How can SaniPath build on the SFD's?

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Case Study: Vellore, Tamil Nadu, India

- Two neighborhoods:
  - Cinna Allapuram (CAP) and Old Town (OT)
- Collaboration with Christian Medical College, Vellore, India and MAL-ED study

Study Objectives

- Objective 1: To understand the dominant pathways of exposure to fecal contamination in two neighborhoods of Vellore, India.
  - Part 1: SaniPath Tool Deployment
- Objective 2: To quantify the associations between <u>household toilets</u> and <u>fecal sludge</u> <u>management</u> (FSM) with fecal contamination in different urban contexts
  - Part 2: Creating SFDs from SaniPath Data
  - Part 3: Extended SaniPath data collection and Spatial Analysis

Part 1: Deployment of the SaniPath Tool

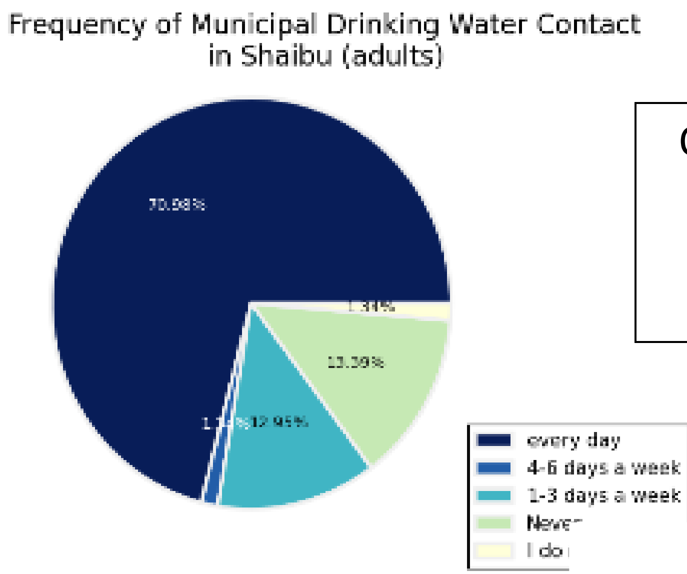
- Systematic, customizable method to collect relevant data on exposure to fecal contamination
- Help guide decision-making and advocacy surrounding urban sanitation
- Synthesize data using open-source software package

SaniPath Field Methods

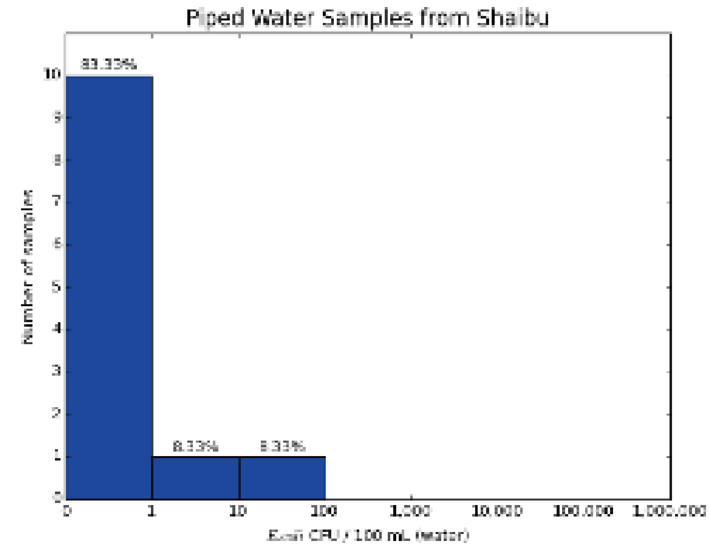
- Environmental Samples
  - 10 public area samples/ neighborhood, 25 HH samples
- Behavioral Surveys
  - Household surveys (100/neighborhood), School Surveys (4/neighborhood), community surveys (4/neighborhood)
- GPS data

SaniPath Tool Exposure Assessment Analysis

Behavior Frequency

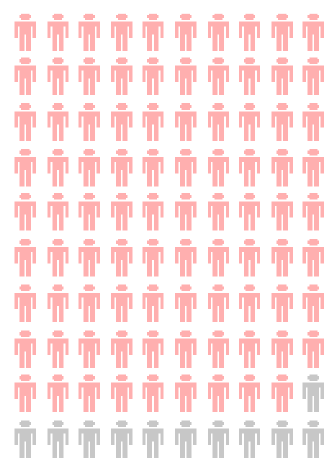


Environmental Contamination



Other parameters: intake volumes, duration of exposure, etc.

Piped Water (Adult)
Percent Exposed = 89%
Log10 Dose 3.1



Tool uses Bayesian analysis to estimate the distribution of environmental contamination and frequency of exposure.

The mean dose and proportion of the population exposed are summarized from simulated distributions and displayed in risk profiles (left).

