EMORY ROLLINS SCHOOL OF PUBLIC HEALTH

Quantitative assessment of exposure to fecal contamination for young children in a crowded, low-income urban environment in Accra, Ghana

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Introduction

Lack of adequate sanitation results in fecal contamination of the environment and poses a risk of disease transmission via multiple exposure pathways. SaniPath study was designed to determine how much different pathway(s) contribute to exposure to fecal contamination. Because acute enteric symptoms are conditional on exposure to enteric pathogens, we aimed for characterization of exposure as a proxy of infection, thus providing an upper limit to the incidence of illness. Our approach may complement epidemiological studies, measuring observed illnesses, which suffer from under-ascertainment.

Objectives

- To compare an extensive set of exposure pathways by microbial risk assessment.
- To provide a systematic method for assessing the impact of fecal exposure pathways as a basis for prioritizing water, sanitation and hygiene intervention strategies by their effectiveness in reducing exposure.

Introduction

We collected over 500 hours of structured observation for behaviors of 156 children (0-1 year, 1-2 years, and 2-5 years), 800 household surveys, and 1855 environmental samples.

Data were analyzed using Bayesian models, estimating the environmental and behavioral factors associated with exposure to fecal contamination. Then, behavior sequences and concentrations of fecal contaminants along with exposure factors (from secondary data or literature review) were used to simulate exposure. 1000 Monte Carlo samples were generated for fecal exposure during a typical child day (14 hours) for three age groups and four neighborhoods. Figure 1 shows an overview of data collection, model structure, input and output. Note the surveillance pyramid showing the relationship between exposure assessment and observable health effects.

Because the behavioral model provided complete information about a child's activities including where these activities occurred, our simulations allowed tracing the sources of ingested fecal microbes through the network, and hence quantifying the contribution of any particular pathway to exposure.

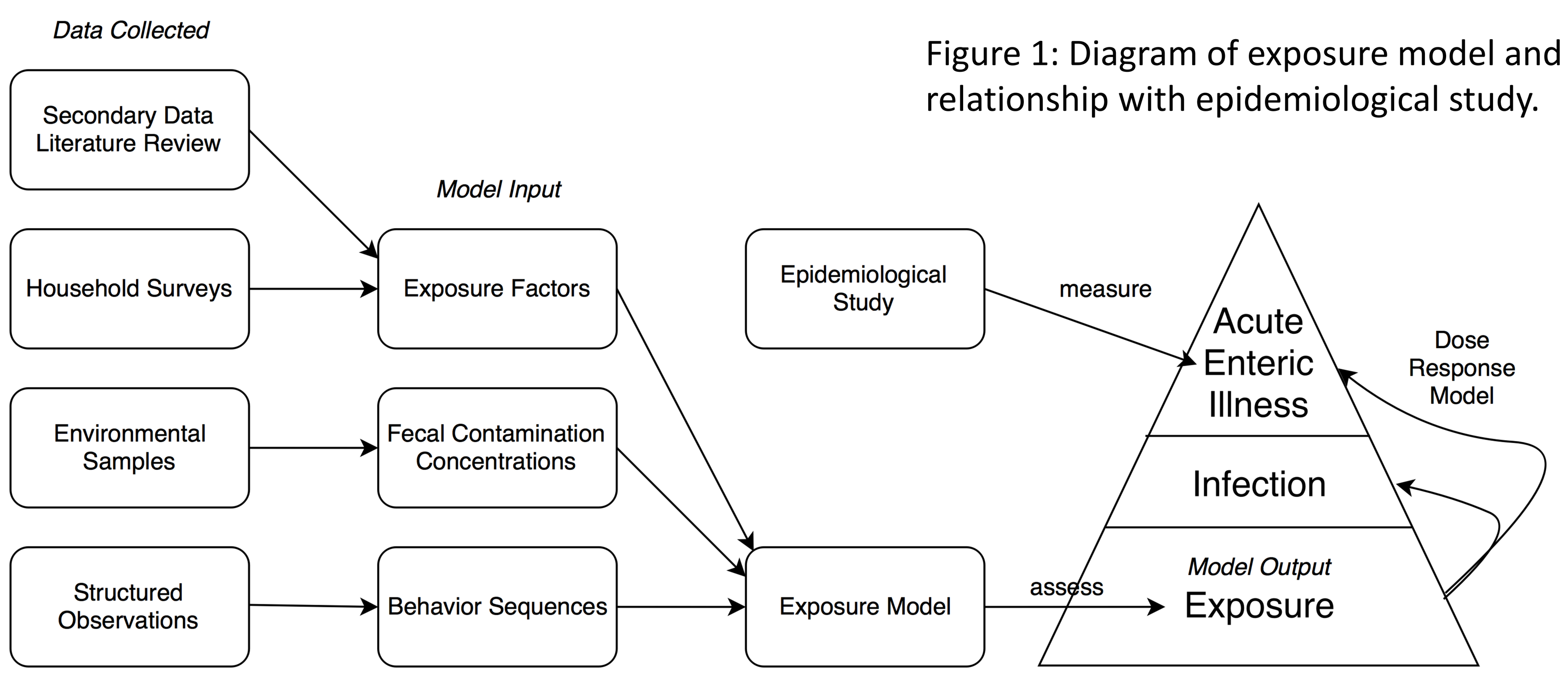

Figure 1: Diagram of exposure model and relationship with epidemiological study.

