Development and sensitivity of a pathogen flow model for sanitation safety planning

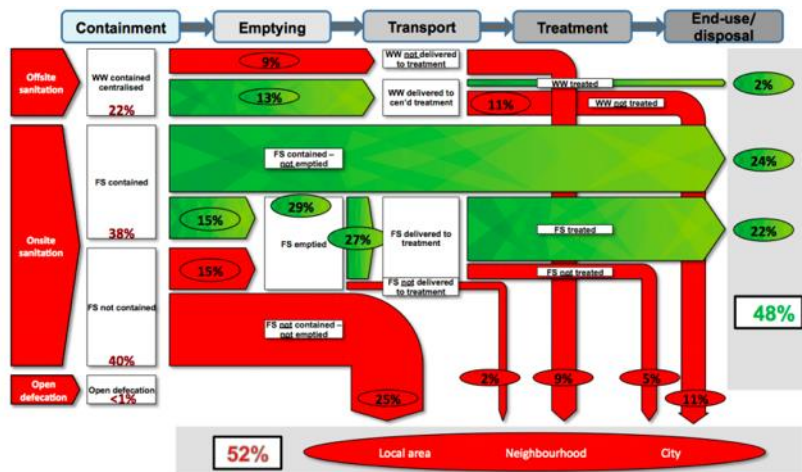23rd – 24th February 2020, Kampala, Uganda

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Introduction

- Shit Flow Diagrams help us determine where *fecal material* ends up for a given sanitation system, but there is a lack of understanding about the fate of *pathogens* in these systems

- The Global Water Pathogens Project (waterpathogens.org) provides a state-of-the-art review on excreted pathogens
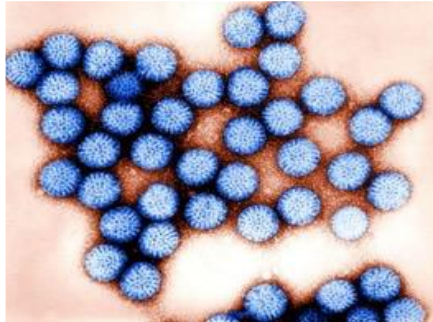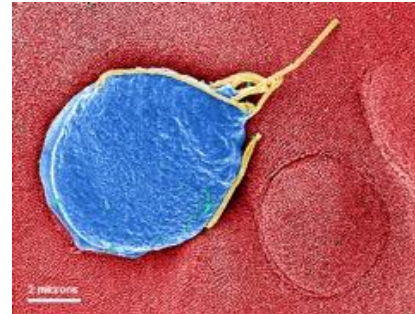
Need for high pathogen (log) reductions
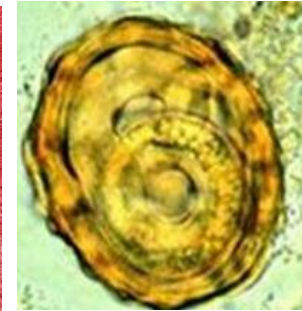

Viruses

Bacteria

Protozoa

Helminths

- Different pathogens have very different characteristics and survive at different rates in sanitation systems

- To protect public health, the overall pathogen reduction needs to be VERY high

% Reduction		Log Reduction Value (LRV)
90%	=	1 log
99%	=	2 log
99.9%	=	3 log
99.99%	=	4 log
99.999%	=	5 log
99.9999%	=	6 log

Objectives

- We developed a pathogen flow model using data from GWPP to predict the fate and transport through the sanitation service chain

- We tested the sensitivity of overall pathogen reduction to different model inputs