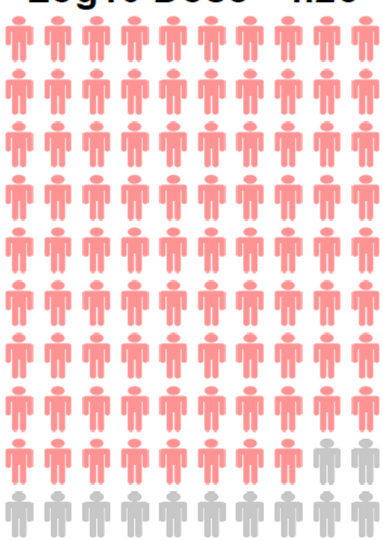
Tool results from CAP

Piped Water Adults
Percent Exposed = 97 %
Log10 Dose= 4.95

Drain Water Adults
Percent Exposed = 57 %
Log10 Dose= 3.78

Tool results from OT

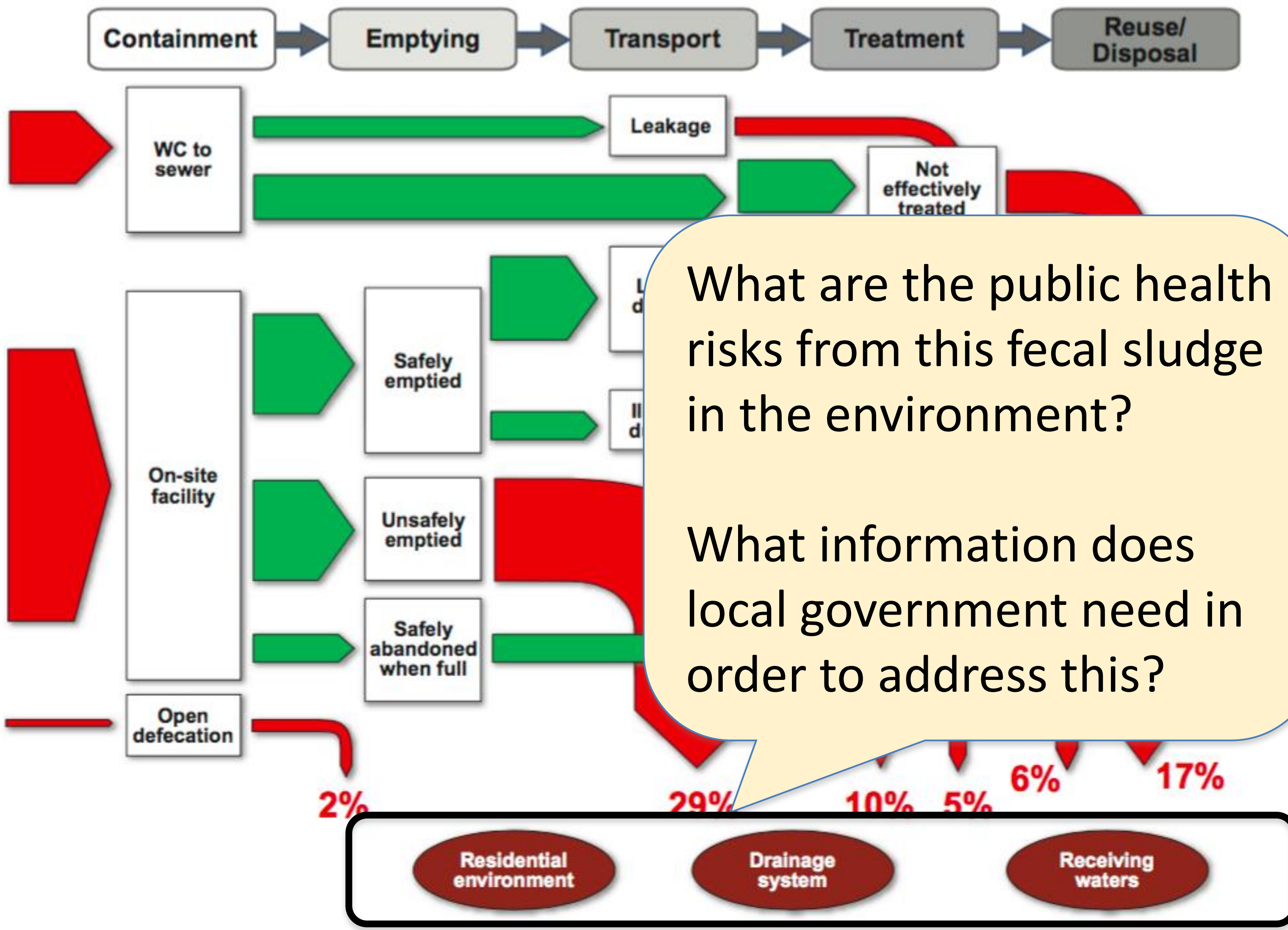
Piped Water Adults
Percent Exposed = 88 %
Log10 Dose= 4.25



Drain Water Adults
Percent Exposed = 76 %
Log10 Dose= 4.1

- Municipal piped drinking water and drain water posed the highest risks of exposure of adults and children living in CAP and Old Town

