City 1, Ghana Exposure Assessment Report

SaniPath

21 December, 2018

Executive Summary

Sanitation quality and access to improved sanitation facilities play an important role in the health of a community. Those communities with low-quality sanitation systems and little to no access carry the greatest disease burden from poor sanitation. To better prioritize sanitation investments and guide intervention strategies to reduce the risk of enteric disease, it is important to assess the contribution that various environmental pathways have on exposure to fecal contamination.

To quantitatively evaluate fecal contamination exposure pathways in urban communities in City 1, Ghana, the SaniPath Exposure Assessment Tool (Emory University, Atlanta, USA, https://sanipath.org) was deployed from 2018-10-11 to 2018-11-13. The exposure pathways of fecal contamination presented in this report include: Drain Water, Produce, Municipal and Piped Water, Surface Water, Flood Water, Public Latrine, Particulate, Bathing Water, Street Food, and Other Drinking Water.

{Insert summary sentence about results (ex. The results from this study show that both adults and children are exposed to fecal contamination through multiple pathways)}

Dominant pathways of exposure are determined by comparing the percent exposed and magnitude of exposure for adults and children in the study neighborhoods. For adults, the dominant pathways of exposure in City 1, Ghana were Drain Water, Surface Water, and Bathing Water. For children, the dominant pathways of exposure in City 1, Ghana were Drain Water, Surface Water, and Bathing Water.

Recommendations to reduce exposure to fecal contamination among adults living in City 1, Ghana include:

- Improve regulations of water quality and improve treatment and distribution mechanisms
- Improve water distribution systems and remove illegal connections
- Promote alternative sources of bathing water

- Improve drainage systems and provide covers for open drains
- Reduce environmental contamination by controlling open defecation, animal husbandry practices, and by improving access to and quality of public latrines
- Educate communities on risk associated with open drains and proper hand hygiene practices
- Improve FSM in communities and reduce open defecation practices
- Provide education about the risk of contact with contaminated surface water and promote hand hygiene

Introduction

Sanitation plays an important role in disrupting the transmission of bacteria, protozoa, viruses, and other pathogens and environmental hazards associated with feces.[1] Exposure, defined as oral ingestion of any number of fecal indicator organisms (*E. coli*), can occur indirectly or directly from various environmental sources. Exposure varies person-to-person based on the magnitude of environmental contamination and behavior related to potential transmission routes (e.g. frequency of potentially 'risky' behaviors). Pathways of exposure refer to environmental sources of fecal contamination, such as flooding, surface water, presence of open drains, piped water supply, or public latrines that facilitate transfer of fecal contamination. Determining the dominant pathway(s) can help inform sanitation investments towards the exposure pathways that pose the greatest risk.

{Insert sentences about country and city context (ex. Income, density, tenure status, urban poor housing conditions, city/country challenges (Census Data))}

{Insert sentence about country and city improved sanitation access}

{Optional: sentence about wealth quintiles and sanitation access}

Low coverage and use of sanitation facilities leads to contamination of food, water, and surfaces, resulting in greater exposure to fecal pathogens. Unfortunately, this exposure can lead to adverse health outcomes such as diarrhea, helminth infections, gut dysfunction, impaired cognitive development, malnutrition, and stunting.[2]

{Optional: Sentences about wealth quintile and diarrhea/malnutrition facts (DHS)}

{Insert sentence about city growth (population, urban growth rate, wealth quintile population, etc.)}

Studies have demonstrated an association between diarrheal disease, soil-transmitted helminth infections, stunting, and childhood mortality with inadequate sanitation access, quality, and use.[3,4,5] In high density urban areas, populations, especially children, are at an increased risk of exposure to fecal contamination due to environmental factors and exposure behaviors.[6] Considering the impact of enteric and diarrheal disease among residents in low-income urban areas, it is important to identify exposure pathways and trends across neighborhoods. By examining environmental contamination and behaviors related to environmental pathways, risk of exposure to fecal contamination can be assessed to provide a public health perspective to inform sanitation investments.