- We validated the model using data from real wastewater and fecal sludge treatment plants
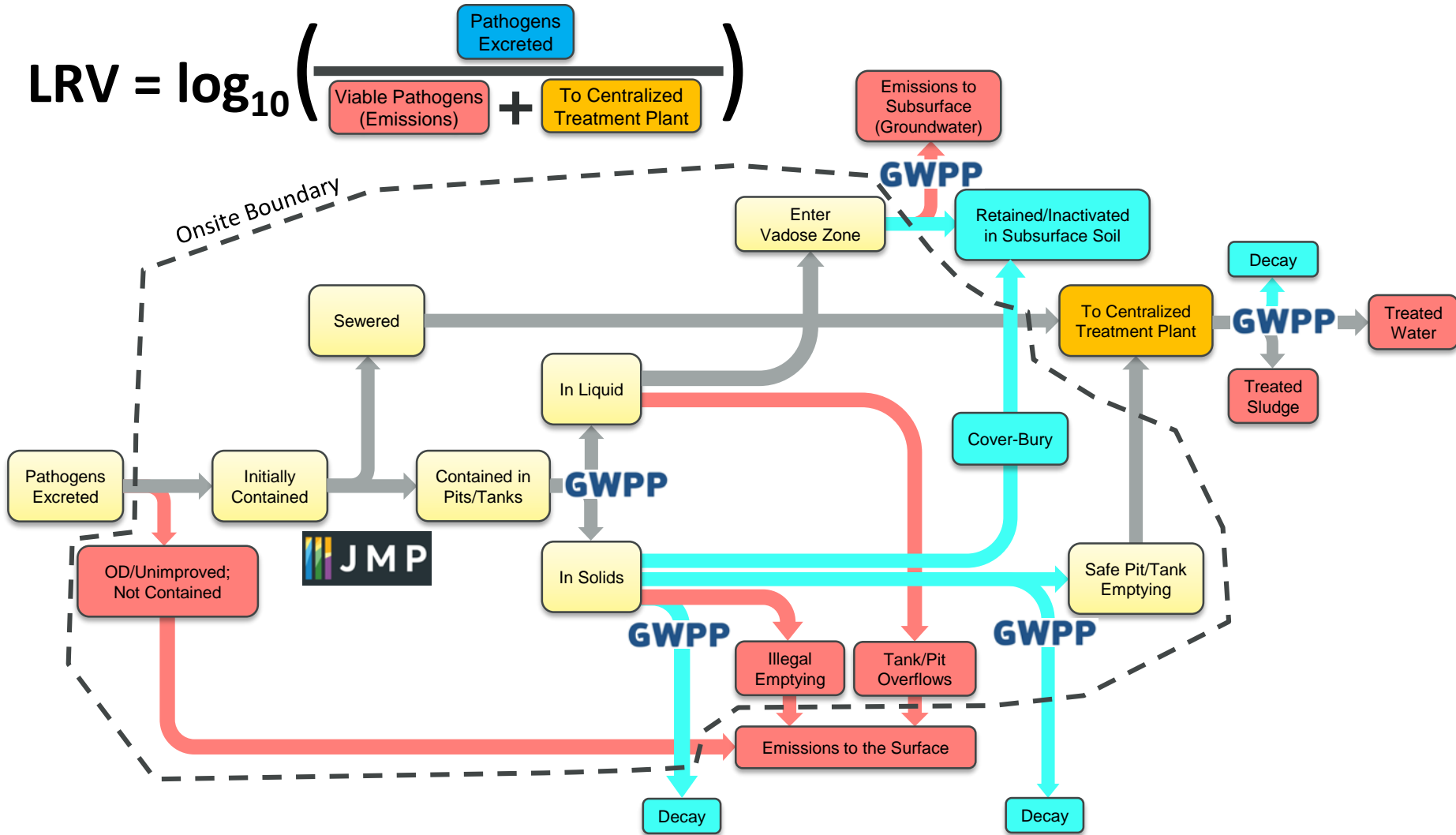
Methods

- Created a database (N = 2,268) for pathogen persistence and reduction in sanitation systems
- Developed a pathogen flow model that draws from this database and predicts the flow of pathogens through the sanitation service chain, using:
  1. User inputs about the sanitation system design
  2. User inputs about population and sanitation behaviors
  3. Persistence model for pathogens in onsite pits and tanks
  4. Pathogen fate models for centralized treatment facilities
- Used Monte Carlo simulations (50,000 runs) to test the sensitivity of modeled pathogen reduction to data inputs (design, operational, environmental, and behavioral aspects of sanitation systems)
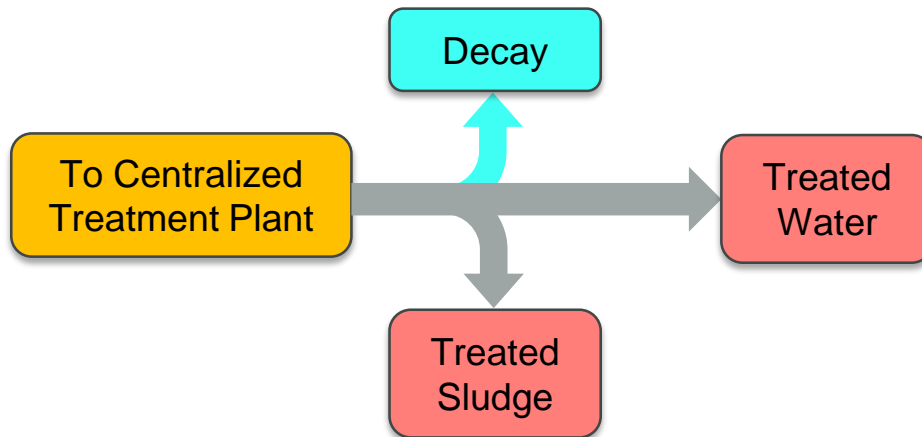
The Pathogen Flow Model

