

Evaluating occupational exposure and health risks during faecal sludge management activities in Kigali, Rwanda- exploration of field sampling, lab, and simulation methods

Abstract: Sanitation workers provide essential services that protect public health, often at the cost of their own health and safety. In this study, we evaluate occupational exposures to sanitation workers at each stage in a faecal sludge collection and waste-to-fuel transformation process in Kigali, Rwanda. We use a unique combination of environmental, behavioural, molecular, and simulation methods to estimate worker exposure and risk to inhaled and ingested pathogens.

Methods: Our methodology combined a participatory research approach with capacity-building strategies which were designed to overcome knowledge gaps in microbial sampling, exposure assessment, and occupational health.

- **Ingestion:** A Monte Carlo simulation based Quantitative Microbial Risk Assessment (QMRA) was carried out to estimate pathogen ingestion and disease by workers due to contaminated hand- and glove-to-mouth events. Three types of inputs were measured directly in this study: 1) concentration of indicator bacteria on worker hands and gloves, 2) ratio of pathogens and indicator organisms in bulk faecal sludge samples, and 3) frequency of hand-to-mouth activity during a work task. The concentration of pathogens and indicators was measured in three types of bulk faecal sludge samples using culture-based methods and qPCR. Pathogen-to-indicator ratios were then used to estimate pathogen concentration in hand rinse samples processed for indicator bacteria. A Monte Carlo simulation was used to estimate a worker's probability of disease, highly credible gastrointestinal disease (HCGI), from exposure to *Cryptosporidium* or adenovirus over an 8-hour work period.
- **Inhalation:** Forty-two task-based air samples were collected and processed for endotoxin using the limulus amoebocyte lysate (LAL) test. Eight-hour (8-h) exposures to endotoxin across eight exposure scenarios were simulated using Monte Carlo simulation.

Results:

Ingestion: Adenovirus exposure during collection tasks posed the highest risk of disease contracting gastrointestinal disease ($P(d)=5.0 \times 10^{-1}$). A high degree of contamination in the glove-rinse samples taken before the task suggests poor storage or poor sterilization of gloves in between tasks or workdays. The high levels of hand contamination seen in the hand-rinse samples taken after the task suggest that gloves did not provide an adequate exposure barrier.

Inhalation: The geometric mean exposure concentrations measured in personal task-based samples ranged from (11-3700 EU/m³), while the estimated 8-hour exposure concentrations had geometric means between (6.7-960 EU/m³). Exposure concentrations of endotoxin were found to increase with decreasing total solid content by mass. The probability of exceedance for all exposure scenarios was above the 0.10 threshold recommended by occupational hygienists.

Conclusions:

Our findings suggest that several interventions may be useful in controlling worker exposure to faecal sludge along the ingestion and inhalation route of exposure. Engineering controls should be prioritized such as enclosure and automation of processes that require workers to handle or come into close contact with sludge. Administrative controls may include storage of gloves in areas that are protected from

airborne contamination as well incorporating regular handwashing and hand-sanitizing practices into standard operating procedures may encourage better decontamination of hands and gloves before, during, and after work tasks. Education on the faecal-oral route or implementation of workplace hygiene programs can also prevent workplace exposures. Finally, protecting the worker with PPE that is properly worn, stored, and replaced at regular intervals can prevent the hand-to-mouth exposures.