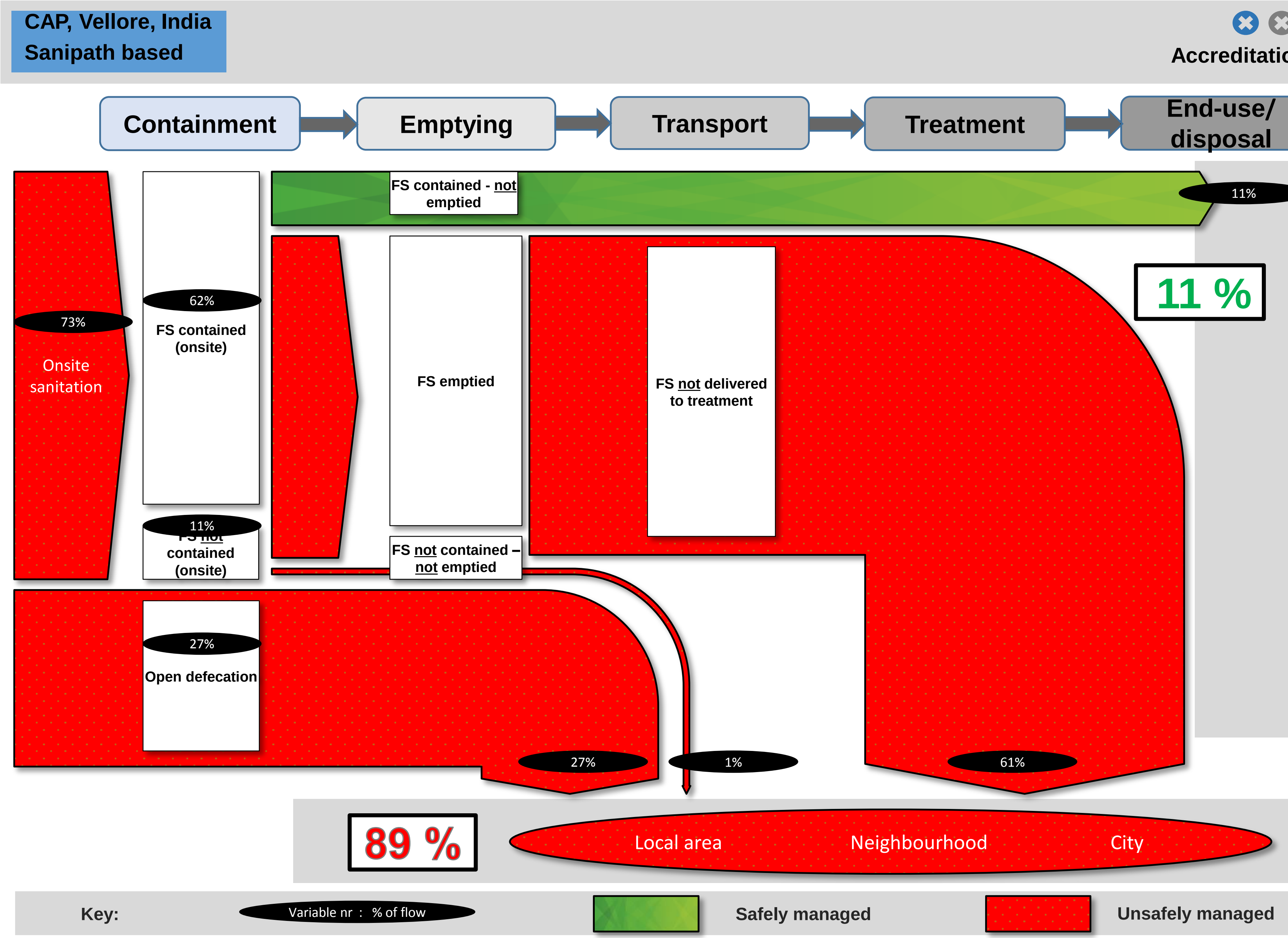
Part 2: Building Shit Flows Diagrams



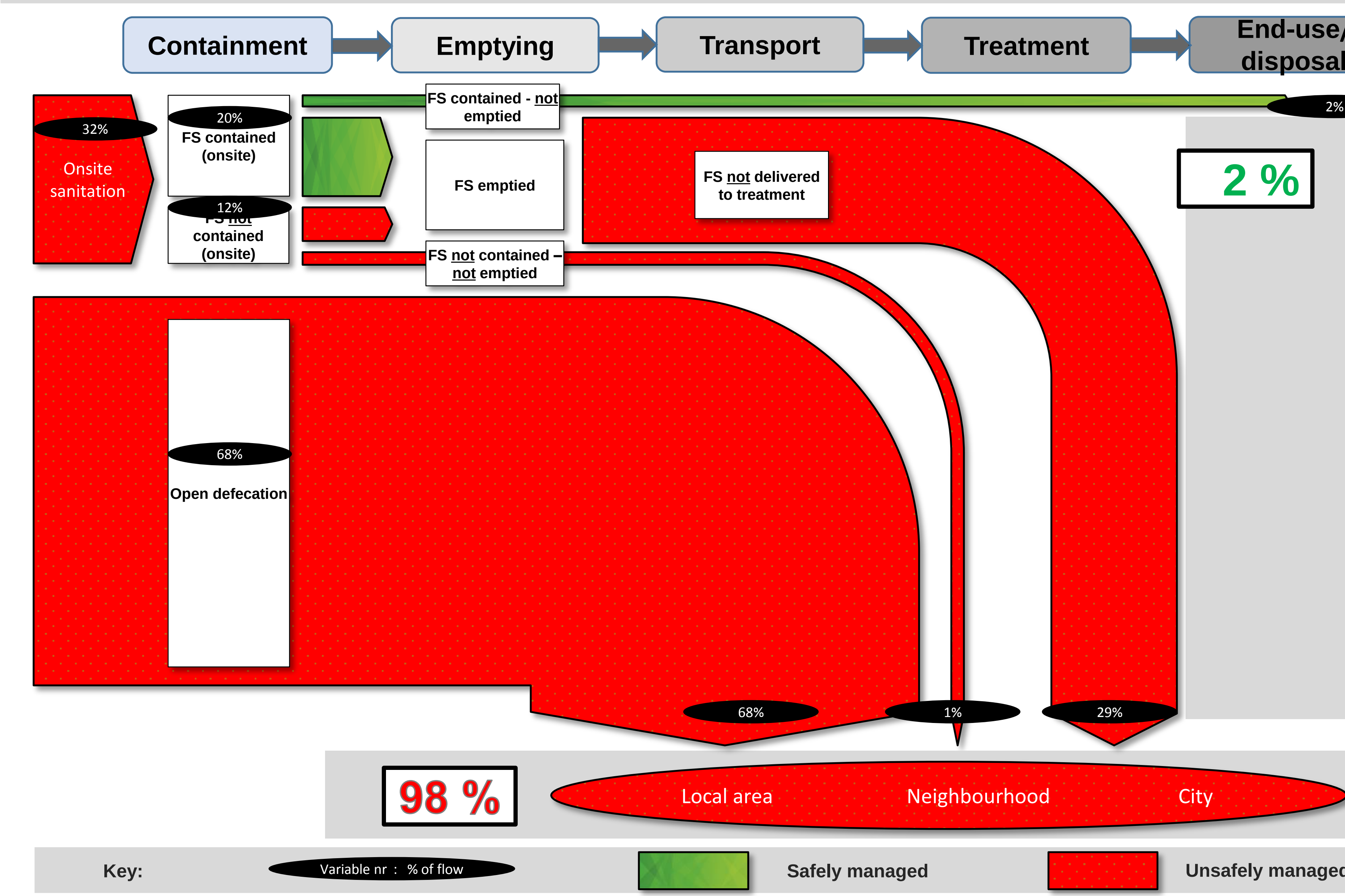
What are the public health risks from this fecal sludge in the environment?

What information does local government need in order to address this?

SFD for Dakar, Senegal (Blackett et al., 2014)


CAP, Vellore, India
Sanipath based
Accreditatio
Containment
Emptying
Transport
Treatment
End-use/ disposal
FS contained - not emptied
11%
11 %
73%
Onsite sanitation
62%
FS contained (onsite)
FS emptied
FS not delivered to treatment
11%
FS not contained (onsite)
FS not contained – not emptied
27%
Open defecation
27%
1%
61%
89 %
Local area
Neighbourhood
City
Key:
Variable nr : % of flow
Safely managed
Unsafely managed