Methodology

The SaniPath Exposure Assessment Tool, developed by the Center for Global Safe Water, Sanitation, and Hygiene at Emory University, was used to quantitatively evaluate the pathways of exposure to fecal contamination in urban environments. Environmental samples from public areas susceptible to fecal contamination and household, school, and community behavioral surveys were collected by Field Team 1 in target neighborhoods (Figure 1).

{Insert sentences about neighborhoods: number, region, demographics, wealth, infrastructure, tenure status, socioeconomic status, wash coverage}

{Insert sentences about where the samples were collected from (local market, homes, businesses, etc.)}

Figure 1. Map of Data Collection Sites

Measuring Contamination

All samples were collected from public spaces and not within households. Environmental samples were tested in the laboratory at Laboratory 1 within seven hours of collection. All samples were analyzed for *E. coli* using membrane filtration methods. Two to three serial dilutions were used for each sample type, optimized to capture *E. coli* within the countable range (0-200 Colony Forming Units (CFUs)). A negative control was processed every day alongside sample analyses.

Measuring Behavior

To assess the frequency at which adults interact with different pathways, the SaniPath enumeration team conducted behavioral surveys in community meetings, household, and school in English. All households in the neighborhoods were asked to participate in the voluntary survey. The study team surveyed the household member who manages the water supply in the home. *{, which was usually: Insert individual's characteristics (typically mother, woman, man, etc.)}* Survey participants in households and community meetings were asked about their frequency of contact with environmental pathways. They were then asked to estimate the frequency at which their children came into contact with or ingested (direct or indirect) pathways. In school surveys, children were asked about their frequency of contact with environmental pathways and were also asked to estimate the frequency of contact at which their parents came into contact with or ingested aspects of the pathways. Table 1 outlines sample sizes for surveys and environmental samples for each neighborhood.

{Insert additional relevant information about sample collection (ex. Micro samples collected but no behavioral info, shared samples btw neighborhoods, etc.) â€“need a warning that if they deviated from the suggested protocol that the results may not be valid.}

Table 1.1 Survey sample size

Neighborhood	Community	Household	School
A	4	100	4
B	4	100	4
C	4	100	4
D	4	100	4
Total	16	400	16

Table 1.2 Environmental pathway sample types and sample size

Neighborhood	Bathing Water	Drain Water	Flood Water
A	0	10	10
B	8	10	10
C	3	10	6
D	10	10	10
Total	21	40	36

Neighborhood	Municipal and Piped Water	Particulate	Produce
A	6	10	10
B	10	10	10
C	10	10	10
D	10	10	10
Total	36	40	40

Neighborhood	Public Latrine	Street Food	Surface Water
A	4	10	0
B	4	10	3
C	10	10	0
D	10	10	0
Total	28	40	3

Neighborhood	Ocean Water	Other Drinking Water
A	0	0
B	0	0
C	0	0
D	0	0
Total	0	0

Calculating Dose

The SaniPath Tool provides information on the frequency of behavior associated with exposure to various environmental pathways and the concentration of fecal contamination in each environmental pathway. The environmental samples are analyzed for *E. coli* as an indicator of fecal contamination. This data is combined with frequency data from behavioral surveys and additional information from the literature (i.e. intake values, duration of exposure, etc.), and analyzed using Bayesian methods. All pathways are analyzed with regard to ingestion of fecal contamination, either direct or indirect. A Monte Carlo simulation is then used to generate risk profiles of exposure to fecal contamination.

Identifying the High-Risk Pathway(s)

Risk profiles, or people plots, are displayed in the visuals throughout the following pages. The number of red people in the people plots visually represents the proportion of people who are exposed to the specific pathway. The magnitude of fecal contamination exposure "dose" is indicated by the shade of red, where darker red refers to greater dose of *E. coli*. The dose is considered to be different if there is a greater than tenfold difference between two neighborhoods or pathways.

