11.479J / 1.851J Water and Sanitation Infrastructure in Developing Countries
Spring 2007

The Role of Water Quantity, Quality, Hygiene and Sanitation in Water-Related Disease Prevention in Developing Countries

and Some Major Water-Related Diseases

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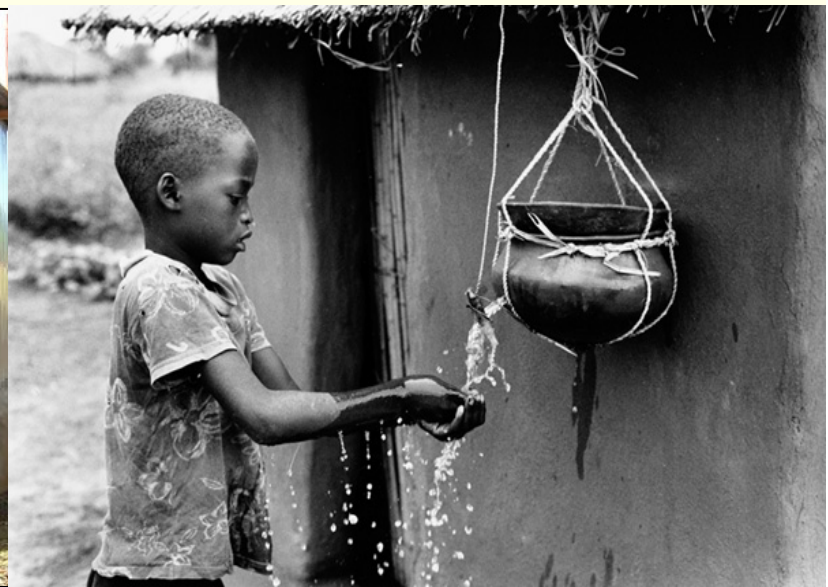
Week 4 - MIT 11.479 J / 1.851J

February 27, 2007



Outline

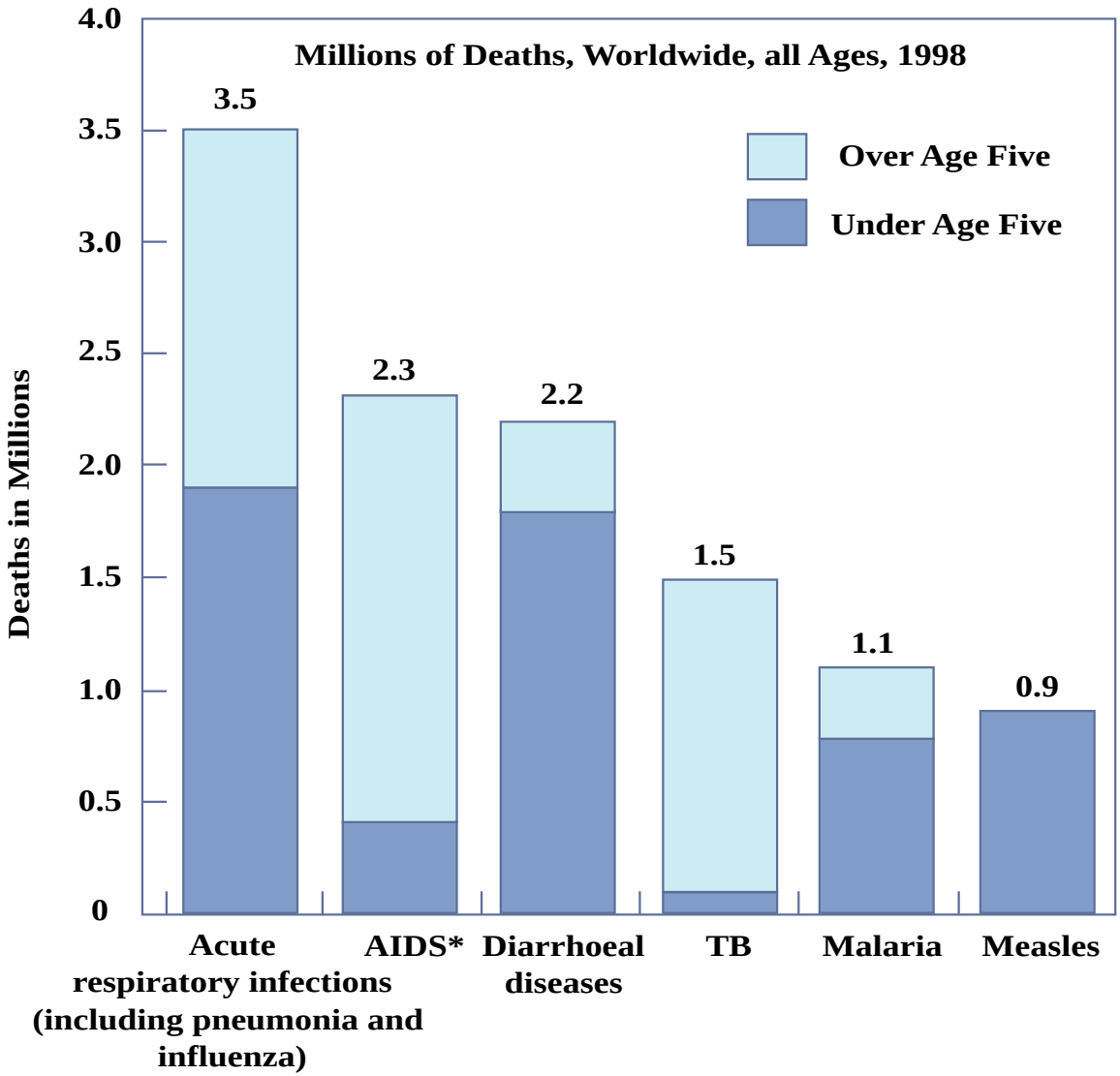
- Global Statistics – Water-Related Diseases
- Examples of Water-borne, Water-washed, Water Contact, Insect Vector Diseases
- Relationship of Water Quantity/Accessibility, Quality, Hygiene, Sanitation (Esrey 1985), (Fewtrell & Colford, 2004)
- Appendix A: Water-Related Diseases – Terms and Definitions
- Appendix B: Further examples of Water-Related Diseases

Water-Related Diseases

Water-related diseases are estimated to claim 3-7 million lives each year. This includes water-borne, water-washed, water contact diseases, as well as water (insect) vector diseases - i.e. those associated with water habitat (e.g. malaria, dengue) and thus with water resources & habitat management.

(WHO, 2004)

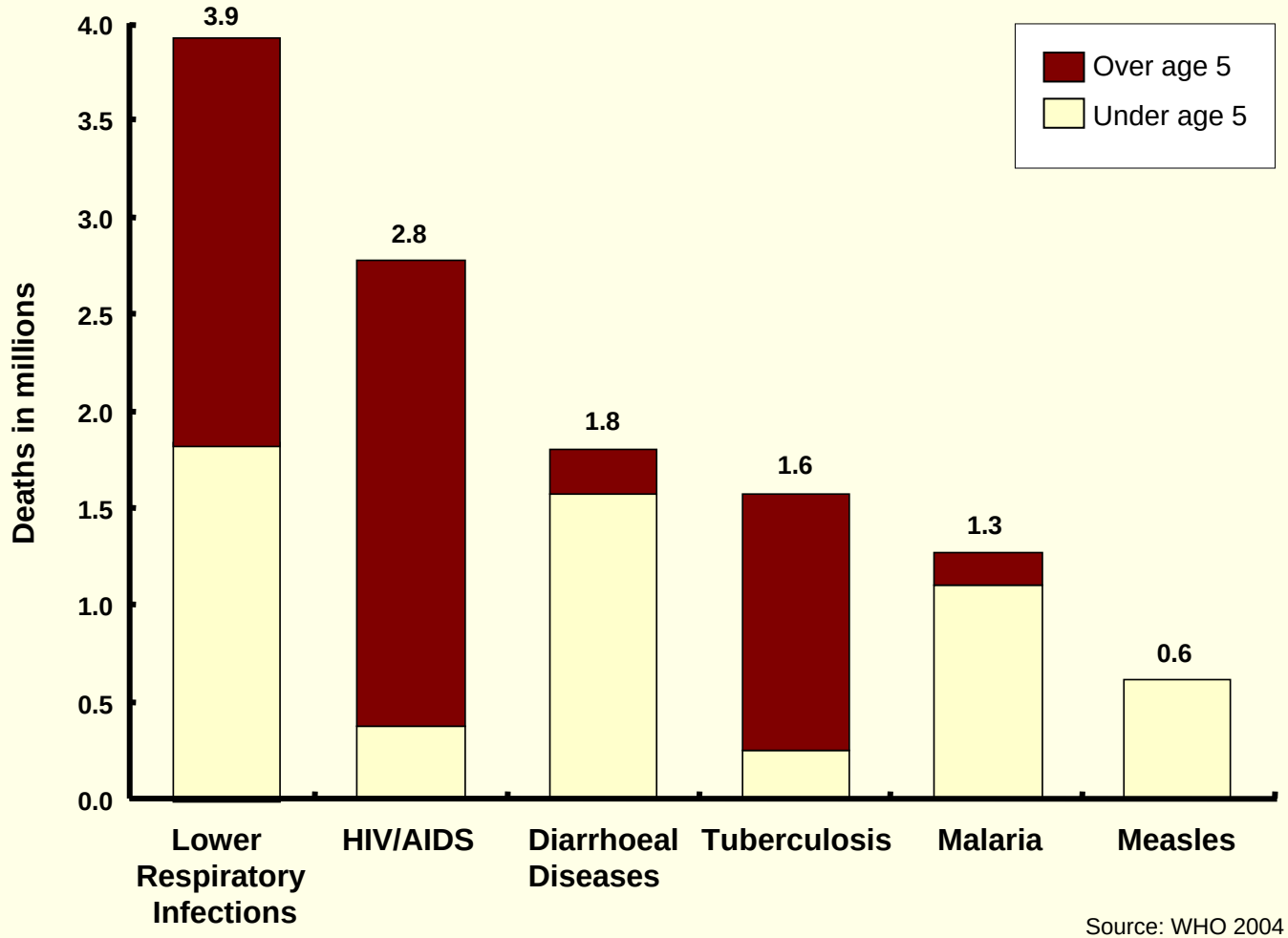
Leading Infectious Killers



(WHO, 1999)

