Faecal constituent flows in urban ecosystems

Questioning our current assumptions and approaches

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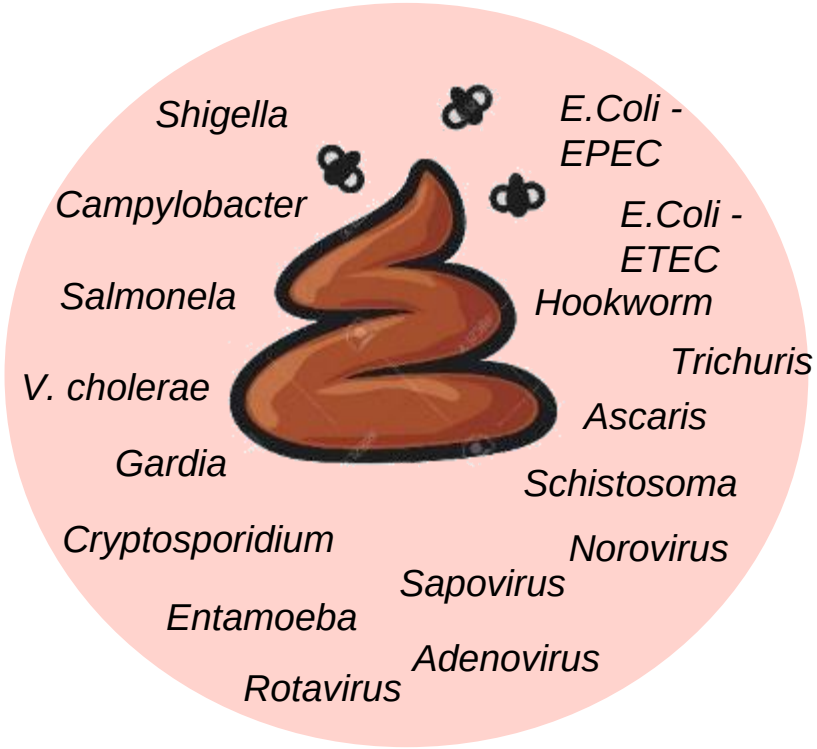
Why pathogen flows in urban eco-systems matter