Results and Discussion

Risk profiles for environmental exposure pathways were generated for all neighborhoods and all relevant pathways in each neighborhood for adults. The SaniPath team has developed an algorithm to identify dominant fecal exposure pathways for each neighborhood. The algorithm is based upon the proportion of the population exposed to those pathways and the corresponding magnitude of exposure to fecal contamination.

Figure 2 shows the people plots generated for all exposure pathways in Neighborhood B. The highest dose of exposure for Adults was seen in Surface Water at 11.927 CFU/Month E. coli, with 46.2 percent of Adults exposed to fecal contamination. Table 2 shows the dose and percent exposed for adults by pathway in Neighborhood B. *(note: 2 log CFU/Month E. coli dose = 10^2 CFU/Month E. coli dose)*

Figure 2: People plots for all exposure pathways in Neighborhood B

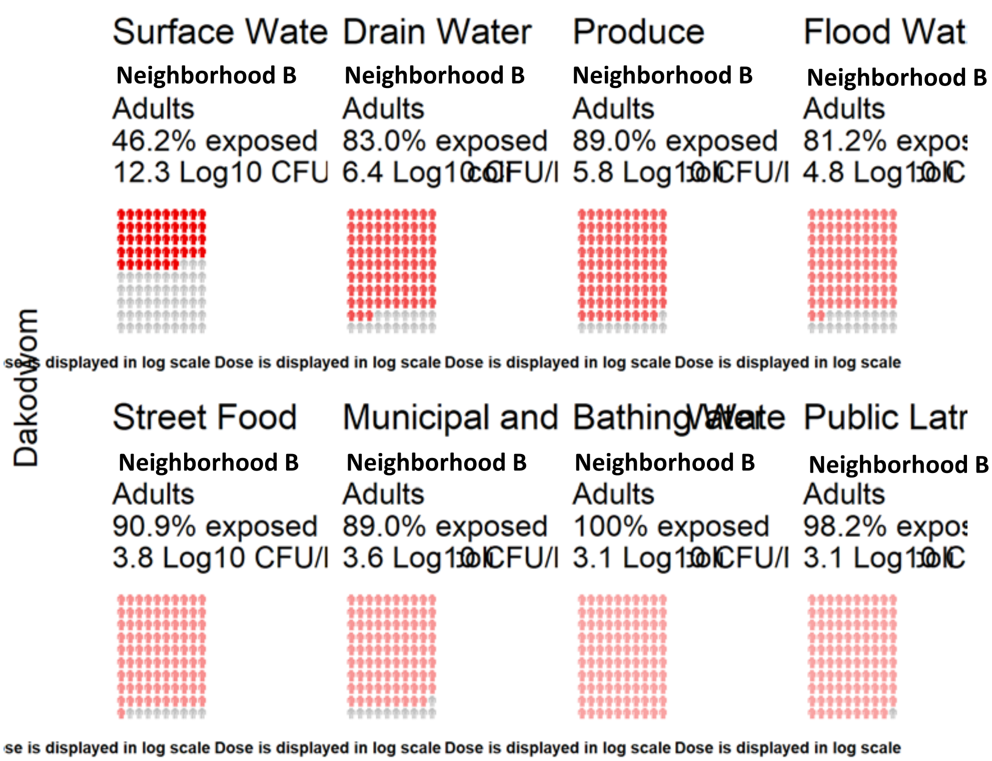

Figure 3 shows the people plots generated for all exposure pathways in Neighborhood C. The highest dose of exposure for adults was seen in Produce at 6.71 CFU/Month E. coli, with 84.4 percent of adults exposed to fecal contamination.