Figure by MIT OpenCourseWare.

Leading Infectious Killers - 2002



Source: WHO 2004

Global Burden of Disease Showing % of Environmental Contribution by Disease (*Reported as "Disability Adjusted Life Years" (DALYs)*

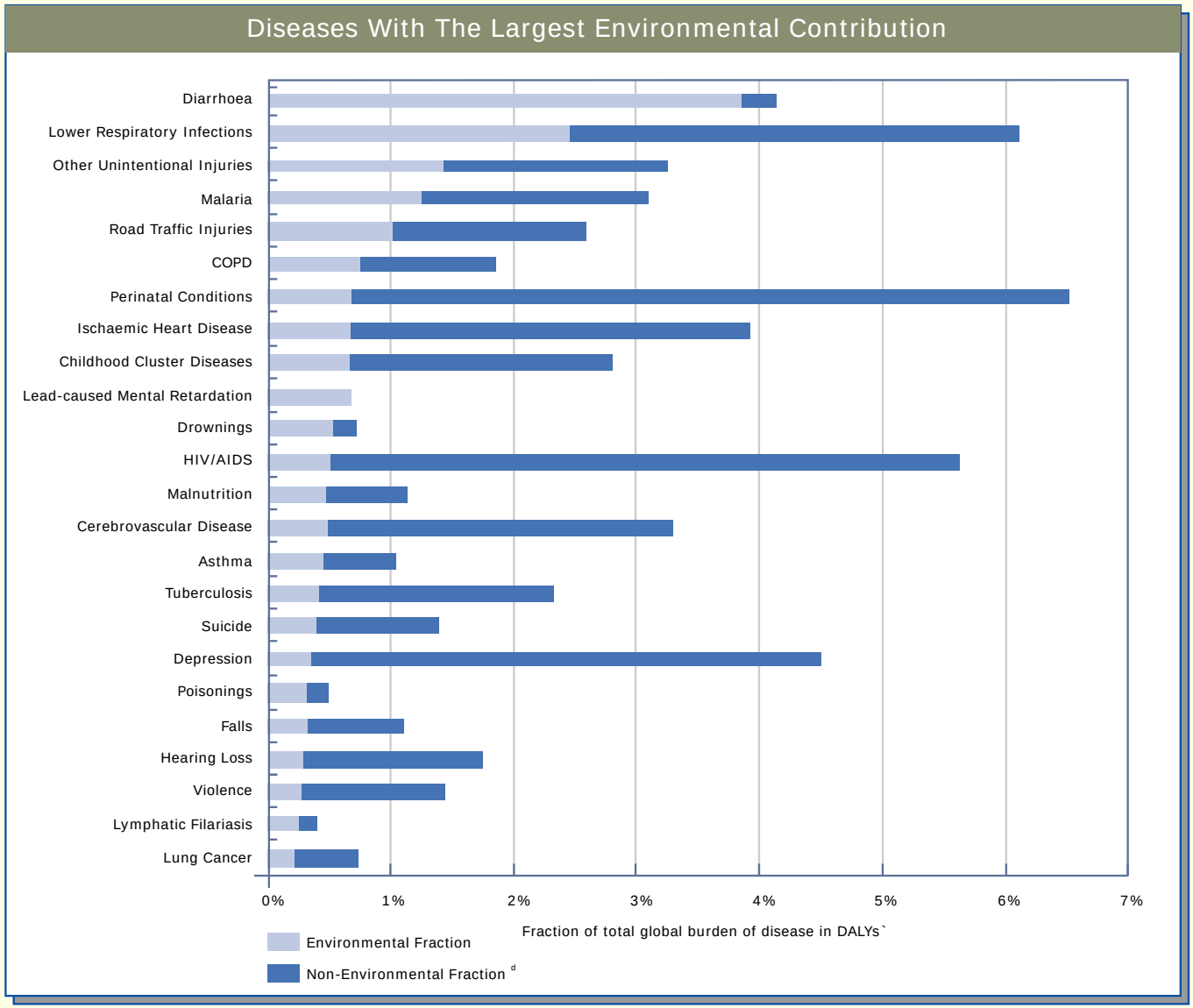
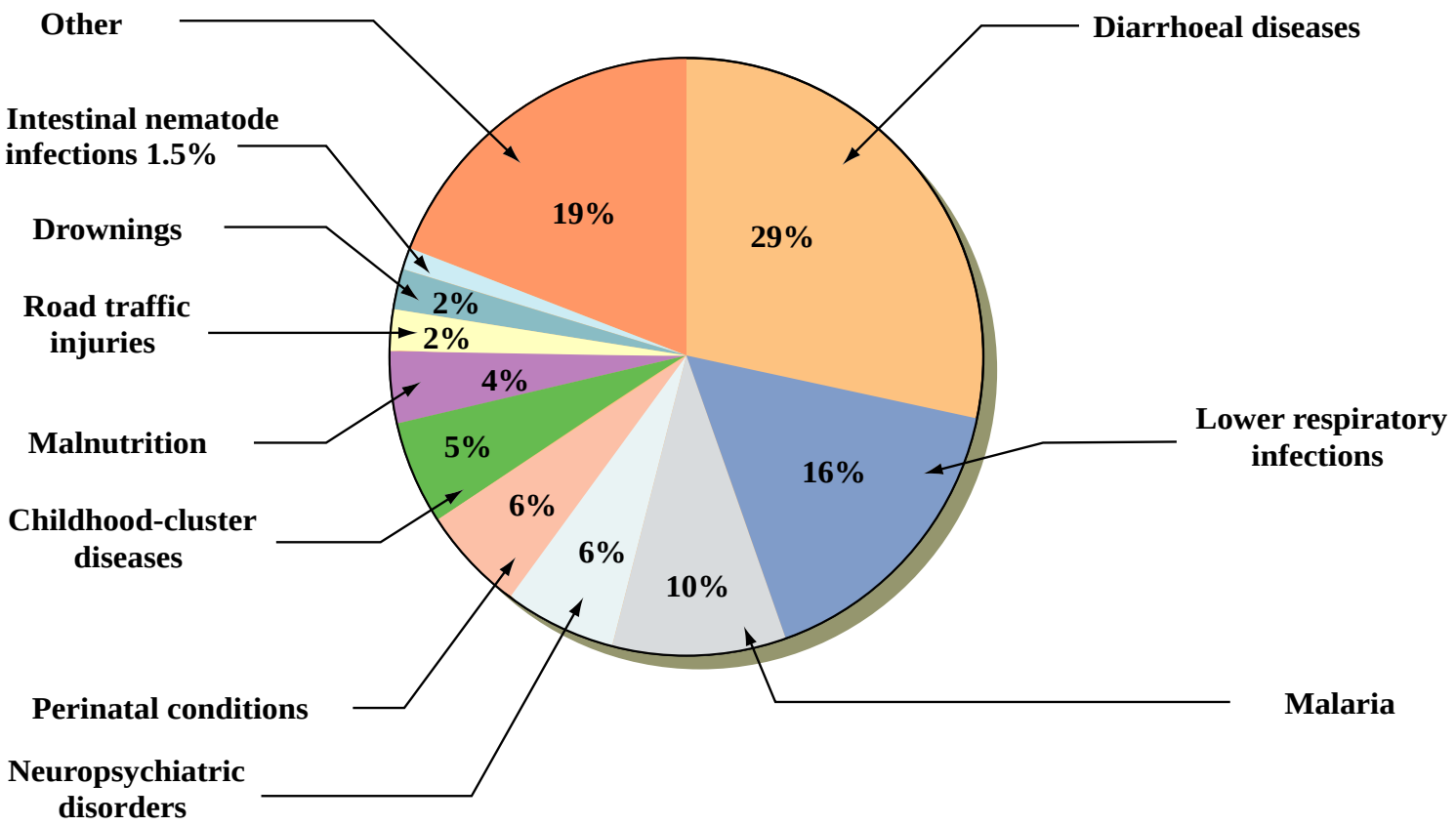


Figure by MIT OpenCourseWare.

