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VERBAL ABSTRACTS
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A Global Analysis of Community Sanitation Coverage and Antibiotic Resistance in the Human Gut

Presenter: Erica Fuhrmeister, Tufts University

Additional Authors: Abby Harvey, Ashlee Earl, Maya Nadimpalli, Amy Pickering

Antibiotic resistance is a growing public health issue and is likely exacerbated in settings with limited access to sanitation infrastructure. In low-and middle-income countries (LMICs), high rates of illness lead to frequent use of antibiotics and therefore excretion of antibiotics, antibiotic resistance genes, and antibiotic resistant bacteria. Previous work has identified low investment in water and sanitation at the country-level as a predictor of increased antibiotic resistance gene abundance in human guts. However, this analysis was limited to wastewater samples in urban areas, missing over 70% of the population in LMICs that are not connected to sewer systems. Understanding the role of community sanitation access in the proliferation of antibiotic resistance across both rural and urban communities would be valuable to inform public policies beyond clinical settings (e.g. stewardship).

In this work, we harnessed publicly available short-read sequencing data to determine the association between community levels of basic and safely managed sanitation and abundance of antibiotic resistance genes in human guts across the globe. We searched the Sequence Read Archives (SRA) for location-specific human gut metagenomes from primarily LMICs and included a random sample of metagenomes from individuals in high-income countries. Sanitation data was obtained from geospatially tagged, nationally representative household survey data sets conducted in LMICs. We identified a total of 28 studies with human gut metagenomes from LMICs that meet eligibility requirements. An additional 9 studies were included from high-income countries. In total, we compiled 1815 human gut metagenomes from 26 countries. Total ARG abundance varied significantly by WHO region (ANOVA p<0.001) with the highest abundance in Africa (mean log10 abundance=2.23) and lowest in the Americas (mean log10 abundance=2.02). Increased access to potentially safely managed sanitation was associated with a decrease in ARG abundance in unadjusted and adjusted analyses (unadjusted p<0.001, adjusted p=0.04).

We will present the results of our primary analysis, as well as our subgroup analyses by income, antibiotic usage in humans and livestock, urbanicity, and age. Current approaches to controlling antibiotic resistance in humans rely on antibiotic stewardship; however, this approach is difficult in LMICs where infectious illnesses are prevalent and unregulated antibiotic usage is common. The results of this work support sanitation as an additional strategy to curb the spread of antibiotic resistance around the world.

A Multimodal Intervention to Improve Hand Hygiene in The Facility and Home During the Peri-natal Period in Cambodia

Presenter: Yolisa Nalule, London School of Hygiene and Tropical Medicine

Additional Authors: Por Ir, Ponnary Pors, Channa Samol, Supheap Leang, Robert Dreibelbis

Globally, infections acquired during birth and the first days of postnatal care account for approximately 15% of all neonatal and 10% maternal deaths. Risk factors are predominantly related to poor hygiene practices in health care facilities and the home environment. Despite advances in other areas of hygiene, effective theory-based hygiene interventions targeting multiple caregivers in both health care and home settings are lacking.

We assessed the feasibility of a novel multimodal behaviour change intervention delivered at the facility-level to improve the hand hygiene practices among midwives and caregivers during childbirth through the return to the home environment. The intervention engaged midwives in redesigning the delivery room and incorporating visual cues, leveraged the social environment to promote new norms, and delivered interactive training. For caregivers, the intervention visually demarcated "clean hand zones" in the facility, improved access to hand hygiene infrastructure, and incorporated nurture-related cues to guide, remind and reinforce practice. The hand hygiene practices of all caregivers present during childbirth and the postnatal care period of 99 women and newborns were directly observed across 8 public health care facilities – half of which received the 6-month intervention.

Multilevel logistic regression models, adjusted for baseline measures, assessed differences in hand hygiene practices between intervention and control facilities. Qualitative and quantitative process data was collected throughout the implementation period via training assessments, monthly facility spot checks and periodic semi-structured interviews of health care staff, new mothers and other caregivers who delivered in the intervention facilities. Feasibility of the intervention was assessed using fidelity, reach, compliance, comprehension, and acceptability indicators. The intervention was associated with increased odds of improved practice prior to labour, delivery or immediate childbirth in the delivery room (adjusted odds ratio [AOR] = 4.7; 95% confidence interval [CI] = 2.7, 7.7), and prior to newborn care in the post-natal care facility ward (AOR = 9.2; CI = 1.3, 66.2); however, the absolute magnitude of changes in behaviour was limited. The intervention was not associated with differences in hygiene practices prior to newborn care in the home environment. All midwife-targeted components were delivered with high fidelity, reach and achieved high levels of compliance, comprehension, and reported acceptability. The household caregiver–targeted components were delivered with varying fidelity and reach which subsequently affected levels of compliance and comprehension. The reported acceptability of the intervention components was very high among household caregivers.

Our results suggest a multi-modal intervention to improve the hand hygiene practices that are critical to maternal and neonatal infection in the facility is feasible. Based on our promising results, we are now engaging key stakeholders for further adaptation of the intervention ahead of a rigorous evaluation of its impact in a large-scale trial.

A Systematic Review of Global Prevalence and Use of Trucked Water as A Potable Water Supply

Presenter: Kaycie Lane, University of Massachusetts Amherst

Additional Authors: Dr. Emily Kumpel

Achieving global access to safe and reliable drinking water has focused on providing water that is on-premises, safe, and reliable globally. However, many communities around the world rely on secondary sources to supplement otherwise inadequate piped water supplies, are located in remote areas or extreme climates where delivery networks and on-site sources are untenable, or are in need of temporary water supplies during emergencies. Trucked water, also called water bowsers, tanker trucks, and water haulers provides a viable water source in many situations. People in almost all regions of the world report using delivered trucked water during humanitarian emergencies, as a result of geographic remoteness, or other underlying socio-political factors. While often viewed as a temporary solution during drought or humanitarian emergencies, there are numerous cities, towns, and small communities where trucked water is a regularly used and important source of water. The safety, reliability, and accessibility of trucked water also vary by context: there are concerns with water quality and quantity and the sustainability of this system as the effects of climate change and shifting populations impact water systems. Understanding the prevalence, use, and impacts of trucked water systems are an important part of understanding how to best improve sustainable water access for populations around the world. We conducted a systematic review of the literature and reviewed available global data around trucked water to understand (1) the number of regions and people served by trucked water, (2) in which scenarios trucked water is used for potable purposes and (3) the challenges and opportunities in trucked water systems and (4) map research needs.

We conducted a systematic literature review of peer-reviewed and grey literature. We identified 61 papers that provided detailed information on trucked water and 57 with a brief reference to it. These studies were reviewed to identify key themes: water quality, costs, contexts used, operations and management, and volumes supplied. Preliminary results highlight that trucked water is more expensive for consumers than other water sources and that it is used as a regular supply system as well as in emergency settings. We also used data from Joint Monitoring Programme (JMP) global surveys from 2000-2017 and estimated that a median of 21.2 million people (with a range of 3.8 -50 million people) in X 146 countries are served by trucked water supply annually, and analyzed changes

by year, region, country, and urbanicity. Notable, through the literature review, at least 5X countries do not report populations using trucked water to the JMP, but 9 case studies of their use were found in literature, highlighting gaps in global data collection on trucked water and/or reliance on trucked water as a secondary water source.

We will present data on the prevalence and trends of trucked water use globally, as well as analyze the reasons for trucked water delivery, the potential for trucked water to provide water to underserved regions, and the challenges that remain for ensuring trucked water supplies are part of global access to safe, reliable, and affordable water.

A Systematic Review of Surface Contamination, Stability, And Disinfection Data on Sars-Cov-2 (January 1-July 10, 2020)

Presenter: Gabrielle String, Tufts University

Additional Authors: Noah Bedrosian, Elizabeth Mitchell, Elsa Rohm, Miguel Rothe, Daniele Lantagne

Key Learning Objectives
- Understand existing data related to WASH and SARS-CoV-2 transmission
- Summarize evidence on stability and persistence of SARS-CoV-2 on surfaces and effective methods for surface disinfection of SARS-CoV-2
- Make recommendations to researchers for improving surface disinfection evidence gaps

Water, sanitation, and hygiene (WASH) interventions are key to reducing the disease burden associated with outbreaks. As SARS-CoV-2 transmission via water or wastewater has not been documented, the hygiene component of WASH, including handwashing and surface disinfection for infection, prevention, and control, is critically relevant. The WHO and the CDC recommend handwashing with soap and water, or alcohol-based hand sanitizers, to prevent SARS-CoV-2 transmission. Additionally, WHO and CDC recommend first using soap to clean a soiled surface, and then disinfecting with an EPA approved household disinfectant or sodium hypochlorite. While SARS-CoV-2 has global impact, people living in low- and middle-income countries are particularly impacted by COVID-19. SARS-CoV-2 transmission is enabled in areas with overcrowded living situations, poor hygiene conditions, and lack of access to personal protective equipment. Additionally, inadequate access to water and sanitation resources compromises the ability to complete effective handwashing and surface disinfection, and shared water resources and sanitation infrastructure have higher surface contamination potential.

We conducted a systematic review to identify and summarize WASH intervention effectiveness at interrupting SARS-CoV-2 transmission routes. The review was developed based on the guidelines for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses and included developing inclusion criteria, conducting the search, selecting articles for inclusion, and summarizing included articles. From two downloads of the NIH COVID-19 Portfolio and the CDC COVID-19 Research Articles Downloadable database, 96,268 articles were screened and 78 met inclusion criteria on surface contamination, stability, and disinfection. Surface contamination was assessed on 3,343 surfaces using presence/absence methods. Laboratories had the highest percent positive surfaces (21%,n=83), followed by patient-room healthcare facility surfaces (17%,n=1,170), non-patient-room healthcare facility surfaces (12%,n=1,429), and household surfaces (3%,n=161). Surface stability was assessed using infectivity, SARS-CoV-2 survived on stainless steel, plastic, and nitrile for half-life 2.3-17.9 hours. Half-life decreased with temperature and humidity increases, and was unvaried by surface type. Ten surface disinfection tests with SARS-CoV-2 and 15 tests with surrogates indicate sunlight and ultraviolet light, and ethanol, hydrogen peroxide, and hypochlorite, respectively, attain 99.9% reduction.

There was: 1) an inability to align SARS-CoV-2 contaminated surfaces with survivability data and effective surface disinfection methods for these surfaces; 2) a knowledge gap on fomite contribution to SARS-COV-2 transmission; 3) a need for testing method standardization to ensure data comparability; and, 4) a need for research on hygiene interventions besides surfaces, particularly handwashing, to continue developing recommendations for interrupting SARS-CoV-2 transmission. Furthermore, as fomites are not a primary transmission route of SARS-CoV-2, attempts to update this review yielded minimal new data. However, evidence on viral surface disinfection presented herein is critical to preparing for future emerging infectious disease outbreaks.

A Toolkit for Costing Environmental Health Services in Healthcare Facilities

Presenter: Darcy Anderson, The Water Institute at UNC

Additional Authors: J. Wren Tracy, Ryan Cronk, Hayley Schram, Nikki Behnke, Jamie Bartram

Environmental health services (EHS) are critical for safe and functional healthcare facilities (HCFs). Understanding costs is important for improving and sustaining access to EHS in HCFs. Yet understanding of costs is poor, and no tools exist to specifically support costing EHS in HCFs in low-and middle-income countries.

We developed a toolkit to guide the following steps of costing EHS in HCFs: defining costing goals, developing and executing a data collection plan, calculating costs, and disseminating findings. Our costing toolkit is divided into eight step-by-step modules with instructions, fillable worksheets, and guidance for effective data collection. It is designed for use by diverse stakeholders involved in funding, implementation, and management of EHS in HCFs and can be used by stakeholders with no prior costing experience. Toolkit users will generate the following key outputs: a data collection plan, contextual assessment on facility characteristics (e.g., facility size, type of services provided) and EHS characteristics (e.g., number and type of improved sanitation facilities), cost spreadsheet detailing line item expenses and associated costs, assessment of data limitations, and a dissemination plan.

These outputs may be used for planning and budgeting for EHS in HCFs, for example by assessing the cost of operating existing EHS or predicting costs of installing new EHS. This toolkit may also be applied for research, such as for cost-effectiveness studies. We present the development, structure, and functionality of the toolkit; provide guidance for its application; and identify good practices for costing, including pilot testing data collection tools and iterating the data collection process, involving diverse stakeholders, considering long-term costs, and disaggregating environmental costs in records to facilitate future costing.

Acceptability And Use Characteristics of Novel Latrine Mats to Increase Latrine Training and Safe Child Feces Disposal in Rural Odisha, India

Presenter: Valerie Bauza, Emory University

Additional Authors: Gloria Sclar, Apurva Ghugey, Thomas Clasen

Background:
In rural Odisha, India, it is common for young children's feces to be unsafely disposed of in the open, even in households with latrines that are used by adults. Past studies have found that a child using a latrine directly is one of the strongest predictors of safe child feces disposal for children under five years old. However, despite the benefits that earlier latrine training can provide for improving child feces management, few studies have focused on latrine training and ways to promote safer child latrine use.