Figure 3: People plots for all exposure pathways in Neighborhood C

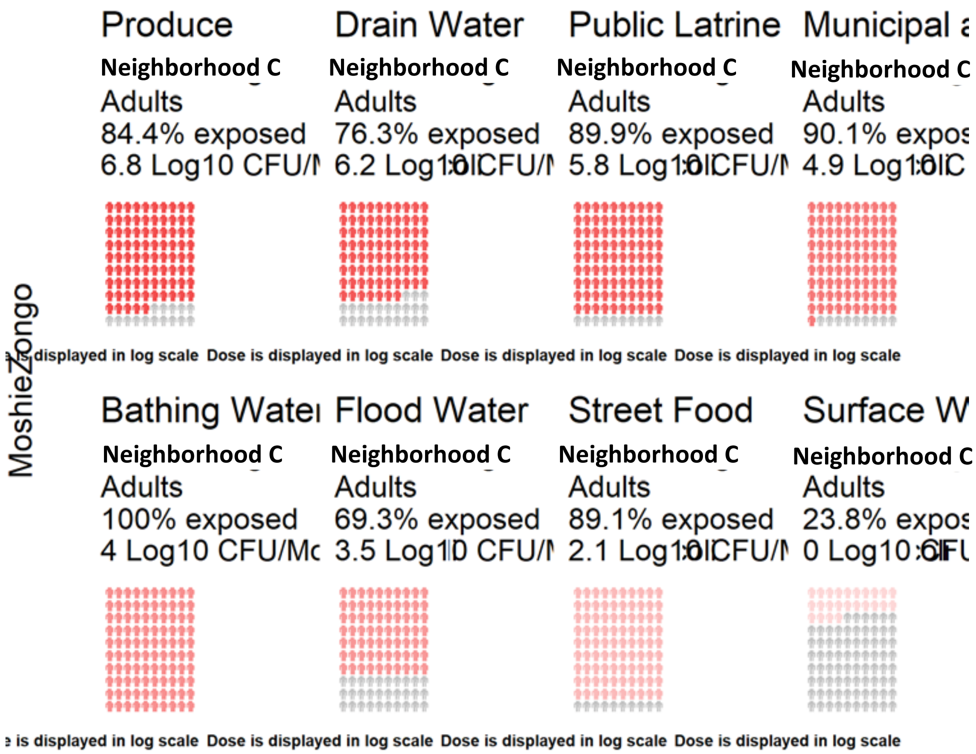

Table 2. Dose and percent exposed across exposure pathways for adults and children in Neighborhood B, City 1, Ghana

Age Group	Metric	Bathing Water	Drain Water	Flood Water
Adults	CFU/Month E. coli	3.079	6.362	4.692
	Percent Exposed	100	83	81.2
Children	CFU/Month E. coli	3.147	7.725	5.728
	Percent Exposed	100	86.2	84.5

Age Group	Metric	Municipal and Piped Water	Produce	Public Latrine
Adults	CFU/Month E. coli	3.511	5.79	3.071
	Percent Exposed	89	89	98.2
Children	CFU/Month E. coli	2.469	5.738	3.349
	Percent Exposed	98.3	94.4	99.3

Age Group	Metric	Street Food	Surface Water

Adults	CFU/Month E. coli	3.769	11.93
	Percent Exposed	90.9	46.2
Children	CFU/Month E. coli	3.735	20.58
	Percent Exposed	99.7	56.1

What are the Greatest Exposures?

Table 3 shows dominant pathways of exposure for all neighborhoods in the study for adults and children in City 1, Ghana.

Table 3. Dominant exposure pathways by neighborhood

Neighborhood	Adults	Children
A	Drain Water	Drain Water
B	Surface Water	Surface Water
C	Bathing Water	Bathing Water
D	Produce, Drain Water, Public Latrine	Drain Water, Produce

It is important to consider cumulative exposure across all pathways within neighborhoods when interpreting results from the SaniPath Tool. The number of dominant pathways within a neighborhood as well as their relative contribution to total exposure has important implications on the potential population-level effect of exposure to fecal contamination on the burden of disease. Figures 4 and 5 provide an example of how the relative exposure to fecal contamination by pathways within a neighborhood can impact the total exposure after addressing the dominant pathway of exposure. In scenario 1, produce is the dominant pathway of exposure within the neighborhood. After an investment or intervention that addresses exposure from the produce pathway, total exposure is reduced to only that contributed by open drains, surface water, and drinking water. In scenario 2, produce, open drains, and surface water are all dominant pathways of exposure to fecal contamination within a neighborhood. After an investment or intervention that addresses exposure from the produce pathway, total exposure remains relatively large due to the contribution from open drains and surface water. This scenario highlights the importance of understanding how the population-level exposure to fecal contamination for individual pathways contributes to total exposure and how cumulative exposure may or may not be reduced to a level that will impact the burden of disease by only addressing individual pathways.