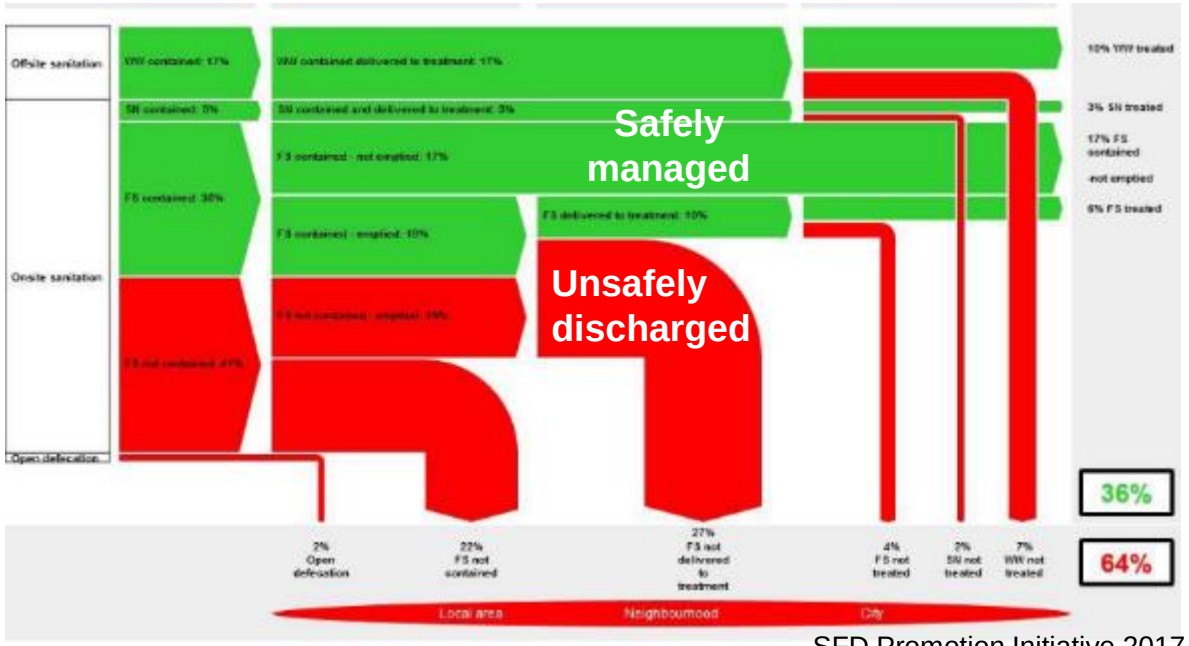
Large numbers of infectious pathogens

- Pathogens excreted in high numbers
- Numerous and varied types
- Persist in the environment



Poor management of sanitation

Failures across the service chain release untreated faecal waste into the environment



SFD Promotion Initiative 2017

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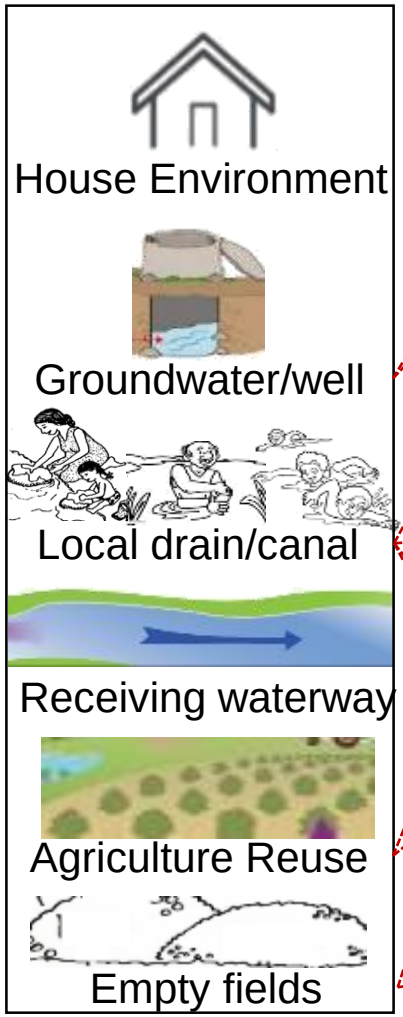
Diseases are spread across the urban environment

Various points of exposure



Multiple transmission pathways

- **Water consumption** - direct
- **Indirect water consumption** – secondary water supply, swimming, bathing, flooding
- **Food: faecal consumption -** contaminated produce through water or soil)
- **Hands & fomite: faecal consumption -** faeces in household environment or poor hygiene)
- **Soil to Skin** –faeces in environment, especially for children playing
- **Water to Skin** – swimming, bathing, washing
- **Vector flies and mosquitos -** faeces in environment or open drain)

Burden of disease

- Diarrhea
- Roundworm & whipworm
- Hookworm
- Trachoma
- Schistosomiasis
- Lymphatic filariasis