(WHO, 2006)

Main Diseases Contributing to the Environmental Burden of Disease, Among Children 0-14 years



a. The environmental disease burden is measured in disability-adjusted life years, a weighted measure of death, illness and disability (DALYs).

Figure by MIT OpenCourseWare.

WHO, Preventing Disease…, 2006, p. 62.

DALYs

- DALYS: first used in *World Development Report (World Bank,1993)*
- An index of population health that combines in a single measure:
  - (i) premature death - “years of life lost from premature death”
  - (ii) morbidity - “years of life lived with disabilities.”
- One DALY can be thought of as one lost year of “healthy life.”
- Costs per DALY can be calculated for various interventions
- Widely used metric in policy discussions, but they are imperfect (e.g. weighting, discounting)
- See - WHO “Global Burden of Disease” data

DALYs and Deaths from Selected Water-Related Diseases (WHO,2000)

	DALYS	Deaths
Diarrheal	63,345,722	2,019,585
Poliomyelitis	188,543	1,136
Diphtheria	187,838	5,527
Typanosomiasis	1,570,242	49,129
Shistosomiasis	1,711,522	15,335
Trachoma	3,892,326	72
Ascarias	1,204,384	4,929
Trachuriasis	1,661,689	2,393
Hookworm	1,785,539	3,477
Other Intestinal Infections	53,222	1,692
TOTAL	76,601,028	2,103,274

Think of DALYs as one lost year of healthy life…

WHO, 2001. World Health Report 2001. Geneva, Jan. 2004

DALYS and Deaths for Selected Water-Related Diseases - Updated

	Diseases	Burden of Disease (DALYs)	Number of deaths
WS / S / H	-diarrhoeal diseases	54.2 millions (3.7%)	1.7 million (3.2%)
S / H	- trachoma - schistosomiasis - ascariasis - trichuriasis - hookworm	10.2 millions (0.7%)	26.2 thousands (0.05%)
Water resources	Vector borne diseases such as - malaria - J. encephalitis	42.8 millions (2.9%)	1.1 million (2%)

WS = water supply, **S** = sanitation, **H** = hygiene

(Bartram, J., 2004)

Cases of Water-Related Diseases in Africa

Condition	Cases in Africa
Malaria	>300 million*
Hookworm	198 million
Ascariasis	173 million
Schistosomiasis	166 million
Trichuriasis	162 million
Lymphatic filariasis	46 million
Onchocerciasis	18 million
Guinea Worm	<0.1 million

Fenwick, 2006, p. 1078.

***Roll Back Malaria (UN, WHO), 2000.**

Rogers, 2006

Water-Related Diseases: Transmission Routes and Prevention Strategies

Transmission	Examples	Prevention Strategy
1. Waterborne	Diarrhea (e.g. cholera) Enteric fevers (e.g. typhoid) Hepatitis A	* Improve water quality • Prevent use from unprotected sources * Improve sanitation
2. Water-washed (water hygiene)	Diarrhea Dysentery Trachoma Scabies	• Increase water quantity, accessibility and reliability • Improve hygiene • Improve sanitation
3. Water-based (water contact)	Guinea worm Schistosomiasis	* Reduce contact with infected water • Control vector host populations • Improve water quality (some types) * Improve sanitation (some types)
4. Insect Vector	Malaria, River Blindness	* Improve surface water management * Reduce need to visit breeding sites * Use mosquito nets

(Bradley, D., 1977; Feachem, R.G. et al, 1983)

1. Waterborne Diseases

- Caused chiefly by drinking contaminated water;
- Mainly enteric diseases transmitted by the fecal-oral route;
- Examples:
  - Diarrheas (e.g. cholera),
  - Enteric fevers (e.g. typhoid)
  - Hepatitis A
- Also, infection by non-fecal organisms which proliferate in water;
- Example:
  - Legionella bacteria via aerosols and droplets

Diarrhea: The Children's Disease

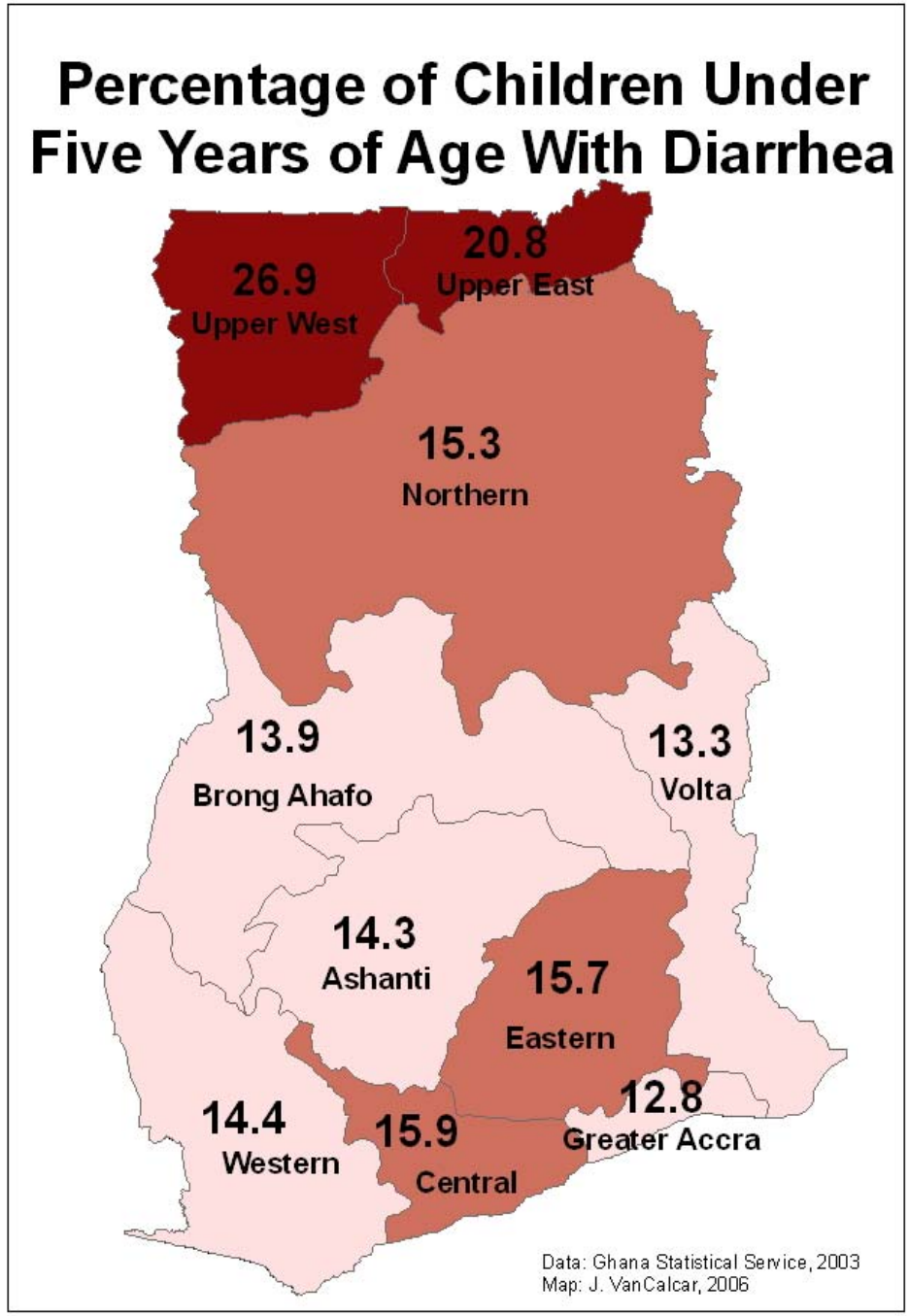
- Kills about 2 million children each year,
- Elderly affected similarly,
- Diarrhea often kills in combination with other childhood diseases, thus it…
- Contributes to 18 million deaths/year,

- Decline in death rates in developing countries in recent years is largely due to oral rehydration therapy (ORT) … and is mostly among adults.