Figure 4. Scenario 1: Total exposure for a neighborhood with one dominant pathway (denotes dominant pathway)*

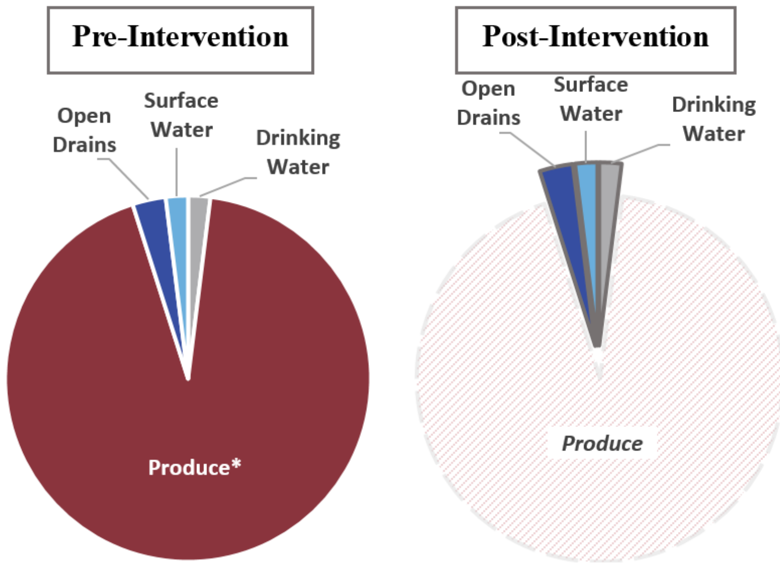

Figure4

Figure 5. Scenario 2: Total exposure for a neighborhood with three dominant pathways (denotes dominant pathway)*

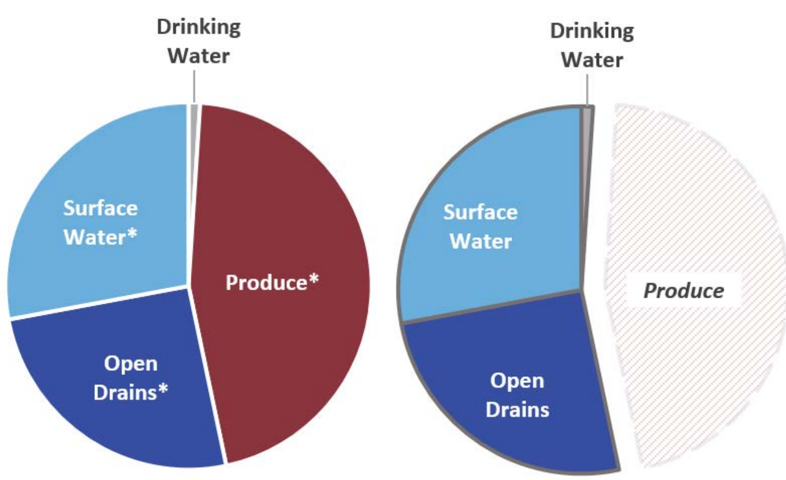

Figure5

What Drives the Risk?

