Engineering for child health: WASH, schistosomiasis and soil-transmitted helminthiases

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What can engineers do for international child health?

• Engineers can improve the environment to prevent disease and injury

• Water and wastewater treatment infrastructure
  • Treatment plants
  • Pipe networks
  • On-site facilities


Image credit: http://roselawgroupreporter.com/2012/12/major-pipeline-among-ideas-for-aiding-arid-west/#/prettyPhoto

Image credit: http://www.valleyviewseptic.com/?area=about_septic_tanks/description_technology
What can engineers do for international child health?

• Different technologies more appropriate to low-income settings
• Minimise cost, maximise reliability and ease of repair

Image credit: https://www.mintpressnews.com/wp-content/uploads/2015/05/lifestraw-africa-003.jpg
What can engineers do for international child health?

• Engineers can also contribute to the design of safe housing

• And to the reduction of indoor air pollution


What can engineers do for international child health?

- Engineers can also contribute vaccine refrigerators, medical sensors, prosthetics and other specialised tools.
- Appropriate technologies are needed to sustain public health improvements in the future.
My research: schistosomes

- Adult worms live in pairs in the blood vessels around the intestine or the bladder.

- The parasite enters the human host through the skin when swimming in freshwater, but leaves in the urine/faeces\(^1\).

- Snail intermediate hosts needed to sustain transmission\(^1\).

1. Colley et al., 2014

Image credits:
- SCIENCEPHOTOLIBRARY: http://www.sciencephoto.com/media/366219/enlarge
- Natural History Museum: http://www.nhm.ac.uk/research-curation/collections/curation-groups/scan/index.html
Schistosome life cycle

Image credit: http://www.uni-bielefeld.de/biologie/Didaktik/Zoologie/html_eng/zyklus_eng.html
Schistosomiasis pathology

- Mainly caused the body’s reactions to schistosome eggs
- Enlargement of the liver and spleen, abdominal distension, fever, diarrhoea
- Liver and kidney failure
- Eggs occasionally enter the central nervous system
- Increased HIV transmission

1. Colley et al., 2014
2. van der Werf et al., 2003
3. Ferrari et al., 2011
4. Secor et al., 2012
Schistosomiasis endemic zones

Global burden of schistosomiasis

• About 291 million people infected with schistosomes\(^1\)
• Around 210 million more suffer continuing symptoms from previous infections\(^2\) – thus perhaps 500 million suffer from schistosomiasis
• Causes 3.1 million DALYs annually\(^4\)
• May cause around 380,000 deaths in Africa annually\(^3\)

Image credits: Aiden Emery, Natural History Museum

1. Global Burden of Disease Study 2013 Collaborators et al., 2015
2. Colley et al., 2014
3. GBD 2013 DALYs and HALE Collaborators et al., 2015
4. van der Werf et al., 2003
Soil-transmitted helminths (STHs)

- Adult worms live in the intestine

- Three main kinds of STH:
  - Roundworm (*Ascaris lumbricoides*)
  - Whipworm (*Trichuris trichiura*)
  - Hookworm (*Ancylostoma duodenale* and *Necator americanus*)

Image credits:
- http://www.britannica.com/animal/whipworm
STH life cycles

Roundworm (A. lumbricoides)

Hookworm (A. duodenale/ N. americanus)

Whipworm (T. trichiura)

Image credits: Adapted from CDC, www.cdc.gov
STH pathology

- Impaired physical and intellectual development\(^1\)

- Other common symptoms include:\(^1\)
  - Abdominal pain and distension
  - Nausea
  - Anorexia
  - Diarrhoea
  - Fever

- Hookworm is a cause of anaemia\(^1\)

1. Knopp et al., 2012

STH burden of disease and endemic zones

- Estimated numbers of people infected:
  - Roundworm: 800 million
  - Whipworm: 480 million
  - Hookworm: 470 million
- Deaths are rare but STHs were estimated to cause 5.18 million DALYs in 2010

Image credits: Pullan et al. http://www.parasitesandvectors.com/content/7/1/37

2. Pullan et al., 2014
Schistosomiasis and STH control

- Preventive chemotherapy is the mainstay of control\(^1\)
  - However, reinfection generally follows\(^2\)
  - The parasites could evolve resistance to the drugs\(^3\)