$$LRV = \log_{10}\left(\frac{\text{Pathogens Excreted}}{\text{Viable Pathogens (Emissions)} + \text{To Centralized Treatment Plant}}\right)$$

$$LRV = \log_{10}\left(\frac{\text{To Centralized Treatment Plant}}{\sum \text{Still viable}}\right)$$

Inputs: Sanitation technologies and behaviors

- Household size
- Type of sanitation facility **JMP**
- Containment of wastes
- Emptying of onsite facilities
  - Time since last emptying
  - Frequency of emptying
- Disposal/conveyance of excreta
- **Use of pit additives**
- **Watertight septic tank**
- Leach system
- **Depth to groundwater**
- **Subsurface soil type**

In fecal sludge, helminth eggs persist longer than viruses and bacteria

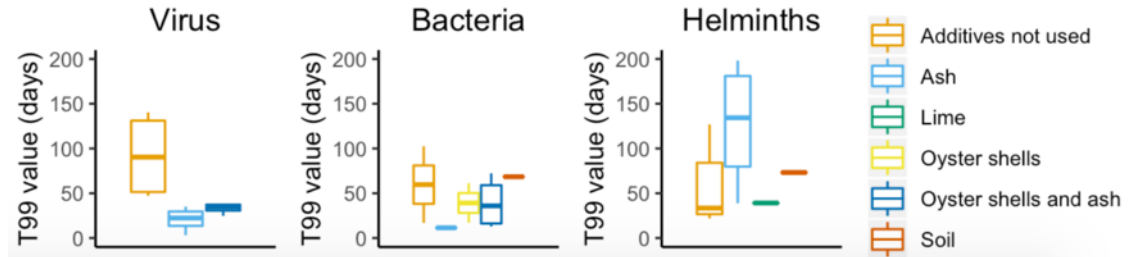The use of different additives (e.g., lime and urea) can cause more rapid pathogen decay in fecal sludge
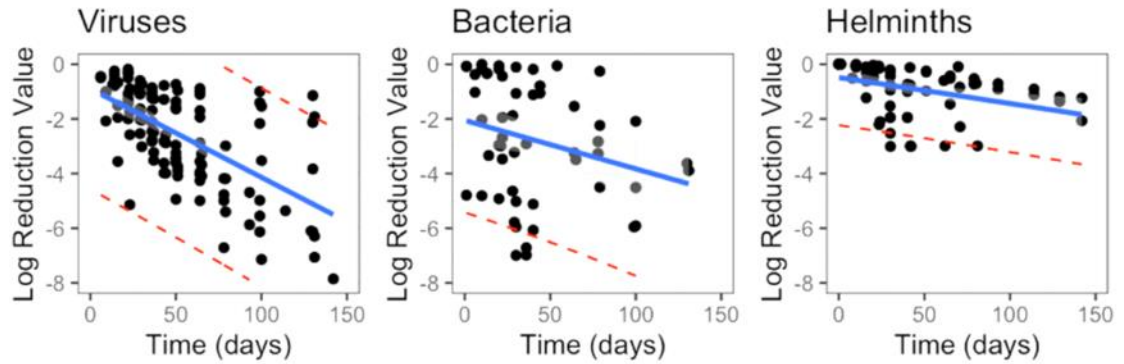