Open drains are a common form of drainage management in developing countries and their accessibility makes them a common dumping site for household waste as well as raw sewage. In City 1, Ghana, open drains are a dominant pathway for adults contributing to total exposure to fecal contamination in 4 neighborhoods. Contamination of open drains varied across the study neighborhoods in City 1, Ghana with 2 neighborhoods having relatively low contamination and 2 neighborhoods having relatively high contamination. Reported behaviors of adults in 4 neighborhoods put them at greater risk of exposure to fecal contamination via ingestion. Behaviors that increase risk of exposure can include walking through open drains, retrieving items that have fallen in drains, accidentally entering drains, or practicing open defecation into open drains. Contamination can occur directly through open defecation, dumping of grey water, black water, or fecal sludge, or it can occur indirectly through interaction with other pathways such as runoff from rain or floodwater or intrusion of contaminated surface water. Throughout City 1, Ghana, 30.0% of open drain samples had feces within 3m of the sampling site which may contribute to the dose observed in the open drain pathway of exposure. Other contributing factors could include the presence of public or household latrines nearby, where 5.00% and 20.0% of samples had present, respectively.

Surface water is an important environmental factor to consider when evaluating human exposure to fecal contamination. Surface water can be used for drinking, personal and household cleaning, cooking, and can be interacted with in varying ways, such as swimming, fishing, or walking through surface water such as rivers and streams. Different uses of and interactions with surface water impact how ingestion occurs and how much water is ingested, ultimately impacting risk of exposure to fecal contamination if surface water is contaminated. NA Surface water can become contaminated in many ways, such as from drainage of rainwater or open drains, open defecation, fecal sludge dumping, cleaning of potties or nappies, hanging latrines, and from other pathways. Behaviors that can play a role in exposure include activities such as cleaning/washing, swimming, fishing, walking through water, or practicing open defecation.

Bathing water can come from many sources and may be stored in the household or used straight from the source. Bathing water can be contaminated directly from the source or through human interactions during storage or use. In City 1, Ghana, bathing water was identified as a dominant pathway of exposure to fecal contamination for adults in 4 neighborhoods. Contamination of bathing water varied across the study neighborhoods in City 1, Ghana with 3 neighborhoods having relatively low contamination and one having relatively high contamination. The reported frequency of bathing or contact with bathing water for adults in 4 neighborhoods was high, putting them at greater risk of exposure to fecal contamination. As noted, contamination can occur directly from using a contaminated source or fecal contamination can be introduced by hands or objects used during storage or bathing. Behaviors that may increase the risk of exposure to fecal contamination are accidental/intentional ingestion of bathing water while bathing, use of unsafe water for bathing, and potentially from improper storage of bathing water. From the bathing water samples in City 1, Ghana, 9.50% of the samples were stored and of those 50.0% were in covered containers.

Options for Action

It should be noted that all samples were collected from the public domain and not at the household level. This was done because government interventions typically focus on improving public services and facilities and may not be able to influence household-level contamination. Therefore, data on household sanitation and hygiene practices, while important, were not incorporated into the analysis when generating the risk profiles. For example, it is possible that some people wash their produce before eating it raw, which, if washed adequately, would reduce the exposure to fecal contamination from produce. However, it is difficult to standardize the reduction in fecal contamination due to hygiene practices because of variability between individuals (i.e. one individual may thoroughly wash their raw produce, while another may not, thus resulting in a difference in the reduction of fecal contamination on the surface of produce). To understand exposure on a household level, further research would be required. The SaniPath Exposure Assessment is designed to assess exposure in a 'worst-case scenario' by conducting the assessment during peak diarrheal season. This allows for valuable data to be collected that can inform risk of exposure to fecal contamination during times with high burden of diarrheal disease so as to maximize potential impact of sanitation investment and intervention. Based upon the results of this study, recommendations can be made regarding the most common dominant pathways that were observed (Table 4). Recommendations are made regarding private domain interventions because some water and food interventions are related to personal hygiene and behaviors.