- Increasing interest in integrated approaches to control
  - Water, sanitation and hygiene (WASH)
  - Health education
  - Environmental modification\(^4\)
    - (Biological control)\(^5\)
    - (Mollusciciding)\(^6\)

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1. Colley et al., 2014
2. N’Goran et al., 2001
3. Fenwick et al., 200
5. Jordan et al., 1980
6. McCullough et al., 1980
WASH Definitions

**WA**ter

Image credits: Aubrey Wade/WaterAid/Panos

**Sanitation**

Image credits: WSSCC
http://www.wsscc.org/resources/resource-photo/toilets-south-africa#3

**Hygiene**

Image credits: UNICEF, UNICEFBANA2011-01020Shafiqui
Systematic review – schistosomiasis, water and sanitation

• Systematically reviewed the literature to compare schistosome infection rates between people with and without water and sanitation
• Synthesised these results in a meta-analysis
• Did indeed find statistically significantly lower odds of infection in those with water and sanitation
• No studies compared soap use during water contact, with infection
‘Safe’ water source associated with significantly less *Schistosoma* infection

Overall *Schistosoma* and water: Odds ratio, OR = 0.53 (95% CI: 0.47, 0.61)
‘Safe’ water source associated with significantly less Schistosoma infection

**S. haematobium** and water: 
OR = 0.57 (95% CI: 0.45, 0.71)

**S. mansoni** and water: 
OR = 0.53 (95% CI: 0.45, 0.63)

**S. japonicum** and water: 
OR = 0.37 (95% CI: 0.30, 0.46)
Sanitation associated with significantly less *S. mansoni* infection

*S. mansoni* and sanitation: OR = 0.59 (95% CI: 0.47, 0.73)
Sanitation associated with significantly less *S. haematobium* infection

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**S. haematobium** and sanitation:  
**OR = 0.69** (95% CI: 0.57, 0.84)
A more qualitative consideration of the schistosome life cycles

• Small numbers of eggs may be sufficient for sustained transmission
• Latrines may not help if eggs wash off the skin or clothes, into the water
• Animal reservoir hosts may also provide eggs
• Prevention of water contact likely to be more effective in controlling transmission
• Water supplies should provide for all water-contact activities (bathing, laundry, swimming), or water contact will continue

Image credits: http://www.volhardinggameranch.com/baboon_in_water.jpg
http://www.bbc.co.uk/nature/life/Water_Buffalo

1. Grimes et al., 2015
National mapping in Ethiopia

- Over 2,000 schools
- 50 children per school tested for schistosomes and STHs
- WASH facilities and practices were also assessed
- WASH scores were constructed
- Schools with 0% prevalence of each parasite were excluded
- The remaining schools’ mean infection intensities were tested against the WASH scores with Kendall’s $\tau_b$
The WASH scores

• **Water score** estimated frequency of school water collection from rivers and lakes

• **Sanitation**: roughly latrine stalls per child, each latrine weighted according to its condition (cracks in floor, presence of door, odour, cleanliness etc.)

• **Hygiene score** developed in a similar way, but considering provisions of soap, ash, water and basins at the latrines
• More water collection associated with slightly (statistically significantly) more *S. mansoni* infection

• Kendall’s $\tau_b = 0.097$
Sanitation, *S. mansoni* and the STHs

- Better sanitation associated with statistically significantly less *A. lumbricoides* (roundworm, $\tau_b = -0.067$)
- And borderline significantly less hookworm ($\tau_b = -0.039$)
- No significantly differences in *T. trichiura* (whipworm) or *S. mansoni*
Hygiene and the STHs

- Better hygiene associated with significantly less hookworm ($\tau_b = -0.076$)
- But with no significant differences in roundworm or whipworm
Conclusions

- Interdisciplinary efforts are central to improving child health
- Various associations have been demonstrated between WASH elements and parasites
- In the national mapping analysis, these were somewhat moderate – perhaps due to the overall very low level of WASH?
- The different parasites can have different relationships with WASH, even when their life cycles are very similar
- Next steps – an intervention study to investigate how well schistosome-specific WASH interventions can prevent reinfection following treatment
Thank you

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- Statistics: Dr Sarah Knowles
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