How to Link Environmental Samples with their Source Population – A Unique Modelling Approach
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What is Environmental Surveillance (ES)? ES refers to the systematic collection of samples from the environment and subsequent analysis for a target pathogen.

Why is it useful? ES can detect pathogens shed in feces of infected individuals non-invasively at low costs for larger populations (compared to diagnostic testing). It can monitor disease transmission by detecting asymptomatic and symptomatic cases and can potentially provide early warning to prevent outbreaks and mitigate further spread.

What are its limitations? In settings with informal sewerage systems, interpretation of samples is limited when the catchment population (i.e., the people whose excreta is captured by a sample) is unknown.

Background: In Kolkata, samples for ES of typhoid and paratyphoid fever were collected from pumping stations and tested for S. Typhi/Paratyphi A. In Accra, samples for ES of COVID-19 will be collected and tested for SARS-CoV-2.

Developing the Models
After researching the unique sanitation infrastructure and sewage drainage systems for each setting, I developed two unique models in ArcGIS to represent the dynamic movement of feces throughout each city.

For Kolkata, I integrated hydraulic structures (i.e., pumping stations and underground pipes) with hydrologic processes (i.e., micro-watersheds) to map the movement of feces throughout the city to the pumping stations sampled for ES (Figure 2). I then estimated the population size and geographic size of the catchment area of each sampled pumping station.

For Accra, I modeled the micro-watersheds to identify seven strategic locations where ES samples could be collected from waterways (Figure 3). These points were selected because they captured areas with large population counts and factors related to COVID-19 transmission (low SES, less sanitation infrastructure, etc.).

Results
Kolkata: The average catchment area was 3.69 km² and included approximately 134,050 people. The model showed that, overall, samples from pumping stations captured approximately 24% of Kolkata Metropolitan Corporation’s total area and 39% of its total population.

Accra: The average catchment area was 7.86 km² and included approximately 109,244 people. The model showed that these seven points would represent approximately 42% of Accra Metropolitan Area’s total area and 46% of its total population.

Contribution to Public Health
This thesis demonstrated a novel approach that combines free, open-access data and mixed methods to model the dynamic movement of feces in different settings with informal sewerage systems. Outputs from the models are being shared with local partners to inform ES projects.

Mapping the catchment areas enables local health authorities to connect ES samples that were positive for the target pathogen to their upstream source population → increases actionability of ES results.

Highly relevant to the emerging use of ES and wastewater surveillance to monitor circulation of SARS-CoV-2 and its variants in many cities around the world. Approach is currently being adapted to a project in Atlanta for under-served communities.