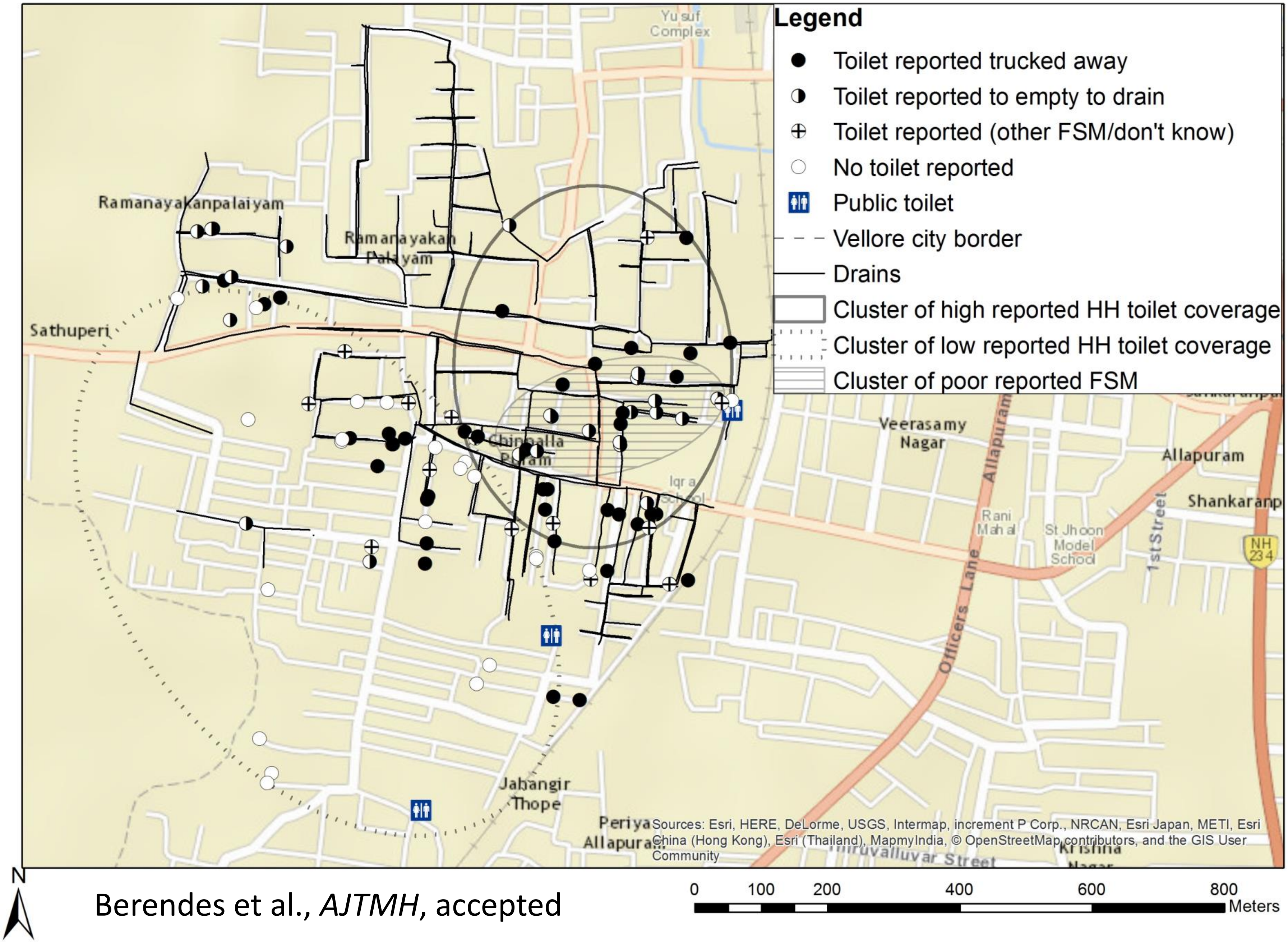
Old Town, Vellore, India
Sanipath based



Part 3: Spatial Analysis

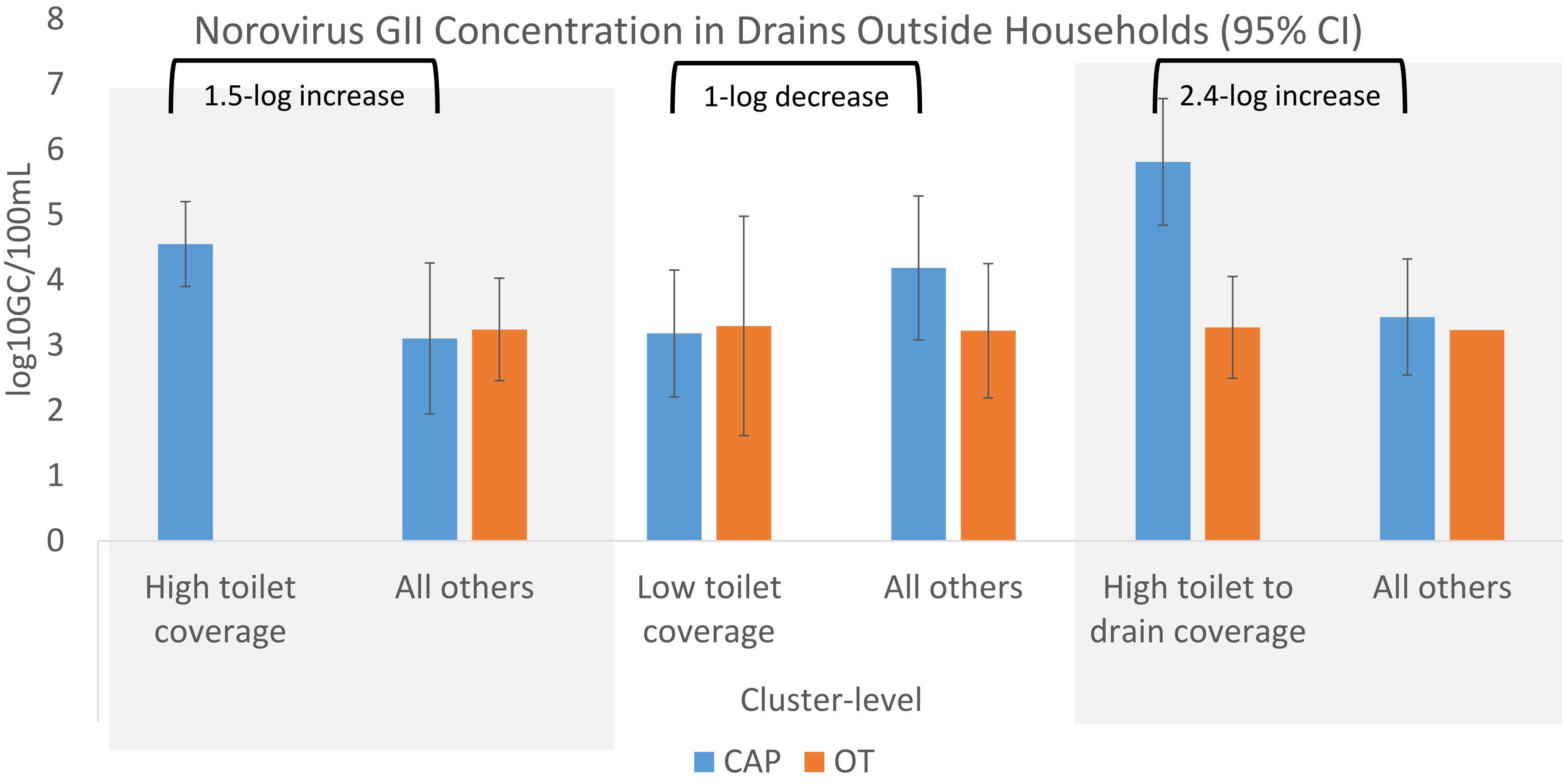
- Kulldorff's Bernoulli Spatial Scan
- Microbial concentrations in environmental samples (outcome) and household survey characteristics (predictors) assessed for spatial clustering

Figure 1a: Sanitation coverage and clustering in Chinnallapuram



Berendes et al., *AJTMH*, accepted

Clustering of Toilets and Poor FSM was Associated with Increased Norovirus GII Concentrations in Drains Outside Households



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Summary Points

- The SaniPath Deployment showed Piped Drinking Water and Open Drains posed the highest risk of exposure in CAP and Old Town
- The SFDs showed that estimated household toilet coverage: 73% (CAP) vs. 32% (OT); estimated proportion of safely-managed excreta: 11% (CAP) vs. 2% (OT)
- Additional spatial analysis showed that areas with higher coverage of toilets and poor FSM had more pathogens in drains

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- Study Participants
- Paper in submission to AJTMH

