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The role of water in linking agriculture, nutrition and health

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Learning Objectives

• Recognize water transmits infectious diseases, which sap nutrition and contribute to stunting and environmental enteropathy (EE); WASH activities appear to decrease stunting via EE.

• Understand how irrigation and water storage (reservoirs) can increase diseases such as malaria and diarrhea while increasing food security and crop productivity;

• Know how excess water allows fungal growth on stored crops, and increases aflatoxin risk;

• Address risks and benefits of water provision through integrated programming which includes water management and low-cost treatment.
Big Picture

• **Thesis**: Eliminating stunting & malnutrition will require **provision of adequate and diverse diets; removing environmental contamination; preventing infectious diseases. Why these?**

• **Systematic review of nutrition programs**: very best programs only deal with ~ 1/3\textsuperscript{rd} of stunting.

• **Stunting most strongly related to gut injury and permeability** – ‘environmental enteropathy’ – which is related to living in a dirty environment e.g. with diarrhea pathogens, toxins, etc.
Up to 1/3rd food deficits

~ 40% of stunting

WASH – CLEAN ENVIRONMENT

Surprise: ‘Diarrheal disease’ only accounts for a much smaller of growth deficits than WASH (5-15% vs 40%).

Aflatoxin – could account for 40% stunting
Agriculture in Nairobi: Sewage
Left: broken sewage main in field. Right: lush fields.
Increased agricultural productivity
Greater food availability, lower food prices, diet diversity, higher income. Nutrition sensitivity: grow high Vitamin A sweet potatoes (higher micronutrients), kitchen gardens, crop diversity
Gender sensitivity, climate change, HIV focus
Water needed for crops, for farm animals (meat protein is good), to keep farmers hydrated and fit for work, …. Irrigation, reservoir construction

What else does the water carry?
# AGRICULTURAL WASTEWATER

<table>
<thead>
<tr>
<th>ORGANISM</th>
<th>TYPICAL SOURCE</th>
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<tbody>
<tr>
<td>ROTAVIRUS</td>
<td>HUMANS; PERHAPS ANIMALS</td>
</tr>
<tr>
<td>HEPATITIS A</td>
<td>HUMANS</td>
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<tr>
<td>HEPATITIS E</td>
<td>HUMANS, SWINE</td>
</tr>
<tr>
<td><em>E. coli</em> (bacteria)</td>
<td>CATTLE, HUMANS</td>
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<tr>
<td><em>Shigella</em> species</td>
<td>HUMANS</td>
</tr>
<tr>
<td><em>Salmonella enterica</em> (bacteria)</td>
<td>CATTLE, POULTRY, SWINE, HUMANS</td>
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<tr>
<td><em>Campylobacter jejuni</em> (bacteria)</td>
<td>POULTRY</td>
</tr>
<tr>
<td><em>Cryptosporidium</em> (protozoan)</td>
<td>CATTLE, HUMANS, OTHER FARM ANIMALS</td>
</tr>
<tr>
<td><em>Microsporidia</em> (fungus)</td>
<td>FARM AND DOMESTIC ANIMALS, HUMANS</td>
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* Causes chronic diarrhea, wasting, malnutrition in people with HIV/AIDS

*Cryptosporidium* – a leading cause of diarrhea children < 24 months; known to cause stunting; and children have x 4 risk of death in next year
Dietary insufficiency leads to malnutrition, which worsens infection. Infection in turn leads to an environmental factor such as water, which worsens malnutrition, completing the cycle.
High potential for domestic animals to contaminate household environment
Poor Sanitation / Hygiene. Fecal Contamination of Domestic Environment

Fecal Ingestion Infants/Children and Enteric Infections

(1) Intestinal Inflammation  (2) Increased gut permeability  (3) Bacteria get into body via leaky gut  
(4) Entire Immune System gets activated

ENVIRONMENTAL ENTEROPATHY
Malabsorption & Malnutrition; Oral Vaccine Failure; ↑ Risk of Infection; ↑ Morbidity/Mortality, ↓ Cognition, Economic Potential
Nice normal intestine. Note long skinny finger-like villi, which absorb nutrients

ENVIRONMENTAL ENTEROPATHY

EE - Nasty blunted villi, and tissue is infiltrated with inflammatory cells. **EE is a state of chronic inflammation**

Korpe & Petri, Trends in Molecular Medicine June 2012, Vol. 18, No. 6
Environmental Enteropathy

Children in highly contaminated environments have leaky, chronically inflamed intestines – 5% less carbohydrate, 15% less protein absorption. Leak lets ‘dirty’ contents of gut into body; chronic inflammation uses up/diverts nutrients, leads to anemia,
Malnourished Children have less diverse, different gut microbiomes

Bacteria Shared With Animals

Figure 4 Schematic diagram indicating the overall differences between microbial communities residing in the gut of a malnourished and a healthy child.

Gupta et al. Gut Pathogens 2011, 3:7
http://www.gutpathogens.com/content/3/1/7
Solutions

• **Classic water and sanitation for household** – water supply NOT same for animals unless treated; hand-washing; human feces kept out of wastewater

• **Agricultural hygiene** – barriers to keep feces and crud out of water - vegetated buffer zones around crops, riparian buffers to slow entry into open water (stream or irrigation canal), manure management, grazing practices ...
Farm practices to control spread of disease are well known

Spring protection box – keeps animals out

Sourcebook of Alternative Technologies for Freshwater Augmentation

WHO 1992
Agricultural Water Projects

• Increase food production
• Increases burden of diseases related to water. Long history of failure to consider health risks. Can undermine benefits of bednet use and intermittent treatment during pregnancy
• Increase in commerce can lead to ↑ HIV
• Water system management can mitigate risk; complement health system changes which may or may not be sustained.
Malaria:
“The construction of irrigation systems and reservoirs in some parts of the world can have a dramatic impact on malaria distribution and on the intensity of its transmission.... Malaria is among the five leading causes of death in under-5-year-old children in Africa.”