Table 4. Recommended interventions for City 1, Ghana

Pathway	Private Domain	Public Domain
Bathing Water	Alternative source of bathing water	Improve the quality (safety, taste, smell) of municipal water
		Water treatment (chlorine)
		Improve water distribution system (no leaks, no illegal connection)
Drain Water	Education about the risk of contact with open drain	Better FSM (liquid/solid waste management)
	Better hand hygiene practice (education)	Improve drainage system
		Cover the open drain
		Reduce open defecation
		Improve animal husbandry/control to reduce animal feces

		Increase access to quality, affordable public latrines that safely contain feces
Surface Water	Education about the risk of contact with dirty surface water	Better FSM (liquid/solid waste management)
	Better hand hygiene practice (education)	Reduce open defecation
		Avoid activity at the contaminated surface water

It is important to consider the dose and frequency of contact when interpreting recommendations as they have implications on what programs are appropriate and feasible based on the context in a neighborhood. For example, if bathing water was a dominant pathway of exposure to fecal contamination and had low dose and high frequency, it wouldn't be advisable to suggest lowering the frequency of bathing as it is in an inherently positive activity.

Strengths and Limitations

The primary strength of the SaniPath Exposure Assessment Tool is that the results focus on the measurement of risk rather than risk perception and rely on primary data collection – both behavioral surveys and microbiological analysis of environmental samples. The Tool can be adapted to different cultural contexts, employs mobile data collection, and provides automated data analyses and data visualizations. In addition, the unique risk profiles provide information for decision making in a format that is easy to understand by a variety of audiences.

However, this Tool does have limitations. The assessment was deployed cross-sectionally and so it is unable to capture temporal and seasonal variability in contamination or behaviors. The information is only a snapshot of exposure at the neighborhood level and may not be generalizable to the entire city unless efforts are made during neighborhood selection to choose neighborhoods representative of the entire city. This assessment also relies on self-reported information about behavior which may be biased due to social desirability or due to adults either over- or underestimating the frequency of specific behaviors. Furthermore, environmental samples were only taken from public areas and household level samples and risk of exposure are not measured. Household or individual level hygiene, or other risk-mitigating behaviors (such as household water treatment) are not considered in the risk profiles in this report.

{In addition to limitations of the SaniPath Tool, there were challenges in-country.}

{Insert sentences about challenges in obtaining data (weather, resources, pathway accessibility)}

Conclusion

The deployment of the SaniPath Exposure Assessment Tool in City 1, Ghana highlighted the roles that environment and behavior play in human exposure to fecal contamination. Behavioral surveys and simple microbiological techniques were used to generate risk profiles for study neighborhoods across environmental pathways, including Drain Water, Produce, Municipal and Piped Water, Ocean Water, Surface Water, Flood Water, Public Latrine, Particulate, Bathing Water, Street Food, and Other Drinking Water. Dominant pathways of exposure varied across neighborhoods and age groups, with dominant pathways for adults including Drain Water, Surface Water, and Bathing Water, and dominant pathways for children including Drain Water, Surface Water, and Bathing Water. Recommendations can be made for potential interventions to reduce exposure to fecal contamination based on behavior and environmental contamination levels in both the public and private domain. Recommendations for to reduce exposure to fecal contamination for adults in City 1, Ghana include:

- Improve regulations of water quality and improve treatment and distribution mechanisms
- Improve water distribution systems and remove illegal connections
- Promote alternative sources of bathing water
- Improve drainage systems and provide covers for open drains
- Reduce environmental contamination by controlling open defecation, animal husbandry practices, and by improving access to and quality of public latrines
- Educate communities on risk associated with open drains and proper hand hygiene practices
- Improve FSM in communities and reduce open defecation practices
- Provide education about the risk of contact with contaminated surface water and promote hand hygiene

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For More Information on SaniPath:

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Disclaimer

The SaniPath Tool and methods were developed by Emory University in Atlanta, Georgia, USA. The Tool software and protocols are freely accessible to users and may be modified or adapted to fit their interests and context. Emory University does not take responsibility of the quality of results generated if modifications are made to either the data collection protocols or analysis.

The recommendations in this report are broad recommendations to guide users in their thinking and application of this evidence-base to their local context. Emory University does not take responsibility for the appropriateness of recommendations or implementation of programs or policy. This report does not reflect the opinions of the University.

SaniPath

This report was generated using the SaniPath Tool

For more information, visit the SaniPath Website at www.sanipath.org