>23 million DALYs due to inadequate sanitation

≈5 million DALYs due to inadequate WASH

DALY - Disability-Adjusted Life Year

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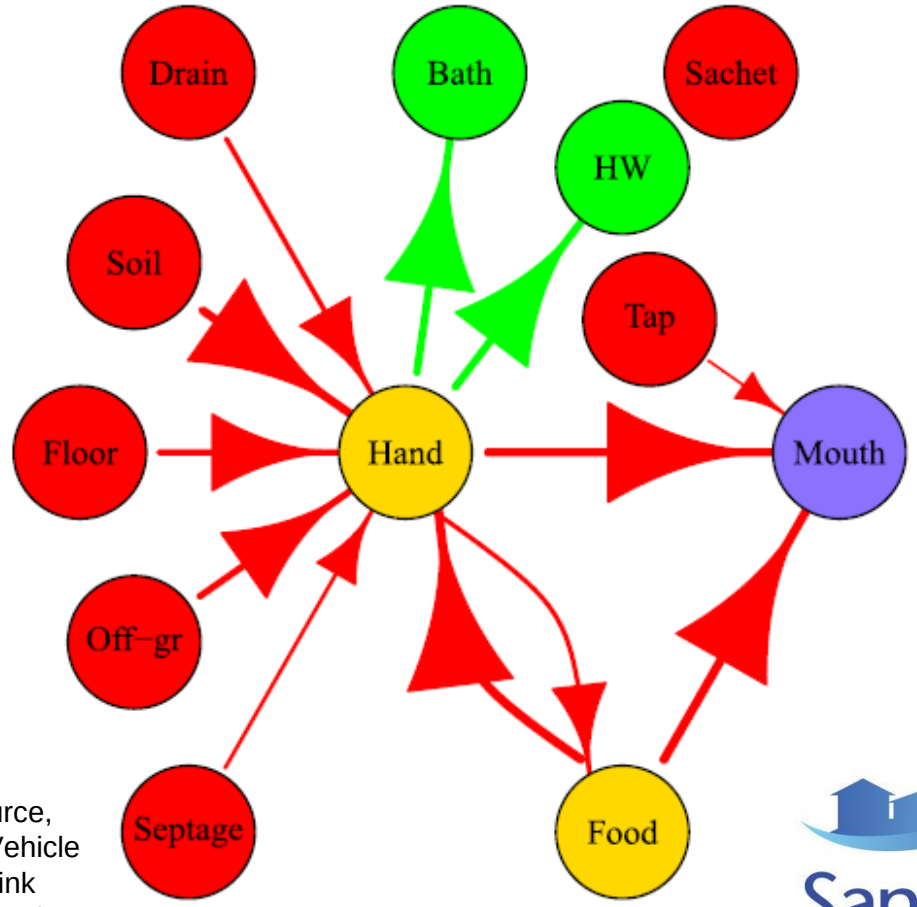
Source: Prüss-Ustün et al 2014, Prüss-Ustün 2016, Pullan et al 2014

Children are particularly at risk from multiple transmission pathways in household environment

Representation of pathways of faecal microbes transferred to children 2-5 years in Accra Ghana



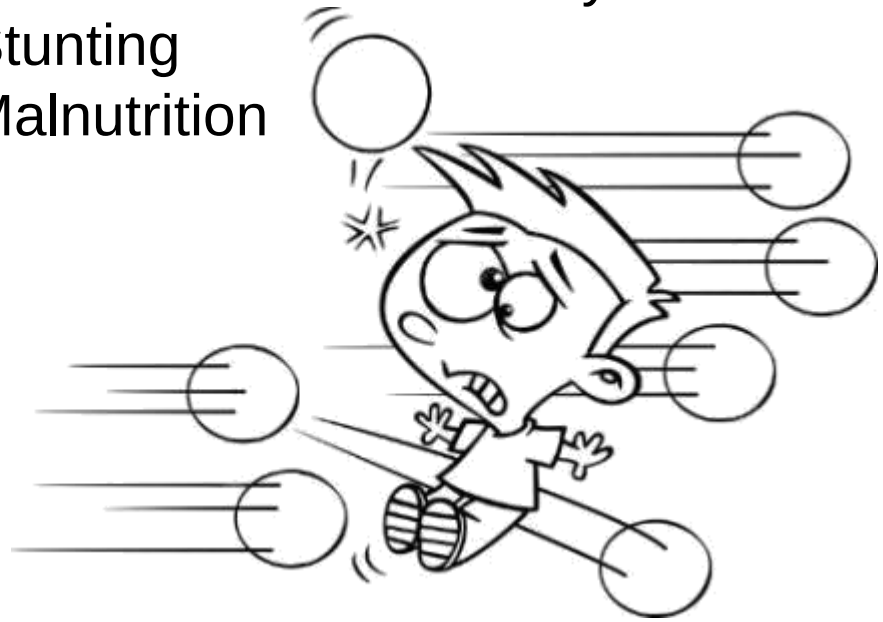
Red: Source,
Yellow: Vehicle
Green: Sink
Blue: Ingestion

Wang, Y. et al. 2017

SaniPath

Inadequate sanitation has a significant impact on child health in low and middle income countries