Methods:
We developed three versions of a wooden latrine training mat that could be placed over a latrine pan to help a child defecate in pour-flush latrines common in Odisha, India. The mats were designed to make the latrine hole smaller and provide stability for a child with handles to encourage earlier latrine training and latrine use. One version of the latrine mat was designed to also enable safe use outside the latrine with a removable tray that could be securely placed under the hole to safely collect feces when the mat was used outside of the latrine. These latrines mat were piloted in households with children <5 years in 8 villages, with feedback collected through focus group discussions after approximately one week of use and semi-structured interviews after approximately two weeks of use. The 'best' version of the latrine mat was then distributed as part of a behavior change intervention to households with children <4 years in 37 villages. Use of the latrine mats was measured over time during the intervention period and discussed during in-depth interviews conducted with caregivers approximately 4 months later.

Results:
Overall, latrine mats had high levels of acceptability and use, and caregivers expressed that latrine mats made it safer and easier for a child to use a latrine. However, we also found that the specific design of the latrine mat influenced the acceptability and ease of use of the mat. Handles attached to the mat and a removable tray that could be placed underneath the mat outside of the latrine were desirable features. However, the addition of a plastic seat to the mat that a child could sit or squat on was found to make the mat more

difficult for children to use despite earlier expressed preference for this version of the mat prior to use. This presentation will give a detailed overview of characteristics of acceptance, use, cleaning, and transition of practices related to using these latrine mats.

Conclusions:
Latrine training mats had high levels of acceptability, were easy to use, and assisted children in transitions to latrine training and latrine use. They could also play an important role in improving child feces management practices and increasing child latrine use.

An Assessment of Portable Kits for Testing of E. coli In Drinking Water

Presenter: Rick Johnston, World Health Organization

Additional Authors: Esther Shaylor, UNICEF

Background
WHO and UNICEF both support national counterparts in monitoring and surveillance of drinking water quality in a variety of settings. In many countries where WHO and UNICEF work, logistical challenges mean that testing drinking water quality in laboratories is often not feasible, due to long distances and travel times required to transport samples. This has led to an interest in portable water quality testing kits, especially for measures of faecal contamination. Both WHO and UNICEF regularly procure portable water quality testing kits for national counterparts, and share an interest in ensuring that the equipment procured can produce results that are reliable and match within reasonable margins the results from standard reference methods. In addition, both organizations wish to catalyse the continuous improvement of existing portable water quality testing products, and the development of innovative new products which might allow more efficient, accurate, or low-cost testing of drinking water quality in the field.

Methods
UNICEF has developed a Rapid Water Quality Testing project to catalyze innovation and continuous improvement of existing portable water quality testing products. WHO has developed a protocol for assessing portable water quality testing kits under laboratory conditions. This presentation will share results from the first set of 20 portable kits assessed, including ten kits based on counting colonies, seven based on the growth of bacteria in suspension in selective media, and three using most probable number methods. Kits were challenged in two phases. A first screening phase was made using a laboratory strain of E. coli (ATCC 25922) in laboratory water, with stocks ranging from over 1000 cells/100 mL to <1. A more detailed second phase involved non-target organisms, varying temperature and incubation conditions, and natural waters spiked with wild E. coli. Some of the trial kits submitted to the UNICEF rapid water quality testing project allow quantification in under ten hours, but the majority were more conventional and yielded results within between 16 and 24 hours of incubation.

Results
Several methods did not pass the Phase 1 screening, either because of inadequate quality control for newly developed products, or low recovery compared to reference methods. Of the kits examined in Phase 2 challenges, no false positives were observed in the presence of Citrobacter, Enterobacter or Klebsiella. Three kits showed low counts in the presence of Aeromonas, and two were difficult to read in the presence of Pseudomonas. More kits showed difficulties in recovering E. coli in the presence of high levels of non-target bacteria. Recovery was lower at incubation temperatures below 30°C, or at 45°C.
[Results from the natural waters/wild E. coli challenges are still being collected but will also be presented].

Conclusions
A number of portable tests are available for E. coli testing in the field which perform well with respect to reference methods, though some have limitations under certain conditions. Several manufacturers are working to develop more rapid, easy, and inexpensive portable tests, and some of the novel products tested show promise but need further development.

Assessing The Effectiveness of Passive Chlorinators in Nicaragua and Honduras, Using Routine Monitoring Data

Presenter: Megan Lindmark, University of Iowa

Additional Authors: Dr. Craig Just, Wesley Meier, Diana Calix, Milton Rocha

Background & Purpose:
Elevating community water supplies from basic to improved sources, to meet SDG 6 continues to be a challenge. One potential solution, community level passive chlorinators can provide community wide disinfection and remove the burden from individuals relying on household interventions. In Nicaragua and Honduras, EOS International has assisted 1000+ communities in installing their own passive chlorinators. Small scale, community level evaluations conducted by EOS indicate that these systems appear to be effective. However, EOS's chlorinator design and monitoring operations have not been formally evaluated in the literature. We have analyzed 8 years of visit data and 12,129 water quality samples, collected by EOS circuit riders to answer the following questions:

1. Are EOS passive chlorinators an effective technology for providing free chlorine residual (FCR)?
2. What are the leading causes of EOS passive chlorinator failure (FCR < 0.2 mg/L)?

Methods:
EOS circuit riders visited 337 chlorinators monthly, between January 2013 and December 2020. During each visit circuit riders collected a water sample for FCR analysis. Technicians also assessed any potential causes of failure if no chlorine was present.
Using all available EOS survey data in mWater, we grouped data by community to evaluate the frequency with which each community received adequate chlorine. We sorted monitoring data points with failures (n=2482) by reason for failure to determine the proportion of each type of failure across the entire dataset. Next, we used ANOVA analyses to determine whether sampling location, age of system, and water source (groundwater vs. surface water) influenced FCR.

Results:
Preliminary results indicate that over 70% of all monitoring samples had FCR concentration >0.2 mg/L; with an average FCR across all samples of 0.58 mg/L. System age and water source did not significantly affect FCR (p value >.05), but sampling location within the distribution system did, with samples taken closest to the tank having significantly higher mean FCR concentrations. Primary schools (n=121) using passive chlorinators had on average much lower FCR than other sampling points.
Human error (habitual or occasional failure to replace chlorine tablets, or failure to purchase chlorine tablets) were responsible for 52.92% of failures. System failure (insufficient water, chlorinator malfunction, ongoing repairs, etc.) accounted for 24.51%. The remaining 22.57% of failures could not be categorized as specific to system or human error.

Implications:
Providing free chlorine residual in piped drinking water is one way to eliminate or at least minimize the potential for waterborne disease, particularly in resource constrained settings. Our analyses indicate that the simple PVC chlorinator devices deployed in Nicaragua and Honduras, are effective in providing this residual. However, the leading cause of system failure could not be attributed to the system itself, but instead to human error. Therefore, thoughtful monitoring support and community capacity building continues to be key to maintain the lifetime and sustainability of both these technologies and safe drinking water access for these communities. More research is required to determine how adaptable these systems can be to settings like healthcare centers and primary schools. These findings suggest that these systems could be adapted to assist many other communities in achieving safe drinking water, and support progress towards Goal 6.

Building Long-term Sustainability of Wash in Healthcare Facilities (HCFS)

Presenter: Victoria Cuellar, Desert Research Institute

Additional Authors: Braimah Apambire, Nancy Gilbert, Steve Werner, Daniel Nyirenda, Flument Mkinga,

Global advocacy to strengthen WASH services in Health Care Facilities (HCFs) has risen due to reports of stark inequalities directly attributed to increased risk of mortality and infection rates, especially in low-income countries.(1) These inequalities are due to lack of sufficient water, sanitation, waste management and cleaning facilities, and to poorly managed existing water systems. Furthermore, due to the lack of proper national statistical frameworks, the health care data generated is extremely limited.(1) As such, there is a definite need to focus on building an evidence-based framework for Monitoring, Evaluation, Resolution, and Learning (MERL) tools for WASH in HCFs.

To fulfill data gaps for HCFs of Rumphi District in Northern Malawi, Desert Research Institute (DRI) and Transform International (TI) undertook a study to understand the barriers to sustainability of WASH systems in HCFs.(2) The study involved onsite assessments, and interviews with professionals and patients from all 18 HCFs in Rumphi District. The research concluded that despite staff availability and commitment, significant gaps in local staff capacity, lack of awareness among patients, insufficient resources and equipment, infrequent trainings, and weak governance led to poorly maintained WASH services and inconsistent hygiene, cleaning and waste management practices. Only 39% of HCFs in Rumphi had consistent access to water, of which, 94% of the sources were contaminated with total coliforms while 56% were contaminated with E. coli.

A comprehensive framework to support WASH in HCFs that incorporates training, ongoing technical support, supervision, and consistent MERL activities is being developed for Rumphi District. This framework, titled STREAMS (systems, training, empowerment and monitoring support), is largely based on the Circuit Rider (CR) methodology developed by the National Rural Water Association. The main CR methodology involves a small group of skilled and trained individuals who provide support through periodic maintenance and informal training visits to strengthen community WASH systems, similar to how rural US water organizations and utilities operate. To address the identified gaps specifically for WASH in HCFs, the framework is being modified to train two types of CRs for HCFs: Technical CRs (scope: repair and maintenance of water and sanitations systems, water quality, climate change resilient water and sanitation) and Quality of Care CRs (scope: hygiene training and monitoring, Infection Prevention and Control (IPC), cleaning, waste management, quality of care and gender equity). The CRs work with Rumphi District Council to ensure long-term sustainability of HCFs. As this project is currently being implemented in Rumphi, data will be gathered on a regular basis to assess progress and program outcomes. By building local capacity and implementing systems to continually improve, maintain, and sustain WASH services, we hope to strengthen the resilience of HCF staff, and make WASH and health services more accessible and available for all.

1) World health statistics 2020: monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2020. Licence: CC BY-NC-SA 3.0 IGO.
2) Apambire, B., Gilbert, N., Nyirenda, D., Wang, C. & Werner, S. (2020). WASH in health care facilities: Assessment of WASH service delivery and sustainability in Rumphi, Malawi. http://transforminternational.org/wp-content/uploads/2020/07/Malawi-WASH-HCF-Assessment-report-2020-02sm.pdf

Child Mouthing of Soil and Contaminated Fomites and Unimproved Sanitation Are Associated with Subsequent Poor Child Developmental Outcomes in Urban Bangladesh (Chobi7 Program)

Presenter: Christine Marie George, Johns Hopkins Bloomberg School of Public Health

Additional Authors: Tahmina Parvin, Md. Sazzadul Islam Bhuyian, Elizabeth D. Thomas, Shirajum Monira, Fatema Zohura, M. Tasdik Hasan, Jamie Perin, Munirul Alam, Fahmida Tofail

Objective:
Millions of young children annually in low and middle income countries are not meeting their developmental potential. Water, sanitation, and hygiene (WASH) program delivery presents a potential approach to improve child developmental outcomes by reducing enteric infections which can lead to malnutrition and poor child growth.

Study Design:
This prospective cohort study of 224-children under 5-years was conducted in urban Dhaka, Bangladesh to investigate the association between household WASH infrastructure and behaviors and subsequent child developmental outcomes. Developmental outcomes were assessed by communication, fine motor, gross motor, personal social, problem solving, and combined developmental scores measured by the Extended Ages and Stages Questionnaire(EASQ) at a 12-month follow-up visit.

Results:
Children who put soil in their mouth at the majority of surveillance visits had significantly lower combined EASQ Z scores(coefficient: -0.53 (95% Confidence Intervals (CI): -0.83, -0.22)) at the 12-month follow-up visit. Children who put visibly dirty objects in their mouths at the majority of visits had significantly lower combined EASQ Z scores(-0.50 (95% CI: -0.79, -0.22)). Children in households with unimproved sanitation had significantly lower combined EASQ Z scores(-0.63 (95% CI: -1.11, -0.16)).

Conclusion:
Children found to put soil and visibly dirty objects in their mouths at the majority of household visits, and those that resided in households using unimproved sanitation had lower subsequent cognitive developmental outcomes. These findings demonstrate the

importance of interventions targeting child mouthing behaviors and sanitation infrastructure in households to reduce exposure to fecal pathogens and improve child cognitive developmental outcomes for susceptible pediatric populations.

Comparison of PCR Methodologies for The Detection and Quantification Of SARS-CoV-2 In North Carolina Municipal Wastewaters

Presenter: Megan Miller, Gillings School of Global Public Health at the University of North Carolina Chapel Hill

Additional Authors: Connor LaMontagne, Alyssa Grube, Collin Knox Coleman, David Holcomb, Jill Stewart

Wastewater surveillance can be valuable for monitoring pathogen presence and prevalence during infectious disease outbreaks in communities. This approach is being applied during the current COVID-19 pandemic to measure the concentration of the SARS-CoV-2 virus in community wastewaters and to monitor disease trends.

Methods for the surveillance of non-enveloped viruses in wastewaters are more common in the literature, and standardization of wastewater surveillance methods for enveloped viruses, such as SARS-CoV-2, is needed. This study compares the performance of two PCR-based methodologies, RT-qPCR and RT-ddPCR, for the detection and quantification of SARS-CoV-2 in influent samples from two NC wastewater treatment plants (WWTPs). Sample collection, processing, RNA extraction, and RT-ddPCR analyses were completed for samples collected over a 24-week period. RT-qPCR assays were performed on identical samples as RT-ddPCR for comparison purposes, and the effects of matrix inhibition on both methods were evaluated for a subset of samples.