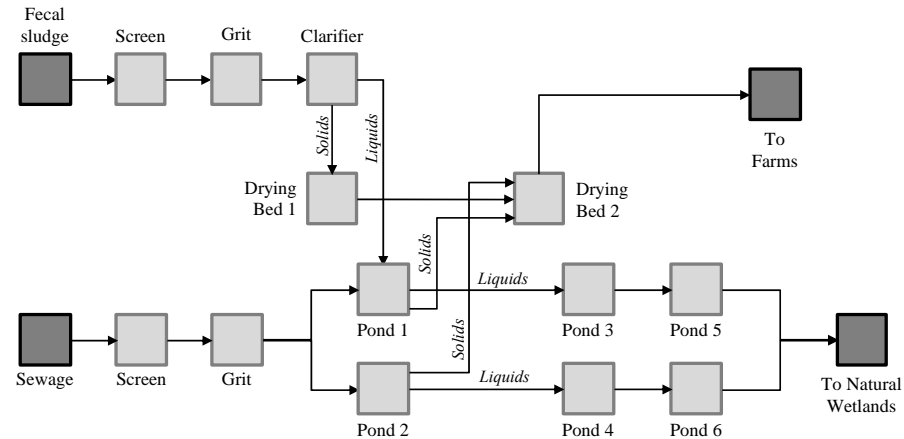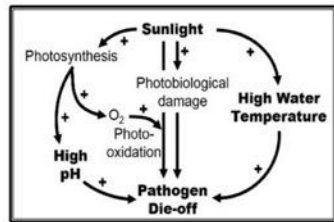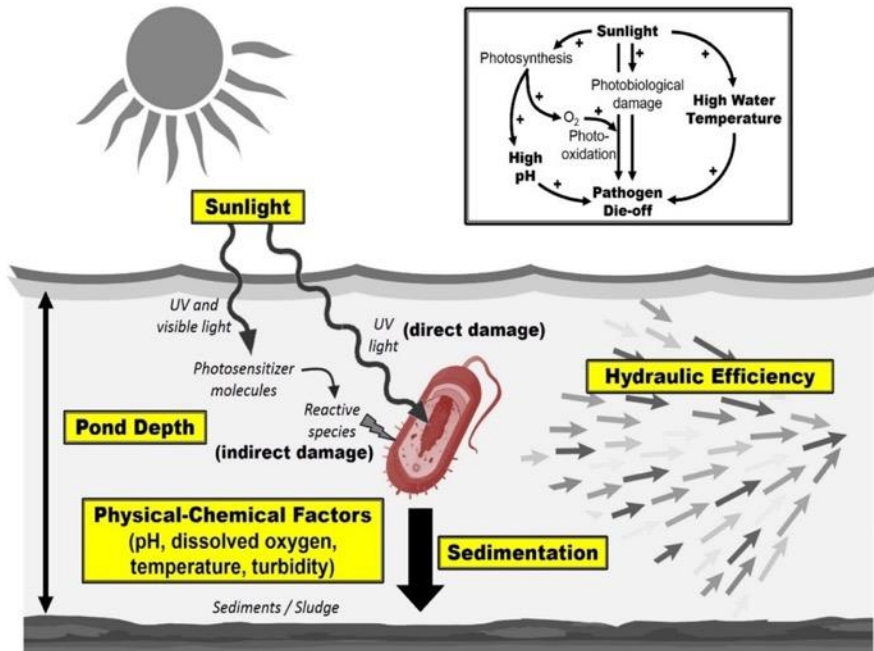Image credit: Dean Satchell, SuSanA Forum

Example: Stabilization Ponds (Lagoons)

Pathogen reduction is affected by:

- Pond depth

- Retention time (pond volume)
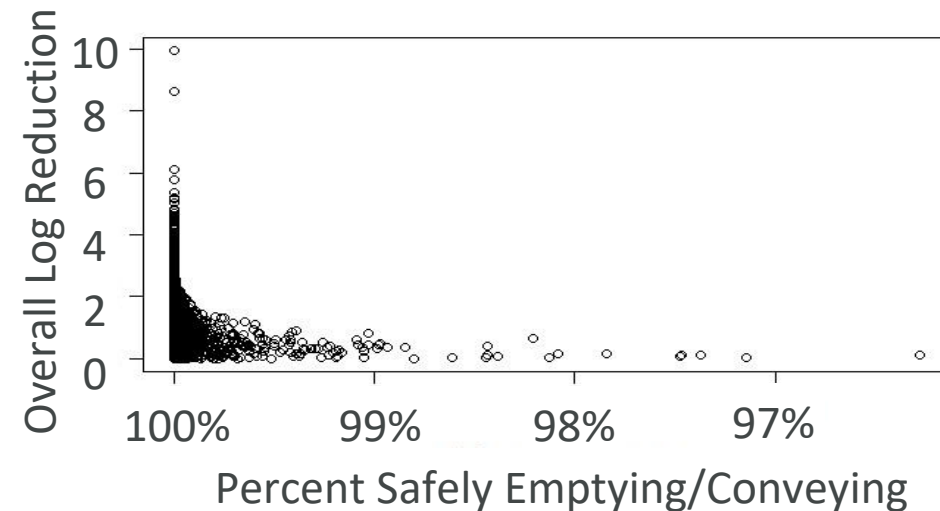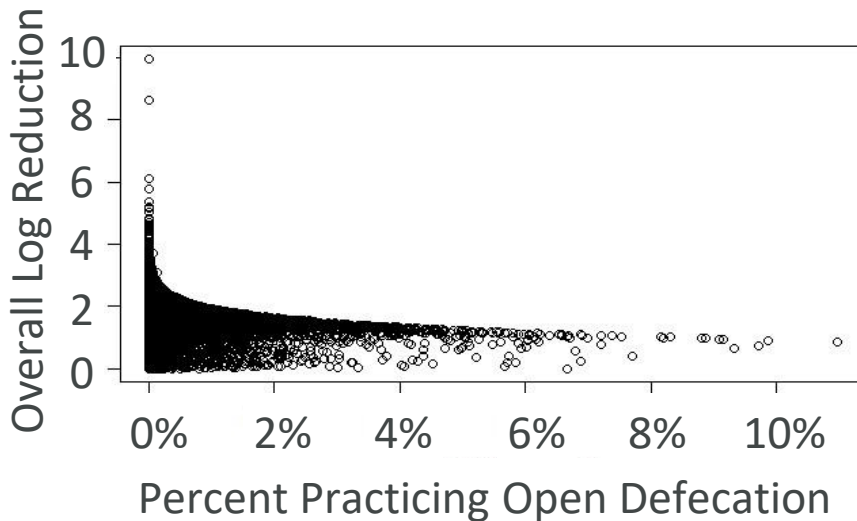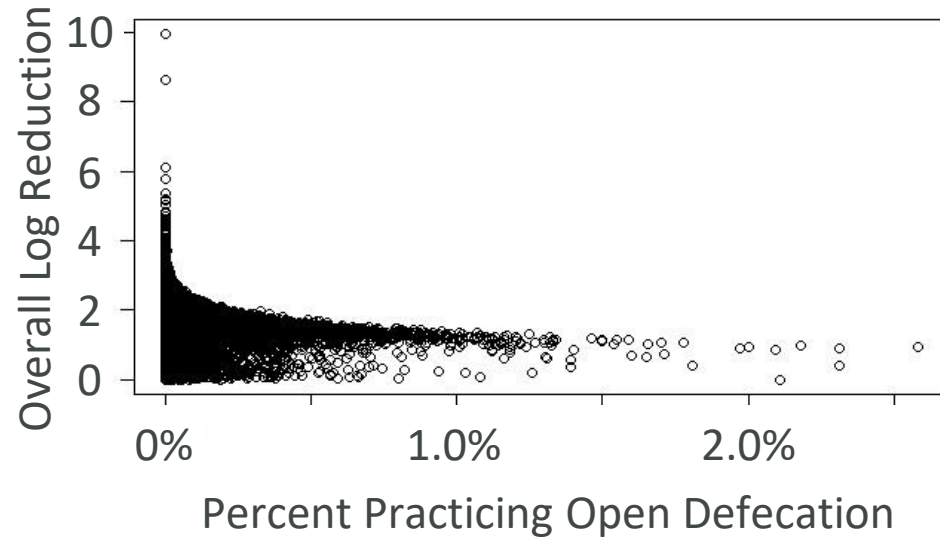
- Sunlight, temperature

Results of Sensitivity Analysis

Overall reduction of pathogens was consistently below 99% until:

- Open defecation is eradicated

- Unimproved sanitation is eliminated

- Safe emptying and conveyance to treatment facility or safe disposal is at 100%

Results of Sensitivity Analysis

Regardless of the efficiency of the centralized treatment plant, the overall pathogen reduction through the entire sanitation service chain remains low until:

1. Eliminate open defecation

2. Provide improved sanitation facilities for 100% of the population

3. Ensure that 100% of the non-sewered population is either safely covering and burying fecal sludge, or getting it safely emptied and conveyed to a treatment plant

Key Take-Away Messages

To minimize microbial hazards from sanitation systems, **onsite sanitation interventions should be prioritized first** before centralized treatment upgrades