- Diarrhoea
- Environmental enteric dysfunction
- Stunting
- Malnutrition



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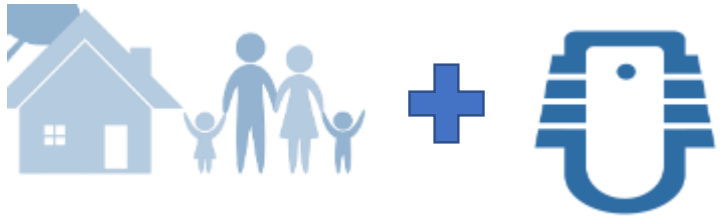
Providing a toilet may not solve the problem

Research has conflicting results on the impact of sanitation on health:

Synthesis of studies found typical 30-40% reduction in diarrheal disease (Wolf 2014)

vs

A RCT study in India found little benefit of latrine interventions on child diarrhoea, helminth infection or malnutrition (Clasen et al. 2014)



General consensus that reducing exposure to pathogens is beneficial for health

However, to achieve health benefits we should consider how to:

- ✓Address the multiple faecal waste discharges to the environment
- ✓Intercept the numerous pathways of exposure (water, food, drains, living area)
- ✓Ensure a certain community coverage is achieved (heard protection)

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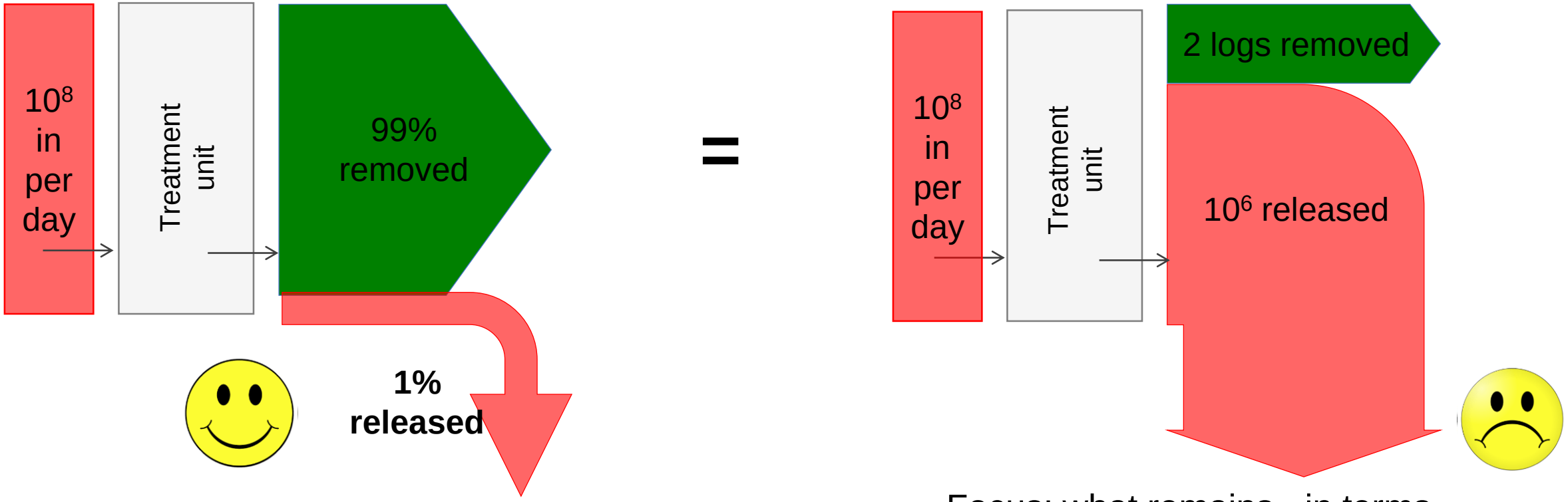
Misperceptions about how much primary onsite treatment removes pathogens

99% pathogen removal **is the same** 2 logs removal



Focus: what is removed

Focus: what remains - in terms of **potential infectious doses**

Source: Mitchell et al. 2016

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Gaps remain – particularly our understanding of how current sanitation investments reduce health risk

Does **regular emptying of sludge** improve the effluent quality?

How pathogens are **separated** into the **sludge versus effluent?**

In which contexts does **leakage** of effluent **to groundwater** matter?