Thank You

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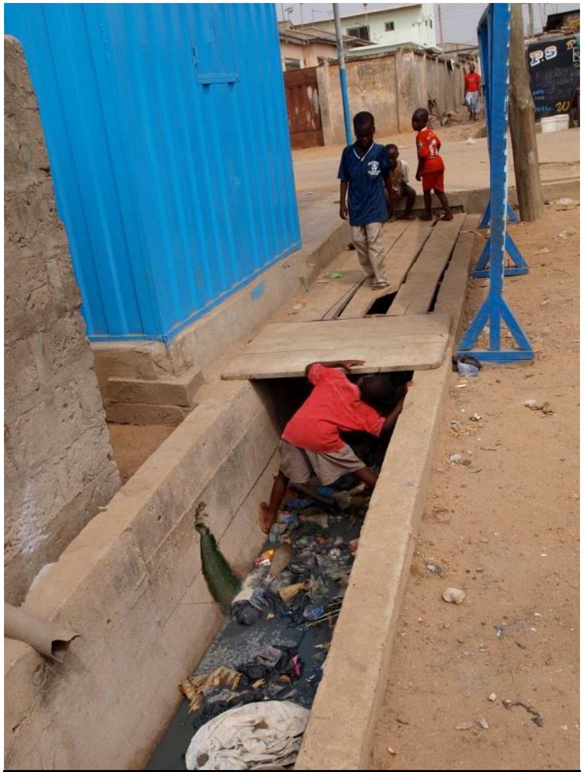
Appendix

Determination of intake values

- The intake value is defined as the volume ingested per exposure event.
- To determine the intake value, we first define the event. We then define the following parameters for children and adults.
  - Exposure Time Unit
    - minutes, days, events
  - Duration of Event
    - in minutes, or not applicable for some exposures
  - Intake Volume
    - in mL

Age group

- Given differences in body size and behaviors, separate intake values are calculated for children and adults.



Child entering a drain to retrieve a ball

Woman washing above a drain

We assume that children and adults come into contact with drains differently. For example, a child may intentionally enter a drain and may stay in the drain longer. An adult may incidentally be exposed to drain water while working near a drain.

Defining the event

- **Drain Water**
  - Event=entering a drain for any reason (accidental, incidental or intentional)
- **Drinking Water**
  - Event= one day of drinking water from a municipal source

Exposure time unit and duration of event

- Exposure Time Unit
  - Some exposures are calculated per day, while others are calculated per event.
    - Drain exposure is calculated in terms of number of drain contact **events per month.**
    - Municipal drinking water exposure is calculated in terms of the number of **days per month** that municipal water is consumed (regardless of the number of times in one day water is consumed).
- Duration of Event
  - For some exposures pathways, like contact with surface water, the duration of event is used in addition to the intake time unit.

Intake Volume and mL ingested/event

- Intake Volume = volume (in mL) that is assumed to be ingested per event
  - Volumes were determined based on a combination of EPA values, literature review and SaniPath Phase 1 data

Exposure Pathway	Age Group	Intake Volume (mL)	Exposure Time Unit	Duration of Event	mL/ Event	Rationale	Assumptions
Drinking Water	Adults	1,043	day	n/a	1043	US EPA value for drinking water consumption per day by adults. Similar averages found in literature review of studies in developing countries.	When participants site how many days per week they drink municipal water, we assume that all of their water consumption on that day is from the municipal source.
	Children	414	day	n/a	414	Same as above but for children	Same as above
Drain Water	Adults	0.06	event	n/a	0.06	Intake volume taken from the US EPA value for an adult wading in water : 3.7ml/hour.	-Any event is likely to lead to high exposure. -There is little or no information about the duration of time adults spend in drains. Therefore, one minute is used to signify 1 drain entry event.
	Children	1	event	n/a	1.0	Inflation of adult US EPA wading value	Same as above with the additional assumption that kids spend more time in drains and have greater contact with drain water.

Methods: Calculating dose

Intake Value= volume ingested*/exposure event

*Volumes were determined based on a combination of EPA values, literature review and SaniPath Phase 1 data

Exposure Pathway	Age Group	mL/ Event
Drinking Water	Adults	1043
	Children	414
Drain Water	Adults	0.06
	Children	1.0

SFDs

- Completed with expert opinion/help of Barbara Evans and Andy Peal
  - Many assumptions made at neighborhood level
    - Neighborhood geology/risk of GW contamination
    - All waste untreated at end because treatment plant/system in Vellore
  - Data based on 100 surveys in each neighborhood
  - Categories of some responses (Likert scale) simplified into point estimates
    - E.g. “6-10” public toilet uses/month approximated as 8
  - Population estimates/estimates for children/adults based on profile of households surveyed

SFD Main messages

- Estimated household toilet coverage: 78% (CAP) vs. 33% (OT); estimated proportion of safely-managed excreta: 11% (CAP) vs. 2% (OT)
  - The only “safely contained excreta” was that which is left at the bottom of a household/public toilet tank (the leftover sludge unable to be emptied)
  - Despite high coverage in CAP, about half of household toilets discharged directly to drains
  - All public toilets had outflow pipes to open drains, but were emptied by trucks
  - Trucks emptied into drains or downstream rivers (no safe containment).

SFD Assumptions

- Data based on 100 households per neighborhood to create neighborhood-level SFD (in contrast to city-level)
- Fates of fecal sludge were adjusted for this diagram
  - Normal "puddles": household environment, drains, receiving waters
    - Actually meant as a relative "scale" of where contamination goes (HH env. = local, drains = neighborhood-level, receiving waters = city-level and beyond)
  - Changed to "local area", "neighborhood", and "city"
    - "Local area" = open defecation (OD, into OD field or drains)
    - "Neighborhood" = Discharge to drains
    - Arrows between "Neighborhood" to "City" = drains and receiving waters (locations where trucks emptied)
- Only "safely contained excreta" was that which is left in the tank itself (at the bottom) and not emptied (small proportion)
- Proportion of household vs. public sanitation "flow" was approximated based on estimated proportion of defecation events in each space
  - Assumed 30 defecation events per month
  - Monthly public toilet use reported from SaniPath questionnaire
    - Therefore proportion of public sanitation use = # monthly public toilet events/30
    - Categories given a point estimate: 0 (0), 1-5 (2.5), 6-10 (8), >10 (12)
  - Household toilet use = 1 – proportion of public sanitation use
    - If user has a toilet, otherwise assumed OD if no toilet

SFD Assumptions cont'd

- Proportion of defecation events that were public toilet/HH toilet/OD adjusted by proportion of population that were < 5 YO children, 5-12 YO children, or adults (roughly estimated from surveys, assuming all households had a child <5 and an adult and using the proportion of 5-12 YOs from the survey)
- Large assumptions based on key informant interviews (KII), observations (O), and expert opinion (EO)
    - Toilets classified as tanks with discharge to drain/emptying, not considered as "septic tanks" because of the lack of drainage fields
    - Frequency of emptying assumed to be regular (KII)
    - Risk to ground water assumed low (EO)
        - Combination of course sand and gravel (EO), 5-10m depth of water table (EO), and 0% chance of groundwater being infiltrated by poor sanitation (O, because water piped into the neighborhood)
    - Emptying assumed to be into rivers and some drains (KII and surveys)
    - Overall, large amount of information on user interface, less on toilet types/emptying
- Because no treatment plant exists in Vellore, all waste was assumed to be untreated at its end