This study found a significant difference between the detection sensitivity of RT-qPCR and RT-ddPCR. RT-ddPCR detected a statistically greater occurrence of SARS-CoV-2 than RT-qPCR for both WWTPs. A decrease in sensitivity differences between the methods was found when values quantified below the RT-qPCR LOD were considered in the dataset. This study suggests that RT-qPCR demonstrates useful analytical sensitivity for the detection of SARS-CoV-2, particularly when values below the LOD/LOQ are considered to a limited extent. RT-ddPCR was found to be the preferred method for quantification purposes of SARS-CoV-2 in wastewaters.

Costs of Basic Hand Hygiene in Domestic Settings – Modelling For 47 Least Developed Countries

Presenter: Ian Ross, LSHTM

Additional Authors:

Learning objectives:
1. The economic cost of basic hand hygiene for domestic settings in 47 least developed countries is US$ 14.5 billion over 10 years.
2. Soap comprises 41% of total costs, followed by initial hygiene promotion (25%) and top-up promotion (17%). Handwashing facilities comprise only 10% of total costs.
3. The costs of delivering hand hygiene in domestic settings to those currently with "no service" are substantial in total, but relatively modest in per capita terms.

Background:
Four in 10 people globally do not have a basic handwashing facility with soap and water available. In 2019, only 17% of 109 countries responding to WHO's Global Analysis and Assessment of Sanitation and Drinking-water (GLAAS) survey reported the size of hygiene budgets or expenditures. When governments do not know what is being spent on hygiene, it is hard to advocate for more funds and to optimally allocate what is available. Planning interventions is difficult if their costs are not known. The aim of this study was to estimate the cost of delivering hand hygiene for all in domestic settings in least developed countries (LDCs).

Methods:
We built a model combining quantities of households to be served and prices of key inputs, such as hygiene promotion programmes, handwashing facilities, and household soap expenditure. For quantities, we used data from the UNICEF/WHO Joint Monitoring

Programme for "no hygiene service" in 47 LDCs. For prices, we collated data from a previous review and new electronic searches, and by contacting investigators of recent impact evaluations. We synthesised data to estimate the "price tag" for scaling up interventions over 2021-2030 in LDCs. We used a disaggregated societal perspective, estimating societal economic costs and provider financial costs separately. We inflated local currency prices to 2019 international dollars (I$). After estimating I$ means and standard errors per cost category, we converted them into 2019 US$ at local purchasing power per country. We made a probabilistic estimation of total cost, via 1,000 draws in a Monte Carlo simulation, modelling prices as gamma distributed.

Results:
The total economic cost over 10 years was US$ 14.5 billion (95% confidence interval: 13.0 - 16.0), which equates to $1.19 per capita per year for total LDC population. The costs of soap, assumed to be borne by households, were $600 million per year (41% of total costs). The provider financial cost, that is the costs of hygiene promotion, was $360 million per year on average (25%), with a further $250 million per year for 'top-up' promotion (17%). The costs of handwashing facilities, assumed to be a purpose-built bucket with tap and stand, were $140 million per year (10%).

Conclusions:
The costs of delivering hand hygiene in domestic settings to those currently with "no service" are substantial in total, but relatively modest in per capita terms. Our study poses the question of who should pay for which components of total cost, and emphasises the need for better data on the relative effectiveness of different promotion interventions for uptake and adherence of behaviours.

Demand "Activation:" The Importance of Sales and Marketing Activities for Increasing the Viability of Sanitation Enterprises

Presenter: Subhash Chennuri, FSG

Additional Authors: Rishi Agarwal

In addition to their supply-side interventions, market-based sanitation (MBS) programs also often invest in demand generation to encourage behavior change; yet these investments frequently fail to translate into high numbers of consumer purchases, which may discourage enterprises from participating, or staying in the market. Demand activation – the active sales and marketing of toilets on behalf of sanitation enterprises – converts potential customers into actual customers, but is not widespread among MBS programs.

The presentation synthesizes insights from structured interviews with 66 sanitation enterprises across three countries, from which we built detailed financial statements to analyze drivers of enterprise profit. We complement these results with findings from a desk review of market-based sanitation (MBS) programs encompassing 600 documents and in-depth research into 13 MBS interventions across the global south, as well as interviews with sector experts and program personnel.

The key findings are:
1. Sanitation enterprises with a relatively larger customer base managed customer acquisition by investing in demand activation through commissioned sales agents as well as unpaid demand deactivators such as local leaders
2. Leveraging independent sales agents is a low-risk, high-return demand activation mechanism for sanitation enterprises
3. Demand activation mechanisms have been sustained where sanitation enterprises were encouraged to manage and pay sales agents rather than relying on donor-funded MBS programs to do so.
4. MBS programs that scale (i.e., delivered basic sanitation to 50,000 people or more) were more likely to have invested in demand activation mechanisms.

The findings emphasize the need for MBS programs to invest in demand activation mechanisms as a fundamental practice to drive growth and viability of sanitation enterprises, sustainability of overall market supply, and scale outcomes during and beyond the life of the program.

Detection And Surveillance Of SARS-CoV-2 In Wastewaters from Treatment Plants Predicted Rise in Reported Covid Infections

Presenter: Connor LaMontagne, UNC Chapel Hill

Additional Authors: Alyssa Grube, Nikhil Kothegal, Collin Coleman, Megan Miller, Jill Stewart

The COVID-19 response has relied on clinical surveillance for identifying positive cases, which has been hampered by limited diagnostic testing capacity and a considerable prevalence of asymptomatic infections. As SARS-CoV-2 tends to shed in human feces, wastewater-based epidemiology (WBE) has been proposed as an environmental surveillance approach for monitoring the transmission of SARS-CoV-2 at the population level. Furthermore, fecal shedding in asymptomatic and presymptomatic cases highlights the potential of WBE to detect infected individuals before they would seek clinical diagnosis. Numerous studies have employed WBE to monitor pathogens, demonstrating its potential as a cost-effective early warning system to prevent outbreaks and monitor elimination of controlled diseases. However, the effectiveness of this approach has not been well-validated on a wide scale for SARS-CoV-2.

As part of the North Carolina Wastewater Pathogen Research Network (NC PATH) collaborative, we assessed the application of WBE to COVID-19 by estimating SARS-CoV-2 concentrations in wastewater and comparing these concentrations to COVID-19 cases in the sewersheds of two wastewater treatment plants (WWTPs) in central NC, including one that services a hospital and a university. Samples of influent and primary solids were collected from the WWTPs weekly from July until December 2020, concentrated via membrane filtration, and subjected to RNA extraction and droplet digital PCR (ddPCR) to quantify SARS-CoV-2 viral RNA for nucleocapsid targets N1 and N2.

To assess the suitability of the wastewater data for predicting COVID-19 trends, RNA copy concentrations were overlaid longitudinally with COVID-19 case data for zip codes serviced by the WWTPs. At least one of the SARS-CoV-2 RNA targets was detected in 90% (n=48) of influent samples over the 24-week period. Initial ddPCR analyses infrequently detected the RNA in primary solids, so subsequent data were collected from influent samples only. Despite some noise in the data, SARS-CoV-2 detection trends roughly predicted case counts for both sewersheds. For the WWTP that served a university, a peak in viral copies preceded a peak in cases by a few days, and the peaks coincided with the return of students to campus in August 2020.

Additionally, comparing the SARS-CoV-2 targets found N1 detected more often than N2 (85% vs. 73% of samples), with the targets agreeing in 79% of samples. Our findings suggest the feasibility of WBE in predicting COVID-19 disease trends. This is despite a suboptimal temporal resolution in our data, attributable to sampling less frequently than recommended by the CDC for epidemic surveillance. Development and optimization of the methods - namely of sample concentration and ddPCR - helped to address issues with sensitivity common in environmental microbiology.

This work contributes to the NC PATH collaborative in optimizing methods and building statewide capacity for WBE of COVID-19 and future epidemics. Results of this work demonstrate a feasible and cost-effective approach to estimating and predicting disease trends at the population level, and may be particularly applicable in settings where resources for clinical diagnostic testing may be limited.

Determinants of Rural Water Point Functionality: But What Is Functionality?

Presenter: Catherine McManus, UNC Chapel Hill

Additional Authors:

Much of the drinking water around the world, especially in rural Sub-Saharan Africa, is provided through the use of water points, communal collection points shared by a community or neighborhood. However, these water points are frequently out of operation, and their users are forced to rely on water sources of lower quality, likely contributing to the high global disease burden associated with diarrheal disease.

This work analyzes a survey of more than 3,700 water points in rural areas of twelve countries in Sub-Saharan Africa to identify community or management determinants of functionality of the water point. While the typical definition of functionality is binary, focusing mainly on operationality, this work considers operationality as well as the frequency and duration of breakdowns as part of the conceptualization of functionality.

Through the use of regression analysis and structural equation modeling, this work identifies factors with the largest effects on functionality. Structural equation modeling, which allows for the identification of causal pathways, improving on the associations determined by regression analysis, also identifies factors which do not have direct effects on, but nevertheless have large total effects on, the functionality of rural water points. These factors, which include the involvement of a paid, trained caretaker in the management of a rural water point, demonstrate that there are important causal pathways by which water point managers can seek to improve the functionality of their rural water point, both directly and indirectly. This work improves upon past functionality studies through the identification of pathways of functionality, rather than just statistical associations. In addition to determinants of functionality, the structural equation model identifies factors which have potentially important implications for inclusion and diversity of rural water point management, including the selection method of water committee members.

Water point managers and water committees should seek to incorporate these factors in the operation of their rural water point, ideally maximizing on the causal pathways identified. Improving the functionality of rural water points worldwide will be a major determinant in the achievement of the United Nations Sustainable Development Goal of a safely managed drinking water source for all worldwide.

Do Water, Sanitation and Hygiene Save Lives? Results From a Systematic Review and Revised Global Burden of Disease

Presenter: Hugh Sharma Waddington, London School of Hygiene and Tropical Medicine and London International Development Centre

Additional Authors: Sandy Cairncross, Sarah Bick

Background:
Respiratory tract infections and diarrhoea are the two biggest killers of children in low income contexts. They are closely related to access to, and use of improved water, sanitation and hygiene (WASH). However, there is no high quality systematic review that quantifies the effect of WASH improvements on childhood mortality. Existing systematic reviews of WASH improvements measure effects on morbidity, under the (often implicit) assumption that morbidity is closely correlated with mortality. This is at least partly because the impact evaluations on which they are based are only designed to detect changes in morbidity with statistical precision, whereas mortality is a relatively rare outcome. There are also ethical concerns about the use of prospective studies like randomised controlled trials (RCTs) to measure mortality.

Study design:
The review addressed this evidence synthesis gap, using the greater statistical power of meta-analysis to pool findings across studies. Drawing on, and updating, the results of a WASH-sector evidence and gap map by the authors, data were collected from RCTs and non-randomised studies (NRS) of WASH improvements that measured or reported childhood mortality in low- and middle-income contexts. The evidence was critically appraised for risk of bias and publication bias. Odds ratios were extracted and synthesised using meta-analysis and meta-regression. Results were applied to the WHO's Global Burden of Disease data.

Key findings:
The searches found 53 studies reporting mortality in childhood, comprising 78 study arms measuring all-cause mortality and 16 arms measuring diarrhoea mortality. Meta-analysis of of intervention studies found 15 percent reduction in the odds of all-cause mortality in childhood, and 50 percent reduction in odds of diarrhoea mortality, relative to control communities. Further analysis explained the statistical heterogeneity across studies by three sets of variables: hygiene and water supply in the public and household domains; age of child; and study design. WASH interventions reduce more deaths in childhood when they include community-wide sanitation and domestic hygiene components when existing water supply is more reliable.

Implications for science and policy:
The results support the hypothesis that faeco-oral infection in endemic disease conditions is transmitted mainly through the water-washed route, owing to inadequate water supply, hygiene and sanitation. The findings suggested that global diarrhoea mortality is under-estimated by at least half a million people every year, mainly people living in Africa. The research also suggests that weak standards of trial reporting, in particular where participant flow diagrams are not required by journals, hold back scientific progress.

Drivers of Wash in Healthcare Facilities Service Levels: Results of A 14 Country Evaluation

Presenter: Laura Kmentt, London School of Hygiene and Tropical Medicine

Additional Authors: Elliot Rogers, Ryan Cronk, James B. Tidwell

Background
Prevention and control of healthcare-associated infections through ensuring adequate Water, Sanitation and Hygiene (WASH) in healthcare facilities is inadequate, especially in low-resource settings. This results in high patient mortality, added healthcare costs and the risk of antibiotic resistance. We aim to identify to what extent WASH is implemented in healthcare facilities in low-and middle-income countries and understand the "drivers" of improvement in their service levels.

Methods
Healthcare facilities were selected from rural areas across India, Honduras, and 12 sub-Saharan African countries. The survey included questions and observations of HCF characteristics; water (source type, distance to source, availability, water storage, treatment), sanitation (type, functionality, condition, and use); hygiene (hand hygiene); waste management (sharps and infectious waste segregation, treatment, and disposal); and administration and training (policies, budget, trainings on WaSH and infection prevention and control).WASH service levels in these healthcare facilities were descriptively analysed, and potential drivers of service level differences were explored using univariable and multivariable mixed-model logistic regression analyses.