Many knowledge gaps

Could different **septic tank designs** improve pathogen removal or inactivation?

Does **secondary treatment** ('safe' under SDG 6.2) sufficiently removes pathogens?

If and where is **upgrading of containment** the right investment?

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Can simplified system modelling help to untangle the mess?

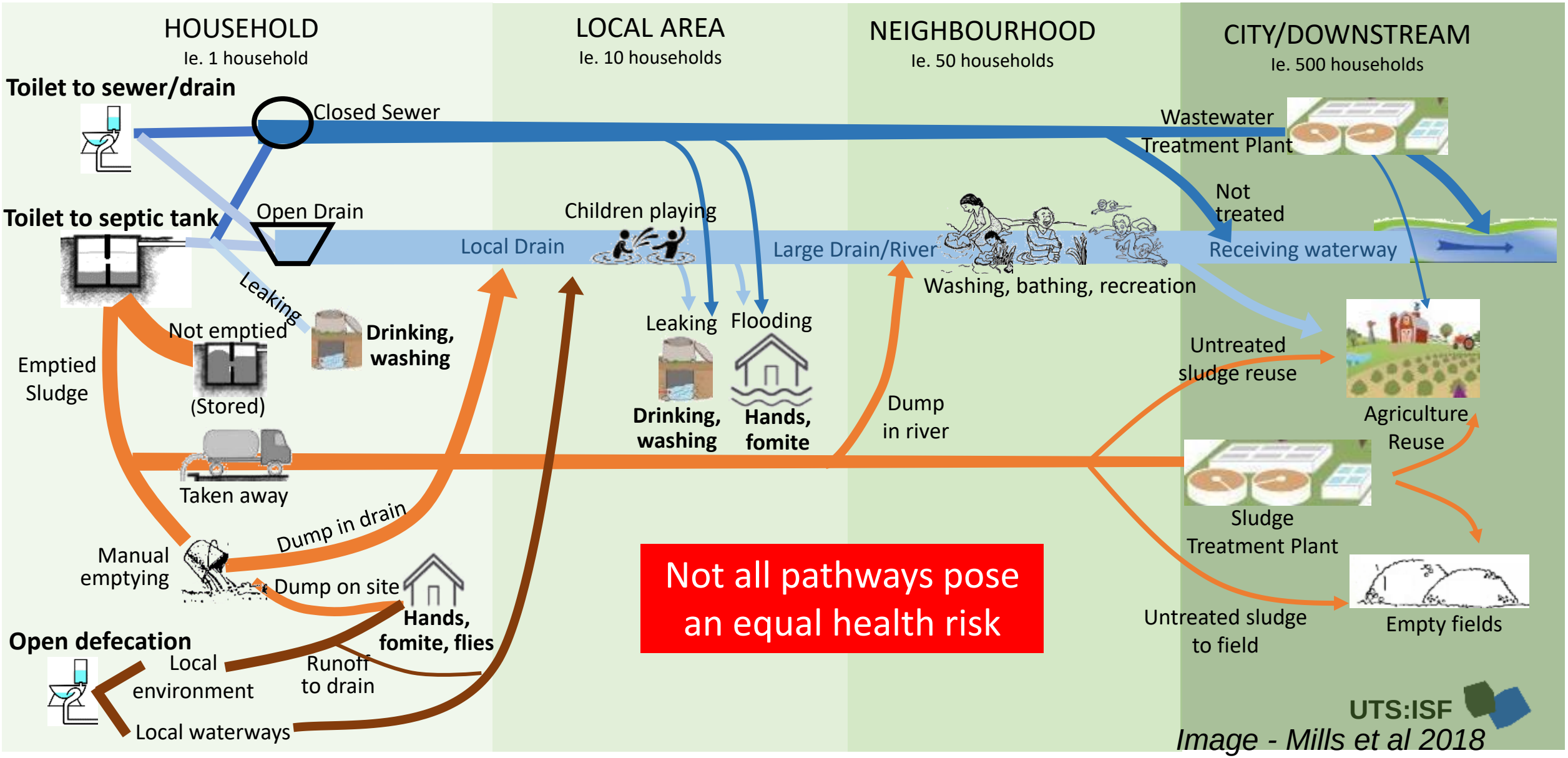
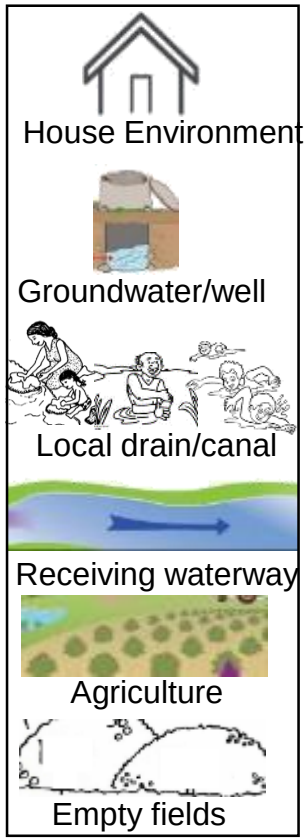