“Where appropriate, countries and communities are being encouraged to reduce mosquito breeding sites by filling in and draining water bodies and through other environmental management schemes.”

WHO http://www.who.int/water_sanitation_health/diseases/malaria/en/
Reservoirs and Malaria Increases

- Bamendjin Dam – **Cameroon** (Atangana 1979)
- Kamburu Dam – **Kenya** (Oomen 1981)
- Manantali Dam – **Mali** (King 1996)
- Climate change, increasing populations, desire to improve agricultural productivity – all argue for increased water impoundment, storage, and delivery via irrigation
- **Example:** Koka Reservoir & Wonji Irrigation Zone, Ethiopia
Malaria Transmission in the Vicinity of Impounded Water: Evidence from the Koka Reservoir, Ethiopia

Solomon Kibret, Matthew McCartney, Jonathan Lautze and Gayathree Jayasinghe
KOKA RESERVOIR

CATTLE – DEFECATE IN WATER

WONJI IRRIGATION AREA

FIGURE 2. Location of the Koka area in central Ethiopia. The triangular points represent each of the study villages.
Closer to reservoir, more malaria

**FIGURE 8.** Relationship between average annual malaria case rates in 13 villages (passively reported) and proximity to the Koka Reservoir between 1995 and 2007. The bars indicate the confidence interval of the observed means.

The equation of the line is given as:

\[ y = -27.5\ln(x) + 62.46 \]

The coefficient of determination, \( R^2 \), is 0.914.
... more malaria, even “out of season”

FIGURE 9. Seasonal distribution of malaria cases passively reported at different distances from the Koka Reservoir (vertical bars indicate 95% confidence intervals).
Control: Leave larvae high & dry

SLOW DRAWDOWN OF WATER – MOSQUITO LARVAE SURVIVE

ABRUPT DRAWDOWN OF WATER – MOSQUITO LARVAE LEFT HIGH & DRY DO NOT SURVIVE
Aflatoxins and other mycotoxins
Aflatoxins - 1

• Aflatoxins are produced by *Aspergillus* fungi which infect maize, groundnuts, many other staple foods. Other toxins are made by other fungi. Toxin production occurs when the temperature is 24°C to 35°C, and crop residual moisture is 7% or more.

• Drought stresses crops, also increase infection rates – this happened this year in the US.

• Toxin production is minimized by good drying practices and by storage minimizing moisture.
Aflatoxins - 2

• Historically, well known cause of liver cancer.
• If large doses eaten, cause rapid death (likely from liver failure) e.g. Kenya 2004.
• Aflatoxins present in dried foods; breast milk; milk, poultry, and meat if animals given feed with aflatoxins.
• Recent data highly suggestive it is a cause of stunting, low birth-weight, enhanced risk of infectious diseases. Estimate: 43% of stunting!
Drying Cassava Dec 8 2012, Kamwenge: note green/yellow fungal discoloration
Aflatoxin (Mycotoxin) Contamination of Staple Foods, Breast Milk, Farm Animal Milk, Meat

Ingestion → ↓ Protein Synthesis, ↓ Nutrient Uptake, ↑ Systemic Immune System Activation (↑ Cytokines)

(1) Increased gut permeability (2) Bacteria translocate (3) Systemic Chronic Inflammation (4) Zinc Deficiency

ENVIRONMENTAL ENTEROPATHY
Malabsorption & Malnutrition; Oral Vaccine Failure; ↑ Risk of Infection; ↑ Morbidity/Mortality, ↓ Cognition, Economic Potential
CONTAMINATED WATER / POOR HYGIENE (PATHOGENS, OTHER STUFF IN WATER)

ENVIRONMENTAL ENTEROPATHY & STUNTING
Malabsorption & Malnutrition; Oral Vaccine Failure; ↑ Risk of Infection; ↑ Morbidity/Mortality, ↓ Cognition, ↓ Lifetime Economic Potential

AFLATOXIN (MYCOTOXIN) INGESTION
FUNGI NEED WATER/MOISTURE TO GROW
Corn (maize), peanuts
Key crops in Uganda

Aspergillus spp. + moisture + warm temperature = Aflatoxin formation which is seasonal

Enteropathy – permeable intestine with documented increased nutrient needs, state of chronic inflammation
Microbiome – less diverse, abnormal nutrient utilization by flora

Aflatoxin ingestion, duodenal uptake - Metabolites bind to DNA, proteins – can measure in blood, urine, tissues
Immunosuppression

Clinical Manifestations:
Cycle of repeated infections
Worsening nutritional status – stunting, underweight, IUGR

Diet, Societal Conditions
Diet: poor diversity, inadequate caloric & micronutrient intake, leading to immunosuppression
Pathogen exposure: Widespread food, water, environment contamination
On the Horizon

• Better information on EE, stunting, and water
• Low-cost ways to treat water for consumption (inexpensive chlorine, permeable clay buckets, other) are being implemented at scale and look to be sustainable.
• More data on the benefits/costs/risks of dietary aflatoxin removal from East & West Africa
• Should allow better judgments on which interventions are most effective AND scalable.
Summary: INTEGRATED APPROACH

• Most recent science suggests contaminated environments, infections, and toxins all change the child’s gut through EE.

• Recent information suggests WASH has much more potential to eliminate malnutrition than had been thought.

• Integrated programming which respects water has the best chance to improve agriculture, nutrition, health. One can’t dig irrigation canals without affecting nutrition & health!
Thanks!

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