Results
Descriptive analysis of the data showed a lack of sufficient WASH across all WASH in healthcare facility sectors (water quality, sanitation, hand and environmental hygiene and waste disposal). With an infection prevention and control protocol (IPCP) and a focal point present, facilities were more likely to treat water before use, have at least basic hand hygiene service level, have access to their own sanitation facilities, and have at least basic water service. Additionally, the presence of an IPCP led to an increased likelihood of the facility being open-defecation free. Offering training to staff led to higher likelihood of hand hygiene service level being at least basic only and showed weak evidence of increasing the likelihood of the facility being open-defecation free. IPCP and training led to no improvement at the multivariable level for lowering the risk of E. coli contamination of water. While the presence of a WASH focal person showed an increase in likelihood for lowering the risk of E. coli contamination, the evidence for this was weak.

Conclusions
More improvement in WASH service level provision for healthcare facilities in the surveyed countries is needed. Installing a comprehensive infection prevention and control protocol, a facility WASH focal person as well as offering in-depth WASH training to staff could be effective managerial interventions to enable substantive improvement in HCF WASH service levels. Further investigation into the effectiveness and implementation possibilities for an infection, prevention and control protocol, a WASH focal person and WASH training for staff at the facilities is highly recommended.

Enhancing Access to Piped Water Among Low Income Households in Uganda

Presenter: Diana Keesiga, NGO

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Approximately eight percent of Uganda's 35.5 million people living in rural areas have access to piped water. The six regional Umbrella Authorities for Water and Sanitation (UAs) operate and manage most piped water supply schemes (WSS) serving rural areas where 54 percent of households earn 55 USD, or less per month. In areas where piped water is available, a connection for households not yet connected would enable women in Uganda to increase market work by 1.5 hours per day.

Whereas lack of supply accounts for majority of the low piped water supply coverage in Uganda, many households live in proximity to exiting WSS but are not able to afford the initial connection cost, roughly 100 USD, and/or pay a monthly water bill. The Ministry of Water and Environment (MWE) has traditionally struggled to target water subsidies to the poor. In comparison to 18 other Sub-Saharan countries, Uganda has the lowest targeting performance to the poor of its piped water subsidies in the period 2002 to 2013.

The USAID Uganda Sanitation for Health Activity worked with the MWE and three UAs to develop and pilot a pro-poor strategy to expand piped water access to marginalized households. The strategy was informed by focus group discussions, tariff analysis and socio-economic surveys at 1,150 households in six towns in Central, Eastern and Northern regions. Results show that over 95% of

households are willing to pay for piped water, 78% can afford a monthly water bill of up to 1.4 USD and over 80% can contribute 14 USD towards the private water connection installation cost. Analysis of historical consumption data from 1,221 connections show that 20% of connections with the lowest monthly consumption, between 0.3-1.6 cubic meters, use only 3% of the total volume of water sold, indicating an opportunity to reduce the water tariff for poor households (i.e. the small volume consumers) with a very moderate impact on revenues.

The Eastern and Central UAs are now piloting the following pro-poor interventions at four schemes: (i) an inverted block tariff (IBT) of 0.3 USD for the first cubic meter (54% reduction) and the nominal tariff maintained for subsequent units (ii) standardizing a subsidized connection cost at either 14 or 28 USD for all households (iii) using a socio-economic survey to improve targeting and allocation of the subsidised water connections to the most vulnerable and (iv) socially marketing private connections to generate interest from a large and diverse proportion of the community within a short time. Application of the IBT at four WSS serving over 26,000 customers started in March 2021. The presentation will focus on: a) the early impacts of the pro-poor approaches on water consumption patterns and revenue b) results from the socio-economic surveys targeting new customers from poorer wealth quintiles and c) response to the social marketing campaign in terms of number of vulnerable households that have paid the connection fee and ultimately been connected.

Evaluation of Cholera Monitoring Tools in Northeastern Nigeria

Presenter: Marine Ricau, Tufts University

Additional Authors: Gabrielle String, Daniele Lantagne, Lise Lacan, Emmanuel Ihemezue

Key Learning Objectives
1. Monitoring WASH activities is important during cholera outbreaks and the WASH cluster and partners had a monitoring program established for cholera.
2. In northeastern Nigeria, we found that the inconsistency and scarcity of reported data made it difficult to interpret the results necessary for a strong response.
3. Recommendations for monitoring include ensuring clarity and rapidity in filling the forms, focusing on outcome and/or output-oriented questions and conducting regular refresher trainings.

Introduction
In northeastern Nigeria, the WASH Cholera Task Force (CTF), led by Solidarités International (SI), was responsible to develop tools for sector-wide monitoring of cholera response and preparedness. The objective of this research was to evaluate and improve the cholera monitoring tools currently used by the CTF partners, consisting of organizations implementing cholera-related activities in northeast Nigeria. Tufts University supported SI in evaluating and updating them to improve cholera related uptake, data collection, and data analysis.

Methods
The existing monitoring tools were composed of three forms accessible through the Kobo application, recording cholera-related activities and completed by the organizations implementing WASH activities. Three different datasets were cleaned and combined for activities between August and December 2019. The datasets were analyzed by form type and activity response category, and were then stratified by groups, such as local governance area (LGA). Additionally, key informant interviews (KIIs) were conducted with monitoring tool users. Questions were designed to understand challenges and barriers to reporting using the current tools, and to collect recommendations for improving tools.

Results
A total of 14 organizations implementing activities in 14 LGAs submitted 723 forms on Kobo. The inconsistency and overall scarcity of reported data made it difficult to interpret the results in a meaningful way. Certain questions and the collection process were unclear, thus leading to inconsistent data collected. Moreover, it was unclear if the lack of data was due to a lack of reporting from organizations, or if it meant that no activity was implemented, and thus it was related to having few cholera cases. Two activity categories, one LGA and one month had a much higher number of activities reported, which may be due to the two organizations that reported the most activities. One organization reported more than 50% of the activities, which is likely because reporting was a requirement of their funding. KIIs covered six reporting organizations and seven persons. The most positive aspects described by the interviewees were the

simplicity of using the platform and the improved reporting that resulted. Informants had access to the consolidated data during the CTF meetings, although the database was not accessible to all. Four informants reported using this data to guide their programming. Despite receiving training during one CTF meeting, some informants highlighted processes and questions that were still unclear. Four informants affirmed reporting weekly on the tools or completing one form per activity, while two said reporting daily or completing one form gathering multiple activities from the same category. Informants indicated that the questionnaires needed some modifications and the addition of output questions.

Conclusion

Findings and recommendations were consistent between data analysis and KII results. The number of forms should be reduced and some questions should be modified, to enhance clarity and rapidity in filling the forms. Moreover, as questions are mostly activity-oriented, the questionnaire should be revised with outcome and/or output-oriented questions, to better support programming improvement. Form use should be clarified through regular refresher trainings. Recommendations developed herein could be useful for other humanitarian settings.

Evaluation of Groundwater Self-Supply Safety and Associated Risk Factors in Urban Indonesia

Presenter: Franziska Genter, Institute for Sustainable Futures, University of Technology Sydney

Additional Authors: Gita Lestari Putri, Cindy Priadi, Juliet Willetts, Tim Foster

Key learning objectives:
1. Faecal contamination was found in a high proportion of self-supply sources
2. Risk factors are inadequate well protection and low socio-economic status
3. Water quality improves significantly due to boiling practices, which are commonly practiced in urban Indonesia

This study investigates the safety of groundwater self-supply at two field sites (Bekasi and Metro City) in urban Indonesia in relation to faecal contamination and associated risk factors.

Self-supply is a ubiquitous response by households to the public water supply inadequacies found worldwide. In Asia-Pacific, over 700 million people depend on self-supply across rural and urban areas. Self-supply is invested in and managed by an individual household, accessible on-premises and unregulated. In urban Indonesia, around 40 million people rely on self-supply for drinking, yet the extent to which self-supply delivers safe water – as well as associated risk factors for faecal contamination – remain unclear.

This study quantified faecal indicator bacteria Escherichia coli (E.coli) using IDEXX Colilert-18 for 493 self-supply sources and at point-of-use for 171 households in the Indonesian cities of Bekasi and Metro. A structured questionnaire was conducted to collect information about the household, water sources and potential on-site contamination sources. A wealth index for household members was constructed based on household assets and dwelling structure using the same approach as the 2017 Indonesian Demographic and Health Survey. E.coli concentration for each water source type at source and point-of-use was comparatively assessed using paired samples Wilcoxon and McNemar's test. The influence of wealth and water quality was investigated using Spearman's rank correlation. Odds ratios were calculated based on univariate and multivariate analysis to examine the influence of risk factors such as wealth, source type, sanitation systems, animals and water storage and treatment on water quality at source and point-of-use.

Overall, E. coli was detected in 66% (n=325) of sources, 56% (n=151) of boreholes, 60% (n=12) of protected wells and 82% (n=166) of unprotected wells. At both study sites, water quality improved significantly between source and point-of-use, with E. coli detected in 30% (n=52) of water samples at point-of-use (p<0.001). In total 98.1% (n=422) of households reported treating their self-supplied water prior to drinking, with boiling being the common method. In Bekasi and Metro, multivariate analysis indicated that unprotected wells were significantly more likely to be contaminated than boreholes (Bekasi: OR=10.96, p=0.002; Metro: 4.08, p<0.001). The analysis found no association between presence of E. coli and proximity to sanitation systems, nor was there an association with ownership of chickens or livestock. In Metro, household members assigned to the higher wealth quintiles had significantly lower likelihood of contamination than household members in the lowest wealth quintile (OR=0.25, p=0.003 for highest quintile). In Bekasi, there was no statistically significant association between water quality and wealth. The type of storage containers and the duration of water storage had no significant influence on water quality at point-of-use.

Groundwater self-supply in urban Indonesia commonly contains faecal contamination with unimproved sources having more frequent and higher levels of contamination than improved sources. Proper treatment and storage increases water safety at point-of-use. Supporting households to invest in safer forms of self-supply could reduce the risk of faecal contamination.

Expanding Safe Water Access and Reducing Indoor Air Pollution in China: A Cluster-randomized Controlled Trial

Presenter: Alasdair Cohen, Virginia Tech

Additional Authors: Zhang Qi, Huang Fayuan, John M. Colford Jr., Isha Ray, Tao Yong

BACKGROUND
Boiling remains the most widely used form of point-of-use household water treatment (HWT) globally and in China. Results from previous research in China suggest that increasing the use of electric kettles for boiling (i.e., treating) drinking water in low-income rural areas could help expand access to safer drinking water, reduce household air pollution, and improve associated health outcomes for households boiling water with solid-fuels or not treating their water. We collaborated with the National Center for Rural Water Supply Technical Guidance, an agency of the Chinese Center for Disease Control & Prevention (China CDC), and CDC agencies in Anhui Province, to design and implement an intervention to promote the use of electric kettles in low-income areas of rural China.

OBJECTIVE
Our objective was to rigorously evaluate the impacts of the China CDC's Rural Electric Kettle Promotion Program on electric kettle adoption, indicators of drinking water quality, indoor air pollution concentrations, and reported health outcomes.

METHODS
We used a parallel arm cohort cluster-randomized controlled (RCT) trial design with a 1:1 ratio to randomize 30 clusters (i.e., villages) to treatment or control arms using stratified randomization by geography (mountains and plains) and by cluster-level proportions of electric kettle use at baseline. Sample size was powered to measure a 15% (or larger) change in electric kettle adoption. Data collection from 900 households (30/cluster) in treatment and control arms consisted of surveys, electricity use meters (affixed to electric kettles), drinking water samples (tested for indicators of fecal contamination), indoor and ambient air pollution monitoring (real-time PM2.5), reported health outcomes (including diarrhea), and direct enumerator observations (as well as data for negative control outcomes). Data were collected at baseline in late 2017 and then at multiple intervals over a 25-month follow-up period. We pre-registered our study protocols on ClinicalTrials.gov (Identifier: NCT03376152) and the Chinese Clinical Trials Register (ChiCTR-IOR-17013373), and also registered a pre-specified statistical analysis plan on Open Science Framework (https://osf.io/bawk7).

RESULTS PENDING
Shortly after the final round of data collection in December 2019, data entry and data cleaning were significantly delayed due to the COVID-19 pandemic. At this writing, we have resumed work with our China CDC collaborators to finish the data cleaning. We plan to complete our pre-specified analyses and prepare a manuscript this summer (2021), with a goal to submitting for publication by the end of the summer or early fall. Thus, we are not currently in a position to share preliminary findings, but are on schedule to do so by or before September 2021.

BROADER SIGNIFICANCE
In China, as well as in other low- and middle-income countries (LMICs) where boiling is already common and electricity access is relatively widespread, the promotion of electricity-based boiling may represent a pragmatic stopgap means of expanding safe water access (and displacing biomass use for boiling) until centralized and decentralized drinking water treatment are more widely available. Results from this RCT will help to inform China's rural water and health policies, while contributing substantially to the literature on HWT adoption and boiling in LMICs.

Experiences of Water Insecurity in Half the World's Population

Presenter: Sera L. Young, Northwestern University

Additional Authors: Hilary J. Bethancourt, Edward A. Frongillo

Introduction: Water security is imperative for physical and mental health. Water security has long been quantified based on water availability or quality. Individual experiences with water access, use, and stability likely better indicate risks to health and well-being, however, because these experiences are more proximal to public health outcomes and reveal heterogeneity that is obscured in aggregate. Data on individual experiences have myriad uses, including tracking progress, assessing needs, measuring impacts, and guiding policy and funding decisions. Therefore, a consortium between Gallup Poll and Northwestern University set out to characterize the national prevalence of water insecurity in relation to socioeconomic and demographic characteristics in low- and middle-income countries comprising half the world's population.