Results

Exposure from different pathways was characterized by fraction exposed (i.e. fraction with a nonzero dose), distribution of log10 dose, and (arithmetic) mean dose. There is variation in exposure between different pathways, and the food pathway dominated (had the greatest contribution to) children's exposure to fecal contamination (in all four neighborhoods, and three age groups).

Variation in behavior drives the variation in exposure among children by age, while variation by neighborhood results from variation in environmental fecal contamination (Figure 2).

Hands played a central and crucial role in fecal microbe transfer by connecting sources (drain, soil, floor, off-ground surface), where the microbes enter the network, with sinks (bath, handwashing, mouth), where microbes flow out of the network. Handling food items even mediated in food intake. (Figure 3)

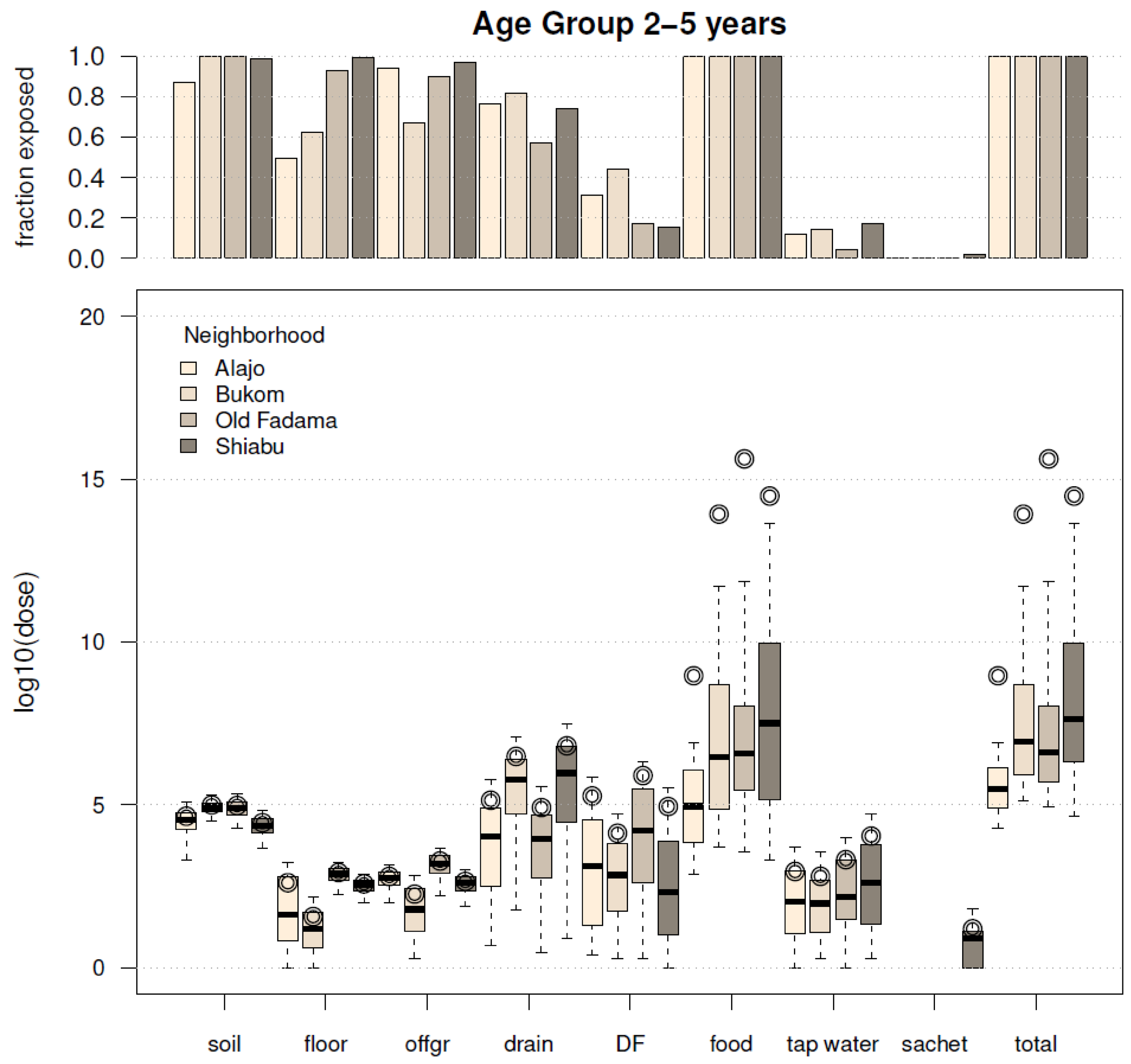

Figure 2: Fecal exposure of pathways for 2-5 years age group by neighborhood. Top graph: bar chart of the fraction exposed (i.e. percent of child days exposed to any number of E. coli among 1000 simulated days). Bottom graph: boxplots of log10 dose of E. coli. Note that the "whiskers" show 5th and 95th percentiles instead of adjacent values. The upper/lower adjacent value is the value of the largest/smallest observation that is less/greater than or equal to the upper/lower quartile plus/minus 1.5 the length of the interquartile range. No outliers are shown in the boxplots, and the circle represents the log10 of the arithmetic mean of non-zero doses.

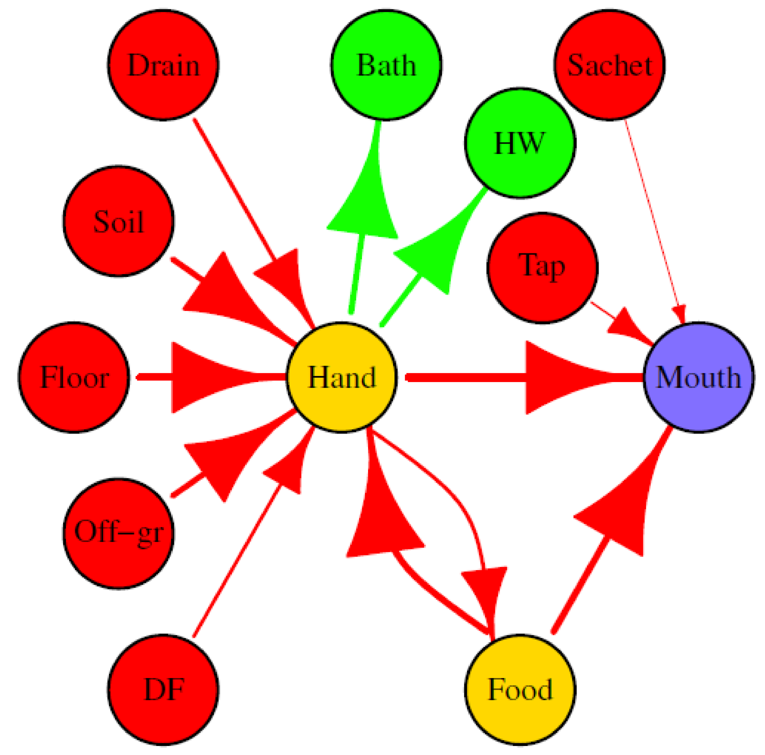

Figure 3: Fecal microbes transfer networks averaged over 1000 simulated child days for 2-5 years old in Shiabu neighborhood. DF = "direct contact with own feces", HW = "handwashing". The size of arrows and edges are proportional to the log10 of the average numbers of fecal microbes transferred (for 1000 simulated child days). The color of nodes represent their role in the network. Red: sources; yellow: vehicles (can be source and sink); green: sinks (remove contamination); purple: ingestion.