Pathogen flow models can be used to evaluate decisions about improvements or interventions to sanitation systems
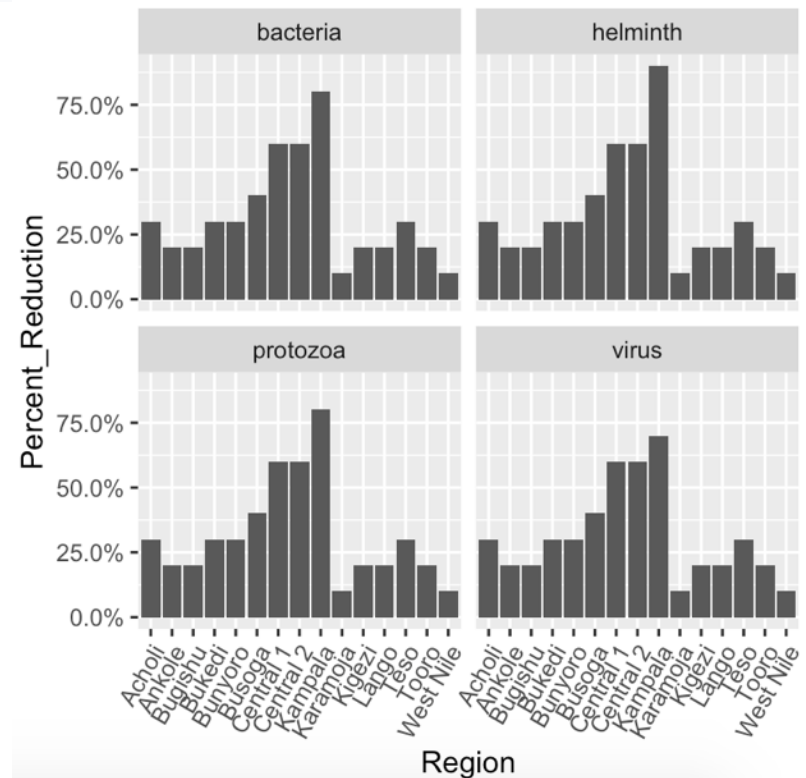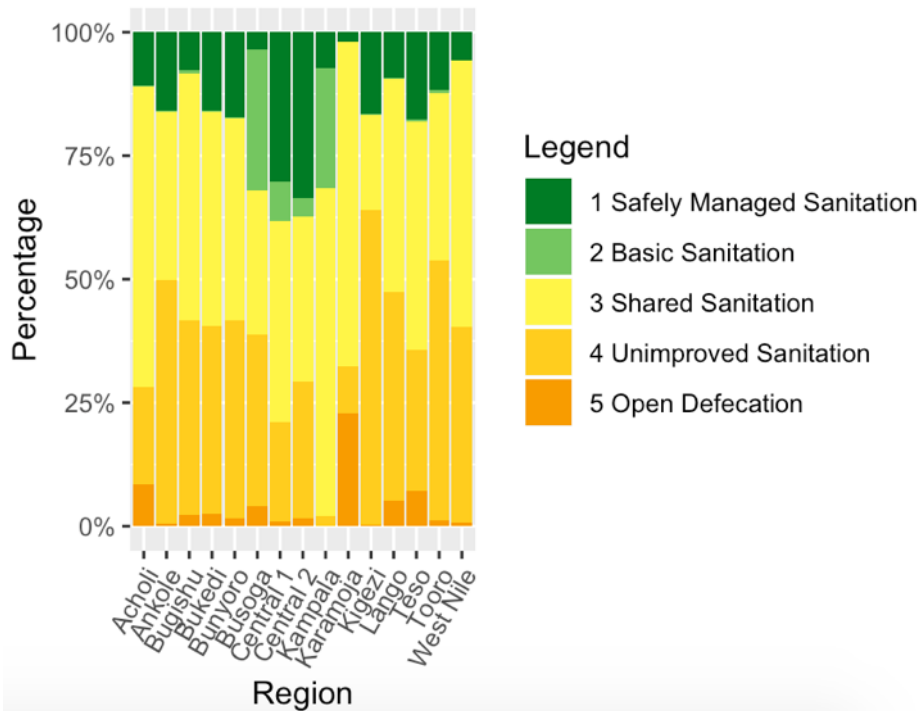
GWPP-K2P: Pathogen Flow Tool

Thank you! Any questions?

Scan this code for more information about our project