Methods: The 2020-2021 Gallup World Poll administered the cross-culturally validated Individual Water Insecurity Experiences (IWISE) Scale in nationally representative samples to individuals ≥15 y (N=43,463) in 31 countries in sub-Saharan Africa (N=21), north Africa (N=4), Asia (N=3), and Latin America (N=3). The scale is composed of 12 items about the frequency in the prior year that individuals experienced water problems that caused emotional distress (e.g., worry, anger) or interrupted their daily lives (e.g., prevented washing hands, bathing, laundering clothes, disrupted food choices). Responses were "never," "1-2 months," "some, not all months," and "almost every month" (scored 0-3, summed range 0-36). Multilevel mixed-effects logistic regression models with random intercepts for country were used to examine the odds of water insecurity (IWISE score≥12) in relation to gender, three age groups (15-24 y, 25-39, 40+), rural/urban residence, marital status, education, number of children and adults in the household, log-transformed per capita annual household income, and difficulty getting by on current income.

Results: Mean IWISE score ranged from 1.6±3.9 in China (with the national prevalence of water insecurity being 3.6%) to 15.3±9.6 in Cameroon (national prevalence 63.9%). The most frequently experienced water-induced problem across most countries was interruption in water supply, followed by feelings of worry and anger about water problems. In models of water insecurity, women and men had similar odds of water insecurity (OR=0.99; 95%CI=0.90,1.10). Higher household income (OR for ln(income+1)=0.95, 95%CI=0.92, 0.99) and being in an older age bracket (OR for 40+ y=0.80, 95%CI=0.66, 0.96) were associated with lower odds of water insecurity. Difficulty getting by on current income (OR=2.58, 95%CI=2.15, 3.11) and each additional child (OR=1.05, 95%CI=1.00, 1.10) were associated with higher odds of water insecurity.

Conclusion: Water insecurity is a major global health concern in many low- and middle-income countries, and there is substantial variation in it both within and across countries. In these first nationally representative data on experiences of water insecurity, those most vulnerable to experiencing water insecurity were younger adults and those with lower per capita household incomes, difficulty getting by on current income, and more resident children. Given the critical role water plays in so many facets of life, including physical, mental, and nutritional health, addressing water insecurity among these and other vulnerable segments of the global population will be key to improving global health and overall well-being.

Fecal Contamination in Play-spaces And on Child Hands Are Associated with Adverse Child Cognitive Outcomes (Reduce)

Presenter: Christine Marie George, Johns Hopkins Bloomberg School of Public Health

Additional Authors: Alves Birindwa, Sara Beck, Timothy Julian, Jennifer Kuhl , Camille Williams, Nicole Coglianese, Elizabeth Thomas, Sarah Bauler, Ruthly François, Angela Ng, Amani Sanvura Presence, Bisimwa Rusanga Jean Claude, Fahmida Tofail, Jamie Perin, Patrick Mirindi,

Objective:

The objective of the Reducing Enteropathy, Undernutrition, and Contamination in the Environment(REDUCE) program is to identify exposure pathways to fecal pathogens that are significant contributors to morbidity among young children in the Democratic Republic of the Congo (DRC), and on developing and evaluating scalable interventions to reduce fecal contamination from these pathways. This prospective cohort study of 270 children under 5 years of age was conducted in rural South Kivu, DRC to investigate the association between Escherichia coli in hand rinse, soil, food, object, surface, stored-water, and water-source samples and child developmental outcomes.

Methods:
Child developmental outcomes were assessed by communication, fine motor, gross motor, personal social, problem solving, and combined scores measured by the Extended Ages and Stages Questionnaire (EASQ) at a 6 month follow-up.

Results:
Children with E.coli present in the soil in their play spaces had significantly lower combined EASQ z scores (coefficient: -0.38 (95% Confidence Intervals (CI): -0.73, -0.03)). E.coli on children's hands was associated with lower communication EASQ z scores (-0.37 (95% CI: -.0.10, -0.01), and E.coli in stored drinking water was associated with lower gross motor EASQ z scores (-0.40 (95% CI: -0.68, -0.12).

Conclusion:
In the REDUCE cohort study, E.coli in child play spaces, on children's hands, and in stored-drinking water was associated with lower developmental outcomes (communication, gross motor, fine motor, and problem solving skills). These results demonstrate the need for interventions to reduce fecal contamination in the household environment to protect the health of susceptible pediatric populations in rural DRC.

Fecal Sludge Management and Pit Latrine Emptying Behaviors in Rural Odisha, India

Presenter: Valerie Bauza, Emory University

Additional Authors: Gloria Sclar, Bethany Caruso, Thomas Clasen

Background:
Safe management of human feces must include a holistic approach: not only must open defecation be eliminated, but fecal sludge must also be safely managed. Pit latrines are the main form of sanitation available in rural areas of low- and middle-income countries, but programs to increase latrine coverage rarely include aspects to increase the sustainability of these latrines long-term, such as promoting safe methods of pit emptying. In India, the government and local organizations have led a number of sanitation campaigns to increase latrine coverage. However, as the construction of many of these latrines is recent, little is known about fecal sludge management (FSM) practices after pits fill.

Methods:
We surveyed households with latrines in rural Odisha, India to understand FSM and pit emptying practices. Surveys were conducted with households in 66 villages in Puri district and 72 villages in Ganjam and Gajapati districts as part of baseline data collection for ongoing trials. We characterized fecal sludge management practices including practices taken when the pit filled, how the pit latrine was emptied, how long sludge was left in the pit before being emptied, where sludge was disposed of, practices of the pit emptier, and determinants of safe FSM practices. We also conducted in-depth interviews with some households that had previously emptied their pit latrine to understand further details around this practice.

Results:
Households included in Puri district had latrines that were mostly single-pit and either self-funded or funded as part of the Swachh Bharat Mission. Households included in Ganjam and Gajapati districts had latrines that were primarily double-pit and built as part of village-wide piped water and sanitation initiative led by a local NGO. The majority of households reported emptying their pit after it filled up. However, only about one-fourth of households with two pits reported switching to use the second pit after one pit filled up, with it still

being most common to quickly empty the filled pit. Pits were most often emptied manually by a hired individual or a family member, and adequate PPE was not always used. Sludge was also commonly left in the open or applied to cultivation fields. Over 90% of households reported emptying the pit within 1 month after it filled, despite the potential to close one pit before emptying so that inactivation of pathogens could occur to allow for safer manual emptying and reuse of sludge on cultivation fields.

Conclusions:
Manual pit latrine emptying and dumping of sludge in open areas or applying to cultivation fields was common. Despite some households having multiple pits, adequate time was not given prior to emptying to allow pathogens to become inactivated, creating a health risk to the people emptying the pits and those residing in the area that the sludge was dumped. These results provide a better understanding of current pit emptying and fecal sludge management practices in rural Odisha, India that could be used to inform future interventions or services related to pit emptying and latrine sustainability.

Financial And Functionality Returns of Professional Maintenance on Rural Water Services in Kenya

Presenter: Pranav Chintalapati, University of Colorado Boulder

Additional Authors: Cliff Nyaga, Jeff Walters, Johanna Koehler, Amy Javernick-Will, Karl Linden

Kitui County is one of 29 counties in Kenya classified as Arid and Semi-Arid Land (ASAL). A county audit of rural water infrastructure has found that nearly a third of all piped water systems are non-functional. Currently, water infrastructure repair and maintenance is a combination of community-based management (CBM) and government intervention. Community water committees charge a per volume tariff to users at the point of collection and use these funds to pay for ad-hoc maintenance and repairs. When major breakdowns occur, communities are reliant on government intervention for equipment replacement and repairs, leading to extended periods of downtime. Recognizing the need for improved maintenance provision, FundiFix, a social enterprise, is using guaranteed-service contracts to provide professional repair/maintenance services to a subset of water schemes in the county to demonstrate a potential solution and promote sustainable service delivery.

This study uses a system dynamics (SD) approach to model the complex socio-financial interactions of piped water service delivery and demonstrate the financial and functionality implications of professional maintenance. The model captures piped scheme functionality under the CBM/government approach with variables such as waterpoint accessibility, spare parts availability and technician training, and is calibrated to data on breakdown frequency and durations, disaggregated by specific components (e.g., pump, pipeline, etc.). Data was also collected on government/donor investment in drilling and equipping new piped schemes, informing the rate at which new schemes enter the CBM/government system. A corresponding financial model tracks the government expenditure on new piped schemes, and cost of repairing existing schemes.

A small fraction (~5 %) of the schemes in the County are served by the professional maintenance service. Operational data from the enterprise informs breakdown frequencies and durations of the serviced piped schemes. Repair, equipment, and administrative cost data informs the cost of service, and service and collection rates as well as subsidies inform income flows to the company. Results show improved functionality rates over time, largely due to reduced breakdown durations and reduced repair costs. The indication is that routine preventive maintenance reduces the frequency, severity and cost of breakdowns.

The model simulates the scale-up of professional maintenance services by transitioning piped schemes from the baseline model into the professional services model. The simulations determine the resource requirements for the enterprise to operate at scale, and the functionality and financial implications of scaling up the maintenance service. Sensitivity analyses investigate how different operating strategies may improve financial and functionality outcomes. Furthermore, the study investigates how diverting portions of government financing from new infrastructure investments towards maintenance may improve overall functionality rates, reduce major repair costs, and reduce the cost of increasing water access to more people. Our goal is to demonstrate broadly applicable financial and operational strategies for the implementation of professional maintenance services to improve rural water sustainability, using SD modelling to capture the complex and dynamic relationships between key variables.

This presentation will provide final study results, building on preliminary work that was presented in a virtual poster session last year.

Frequency And Drivers of Handwashing for Covid-19 Prevention: A Multi-country Rapid Assessment

Presenter: Sarah Bick, London School of Hygiene & Tropical Medicine

Additional Authors: Max Friedrich, Astrid Hasund Thorseth, Om Prasad Gautam, Ian Gavin, Robert Dreibelbis

With the emergence of the global COVID-19 pandemic, WaterAid rapidly implemented hygiene behaviour change programmes in multiple countries targeting key COVID-19 prevention behaviours. Using a 'do no harm' strategy, the initial hygiene response was delivered through multiple channels, including mass media, digital and social media targeting over 100 million people. This research analysed data from a mid-term assessment in seven countries where WaterAid responded to COVID-19 (Ethiopia, Ghana, Nepal, Nigeria, Rwanda, Tanzania and Zambia) in order to enable an adaptive COVID-19 response sensitive to emerging drivers of behaviour. Cross-sectional surveys were conducted between October and November 2020 in areas targeted by WaterAid's COVID-19 first-phase response sampling adults at the household level. Data on COVID-19 prevention behaviours, potential determinants and exposure to messages were collected via face-to-face interviews using mobile technology (mWater). The objectives of this analysis were to assess the prevalence of self-reported handwashing behaviour within and between countries, and how various determinants – knowledge, norms, motives, barriers and exposure to COVID-19 prevention messages – relate to behaviour.

Two handwashing outcomes were included in this analysis: self-reported handwashing at key moments and reported change in frequency of HWWS since the start of the pandemic. Principal components analysis (PCA) of self-reported handwashing moments allowed us to further disaggregate these data into three separate indicators: binary indicators of HWWS after toilet use and HWWS before eating, and a composite measure of HWWS related to COVID-19-specific moments (after touching frequently-touched surfaces, contact with someone outside the household, or sneezing/coughing). Theoretically-informed constructs of determinants were identified and compared against behavioural outcomes using mixed effects regression analyses.

Data from 3033 individuals were analysed. Reported HWWS before eating (93%) and after toilet use (83%) were common. In contrast, 45% of respondents did not report HWWS at any of the three COVID-19 specific handwashing moments and only 13% reported HWWS at all three; 80% reported having increased their handwashing behaviour in response to the COVID-19 pandemic. Outcomes were broadly similar across countries. Access to soap and water were not associated with self-reported handwashing moments, although individuals with constrained water supply access had reduced odds of reporting an increase in HWWS. 94% of participants reported exposure to COVID-19 prevention messages, and 90% to messages specific to HWWS. In multivariable regression analyses, knowledge of key moments for handwashing, descriptive norms related to handwashing (perception that others practice HWWS), and the motive of protecting others from infection emerged as predictors of outcomes, and self-management (forgetting, being too busy) was a significant barrier. Exposure to messages specific to handwashing, not general COVID-19 prevention messaging, was associated with a higher proportion of respondents practicing HWWS at COVID-19 prevention moments.

Despite intensive interventions and a high reach of COVID-19 prevention messages, HWWS at key moments for COVID-19 prevention – as measured through our composite index of self-reported handwashing – is not consistently practiced. While self-reported handwashing is likely a reflection of knowledge, our findings suggest that an adapted COVID-19 hygiene response should focus on key moments for HWWS specific to COVID-19 prevention, and should target perception of others' behaviour, motives of protecting others, and address self-management as a barrier to behaviour, as well as country-specific priorities, in order to maximise impact of global hygiene interventions in the COVID-19 context.

From Covid to The Next Disease: National Wastewater Surveillance System (NWSS)

Presenter: Barry Liner, WEF

Additional Authors:

The Water Environment Federation, under funding from The U.S. Centers for Disease Control and Prevention (CDC), is managing the water sector component of the National Wastewater Surveillance System (NWSS). As part of this effort, WEF will provide training and discuss opportunities for involvement in the NWSS.