Diarrhea and Dysentery

- Caused by viruses, bacteria, and protozoa
- Cause loose, watery stools, dehydration, and lowered resistance to other infections
- Cholera (a classic fecal-oral disease)
  - Caused by bacteria *Vibrio cholerae,*
  - Transmitted by ingestion of contaminated water or food (e.g. shellfish) contaminated with feces from an infected person,
  - Can kill in hours due to massive dehydration
  - Endemic in many parts of world
  - Major outbreak in S. America in early 1990s

Diarrhea in Children under 5 Years in Ghana

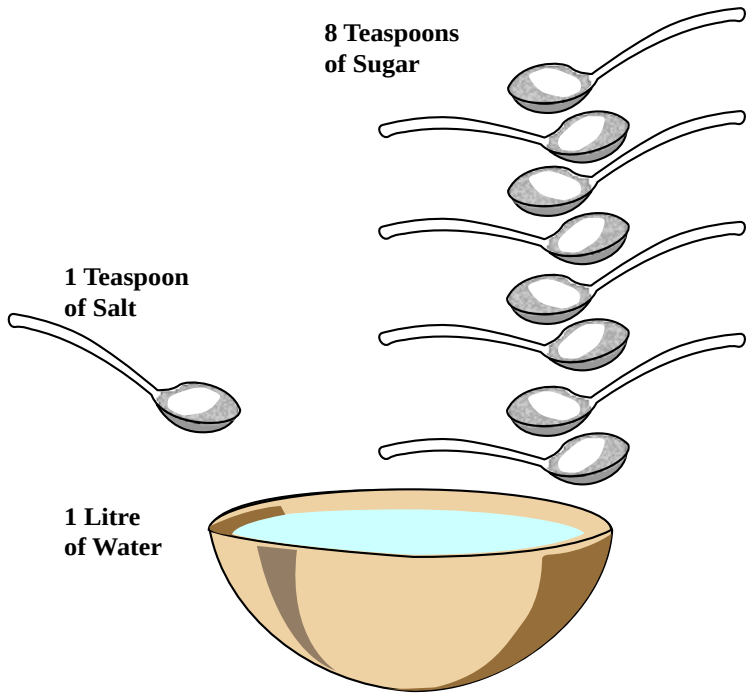


Controlling Diarrhea & Dysentery

- Water-borne and/or water-washed categories of control
  - Improve water quality
  - Improve sanitation
  - Increase quantity of water
  - Improve hygiene
- Education
  - Prevent use of unimproved sources
- Oral Rehydration Therapy (ORT)

Oral Rehydration Solution

The discovery that sodium transport and glucose transport coupled in the small intestine so that glucose accelerates absorption of solute and water (is) potentially the most important medical advance this century."
– The Lancet, August 5 1978



A simple ORS "recipe"

ORS Solution
Sodium chloride, 2.6 g/L
Glucose, anhydrous, 13.5 g/L
Potassium chloride, 1.5 g/L
Trisodium citrate, dihydrate, 2.9 g/L
(Total weight 20.5 g)

Figure by MIT OpenCourseWare.

2. Water-Washed (Water Hygiene) Diseases

- Diseases whose exposure is reduced by the use of water for personal and domestic hygiene:
  - Hand-washing – esp. after defecation, handling feces, food washing.
  - Domestic Washing: clothes, floors, other household chores
  - Bathing and other personal hygiene
  - Cleaning of cooking and eating utensils
- Includes many enteric organisms, as well as diseases of the skin and eyes (eg. trachoma) and insect infestations (eg: scabies caused by mites; pediculosis caused by lice).

Trachoma

6 million visually impaired, 146 million threatened by blindness

Photographs removed due to copyright restrictions.

Trachoma Transmission

- Primary transmission: Person-to-person transmission occurs by ocular and respiratory secretions
- Secondary transmission: insect vectors such as house flies, especially affecting children. Flies feed on discharge from infected eye and transmit it to another child

The Role of Water in Prevention of Trachoma

- Person-to-person transmission is controlled by frequent washing of infected eyes.
- Water quantity and accessibility are key to prevention of trachoma.
- More water helps keep household cleaner.
- More water means flies have more sources of moisture and are less likely to seek water from children’s eyes.

Trachoma – WHO “SAFE” Program

- **S = Surgery** – the simple surgical procedure to correct trichiasis (raking of the cornea by the inverted eyelid which causes scarring which leads to blindness)
- **A = Antibiotic** – for early stages of trachoma, (tetracycline ointment or sulfonamides) to stop the infection
- **F = Face Cleanliness**
- **E = Environment** (hygiene and sanitation).

Trachoma Control and Prevention

- **Step 1. Case Identification**: Identify communities with blinding trachoma through Trachoma Rapid Assessments (TRA).
- **Step 2. Surgery**: Provide surgery (tarsal rotation surgery for patients with trichiasis) Uptake is improved when surgery is provided in the village at no cost.
- **Step 3. Medication**: Reduce active disease and transmission of infection, particularly in children, through topical tetracycline or oral azithromycin.
- **Step 4. Hygiene Education**: Encourage facial cleanliness in children through health education messages.
- **Step 5. Environmental Water/Sanitation**: Improve the water supply and reduce fly density through improved community and family sanitation practices.

3. Water-based (Water Contact)

- Exposure by skin contact with infested water
  - Example: schistosomiasis: the free-living larvae released from aquatic snails (the intermediate host) invade the skin.
  - Example: guinea worm

Dracunculiasis – Guinea Worm

- Caused by Dracunculiasis worm
- Carried by cyclops – a small crustacean
- Wide but patchy distribution in Africa and Asia

Photographs removed due to copyright restrictions.

Dracunculiasis – Guinea Worm

- Produces arthritis of joints and disables those with infections for weeks at a time
- May infect entire villages

Photograph courtesy of Kelly Doyle.

Guinea Worm – Life Cycle

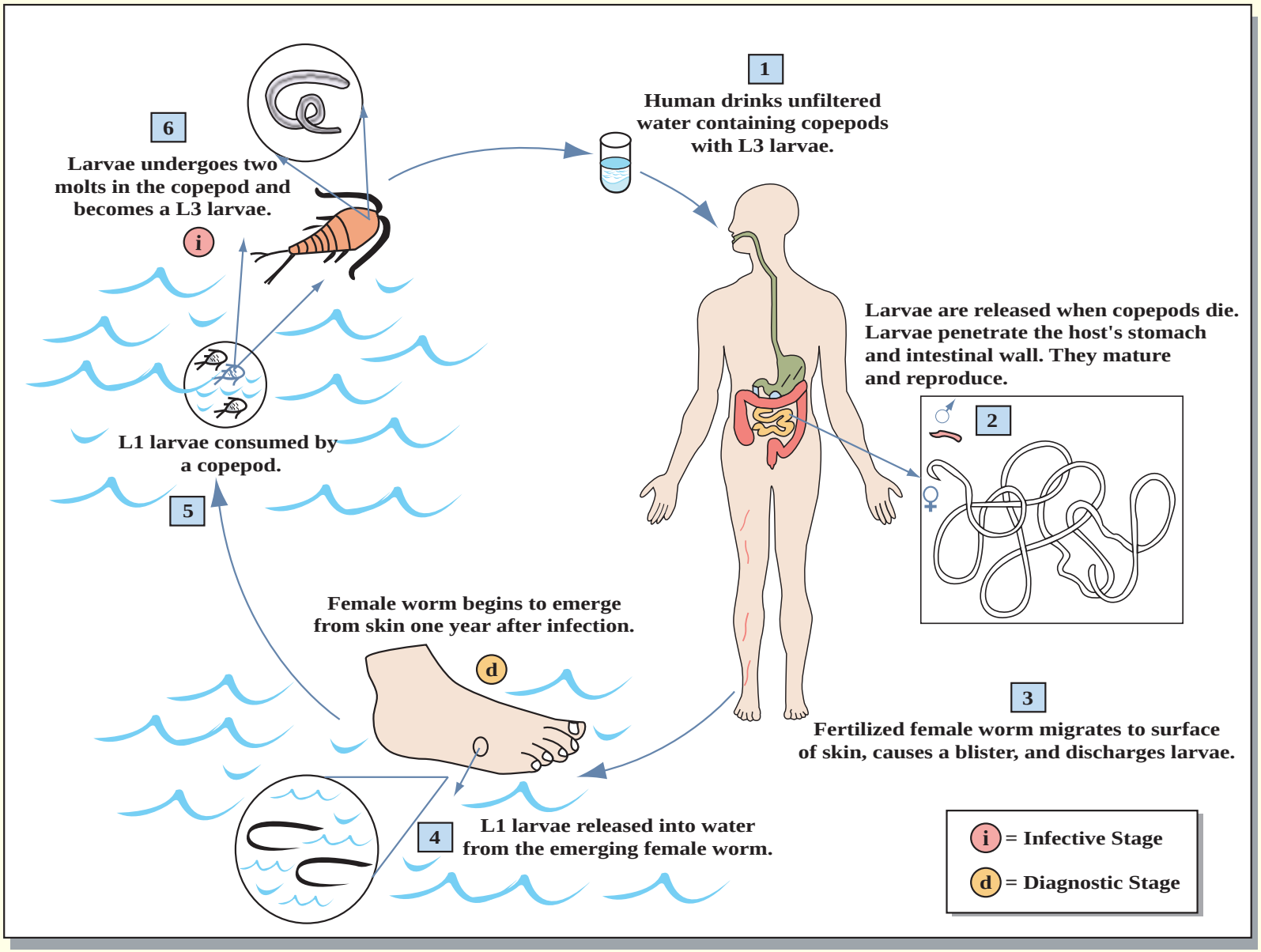


Figure by MIT OpenCourseWare.