Image - Mills et al 2018

Bringing together sanitation and health assessments

to improve understanding of pathogen flows and compare health risks

Pathogen concentration at point of exposure



Volume consumed/ time exposed

- **Water consumption**
- **Indirect water consumption**
- **Food consumption**
- **Fomite & Hands**

- **Soil to Skin**
- **Water to Skin**
- **Vector flies**

Based on literature, SaniPath, Participatory Risk Assessment

= Dose of each pathogen consumed per person per day

QMRA Approach to calculate DALY

- Dose response relationship for each pathogen
- Probability of illness of each pathogen
- Frequency of exposure and proportion population exposed
- DALY for each pathway and overall

Based on literature, commonly used in water quality risk assessment

Apply the model to different scenarios to assistt with decision making

Test different improvement to the sanitation system

Compare how DALY changes for different exposure pathways and overall

DALY - Disability-Adjusted Life Year

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Systems modelling to understand and assess improvements

Modelled change in estimated DALY per person per day from base case for different sanitation improvement options

Point of exposure

Sanitation improvement

Improvement Option (refer to base case in Table 2, and detailed of options described in S7)	Household Environment	Groundwater	Local Drain	Community Drain	Downstream Waterway	Fresh Produce	Downstream Environment	TOTAL	Explanation of the Results.
1a. Reduce leakage from sewer and drain into groundwater (as 25% population assumed to use groundwater daily for drinking)	0%	↑	0%	0%	↓	0%	0%	↑	A very small change in leakage flows from sewer and drain (2% change) resulted in an overall reduction in health risk, despite a slight increase in risk in relation to downstream waterways
1b. Reduce groundwater use for drinking by half by providing an alternative water supply	0%	↑	0%	0%	0%	0%	0%	↑	The health risk associated with the groundwater pathway was significantly reduced. Groundwater risk reduction by providing an alternative water supply may have a greater positive impact than reducing groundwater pollution (1a).
2. Cover local drains	0%	0%	↑	0%	0%	0%	0%	↑	Covering drains reduced exposure and related health risks through this pathway, and resulted in a major overall reduction in health risk due to significance of this pathway.
3a. Toilet and septic tank effluent to sewer (not drain)	↓	0%	↑	↑	0%	↑	0%	↑	Reduction of faecal flows to open drain reduces subsequent exposure at local and community drains, but moves pathogen flows so increases risk at household due to no improvement in the sewer overflow/flooding.
4b. Increase sludge emptying and its delivery to sludge treatment plant	↑	0%	↑	↑	0%	↑	↑	↑	treatment reduced health risk in the downstream environment, however the population exposed was small so the overall reduction in health risk is small.
5. Improve faecal sludge treatment and wastewater treatment	0%	0%	0%	0%	↑	↑	0%	↑	Traditional treatment solution that only addresses downstream exposure pathways. This option only resu… reduction in overall health risk since emptying and conveyance were unchanged.
6. Cover drains, reduce groundwater use, discontinue reuse of untreated sludge and wastewater for food production	0%	↑	↑	0%	↑	↑	↑	↑	A non-traditional solution that addresses the key exposure pathways and resulted in the highest overall reduction in health risk compared to the base case.