WEF is developing, managing, and providing training for a nationwide network of water utilities, public health agencies, and laboratories participating in wastewater-based disease surveillance. Wastewater-based disease surveillance involves the testing of wastewater to evaluate the presence of pathogens among a population. Wastewater-based disease surveillance has been used to study the presence and trends in coronavirus infections in communities and is increasingly viewed as a valuable tool during the current pandemic and for future public health research. For example, up to 80 percent of infected people pass on traces of coronavirus through their waste and so strategic sampling of wastewater can provide information on the infection trends of the virus in a community. In addition to training and the utility WBE community of practice, the effort also features activities such as technology validation for rapid detection of pathogens in wastewater and outreach to small and medium sized utilities to enable participation.

WEF supports CDC in the development, dissemination, and adoption of guidance and best practices for the prevention and control of infectious diseases within the water and wastewater sector. The NWSS focuses on information sharing and problem-solving to implement projects that pilot new approaches and technologies in wastewater-based disease surveillance. The training program targets frontline wastewater and public health personnel with training in surveillance activities to advance understanding of the spread of disease in communities. We seek to provide the critical training to water, public health, and laboratory professionals, ensuring that all three sectors understand the interrelationships and opportunities for collaboration.

Functionality And Resilience of Hand-pumped Boreholes in Sub-Saharan Africa

Presenter: Donald John MacAllister, British Geological survey

Additional Authors: A.M. MacDonald, S. Kebede, M, Owor, T, Mkandawire, H. Fallas

In sub-Saharan Africa as many as 184 million people rely on hand-pumps. Thus, hand-pumps are, and will remain, a crucial water source in a changing climate, although as many as one in three are non-functional at any time. Drawing on the results of three studies we demonstrate that hand-pumps are resilient and safe, and we examine the physical factors that determine hand-pump functionality.

In the first study we analysed the performance of 5196 water points (hand-pumps, motorized boreholes, springs, open-sources) and the success of a proactive maintenance programme during the 2015-16 drought in Ethiopia. Water sources were visited every week for 12 weeks to gather data on access and functionality. The second study, again in Ethiopia, involved monitoring 51 groundwater points (hand-pumps, springs, hand-dug wells) over an 18-month period in 2016. Water sources were equipped with water level loggers and were tested monthly for thermo-tolerant coliforms.
All sources were put under considerable strain during the drought. Most demand was placed on motorised boreholes in lowland areas. However, increases in functionality of motorised boreholes, as a result of the maintenance programme, lagged behind those of hand-pumps. Functionality was low for both sources at the on-set of the drought (65% and 75% respectively). Motorised boreholes had longer downtimes due to a lack of appropriate and/or accessible maintenance skills. Water level monitoring showed that hand-pumped boreholes recovered most quickly from daily abstractions. All sources were contaminated with thermo-tolerant coliforms during the rains marking drought cessation but hand-pumped boreholes were least affected.

Our results show that hand-pumped boreholes are resilient and less prone to contamination than springs and hand-dug wells. However, like the other sources we studied, hand-pumps had low levels of functionality at the onset of the drought. To better understand the factors affecting functionality we systematically dismantled 150 hand-pumped boreholes in Ethiopia, Uganda and Malawi in 2017. We conducted detailed inspections of hand-pump components and borehole design. Water levels were measured and a pumping test was conducted to measure aquifer yield (transmissivity).

In each country specific contextual factors influence functionality. In Ethiopia deep water levels (>60 m) strongly influence functionality. Many hand-pumps operate beyond lift limits (45 m). Aquifer yield is an order of magnitude larger for fully functional hand-pumps than partially functional hand-pumps in Ethiopia. In Uganda many hand-pumps are installed in aquifers with transmissivities close to the minimum required to sustain a hand-pump (c.1 m2/d). The use of galvanized steel components, along with corrosive groundwater, results in high rates of corrosion in Uganda. In all three countries hydrogeology, borehole design and pump condition interact to determine functionality outcomes.

Our results reinforce the importance of appropriate borehole siting and design, on-going operation and maintenance and use of appropriate and good quality materials. When supported by responsive and proactive maintenance hand-pumped boreholes, which are less prone to contamination than other shallow groundwater sources, are a resilient water source in a changing climate and are capable of providing water continuously during drought.

Health And Safety Practices Among Pit and Septic Tank Emptiers

Presenter: Godfrey Tamba, USAID-Uganda Sanitation for Health Activity (USHA)

Additional Authors: Eng. Osbert Atwijukye

Every business has the legal responsibility to ensure the health and safety of its employees and other people affected by business activities such as clients. Absence of health and safety measures/practices in any business leads to recurring illnesses, loss of lives, accidents which may either result in permanent disabilities or minor injuries among employees or any other persons affected by the business, resulting in significant costs or losses to the business.

To understand health and safety practices (HASP) among pit and septic tank emptiers in Uganda, a study was carried out in Central West (CW) and Central East (CE) regions of USAID-Uganda Sanitation for Health Activity (USHA), which included Kampala. The goal was to learn about faecal sludge hazards in pit emptying business, health and safety practices, barriers, and the impact of health and safety measures on pit/septic tank emptiers.

The study used a purposive sampling method to sample 19 pit and septic tank emptiers who were manual, semi-mechanical and mechanized using cesspool. 69% were below 30 years and school dropouts. 63% had suffered from illnesses. Slips, falls, cuts, pathogens, ergonomic, chemicals, stress caused by latrine status and community rejection, poor roads, ignorance, alcoholism, sharps, repetitive lifting, and lack of protective gears were among the hazards. 100% of respondents conduct a site inspection before executing the work but more than half of them (53.0%) are unaware of health and safety policies. 57.9% have never had any form of health and safety training. However, 89.5% wear partial PPE, 79% use Jez, Omo detergent, paraffin, or petrol as a disinfectant, and 84.2% seek medical help on a weekly (5.3%), monthly (26.3%), quarterly (42.1) or annual (10.5%) basis. Unfortunately, 5.9% mentioned vaccinations as their personal protective equipment. Cow milk, deworming, tetanus, hepatitis B and typhoid vaccinations were the treatments received by the emptiers.

Based on the findings, pit and septic tank emptiers are to some extent aware of the faecal sludge hazards and their causes. However, the health and safety practice among emptiers is lacking with no clear operational health and safety guidelines. This is because the pit/septic tank emptying business in Uganda is highly dominated by informal private players who are not regulated. Therefore, a need to set operational health and safety guidelines, regulate and train pit/septic tank emptiers.

Health Impacts of Boiling Drinking Water with Solid Fuels

Presenter: Emily Floess, North Carolina State University

Additional Authors: Ayse Ercumen, Angela Harris, Andrew Grieshop

Globally, 1 billion people lack access to safe drinking water, contributing to 1.7 million deaths annually due to unsafe water, sanitation, and hygiene. Boiling unsafe drinking water is a common treatment method in low-income settings. However, 2.8 billion people globally cook and heat using solid fuels, resulting in 2.6 million deaths annually from illnesses related to poor household air quality. Many of the countries with high solid fuel use also have limited access to safe drinking water.

This study bridges the areas of water quality and indoor air pollution (IAP) by conducting a Monte Carlo simulation to quantify the health tradeoffs from boiling drinking water with solid fuels. In this study, we demonstrate the scope of the environmental health impact of interlinked water and household energy systems, identify screening models used to generate health impact assessments for baseline and intervention scenarios, and compare and assess the tradeoffs in different intervention scenarios.

We focus on three different countries as case studies: Malawi, Uganda, and Vietnam, each of which have different rates of boiling as a household water treatment, but all of which have high solid fuel use. We modeled 24-hour indoor fine particulate matter (PM2.5) exposure and daily doses of three key pathogens (campylobacter, cryptosporidium, and rotavirus) for different scenarios of boiling water, using both clean and dirty fuels, to calculate the total change in disability adjusted life years (DALYs) from IAP and drinking water. Pre- and post-boiling microbiological water quality of improved and unimproved sources were characterized.

For different boiling scenarios and source water quality, average reductions of DALYs from diarrhea ranged from 0 to 1500 per 10,000 people. Replacing traditional wood stoves with clean electric stoves reduced the IAP by an average of 200 DALYs per 10,000 people. For households with very high baseline IAP, boiling water in addition to cooking on the same stove is associated with limited increased risk from indoor air pollution due to the log-linear nature of the relative risk curve. In some scenarios, post-treatment water quality was worse than the source water quality due to recontamination, resulting in increased PM2.5 exposure with little to no benefit.

For scenarios with effective boiling, we estimate a net decrease in DALYs (including changes in both IAP and DI values) from boiling water regardless of fuel type. However, we find a net increase if water is ineffectively boiled using solid fuels. We find that if cooking is not already taking place in a home, improved stoves should be used to boil water.

In most scenarios, boiling water results in a net decrease in DALYs and replacing traditional stoves with improved stoves coupled with effective boiling practices significantly reduces total DALYs.

This study emphasizes the need for education on proper boiling and water storage practices and the need for cleaner methods of boiling water and alternative treatment methods. Further work should investigate trade-offs in health impacts/benefits and costs for different water treatment scenarios in real-world settings.

Identifying Drivers of Successful Community-Based Water Treatment of Fluoride in Rural India

Presenter: Gokul Sampath, Massachusetts Institute of Technology - Department of Urban Studies and Planning

Additional Authors: Katherine Alfredo

Worldwide, India is the largest user of groundwater resources and one of the countries most impacted by fluoride contamination. In rural areas of Maharashtra, where alternate sources are rarely available and piped water is not plausible, communal water treatment facilities are installed by companies under a government contract for a period of three to five years. At the end of the contract period, the facility is transferred over to the community. The practice of turning facilities over to communities is part of recent policy reform, mainly the Government of India Sector Reform Pilot Programme (initiated in 1999) and Swajaldhara (initiated in 2002).

These schemes involve the decentralization of planning and administration of water supply to the Gram Panchayat (village council) level (GOI, 2007). However, most water treatment plants are abandoned soon after the transfer to community-ownership. Recognizing that the transition to community-owned water systems is not working, the Maharashtrian state government is actively searching for solutions to the lack of community take-up of their water treatment plants. There are few empirical studies identifying the social, technical, economic, and institutional factors conducive to successful collective management of water treatment systems.

Using Ostrom's social-ecological framework (2009), we attempt to identify the determinants of successful management of community-based water treatment systems. Following 11 villages over time --- from the point when the utility was about to be handed over to the community to 18 months after hand-over --- the study tracked the utilities using household surveys, lab-in-field experiments, technical analyses of the treatment systems, operator interviews, and in-depth case studies to investigate what factors influence success. On average, respondents were more willing to contribute to a pay per month (WTPM) scheme, saying they would pay approximately 2.8% of their annual household income for water from a community owned and operated scheme. However, while less

were willing to contribute towards a pay-per-use scenario (willingness to pay per container, WTPc), those that would hypothetically contribute proposed to chip in 12.1% of their monthly household income towards sustaining the treatment plant.

After 1.5 years, only one treatment plant remained functional. On most lists, these communities would be counted as "having access" despite most systems no longer functioning; it is our conclusion that this development framework is flawed, but fixable. We demonstrate that success does not rest with preferences for treated water, knowledge, cooperation, or incidence of fluoride and fluorosis, but the amount with which the community participates in decisions at the village governing body level and the amount of support by village leaders for managing the treatment plant. This means that a dynamic method of tracking resilience such as instituting adaptive management planning could have significant impacts on rural water treatment infrastructure resilience and treatment efficiencies.

Impact of District-wide Alcohol-based Hand Rub Program on Healthcare Worker Hand Hygiene in Rural Uganda

Presenter: David Berendes, Centers for Disease Control and Prevention

Additional Authors: Matthew Lozier, Maureen Kesande, Olive Tumuhairwe, Adelline Twimukye, Mohammed Lamorde, David Berendes

Background:
Alcohol-based hand rub (ABHR) is a ubiquitous hand hygiene option in healthcare settings in high-income countries and can help protect healthcare professionals (HCP) from acquiring or spreading infectious diseases, including COVID-19 and Ebola. In low-resource settings, some hospitals have access to ABHR, but many small and rural healthcare facilities (HCF) lack access and rely on handwashing with soap. We analyzed the impact on hand hygiene adherence (HHA) of local ABHR production and distribution to all 30 government HCF in Kabarole District, Uganda, from August 2018–November 2020.

Methods:
ABHR was produced by the Infectious Diseases Institute following the WHO protocol. We intended to use a crossover design to assess associations between ABHR provision and HHA. Fifteen HCFs received ABHR during phase 1 (February–June 2019); the other 15 HCFs received ABHR during phase 2 (July–November 2019). Each HCF received a 20-L jerrycan of ABHR, 1-L pump bottles for each patient care area, and 60-mL bottles for each HCP. Replacement jerrycans were available as needed. At the beginning of phase 1, and unrelated to this project, WHO/UNICEF distributed commercial ABHR to all 30 HCFs for Ebola preparedness, making ABHR available at all HCFs during both phases. Since December 2019, all HCFs have received locally-produced ABHR and jerrycan refills. We observed HHA before and after patient contact at 15 HCFs at baseline (August 2018; before ABHR distribution), and all 30 HCFs at follow-up 1 (June 2019), follow-up 2 (November 2019), and follow-up 3 (November 2020). We defined HHA as using ABHR or water and soap ("handwashing") and compiled HHA from before and after patient contact. During follow-up 3, we conducted three focus group discussions (FGDs) stratified by healthcare level with HCPs from participating HCFs. FGDs were audio-recorded, transcribed, and analyzed thematically using NVivo version 12 software.