Guinea Worm – Life Cycle

- Humans ingest cyclops through drinking water
- Female worm develops and posterior end lies just beneath blisters on the skin
- When water is spilled on the blisters, the Guinea worm larvae are released
- If larvae are washed into a well or water body containing cyclops, they infect the cyclops and continue their life cycle

Guinea Worm Eradication Campaign

- Twenty+ Year Campaign: 1986 – 2006. Founded by Carter Center.
- Leadership: The Carter Center
- Partnership: CDC, WHO, UNICEF, Ministries of Health and many other partners;
- Achievements: 99.5% reduction from an estimated 3.5 million cases in 1986 to 11,510 reported cases in 2005.
- Current Focus: The Carter Center continues to concentrate on the countries with the heaviest burden of Guinea worm disease: Sudan and Ghana. Sudan represents almost half of all reported cases, as many parts of the country are inaccessible to health care workers due to a 21-year civil war.

http://www.cartercenter.org/healthprograms/program1.htm

Reported Cases of Guinea Worm – 2005

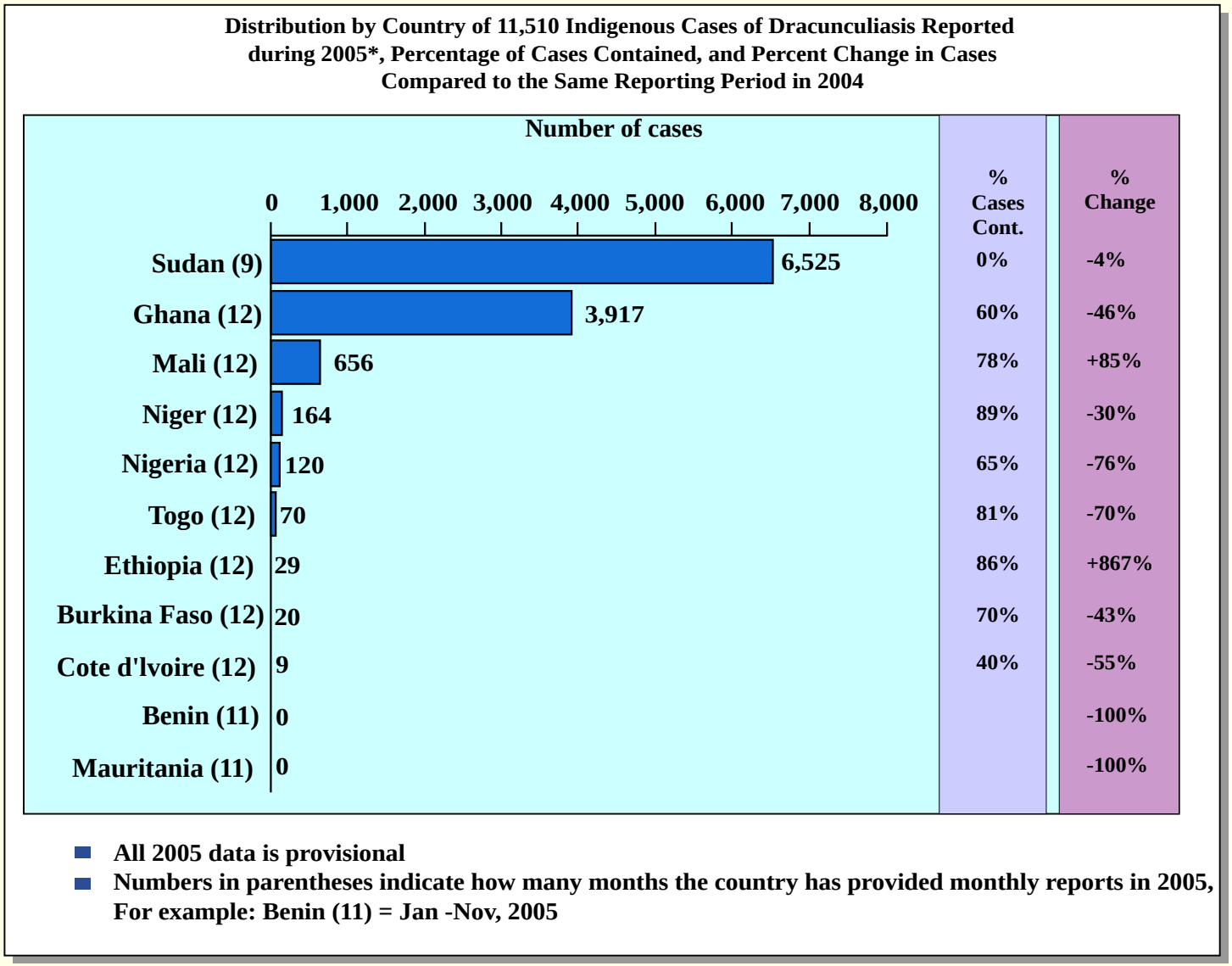


Figure by MIT OpenCourseWare.

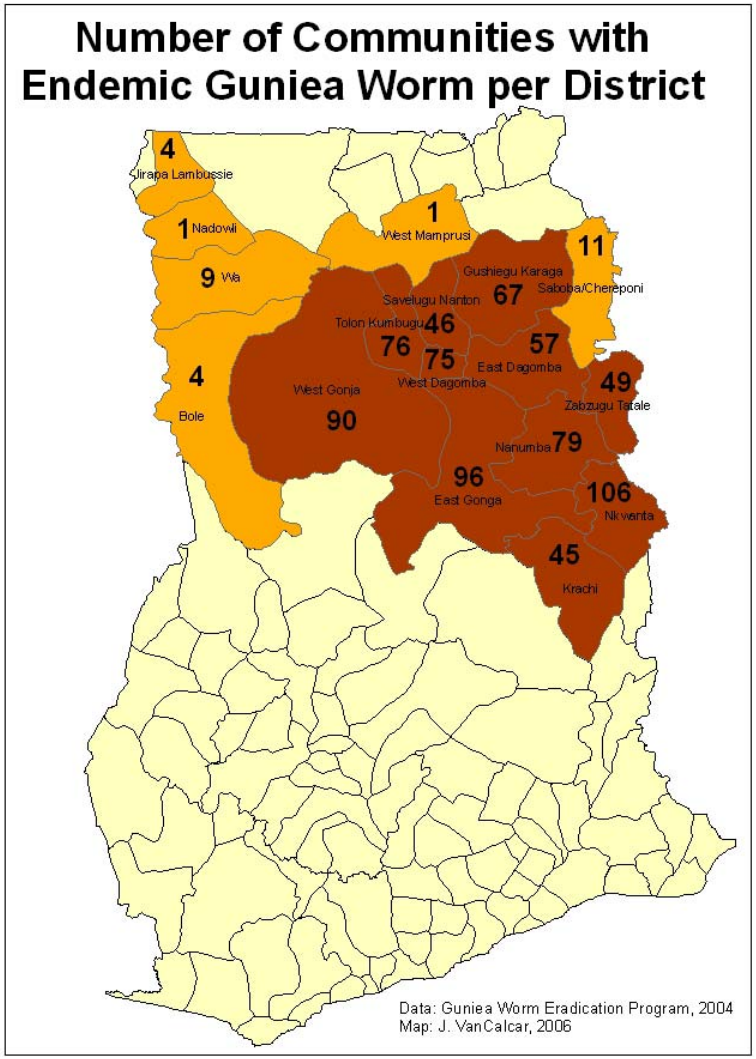
Example of Guinea Worm Source:

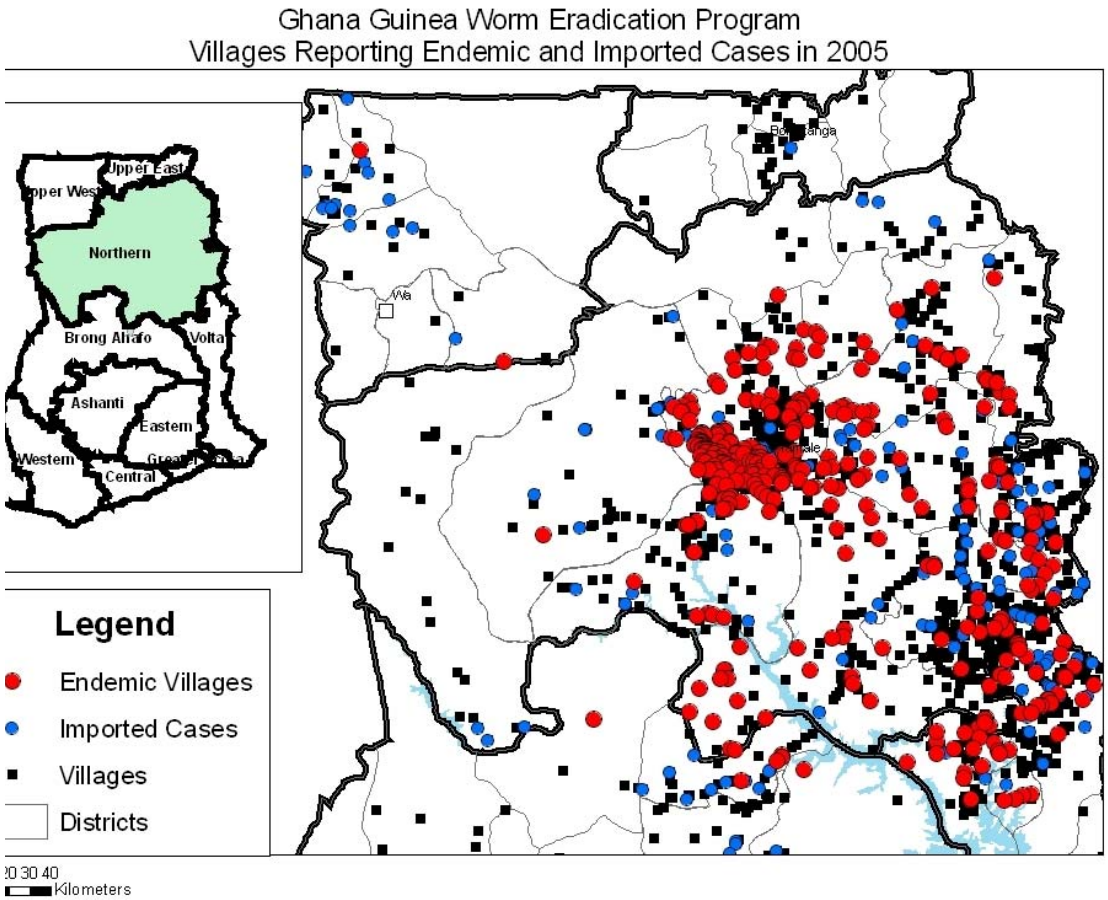
Tugu, Ghana,

Highest guinea worm endemic village in Ghana

(60 recent cases – Jan, 2007)

Mapping Guinea Worm





Courtesy of the Guinea Worm Eradication Campaign.

Guinea Worm Control

Source → Transmission → Susceptible Person

ELIMINATE ONE AND THE DISEASE IS CONTROLLED
Usually best to go after all three

- Treat source with pesticide – Abate® (BASF),
- Provide alternate, safe drinking water sources,
- Cloth filtration of water to remove cyclops,
- Treat infected people.

Installation of Borehole Well in Tugu, Ghana

Tugu Villagers Watching Borehole Drilling

Guinea Worm Control Cloth Filtration

4. Water (Insect) Vector

- Diseases spread by insects which breed or bite near water habitat
  - Mosquitoes
    - Malaria
    - Yellow fever
  - Flies
    - Sleeping sickness
    - River blindness

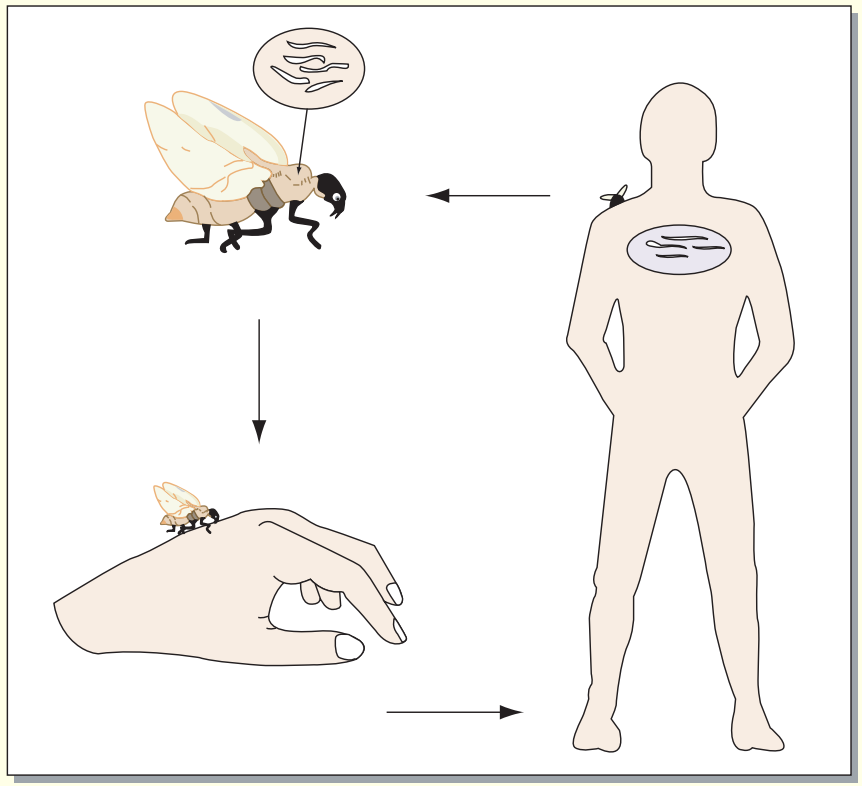


Figure by MIT OpenCourseWare.

Malaria

- 40% of world's population at risk (sub-Saharan Africa)
- 300 million acute illnesses
- 1.3 million deaths annually
- Kills an African child every 30 seconds
- In areas with severe malaria problems, inhabitants develop immunity at an early age
- Cost for immunity is an infant mortality rate of 10-20%
- Development projects such as dam construction, which may increase mosquito populations, may or may not increase malaria based on degree of local immunity.

Malaria

- Development delays in children
- Large economic cost
  - Responsible for
    - 40% of public health expenditure
    - 30-50% of inpatient hospital admissions
    - 50% of outpatient admissions
  - Indirect costs
    - Absenteeism from work
    - Loss of unpaid work
    - Loss of future income from fatalities

Malaria

- Carried by female mosquitoes of the genus Anopheles
- Anopheles mosquito is an ideal vector for malaria because of its high density in infected areas and frequent biting of people.
- Caused by four species of protozoa parasites - *Plasmodium sp.*
- Acute bouts of fever which recur at regular intervals

Malaria

1. *P. falciparum*
   - Causes falciparum malaria – esp. in humid tropics
   - Most serious form of malaria – often fatal
2. *P. vivax*
   - Causes vivax malaria
   - Found in regions with distinct cool or dry seasons
   - Transmission is seasonal
3. *P. malariae*
   - Causes quartan malaria
   - Characterized by bouts of fever every three days
   - Patchy distribution in tropics and subtopics
4. *P. ovale*
   - Causes ovale malaria
   - Found mostly in W. Africa

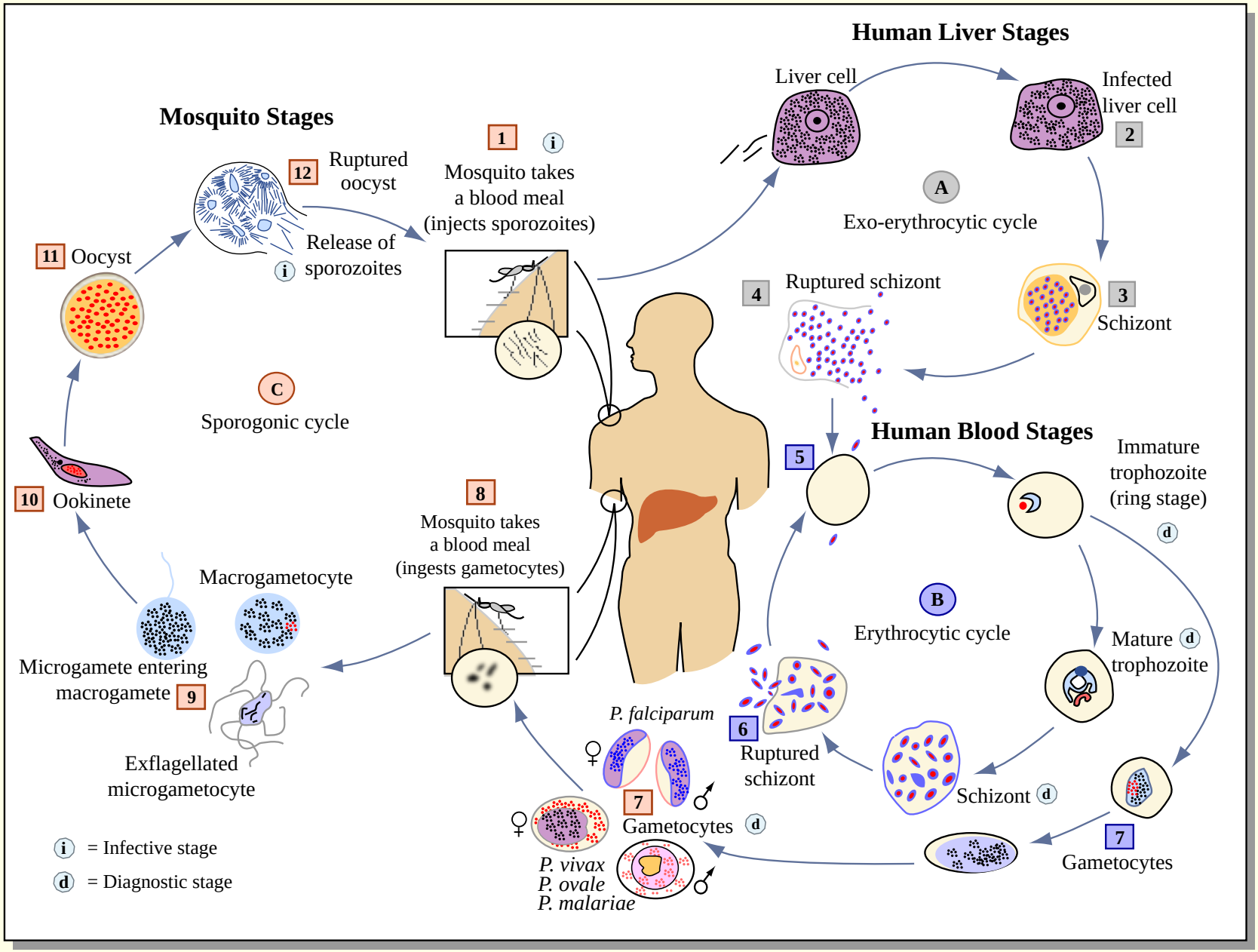


Figure by MIT OpenCourseWare.