SFD Limitations

- **SFDs**
  - Household survey provided large amount of information about user interface, key informant interviews/surveys provided some neighborhood-level information about emptying practices (assumptions made on the neighborhood-level), and expert opinion was required with regard to topology and groundwater risk.
  - Rough population-based proportions of defecation practices from household survey
  - Engineering assumptions made regarding toilet design and containment (expert opinion)
  - Arrows between neighborhood-city represent discharge to drains (from households) and truck emptying into rivers downstream
    - “local”/”neighborhood”/”city” reflect scale of sludge flow

Cluster Analysis

- Kulldorff’s Bernoulli Spatial Scan
  - Binary data
    - Household toilet (yes/no), Toilet to drain (yes/no)
  - Uses a moving ellipse to compare the actual prevalence of HHs within the ellipse with that attribute with the expected prevalence of households within that ellipse with that attribute (based on neighborhood average)
    - Tests for statistical significance
  - Simple example
    - 33/100 households in a neighborhood have a toilet
    - So, an ellipse containing 10 households should have 3-4/10 households with a toilet
    - An ellipse containing 10 households where 10/10 households have a toilet might be a significant cluster of “high coverage” of household toilets

Analysis

- Microbial concentrations in environmental samples
  - Modeled as outcome
    - Linear regression (concentration of *E. coli*, *EAEC*, or NoV)
    - Logistic regression (presence/absence of *EAEC* or NoV)
- Household survey characteristics
  - Used as predictors
    - Household-level
    - Cluster-level
- Both assessed for spatial clustering

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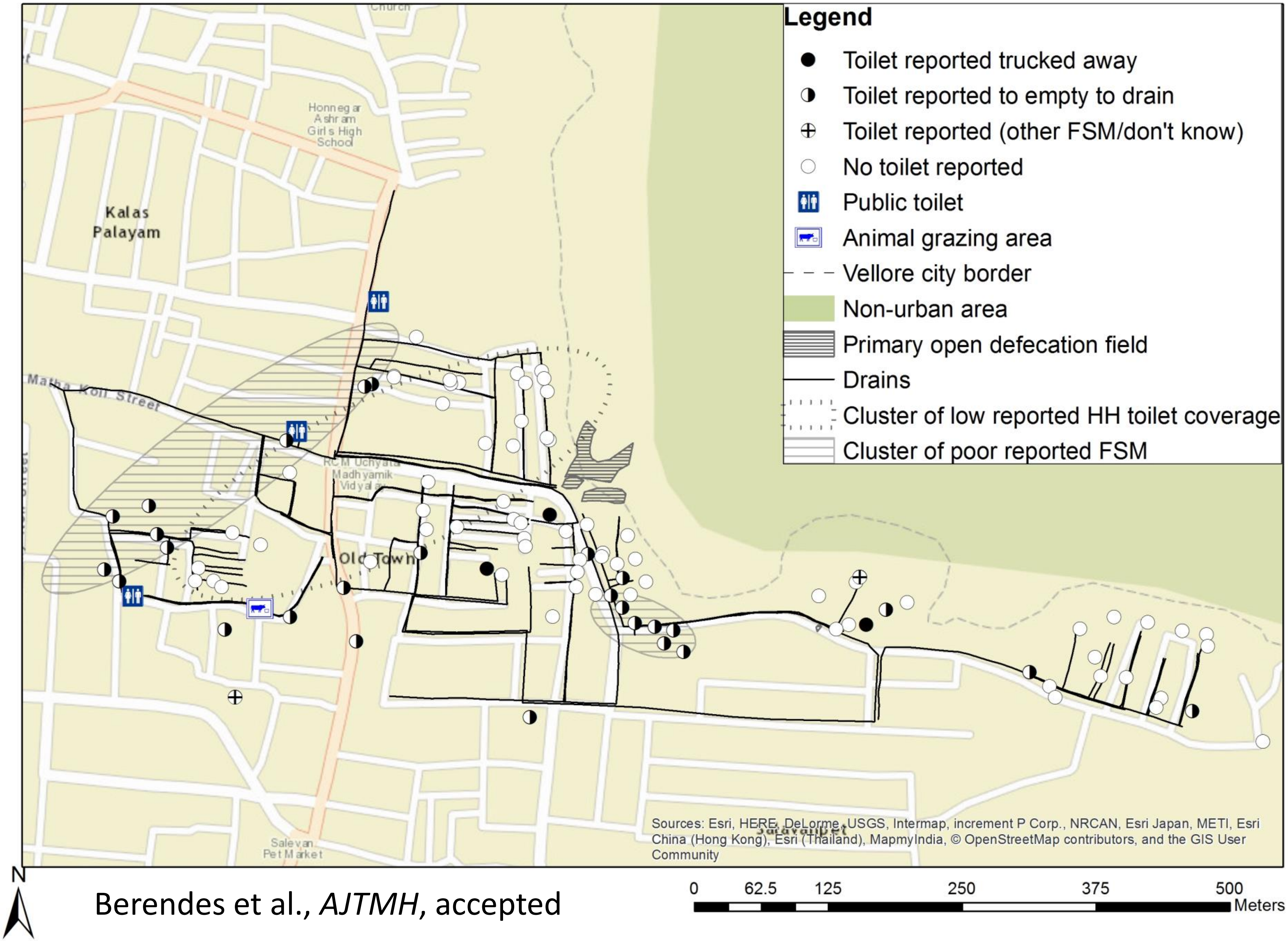
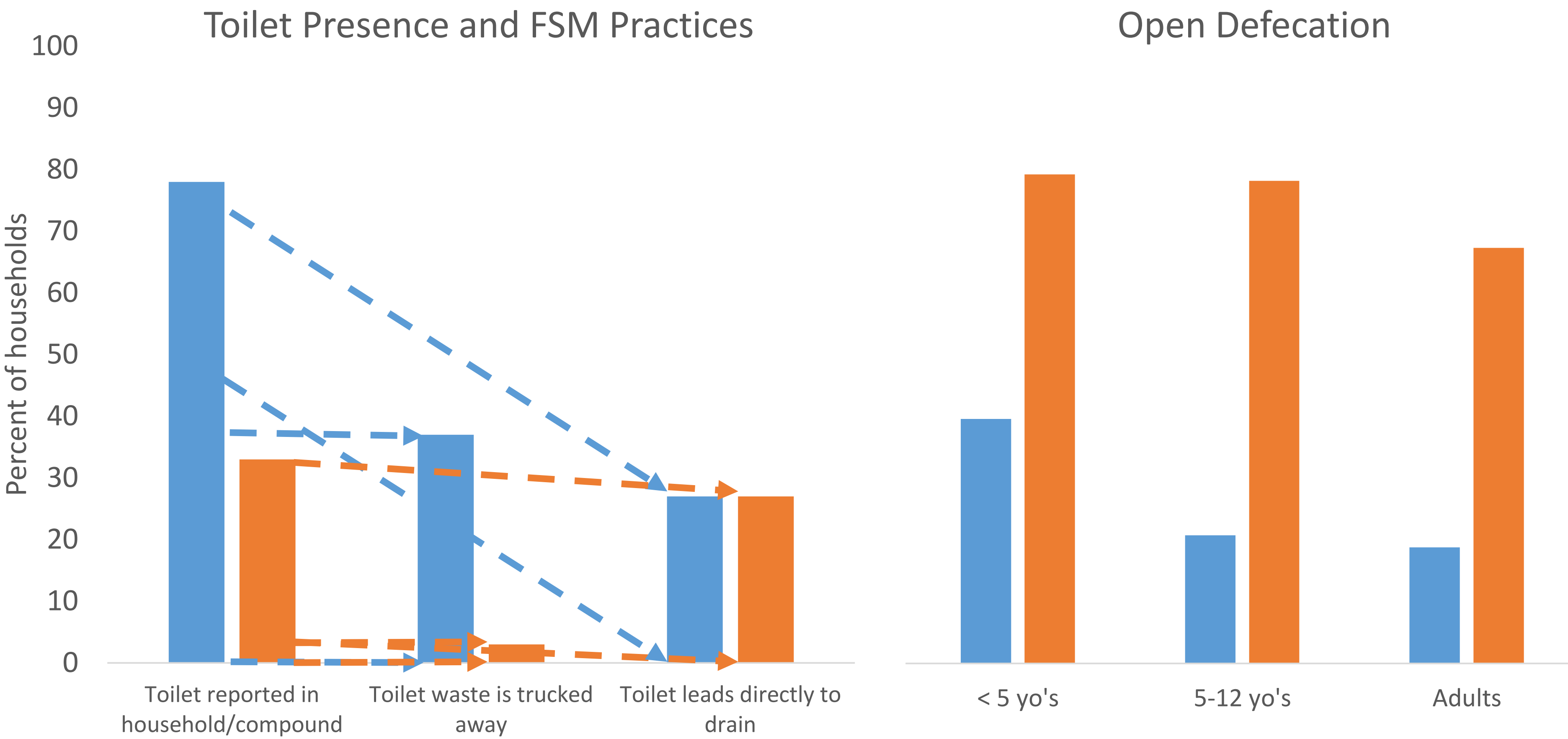
Figure 1b: Sanitation coverage and clustering in Old Town



