Related Diseases: Slide 123...

**Concentration of Hepatitis A Virus in Various Body Fluids**

<table>
<thead>
<tr>
<th>Body Fluids</th>
<th>Infectious Doses per mL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^0$</td>
</tr>
<tr>
<td></td>
<td>$10^2$</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
</tr>
<tr>
<td></td>
<td>$10^{10}$</td>
</tr>
</tbody>
</table>


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124. Overview of Waterborne and Water-Related Diseases: Slide 124...

**Hepatitis A – Clinical Features**

- Jaundice by age group:
  - <6 yrs: <10%
  - 6-14 yrs: 40%-50%
  - >14 yrs: 70%-80%
- Rare complications:
  - Fulminant hepatitis
  - Cholestatic hepatitis
  - Relapsing hepatitis
- Incubation period:
  - Average 30 days
  - Range 15-50 days
- Chronic sequelae:
  - None

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### Global Patterns of Hepatitis A Virus Transmission

<table>
<thead>
<tr>
<th>Endemicity</th>
<th>Disease Rate</th>
<th>Peak Age of Infection</th>
<th>Transmission Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low to high</td>
<td>Early childhood</td>
<td>Person to person; outbreaks uncommon</td>
</tr>
<tr>
<td>Moderate</td>
<td>High</td>
<td>Late childhood/young adults</td>
<td>Person to person; food and waterborne outbreaks</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Young adults</td>
<td>Person to person; food and waterborne outbreaks</td>
</tr>
<tr>
<td>Very low</td>
<td>Very low</td>
<td>Adults</td>
<td>Travelers; outbreaks uncommon</td>
</tr>
</tbody>
</table>

**1987-97 average incidence**

**2002 incidence**

Source: CDC

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Hepatitis E Virus

Source: CDC

(c) 2008, Jeffrey Griffiths, MD, MPH

Hepatitis E in Chad, Update 3

15 September 2004:
Between 26 June and 12 September a total of 1292 cases and 42 deaths (case fatality rate 3.3%) of suspected hepatitis E cases have been reported from refugee camps Goz Amer, Goz Abal and neighbouring villages. The overall weekly number of reported cases is gradually decreasing.
A preliminary assessment of the water and sanitation situation in Goz Amer conducted by the WHO investigation team has shown that the location of water points and latrines in the camp does not ensure water safety and that current methods for water chlorination are not effective.
Urgent control measures recommended include the systematic chlorination of all water points in the camp, increasing soap distribution, and social mobilization and health education activities to improve the community's awareness of the disease and understanding of control measures.
Further epidemiological studies are currently being conducted to identify potential sources of infection.
129. Hepatitis E – Clinical Features

Hepatitis E – Clinical Features

- **Incubation period:** Average 40 days
  Range 15-60 days
- **Case-fatality rate:** Overall, 1%-3%
  Pregnant women, 15%-25%
- **Illness severity:** Increased with age
- **Chronic sequelae:** None identified

130. Geographic Distribution of Hepatitis E

Geographic Distribution of Hepatitis E

![World map showing the geographic distribution of Hepatitis E](source:www3.niaid.nih.gov)
Hepatitis E Virus Sequences in Swine Related to Sequences in Humans, the Netherlands

van der Poel WM et al. EID 7 2001 970-976

- HEV strains from swine in the Netherlands were clustered in at least two groups, together with European and American isolates from swine and humans. HEV in swine in the Netherlands are genetically closely related to HEV isolates from humans.

Hepatitis E Virus Epidemiology in Industrialized Countries...

20/46 sewage samples Barcelona were HepE (+).

Others:
1/5 Washington DC
1/4 Nancy, France
Xenozoonosis

"HEV has been detected in sewage in Spain (23). The discovery of HEV in swine in the Netherlands suggests that humans may become infected by contact with sewage of animal origin or even through contact with surface waters."

"In addition to the public health concern about zoonosis, there is also the concern for xenozoonosis, the inadvertent transmission of pathogens from animal organs to human recipients. Nonpathogenic pig HEV strains may become pathogenic for humans after xenotransplantation, as a result of species jumping, recombination, or adaptation in immunocompromised xenotransplantation recipients (25)."

(quoted from van der Poel et al 2001)

Cryptosporidium

(more later)
135. **Entamoeba histolytica**

![Diagram of Entamoeba histolytica](image1)

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136. **Giardia**

![Diagram of Giardia](image2)

(Remember stunting?)

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137. Schistosomiasis

Schistosomiasis

138. Schistosomiasis-Endemic Area

Schistosomiasis-Endemic Area
139. Schistosomiasis

**Schistosomiasis**

- > 200 million infected, 600 million at risk
- *S. haematobium*, *intercalatum*, *japonicum*, *mansoni*, *mekongi*.
- 85% now in sub-Saharan Africa
- 11,000 deaths per year, 1.7 million DALYs
- **CHRONIC morbidity** – growth stunting, cognitive impairment, hepatic fibrosis, urinary obstruction and cancer
- Play, fishing, washing, agricultural work, other water supplies...

140. Anning River Valley

**Anning River Valley**

*Berkeley School of Public Health: Anning River Valley 20 villages surveyed*

- 10 – 60% Prevalence
- Possible Interventions:
  - Focal molluscicide spraying
  - Medical Rx
  - Drug prophylaxis
  - Environmental modification
  - Cercariaid control
  - Waste treatment

*Image not available due to my copyright restrictions.*
141. Dry Months

Dry Months


Image not available due to my copyright restrictions.

142. Population Density

Population Density


Image not available due to my copyright restrictions.
143. Seasonality and Temporality

Seasonality and Temporality

- Climate determines the range of pathogens, weather determines the exposures
- Example: freezing in north kills pathogens, lack of same means year-round transmission in warmer climates
- Increasingly, specific diseases being related to time and space...

144. Seasonal Characteristics of Ambient Temperature

Seasonal Characteristics

Fig. 3. Seasonal characteristics of ambient temperature. (a) Ten years of data superimposed in one scatter plot overlaid with a fitted cosine curve to denote the systematic seasonal pattern.

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Back to Square One...

What is the value of simple hygiene?

* e.g., having enough water to clean yourself, and soap?

**Interpretation:** Handwashing with soap prevents the two clinical syndromes that cause the largest number of childhood deaths globally—namely, diarrhoea and acute lower respiratory infections. Handwashing with daily bathing also prevents impetigo.

Images not available due to copyright restrictions.

Conclusions:

- Water is a *vector* for transmission
- Keeping poop (pathogens) out of water keeps people from getting the pathogens
- Treating water kills pathogens
- Water is critical for decreasing the incidence of diseases *other* than just diarrhea (trachoma, pneumonia...)
- We need water for crops and livelihoods
- We need water for industry