Legend:

Change in DALY pppy from base case	Improvement in health risk	Worsen health risk

Relative change	No change	Small (±1-3%)	Medium (±4-13%)	High (>14%)
	0%	↑	⇧	⇧

"Improvements" may just shift the pathogens elsewhere

Non-conventional solutions may be needed to address priority pathways (i.e. covering drain)

Focusing on treatment may have low overall impact if exposure risk is highest upstream

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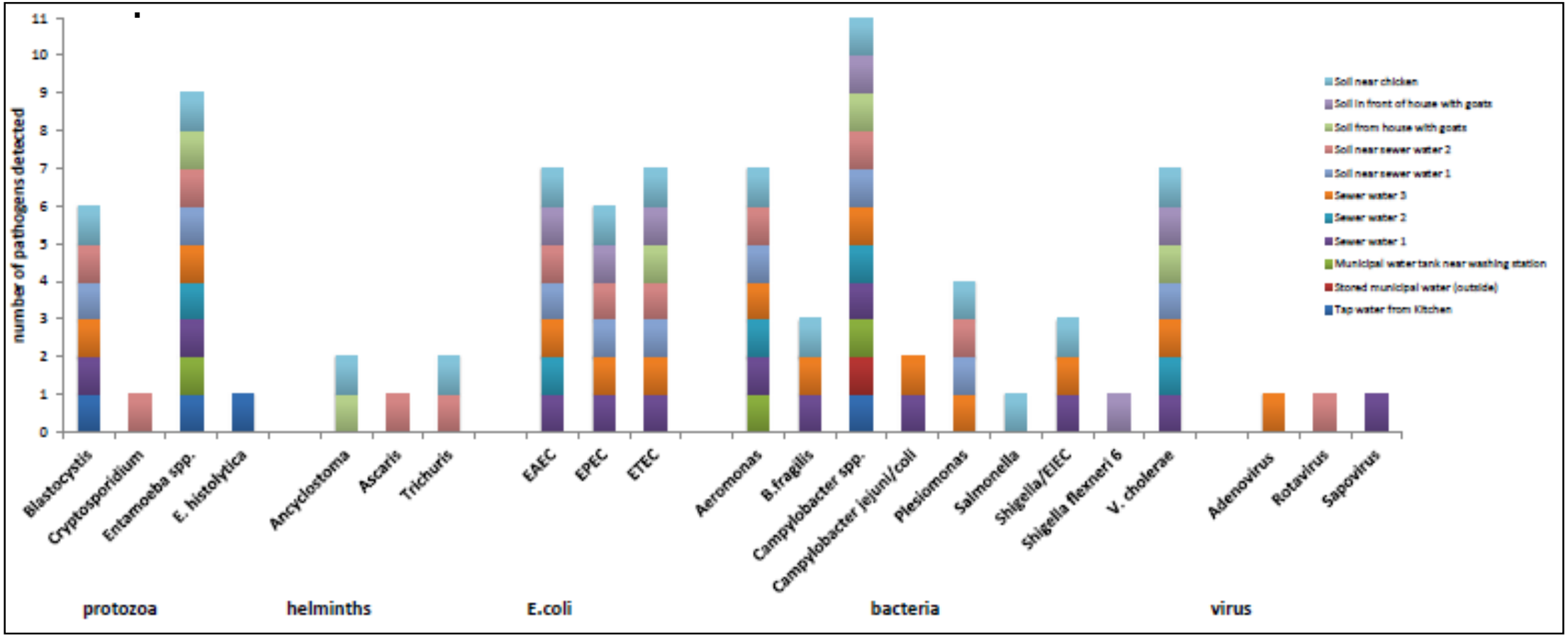
Source: Mills et al 2018

New methods and research

Improving our understanding of the mysterious flow of pathogens in urban areas

Pathogens found in water and soil samples in Dhaka Bangladesh using TAC



Source: Ahmed, T. et al. 2017, Icddr,b and University of Virginia.