Berendes et al., *AJTMH*, accepted

Neighborhood-level toilet coverage varied significantly; FSM was universally poor



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All between-neighborhood differences significant at 0.001 level

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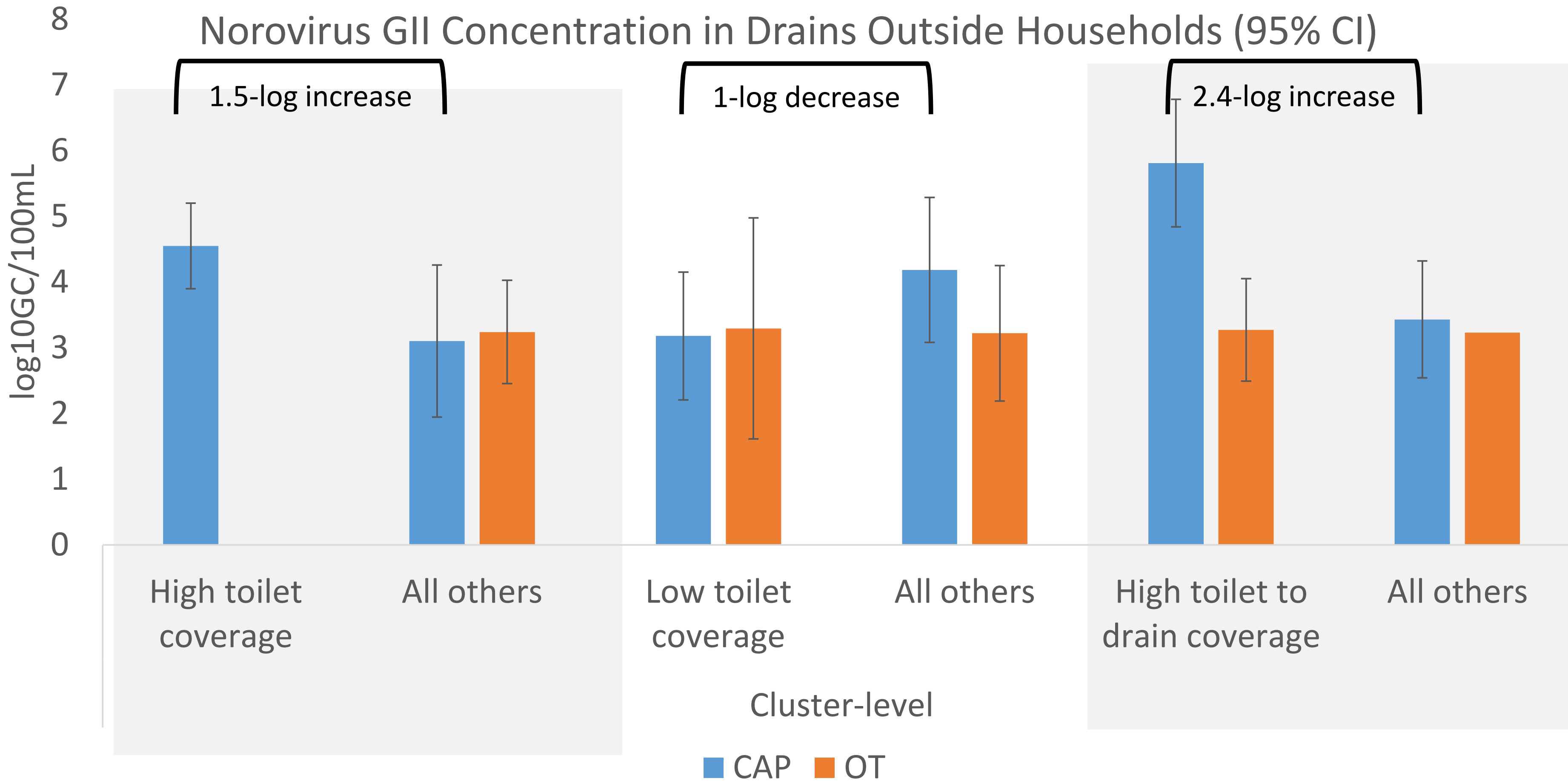