Life Cycle of the Malaria Parasite

- Female mosquito bites infected human and ingests gametocytes

- Sexual cycle in an anopheline mosquito
  - 10-15 days
  - Female gametocytes become macrogametes and male gametocytes become 6-8 sperm-like microgametes
  - Male and female gametes fuse to form zygote
  - Zygotes form worm-like ookinetes that penetrate the gut wall and encyst to form an oocyst

Life Cycle of the Malaria Parasite

- Sexual cycle in an anopheline mosquito, cont.
  - In 6-7 days, the contents of each cyst divide into thousands of slender sporozoites
  - The cysts burst, and the sporozoites migrate through the body
  - Sporozoites enter the salivary glands and await transfer to a human host
- Infected mosquito bites another human
- Incubation cycle in the liver
  - Sporozoites migrate to the liver and rapidly reproduce asexually

Life Cycle of the Malaria Parasite

- Fever-producing cycle in the blood
  - Infection spreads to red blood cells where amoeba-like trophozoites develop
  - Each trophozoite in an individual blood cell develops into a schizont which divides into 6-36 daughter merozoites
  - Following rupture of the blood cell, these escape into the blood stream and infect other blood cells and repeat cycle
  - After 10 days, the shock of the nearly simultaneous release produces chills followed by fever in response to the toxins from the emerging parasites

Life Cycle of the Malaria Parasite

- The chill-fever cycles are species-dependent and range from 48-72 hours
- After a period of schizogony, some merozoites become gametocytes and can be ingested by another mosquito
- http://www.who.int/tdr/diseases/malaria/lifecycle.htm (accessed 2..27.07)

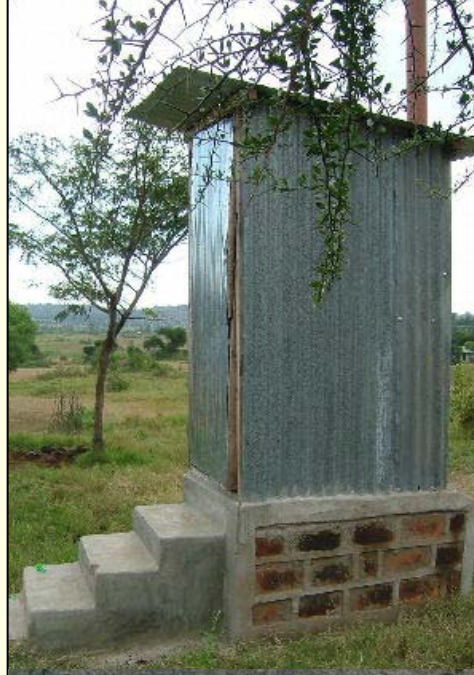
Malaria Control

- Roll Back Malaria Campaign (2001-2010)
- Chemotherapy of infected people
  - Difficult to treat everyone in an infected area
  - Increasing resistance to antimalarial drugs
- Control adult mosquitoes
  - Spray inside walls of homes with insecticide
  - Mosquito nets – spray with pyrethroid
- Eliminate breeding sites

Status of Research on Efficacy of the Different Categories of Environmental Interventions to Reduce Water-Related Diseases

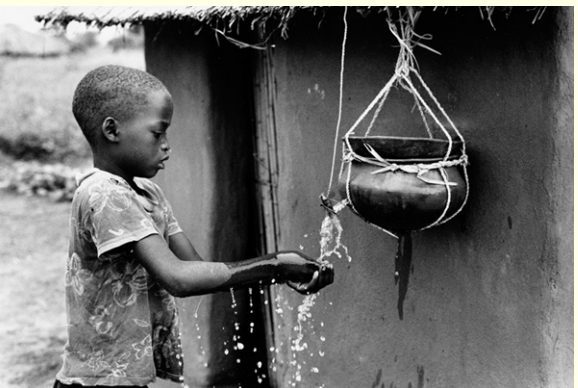
QUANTITY - Sufficient water quantity from protected, "improved source"

SANITATION



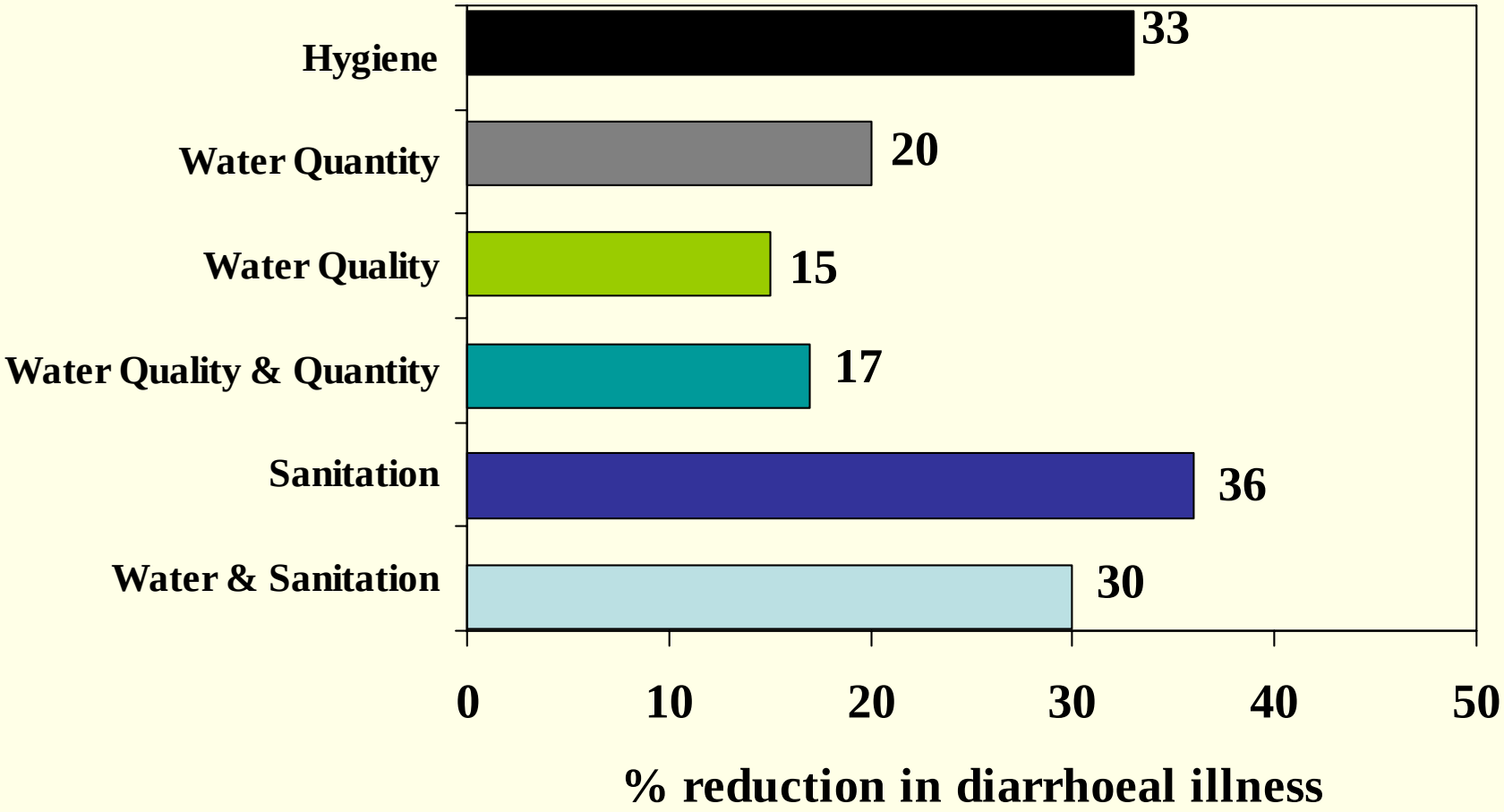
Environmental Prevention Strategies for Control of Water-Related Diseases