Discussion

Using the exposure model, we are able to prioritize pathways and identify suitable types of intervention to reduce the total exposure:

1. **High frequency and high dose**: High priority pathway. Reducing probability of contact with fecal contamination (e.g. using clean cutlery instead of hands for eating) and reducing environmental fecal contamination (e.g. improved food hygiene and safer agricultural practices) are both important.
2. **Low frequency, but high dose**: Event-like exposure (exposures due to rare contact events, e.g. drain pathway). Interventions must be aimed at reducing the likelihood of these exposure events. For example, covering drains to reduce contact rates.
3. **High frequency, but low dose**: Chronic exposure (e.g. floor/off ground surface pathway). For such pathways it may be difficult to reduce frequency, but possibly the dose is low enough to make these pathways a low priority for intervention.
4. **Low frequency and low dose**: Poses little risk and not a priority for intervention (e.g. sachet pathway).

Conclusions

- This exposure assessment model uses data on environmental contamination and behavioral to develop a comprehensive quantitative evaluation of multiple exposure pathways to fecal contamination.
- The most influential exposure pathway(s) and its characteristics can be identified to help prioritize the interventions that effectively reduce the total exposure to fecal contamination and the health risks from this exposure.
- The food pathway is the dominant fecal exposure pathway in Accra, Ghana, sanitation intervention and policy should focus on waste water used for irrigation, safe food preparation, and hygienic food handling practices.
- The fecal microbe transfer network demonstrates the pivotal role of hands in all exposure pathways.

References

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