Development and Validation of the SaniPath Rapid Assessment Tool: Characterizing a Complex Problem with a Simple Tool

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In 2008, for the first time in history, the number of people living in cities outnumbered the population in rural areas.

By 2050, the United Nations projects that 65% of global population will live in cities.

Rapid growth outpaced ability of government to provide basic services.

Crowded Population ➔ Blurring Spaces ➔ Communal Exposure ➔ Disease Transmission
background: how should policy makers prioritize sanitation investments?
key goals of rapid assessment tool

**Guide** users through the collection of relevant data to inform their understanding of risk of exposure

**Provide** users with easy to use software interface for data entry that can be customized for different contexts

**Generate** data on relative exposure to fecal contamination in low-income, urban neighborhoods

**Synthesize** these data to guide community, government, and service providers in their decision-making process
We examined a wide range of exposures in both public and private domains and via common vehicles during different seasons in four low-income urban neighborhoods.

### PATHWAYS
- Marine and Surface Waters
- Sand
- Drinking water - piped water
- Sachet, stored HH water
- Open drains and flooding
- Urban agriculture (wastewater irrigation)
- Primary schools and nurseries
- Public latrines
- Households

### Human Behavior
- Key Informant Interviews
- Focus Group Discussions
- Household Surveys

### Environmental Fecal Contamination
- Environmental Samples
- Microbiological Analyses:
  - **Pathogens** (norovirus, adenovirus, helminths)
  - **Microbial indicators**
    - *E. coli*, enterococci, coliphage

**Total Environmental Samples: 1855**
We examined a wide range of exposures in both public and private domains and via common vehicles during different seasons in four low-income urban neighborhoods.
methods: the rapid assessment process

1) Conduct Key Informant Interviews & Transect Walks
2) Determine target neighborhood, modules, & sampling sites
3) Preliminary Assessment Report

5 & 6) Behavioral & Environmental Data Collection

7) Data Entry
8) Risk Characterization & Summary Statistics
9) Final Report

Sarah Abraham, Martha Ormiston, Gilad Fried, and Juan Pablo Bravo from The Noun Project created the icons interview, neighborhood, water, and computer. Schematic created by Suraja Raj
methods: data collection on water and sanitation behavior, and environmental contamination

- Household Surveys
- Community Surveys
- School Surveys
- Membrane Filtration
- IDEXX Quantitray/2000

Photo Credit: Suraja Raj
methods: environmental and behavioral data are combined to estimate exposure to fecal contamination

Environmental contamination

- Produce Samples from Shaibu

Behavior Frequency

- Frequency of Fruits/Vegetables Contact in Shaibu (children)

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

Risk of Exposure

*These values were determined based on a combination of EPA values, literature review and SaniPath Phase 1 data
methods: environmental and behavioral data are combined to estimate exposure to fecal contamination

Environmental contamination

average \( E. \ coli / \text{mL} \times \text{mL ingested / event} = \text{DOSE (CFU } E. \ coli \text{ ingested / event)} \)

- Oral route only
- Direct ingestion: drinking water, accidental water, and produce
- Indirect ingestion: hand contamination, hand-to-mouth contact behavior

*Volumes were determined based on a combination of EPA values, literature review and SaniPath Phase 1 data
risk of exposure from three pathways in one neighborhood for adults
risk of exposure from *piped water* in two neighborhoods
pilot testing in Accra, Ghana

- Piloted tool in same neighborhoods in Ghana as the Phase 1 in-depth study
- Tested the tool for usability & consistency of data collected
- Compare Rapid Tool risk assessment results to results from Phase 1 in Ghana
phase 1 vs. rapid tool pilot: phase 1

Highest Risk
Produce

Frequency (events/month)

Dose (CFU/event)

Latrines Phase 1
Ocean Water Phase 1
Produce Phase 1

Shiabu
phase 1 vs. rapid tool pilot: rapid tool pilot

Highest Risk
Produce
deployment in Vellore, India

- We tested the Rapid Assessment Tool in two neighborhoods in Vellore, India—a completely different context from Accra. Characteristics of Vellore include:
  - Water scarce area
  - Not coastal
  - Lots of animals
  - Lots of open defecation

- We are collaborating with Christian Medical College, Vellore and the MAL-ED study to validate our environmental risk assessment with health outcome data.
  - Stool samples to look at enteric disease outcomes
  - Matched data collection
  - Link to health outcome data from Mal-ED to provide environmental exposure data
next steps in tool development

**Incorporate** more sophisticated analysis

**Create** a centralized database

**Develop** a mobile application

**Add** pathways or modules

**Pilot** tool for pre/post sanitation intervention monitoring
Rapid Assessment Tool Development Team

Bill & Melinda Gates Foundation:

Alyse Schrecongost, Erica Coppel

Center for Global Safe Water, Emory University:

Christine Moe, Clair Null, Peter Teunis, Monique Hennink, Kelly Baker, Amy Kirby, Kate Robb, Habib Yakubu, Heather Reese, Katherine Roguski, Megan Light, Steven Russell, Deema Elchoufi, Andrew Wang

Water Research Institute: Joseph Ampofo

TREND: Nii Wellington

Research Triangle Institute: Matthew Scruggs, Megan Tulloch, Amir Mokhtari, Stephen Beaulieu

Improve International: Susan Davis

Christian Medical College, Vellore: Gagandeep Kang
Thank You

Please visit
www.sanipath.com

Come to Workshop 1A!
Thursday 9:00am-12:30pm
Appendix
one step further...