HYGIENE

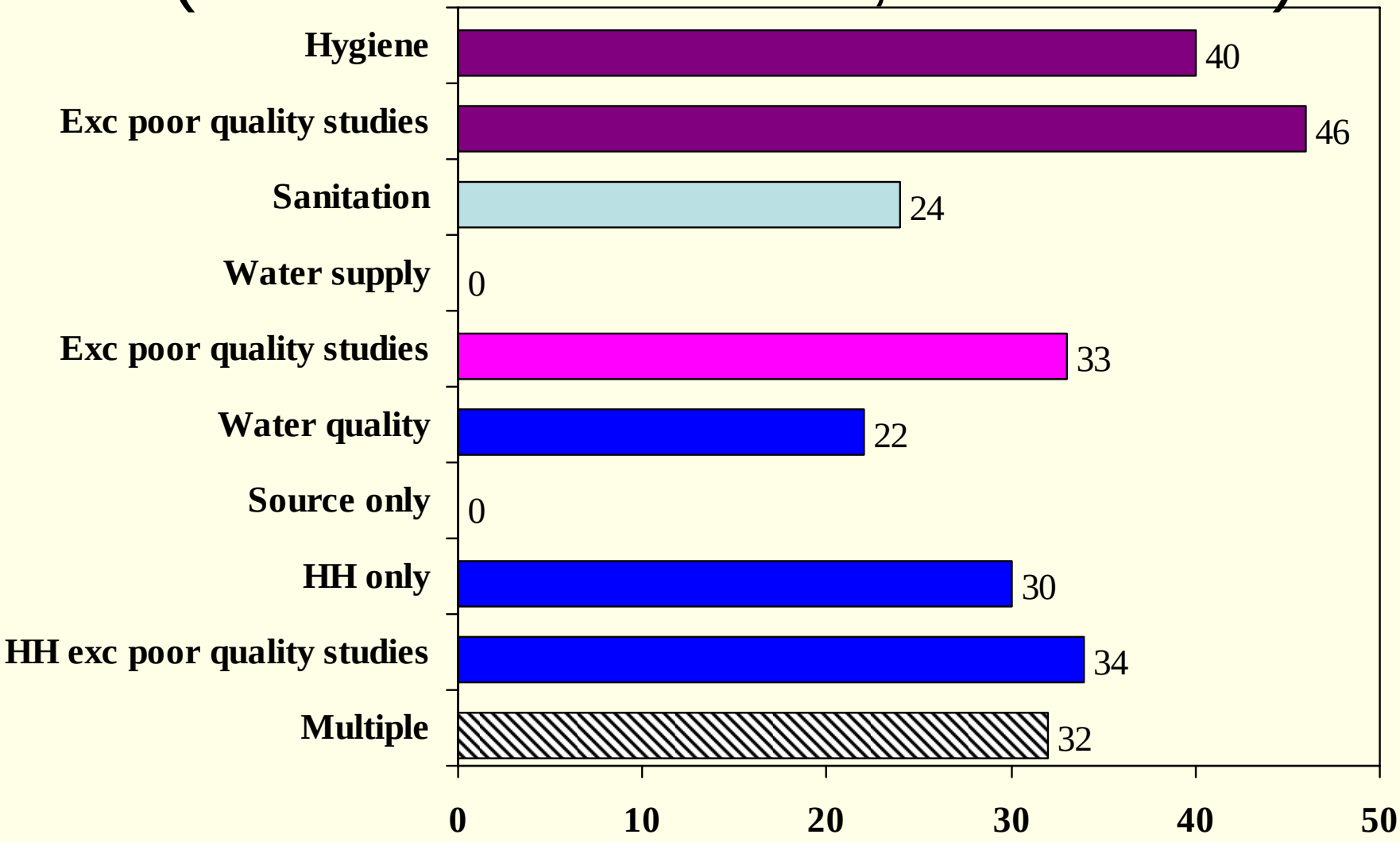


WATER QUALITY Community or Household Water Treatment and Safe Storage at point of use

Esrey, MetaAnalysis (1985)
(reviewed 68 studies from 28 countries)

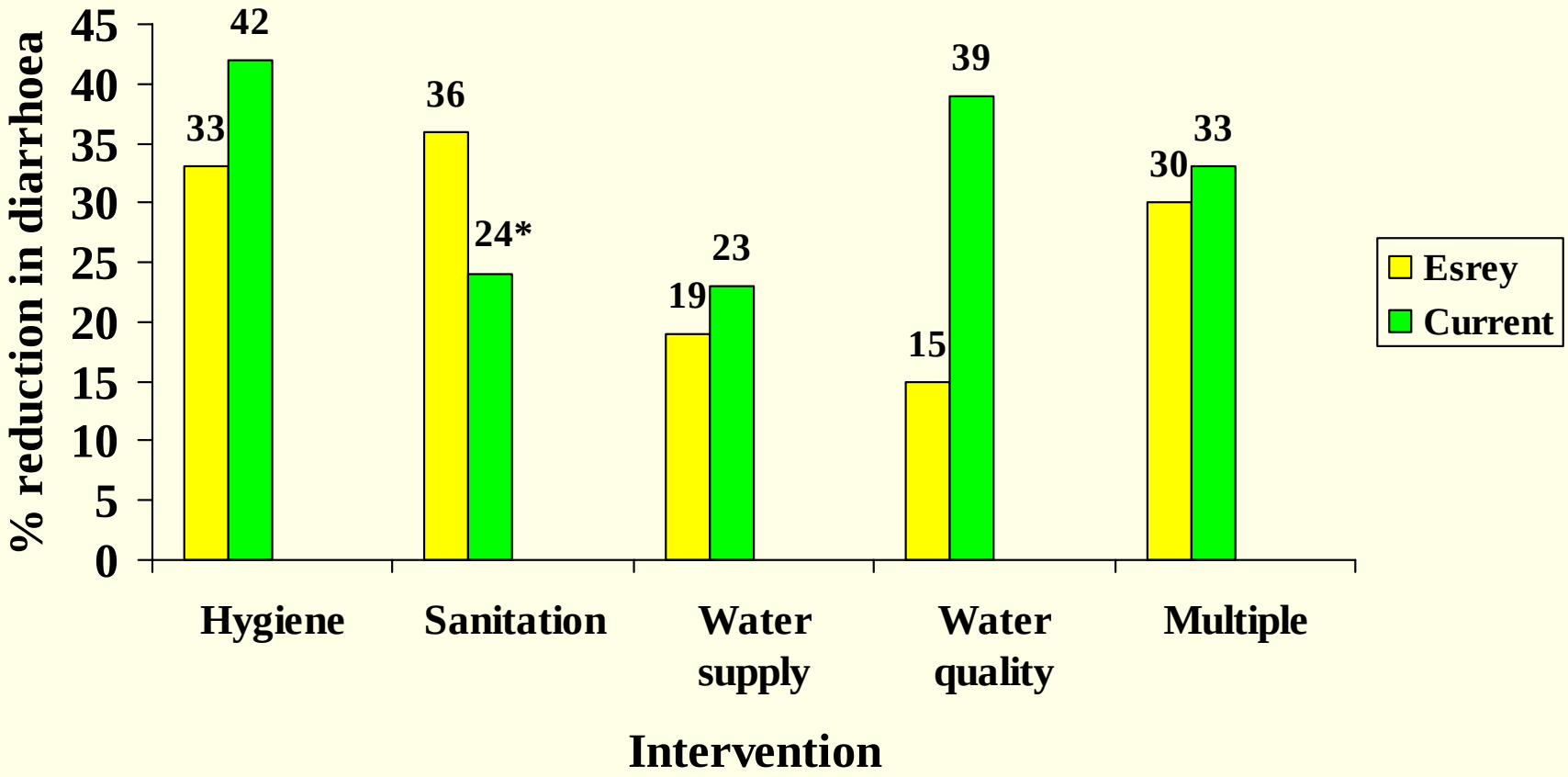


Fewtrell & Colford MetaAnalysis (2004) (reviewed 64 studies, world wide)



(Fewtrell, L and Colford, J., 2004)

Comparison of Esrey (1985) and Fewtrell & Colford MetaAnalyses (2004)



(Fewtrell, L and Colford, J., 2004 and Esrey, S. 1985)

References

- Esrey, S.A., Feachem, R.G. and Hughes,J.M."Interventions for the Control of Diarrhoeal Diseases among Young Children: Improving Water Supplies and Excreta Disposal Facilities. *Bulletin of the World Health Organization* 63, 757-772.1985.
- Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D. Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. Wiley, Chichester. 1983.
- Fewtrell, L., and Colford, J. "Water, Sanitation and Hygiene: Interventions and Diarrhoea – a Review." World Bank, Washington DC. 2004
- Rogers, P. Water and Child Health: An Environmental Perspective Presentation to the World Health Organization's Task Force on the Children's Environment and Health Action Plan for Europe (CEHAPE), Limassol, Cyprus, October 16-17, 2006.
- Sobsey, Mark. http://www.unc.edu/~sobsey/ (accessed Feb. 13, 2006)
- WHO, 2002 and 2004 – http://www.who.int/
- WHO, 2006. Preventing Disease through Healthy Environments.
- http://www.who.int/quantifying_ehimpacts/publications/preventingdisease/en/