Results: We recorded HHA from 38 HCPs at 15 HCF (334 observations) at baseline, 69 HCPs at 30 HCF (612 observations) at follow-up 1, 70 HCPs at 30 HCF (616 observations) at follow-up 2, and 59 HCPs at 29 HCF (528 observations) at follow-up 3. HCPs included nurses (34%), midwives (24%), clinical officers (13%), and laboratory technicians (29%). HHA was 5.3% at baseline (0.3% ABHR, 5.0% handwashing), 43.2% at follow-up 1 (37.1% ABHR, 6.1% handwashing), 24.9% at follow-up 2 (23.5% ABHR, 1.4% handwashing) and 45.5% at follow-up 3 (41.7% ABHR, 3.8% handwashing). Overall, HHA occurred more frequently with ABHR (28.6% ABHR, 3.7% handwashing) and after patient contact (47.5% after, 16.7% before). HCPs reported feeling more prepared for COVID-19 with access to ABHR and preferred ABHR to handwashing for mitigating COVID-19. Lost or broken 1-L pump bottles, difficulty obtaining ABHR refills, and staff using un-labelled water bottles for ABHR were reported maintenance and operations challenges.

Conclusion:
ABHR availability appears to be associated with increased HHA, which was highest during Ebola (follow-up 1) and COVID pandemics (follow-up 3). Local production of ABHR is feasible, but periodic monitoring of ABHR dispensers for functionality, replacement of missing/broken ABHR dispensers, and timely refills are important for sustaining the program.

Improving Equity in Intermittent Water Supplies Through Operational Strategies

Presenter: Negin Ahadzadeh, University of Toronto

Additional Authors: David Meyer

Intermittent Water Supplies (IWSs; piped water supplies providing water for less than 24 hours a day) affect approximately one billion people around the world. Intermittent service can be associated with many health risks due to water quality degradation, and/or inequitable access to a sufficient quantity of water. Given the prevalence of IWSs, we urgently need feasible strategies to mitigate their impact on consumers. Computer simulations can be used to efficiently explore and discover potential IWS-improvement strategies. However, the complex nature of water flow, water quality, and contaminant intrusion of IWSs cannot be accurately modeled with common hydraulic software.

Several studies try to model some aspects of IWSs using detailed hydraulic tools which require detailed network information making them expensive to calibrate and challenging to generalize. Instead, we take a very different modelling approach and construct a highly simplified model of an IWS as a single pipe with consumers, who leave their taps open, distributed along the pipe. Hydraulically, we model this scenario as a pipe with a long, narrow orifice cut along its entire length (i.e. a slot). The flow rate out of the pipe's slot (to consumers) at a given point depends on the pressure at that location, allowing us to study the variation in pressure and demand along an intermittent pipe. We quantify equity in the volume of water consumers can access along the pipe with two metrics: the Gini coefficient, and the ratio of the minimum to the maximum volume of delivered water. Both metrics are utilized to determine the equity implications of supply pressure, pipe size, population growth, distribution of population, network topology, and feeding the system with local groundwater.

We use our novel model to demonstrate that all else being equal, volumetric equity is improved when intermittent utilities: (i) lower their supply pressure to a level that depends on the flatness of the network; (ii) use larger diameter pipes; (iii) locate supply reservoirs close to areas with dense population, but far from areas with high per-capita demand; and (iv) supply the network from multiple points. Where the last point may help explain the prevalence of utility-operated tube wells being used within a city to augment intermittent water supplies. While such tube wells can improve volumetric equity in many intermittent supplies, they are also the cause of untreated water being distributed in many IWS (e.g. 30% of water in Delhi, India) inducing inequity in water quality. The quality-quantity trade-off associated with such tube wells requires further study. IWSs are remarkably prevalent, but they are also remarkably varied. Our simple model provides utilities, researchers, and policymakers a simple framework for exploring and understanding the equity implications of environmental variables (like topology) and utility decisions like supply pressure.

Investigating The Temporal Variability of Poultry Feces Risk Perceptions and Management Self-efficacy In Rural Uganda

Presenter: Jeremy Lowe, North Carolina State University

Additional Authors: Ayse Ercumen, Chris Prottas, Sarah Zikusooka, Angela Harris

Though domestic animal ownership has reported financial and nutritional benefits, it has also been associated with enteric diseases, and inadequate sanitation and hygiene can lead to children touching and ingesting animal fecal matter along fecal-oral transmission pathways. The outcomes from recent WASH impact evaluations call for a practice of transformative WASH, which prioritizes the management of animal fecal contamination in the household environment to interrupt zoonotic transmission pathways and reduce the overall burden of disease in children. Health risk perceptions have a role in influencing WASH behaviors like the use of basic water and sanitation services, and again may prove insightful when managing animal fecal contamination. Further investigation is needed to understand the role of risk perceptions and self-efficacy in determining animal feces management behaviors.

A randomized-controlled trial of a hygienic poultry management program was conducted in rural Western Uganda in 2020, and 1305 households (664 treatment and 641 control) participated from the Masindi and Kiryandongo districts of Uganda, with a baseline survey in October 2019, a midline survey in September 2020, and an endline survey in December 2020. Constructs representing participant

health risk perceptions, self-efficacy, and perceived difficulty with 4 poultry feces management behaviors (corralling poultry, washing hands after handling poultry feces, disposing of feces in the compound, and preventing children from touching poultry feces) were captured in structured midline and endline surveys.

The poultry management intervention did not have an impact on the participant health risk perceptions or perceived difficulty and self-efficacy in their poultry feces management behaviors, and results from this trial are being presented in another session. This study will present an analysis of the intra-person variability in these constructs between midline and endline survey rounds from both control and treatment study arms using paired Wilcoxon rank-sum tests. Results from ordinal logistic regression models will also be reported to identify the social determinants of the poultry feces risk perceptions and management self-efficacy. When asked about the likeliness that their child would develop a diarrheal illness after putting poultry feces in their mouth, 76.9% (691 out of 898) of respondents said it was either 'likely' or 'very likely' in the midline survey. When asked about their confidence they could always keep poultry corralled, 68.4% (538 out of 786) of respondents said they were either 'sure' or 'very sure' in the midline survey. When asked about the same construct at the time of the endline survey, 47.5% (162 out of 341) of respondents increased their confidence and 27.3% (93 out of 341) of respondents decreased their confidence (Wilcoxon rank-sum test, P < 0.001), suggesting that self-efficacy beliefs are subject to temporal variation. Similar associations will be reported for respondent risk perceptions and self-efficacy for other poultry feces management behaviors.

Insights from this work will inform new behavioral interventions that aim to reduce levels of animal fecal contamination in household environments. Understanding risk perceptions and self-efficacy can provide understanding of barriers households face related to child exposure to animal fecal contamination and separating animals from living spaces.

Legionella Bacteria in Premise Plumbing Supplied by Aging Potable Water Infrastructure Impacted by Prolonged Stagnation

Presenter: Monica Lee, Johns Hopkins Bloomberg School of Public Health

Additional Authors: Natalie G. Exum and Kellogg J. Schwab

The COVID-19 pandemic prompted the shutdown of many businesses, schools, and other facilities across the world, leading to water stagnation within building premise plumbing. Prolonged water stagnation can negatively impact water quality due to reduction in residual chlorine, biofilm formation and growth of opportunistic premise plumbing pathogens. Buildings with water supplied by aging potable water infrastructure are of significant concern due to the propensity for system deficiencies and reported waterborne disease have increased as drinking water distribution systems age.

This study characterized the microbial water quality over the course of one year in a three-story residential building within an aging urban infrastructure affected by the COVID-19 building shutdown. Impacts to water quality from water stagnation, seasonality, and hot water line thermal shock treatment were examined. Water samples were periodically collected from hot water lines to 12 showers during shutdown and subsequent reduced reoccupation at first draw (Time =0) and after a five-minute flush (Time=5). The opportunistic pathogen Legionella pneumophila (Lp) was quantified via most probable number (MPN) culture method, and parameters including free chlorine, temperature, pH, total organic carbon, and turbidity were measured. The geometric mean of Lp was the highest (670 MPN/100mL) at initial sampling during building shutdown, decreased one order of magnitude after one thermal shock treatment of hot water lines (22 MPN/100mL) and over a 10-month period following limited building re-occupancy, gradually increased one order of magnitude. The Lp concentrations at individual showers were highly variable, ranging from 0 to 12,898 MPN/100mL across all sampling events, locations and draws. During fall-winter months (September to March), there were lower Lp concentrations at all locations and draws, and higher Lp concentrations during spring-summer months (April to August).

The results indicate that a thermal heat shock treatment can immediately reduce Lp concentrations, but an improved treatment approach is required to prevent gradual resurgence of Lp within premise plumbing. This study highlights the variability of microbial water quality within a building water system across seasons as well as post thermal treatment and with increasing building water use following re-occupancy. These data reflect the need for robust water management plans for all buildings.

Overview Of Gaps in Access to Safely Managed Sanitation in The U.S. For SDG 6

Presenter: Jillian Maxcy-Brown, University of Alabama

Additional Authors: Mark Elliott, Eddy Perez, Katherine Selchau

The Joint Monitoring Programme estimates 99.97% of residents in the U.S. had access to at least basic sanitation in 2017 while 0.03% (roughly 97,000 people) had access to unimproved sanitation and zero were reported to be using limited sanitation or open defecation (WHO & UNICEF, 2020). However, recent publications focusing on underserved populations in urban (Capone et al., 2020) and rural (Maxcy-Brown et al., 2021) areas of the U.S. reveal lack of sustained access to basic sanitation is far more widespread.

Our work collects data from numerous reports to develop a more comprehensive documentation of onsite and decentralized wastewater inadequacies throughout the U.S., including open defecation, failing septic tanks, straight piping, cesspools, honey buckets and outhouses. These inadequacies are preventing the achievement of SDG 6.2 which aims to "achieve access to adequate and equitable sanitation and hygiene for all and end open defecation" by 2030 (United Nations, 2015). It is estimated that there are at least 500,000 persons experiencing homelessness who rely on either shared facilities in shelters or open defecation when unsheltered (Capone et al., 2020). Up to 25% of U.S. homes must use onsite wastewater treatment systems, but it is estimated that at least 65 percent of land in the U.S. have conditions that are not suitable for conventional septic systems (Siddoway, 1988). In these cases, residents must employ more expensive advanced engineered systems or live without safely managed sanitation. In some rural areas, local residents know that there are isolated homes discharging untreated wastewater directly to the surface through what are commonly called 'straight pipes.' While straight pipes are often dismissed as unfortunate anecdotes, our recent study found documentation of straight pipes in 15 states and some counties where half of homes use straight pipes (Maxcy-Brown et al., 2021). Even though large capacity cesspools have been banned by EPA, they are still known to be located in at least Alabama (Flowers, 2020), Hawaii (Hawaii Department of Health, 2021), Mississippi (U.S. Water Alliance & Dig Deep, 2019), New York (Hall, 2020), and Oregon (Rush Locates, n.d.). In Hawaii alone, approximately 88,000 cesspools discharge roughly 53 million gallons of untreated sewage daily (Hawaii Department of Health, 2021). In 1990, nearly two thirds of rural communities in Alaska used honey buckets, a large bucket with a seat attached, for toilets, though most rural communities have made some progress (Eddy, 2004). The 1990 Census (the last decennial census to collect wastewater data) reported 1% of all residents relied on "other" wastewater management, including outhouses (U.S. Census Bureau, 1995). Although outhouses do not always constitute as unimproved sanitation, it is difficult to know if they are safely managed. Currently available data are not classified according to the category/typology of inadequacy or failure and have numerous limitations. These data gaps prevent adequate estimation of the costs and benefits for providing proper wastewater management to all U.S. residents. This presentation will give an overview of our findings on how widespread the use of inadequate wastewater management techniques is in the U.S. and describe ongoing health implications.

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Pathways To Progress of Collaborative Systems Approaches: Evidence from Eleven Cases in East Africa

Presenter: Kimberly Pugel, University of Colorado Boulder

Additional Authors: Amy Javernick-Will, Karl Linden

Systems approaches build and strengthen the systems (policies, institutions, planning capacity, financial resources, monitoring structures, etc) that ensure a water or sanitation service will reliably be delivered to the public. Alongside the water, sanitation, and hygiene (WASH) sector's growing attention toward systems approaches has been an emergence of collaborative systems approaches, including "collective action" and multi-stakeholder partnerships. These collaborative approaches bring local WASH stakeholders (local

and national government agencies, private sector, non-government organizations, donors) together to actively work to address shared, complex problems through joint actions and shared responsibilities (Darteh et al., 2019; MWA, 2020; SWS, 2020). Thus, they are typically applied when a system is so complex that no single actor could strengthen it alone.

WASH implementers and donors (Agenda for Change, the Hilton Foundation, the Millennium Water Alliance, the USAID Sustainable WASH Systems Learning Partnership, among many others) are increasingly talking about, and applying, "collective action". Although growing in popularity and supported by anecdotal evidence, there is a lack of empirical evidence regarding how these approaches can be designed successfully in WASH contexts to make progress on complex systems challenges. In this session, we will present final, novel results from a four-year research effort that seeks to answer the research question: What combinations of conditions lead to progress of collaborative approaches in the WASH sector?