We can estimate the frequency and dose distribution using Bayesian analysis instead of simply using point estimates.

Ocean Water Example:

- A log10 *E. coli* concentration $\rightarrow$ normal distribution $N(\mu, \sigma^2)$;
- Frequency of ocean water exposure $\rightarrow$ negative binomial distribution $NB(r, p)$.
- Estimate all parameters by utilizing the data collected and run simulations.

Distribution gives more information about the variance in dose and the percent of people expose to the pathway.
Scatter Plot of 1000 Simulation Risk of Ocean Water in Shiabu Phase 1

Histogram of 1000 Simulation Log10 Dose For Phase 1 Shiabu Ocean Water

Histogram of 1000 Simulation Ocean Water Contact Per Month For Phase 1 Shiabu Ocean Water
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.

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

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Age Group</th>
<th>Intake Volume (mL)</th>
<th>Exposure Time Unit</th>
<th>Duration of Event</th>
<th>mL/Event</th>
<th>Rationale</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking Water</td>
<td>Adults</td>
<td>1,043</td>
<td>day</td>
<td>n/a</td>
<td>1043</td>
<td>US EPA value for drinking water consumption per day by adults. Similar averages found in literature review of studies in developing countries.</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>414</td>
<td>day</td>
<td>n/a</td>
<td>414</td>
<td>Same as above but for children</td>
<td>Same as above</td>
</tr>
<tr>
<td>Drain Water</td>
<td>Adults</td>
<td>0.06</td>
<td>event</td>
<td>n/a</td>
<td>0.06</td>
<td>Intake volume taken from the US EPA value for an adult wading in water: 3.7ml/hour.</td>
<td>-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.</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>1</td>
<td>event</td>
<td>n/a</td>
<td>1.0</td>
<td>Inflation of adult US EPA wading value</td>
<td>Same as above with the additional assumption that kids spend more time in drains and have greater contact with drain water.</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Age Group</th>
<th>mL/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking Water</td>
<td>Adults</td>
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</tr>
<tr>
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<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>1.0</td>
</tr>
</tbody>
</table>

mL ingested / event \times \text{average } E. coli / mL = \text{dose (CFU } E. coli \text{ ingested / event)}
three approaches for collecting information on exposure behavior

• Same basic questions about types of exposure and frequency
  • Community participatory meetings
  • School survey – target 9-12 year old children
  • Household survey

• Different approaches seem to work better in different neighborhoods depending on how well participants know and trust each other.
Adult HH Survey Data, Bukom

<table>
<thead>
<tr>
<th>Categories</th>
<th>N (%)</th>
<th>Categories</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1</strong></td>
<td></td>
<td><strong>Phase 1.5</strong></td>
<td></td>
</tr>
<tr>
<td>(N=199)</td>
<td></td>
<td>(N=100)</td>
<td></td>
</tr>
<tr>
<td>Beach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>16 (8.0)</td>
<td>&gt; Monthly</td>
<td>15 (15.0)</td>
</tr>
<tr>
<td>5-10 times / month</td>
<td>6 (3.0)</td>
<td>Monthly</td>
<td>5 (5.0)</td>
</tr>
<tr>
<td>1-4 times / month</td>
<td>46 (23.1)</td>
<td>&lt; Monthly</td>
<td>31 (31.0)</td>
</tr>
<tr>
<td>Never</td>
<td>131 (65.8)</td>
<td>Never</td>
<td>49 (49.0)</td>
</tr>
<tr>
<td>Produce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>73 (36.9)</td>
<td>Daily</td>
<td>31 (31.0)</td>
</tr>
<tr>
<td>Few times / week</td>
<td>77 (38.9)</td>
<td>Weekly</td>
<td>33 (33.0)</td>
</tr>
<tr>
<td>Weekly</td>
<td>8 (4.0)</td>
<td>Monthly</td>
<td>24 (24.0)</td>
</tr>
<tr>
<td>Never</td>
<td>39 (19.7)</td>
<td>Never</td>
<td>12 (12.0)</td>
</tr>
<tr>
<td>Public Latrine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>130 (65.3)</td>
<td>&gt; Monthly</td>
<td>89 (89.0)</td>
</tr>
<tr>
<td>Few times / week</td>
<td>51 (25.6)</td>
<td>Monthly</td>
<td>4 (4.0)</td>
</tr>
<tr>
<td>Weekly</td>
<td>7 (3.5)</td>
<td>&lt; Monthly</td>
<td>1 (1.0)</td>
</tr>
<tr>
<td>Never</td>
<td>7 (3.5)</td>
<td>Never</td>
<td>6 (6.0)</td>
</tr>
</tbody>
</table>
Comparing the results from the three approaches to collect information on key behaviors:

Fairly good agreement on adult behavior
Comparing the results from the three approaches to collect information on key behaviors

**Weak agreement about child behavior**

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**Drain Water Contact Among Children in Bukom**

- **Never***: 40.0%
- **< monthly***: 25.0%
- **monthly***: 15.0%
- **> monthly***: 20.0%

*Difference between surveys was statistically significant at p-value = 0.5*
phase 1.5 vs. phase 1 environmental contamination
phase 1.5 vs. phase 1 environmental contamination in Shiabu

[Box plot diagram showing the comparison of Log E. coli concentration across different environmental samples in Phase 1 and Phase 1.5. The samples include Drain Water, Sand, Soil, Sediment, Swabs, Ocean Water, Piped Water, and Produce. Each sample has two bars representing the median and interquartile range for Phase 1 (N=161) and Phase 1.5 (N=79).]
phase 1.5 risk plots