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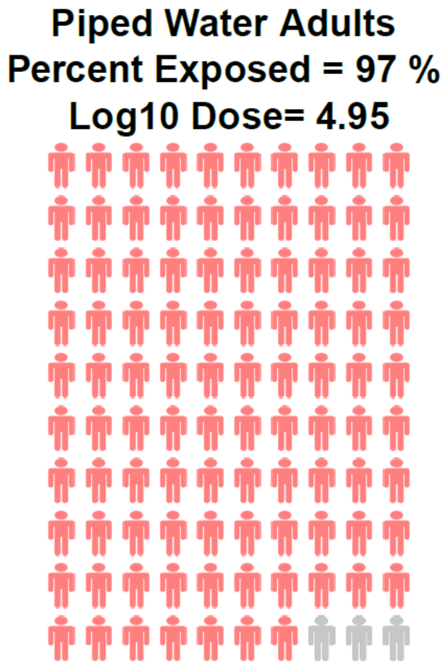
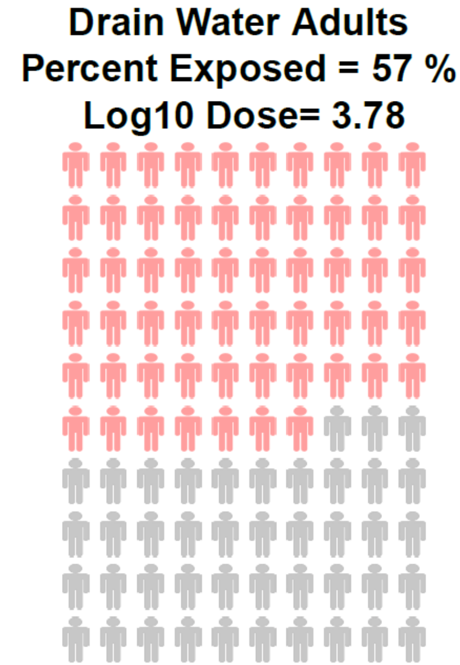
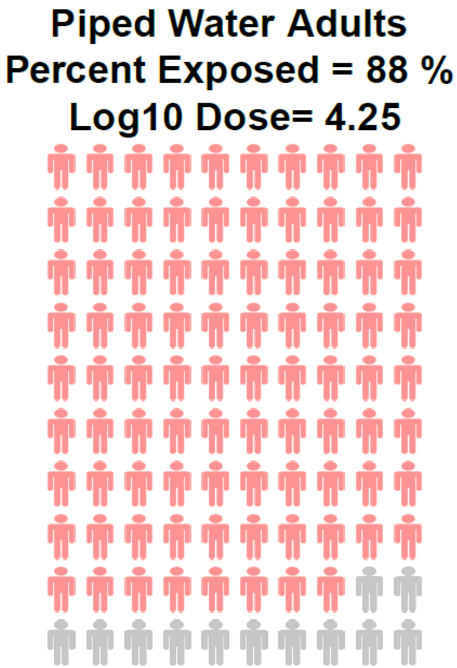


Tool results from CAP:

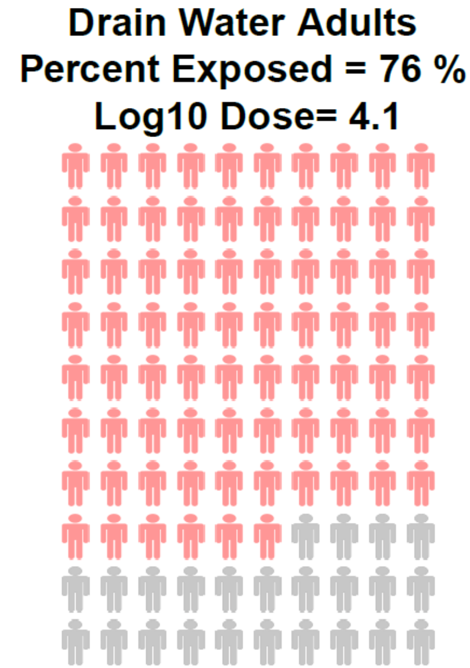
- Risk of exposure to piped drinking water is highest in both adults and children
- Drain water is the pathway that has second highest risk of exposure





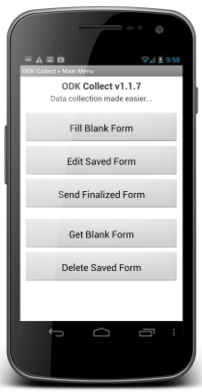
Tool results from OT:

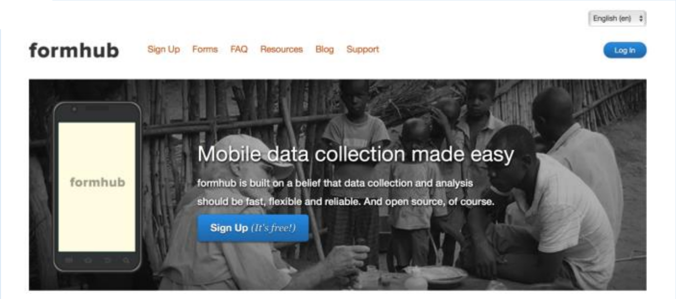
- Risk of exposure to piped drinking water is highest in both adults and children
- Drain water is the pathway that has second highest risk of exposure

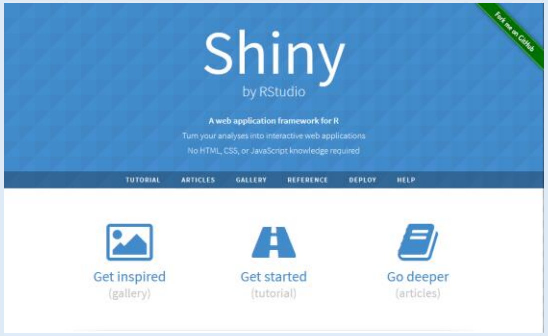


Overview of Tool Architecture

“The Cloud”







Mobile Data Collection

Data/Form Repository

Analysis and Dashboard

Mobile Data Collection

- Free and open-source
- Widely used
- Only requires a data connection to download forms and upload data
- Available on inexpensive, ubiquitous Android phones and tablets

OPEN DATA KIT

Analysis and Dashboard: Shiny Package

- Web-based version of **R**, a widely-used and open-source statistical programming tool
- For SaniPath, allows complex Bayesian analysis that turns raw data into risk-profiles
- Online dashboard allows users to generate and view risk profiles and reports as soon as data have been uploaded to Formhub

Strengths and Limitations

A simple tool to characterize a complex system…

Strengths

- Significantly more rapid than in-depth exposure assessment (SaniPath Phase 1)
- Systematic but flexible
- Focuses on risk behavior rather than risk perception
- Provides data for decision making
- Can be adapted to cultural contexts
- Includes quantitative environmental microbiology
- Uses mobile data collection and automated analyses

Limitations

- Requires basic laboratory capacity and equipment
- Does not (currently) provide specific recommendations based on results
- Cost could be prohibitive
- One deployment does not capture temporal and seasonal variability
- Limited sample size gives low resolution risk comparison
- Does not assess private domain
- Could be improved with studies of reliability and consistency of results