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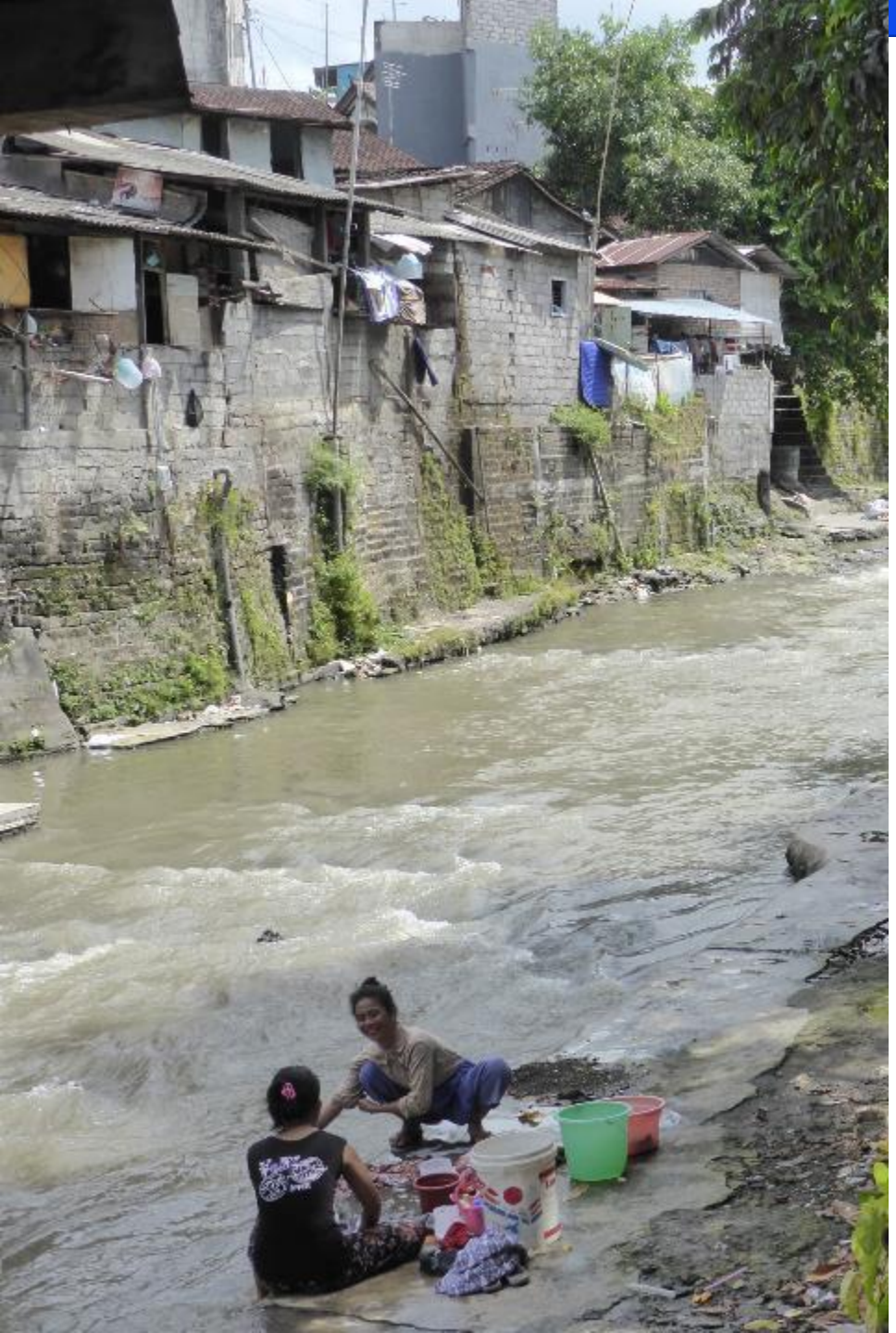

Moving forward – key gaps

- Understanding the **complementarity of different tools** (what to use and when): Sanitation Safety Planning, Shit Flow Diagram, SaniPath, System modelling.
- **Empirical research on the impact of sanitation** improvements on pathogen discharge (e.g. emptying, treatment technologies)
- **Examine the fate of different pathogens** in urban environments and treatment technologies
- Further **application of emerging methods to monitor multiple pathogens** in the environment (e.g. qPCR) particularly in developing country contexts
- **Develop improved decision making** frameworks to support multiple objectives: economic, health, environment

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Thank you

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