We analyzed over 4,000 pages of documentation and 40 interviews across eleven cases of collaborative approaches in East Africa. Using fuzzy-set Qualitative Comparative Analysis (fsQCA), we investigated what drives and impedes progress of these approaches. The outcome was defined as "progress being made toward a difficult activity", which included standardized measures to compare (a) the incremental progress made and (b) the difficulty of activities across cases.

Our results showed four pathways of conditions that worked together to make progress, indicating that there is no one way to design collaborative approaches. Collaborative approach designs should be driven by key contextual factors including political dynamics, priorities, and capacities. However, one factor was unquestionably required for progress: All four pathways relied on having a local government that is supportive of the effort and will carry out activities recommended by the coalition. Pathways then either required a hub with convening power and capacity OR required the problems to be identified collectively by the stakeholders, but not both. We also investigated which factors contributed to *lack* of progress of collaborative approaches, which revealed a warning for implementers new to an area of operation who seek to apply an existing solution without sufficient government buy-in.

This presentation will discuss key trade-offs present in collaborative approaches, including the benefits and risks of predetermining solutions, and the value added by convening power of the hub organization. This work therefore provides an evidence base for implementers and funders, calling attention to fundamental decisions that can be tailored to the context in which it is being applied to make progress towards achieving sustained WASH service delivery.

Principles For Decolonizing WASH Research: Synthesis of Findings from Interviews LMIC With Researchers and Donors

Presenter: Justine Lee, World Vision

Additional Authors: Ben Tidwell

Background
Recent calls for Anti-colonialist, Antiracist, Antisexist, and other kinds of initiatives countering unjust systems of power and policies in global health have been prompted by a more general societal focus on these issues. However, many of these initiatives are still framed from the perspective of those in the West, or are limited to isolated articles seeking to provoke a larger debate. Our Research Equity Initiative sought to be informed by directly capturing the challenges faced by earlier career and senior researchers in low- and middle-income countries (LMICs) in a systematic way, but directed by the perspectives and concerns of these researchers. Then, perspectives of donors and other stakeholders were captured, with a consensus to be reached about a general set of principles and guidelines to promote equity in WASH research.

Methods
We conducted 24 semi-structured interviews, 12 with senior researchers and 12 with early career researchers, across 6 countries. Interview guides, and in fact the entire research design, were created in consultation with the researchers. We asked about direct experiences and observations of discrimination across funding acquisition, project implementation, dissemination, and career advancement and recognition. We analyzed these interviews using the Socio-Ecological Model to understand where intra- and inter-institutional changes were needed or where larger cultural phenomena were driving inequities. We then conducted 10 interviews

with key WASH research donors, assessing their perceptions of major obstacles faced by LMIC researchers for how they aligned with those reported by the researchers, and documenting key internal successes and failures among those donors and barriers to seeing change within those organizations.

Results

At the interpersonal level, common issues included language barriers leading to perceived inferiority, community discrimination against local researchers, and viewing local staff as simply for data collection. At organizational level, challenges with budget development, time allocations for research, and subjectivity of salary levels discriminated against LMIC researchers. At community/systemic levels, inequitable power dynamics led to challenges in allocating budget and authorship to LMIC researchers, legal requirements restricted who could be employed or lead projects, and a lack of local perspective incorporated into design meant the research was irrelevant at local level.

Conclusion

From these findings, the following four principles for research equity were developed:

- Equity in the inclusion of researchers: We will ensure that lead and junior researchers, and all staff reflect the diversity of the contexts in which the research takes place.
- Equity in defining research questions: We will ensure that there is diverse representation in co-designing research questions and methods, including community-level participation and engagement, and that questions address systemic injustices, not just community-level symptoms.
- Equity in selected metrics and outcomes: We will ensure that research metrics co-designed during the start-up phase will capture disaggregated data on standard indicators as well as a broader understanding of the diversity of experiences of users from their own perspectives.
- Equity in dissemination of results: We will ensure that the balance of interpretation, authorship, attribution, and presentation opportunities are pro-equity and that there is data sharing among researchers, practitioners, and decision-makers.

Psychosocial Factors Mediating the Effect of the Chobi7-Mobile-Health-Program on Handwashing with Soap and Water Quality

Presenter: Christine Marie George, Johns Hopkins Bloomberg School of Public Health

Additional Authors: Sazzadul Islam Bhuyian, Elizabeth D. Thomas, Tahmina Parvin, Shirajum Monira, Fatema Zohura, M. Tasdik Hasan, Md. Abul Hasem Khan, Sanya Tahmina, Farzana Munmun, David A. Sack, Jamie Perin, Munirul Alam

Household members of diarrhea patients are at higher risk of developing diarrheal diseases(>100 times for cholera) than the general population during the 7 days after the diarrhea patient is admitted at a health facility. There is growing evidence demonstrating that theory-driven water, sanitation, and hygiene(WASH) interventions are likely to yield greater behavior change than those based on health education alone.

The Cholera-Hospital-Based-Intervention-for-7-Days (CHoBI7) mobile health (mHealth) program is a theory-driven WASH intervention initially delivered to a diarrhea patient by a health promoter during a health facility visit and reinforced through weekly voice and text messages. In the recent randomized controlled trial(RCT) of the CHoBI7-mHealth program in Bangladesh this intervention significantly reduced diarrheal disease and stunting, and increased handwashing with soap and stored drinking water quality over the 12-month program period. The aim of this study was to assess the underlying mechanism of change of this intervention. Handwashing with soap was measured by 5-hour structured observation. Stored drinking water quality was assessed by the presence of Escherichia coli during unannounced spot checks. Psychosocial factors were measured among 1468 participants in the CHoBI7-mHealth RCT. Perceived susceptibility, response efficacy, self-efficacy, dirt reactivity, and diarrhea knowledge were mediators of the CHoBI7-mHealth program's effect on stored drinking water quality at the 1-week follow-up. Self-efficacy, response efficacy, and diarrhea knowledge were mediators of the intervention's effect on handwashing with soap habit maintenance and stored drinking water quality at the 12-month follow-up. This study demonstrates how theory-driven approaches for intervention design can facilitate WASH behavior change.

Sensing Inconsistently Used Water Treatment Devices in South Africa

Presenter: David Meyer, University of Toronto

Additional Authors: Courtney Hill, Kelly McCain, Pascal O. Bessong, Elizabeth T. Rogawski McQuade, and Natasha C. Wright

KEY LEARNING OBJECTIVES

The audience will leave our presentation able to:

1) Describe the advantages of non-linear methods of quantifying consistency of use
2) Suggest three potential ways in which cheaper sensors can enable new methods of measuring and increasing WASH behavior change
3) Justify why households with high but imperfect adherence are strategic targets of behaviour change messaging
4) Critique research reporting WASH outcomes without reference to objective data on consistent use
5) Adapt use instructions for contact-time-based water treatment devices to account for inconsistent use

MOTIVATION:

Occasional lapses in the use of household water treatment and safe storage (HWTS) devices can cause dramatically non-linear declines in the derived health benefits. Current measures of device use fail to capture this non-linearity, even when sensors are used. This work A) describes the design of a $20 consistency-of-use sensor and B) demonstrates how sensing consistent use is important for device design and program efficacy through three examples using field data from 232 SmartSpout sensors.

METHODS:

A. To measure the consistency of device use, we invented and validated a novel sensor embedded in the handle of an HWTS device that measures how consistently the device is used. We define consistent use nonlinearly as the proportion of days on which a device was used each day for at least 7 previous days.
B. To demonstrate the importance of sensing consistent use, we provide three examples: B1) comparing the probability of single-day and consistent use in theory and in sensed data; B2) contrasting sensed and surveyed measures of use consistency; and B3) deriving and demonstrating a probabilistic relationship between use prevalence and contact time in HWTS devices.

RESULTS:

A1. Deployed SmartSpouts gathered objective data on >60,000 water withdrawals from three different types of water treatment or safe storage devices over 9 weeks in Limpopo, South Africa. We used SmartSpout data and a (non-linear) consistent use metric to:

B1. Demonstrate how households with high-but-imperfect use prevalences are strategic targets for behavior change efforts (e.g. increasing a household's use from 89 to 99% of days improves that household's consistent use by 49 percentage points);

B2. Emphasize that while surveys overestimate use, they dramatically overestimate consistent use (by 53 percentage points in our study); and

B3. Derive and demonstrate a probabilistic model showing how use prevalence affects the mean and range of contact times in HWTS devices. With this model, designers and distributors can account for user behavior in their device designs and user instructions. Our model of contact times has implications for all household-level disinfection devices reliant on contact times, including those using chlorine, iodine, bromine, silver, and/or solar radiation.

CONCLUSIONS:

B1. Households with high, but imperfect usage could prove efficient targets for behaviour change efforts. Sensors will likely be required to identify such households.

B2. Studies without objective, longitudinal data on the consistency of HWTS use should be interpreted with caution as previous studies have shown that inconsistently used interventions provide few health benefits.

B3. User instructions on draining and filling contact-time-based HWTS devices should include probabilistic considerations of minimum and maximum contact times.

Future development and deployment of HWTS devices should focus on devices whose efficacy and safety is insensitive (robust) to users and their use consistency. A) The dramatically reduced cost of sensors (10x less than published alternatives) increases how many water treatment sensors can be deployed by an order of magnitude, enabling widespread sensor use for (and potentially beyond) research.

The Friction of Distance: Decision Making Factors Governing Arsenic Safe Water Source Selection in India

Presenter: Katherine Alfredo, University of South Florida

Additional Authors: Tanya O'Garra

Naturally occurring arsenic in drinking water sources is a major threat to rural health in West Bengal, India. Scholars in the field of public health have demonstrated the positive effect of arsenic awareness campaigns in eliciting village households to switch to safer arsenic free water sources. However, comparatively less attention has been paid to the specific factors that contribute to households' water source decisions. In the developing world, fetching water for cooking and drinking is a substantial burden that affects the water quantity and quality households demand. In the peri-urban context of West Bengal, where most houses have an unsafe tube well on their premises, and safe community sources are located at the village center, distance to safe sources may be a key factor in shaping households' water source choices.

This research seeks to quantify the relationship between distance to water source and safe source usage by consumptive task (cooking and drinking). We enrolled 125 households in a 3-month long water usage study in the severely arsenic affected district of Nadia, West Bengal during the summer of 2016 to answer three questions. First, does the percent of safe source water consumed by households vary by task (cooking vs drinking)? Second, is there a relationship between distance to the safe source and the amount of safe source water used by households? Finally, does distance to source modify the positive association between health information and households' consumption choices mentioned in previous research?

Using a two-part regression model, we found that retained knowledge about the importance of switching to known safe sources positively predicted households' decision to fully adopt a safe community source, irrespective of their distance to it ($p<.05$). However, for households that still consumed some unsafe water, distance was strongly and negatively associated with safe water consumption ($p<.01$). This relationship varied based on consumptive task (cooking versus drinking).

These results suggest that informing households about the importance of source switching for both cooking and drinking water can overcome the friction of distance, or the reticence to collect water from distant safe sources. Using basic exposure risk calculations, we first compared household's exposure risk according to default ingestion volumes of drinking water only (model one), then default ingestion of both drinking and cooking water (model two), and finally actual measured consumption volumes for both (model three). Actual water consumption was calculated from a rigorous daily household water usage survey over an eight-day period. The risk of arsenic exposure increases significantly ($p<0.05$) when considering actual measured consumption for both cooking and drinking. The median adult exposure for arsenic increases from 5.9E-5 to 4.4E-4 when cooking water quantity and contamination are considered over a drinking water only model. This demonstrates that the added arsenic exposure from using unsafe cooking water can considerably increase overall exposure.

The Role of Public Markets in Produce Safety in Low-Middle Income Countries (LMICs)

Presenter: Mindy Panulo, The polytechnic-WASHTED CENTRE

Additional Authors: Jones Chipinga, Effita Masoamphambe, Kondwani Chidziwisano, Derek Cocker, Tracy Morse

Background
Morbidity and mortality from the consumption of unsafe food remains a significant risk to health in low- and middle-income countries. However, addressing this issue is compounded by informal and unregulated nature of food systems in these settings. Pinpointing sources of contamination and identifying the critical points at which this can be controlled. particularly for ready to eat produce, is essential to reducing the public health risk. As such, we examined the risks associated with public markets in rural and urban Malawi using a hazard analysis critical control point method.

Methods

Six urban and three rural markets in Malawi were evaluated between November 2020-January 2021. Data was collected through checklists, narrative observations and key informant interviews with vendors (n=18) and market chairpersons (n=9). Each market assessment was conducted over four days, focussed on vendor practices, sanitary conditions and sanitary facilities in the market. Quantitative data from the checklist were extracted, cleaned manually and analysed. Qualitative data from interviews were voice recorded, transcribed and analysed thematically. Data from the narrative observations were analysed by identifying key behaviours. To validate critical control points identified through observation, microbiological analysis was conducted in four urban markets to establish the presence of contamination and ESBL bacteria. Samples were taken of food, vendor stall environments, stored water, source water, drains and river water. All samples were processed on ESBL CHROMagar™ media for identification of ESBL Enterobacteriaceae and water samples were processed in parallel using the IDEXX Colilert Quanti-tray method, to quantify contamination.

Results
Of the 90% (n= 8) of the markets that had toilets, 54% did not provide anal cleansing materials, with evidence of faeces on latrine walls (37%). Forty-two percent of markets did not have handwashing facilities, 78% had no refuse collection areas, and mixed waste was observed in all drains. Critical control points identified included: provision of safe water, safe storage and display of produce off the ground on clean surfaces, safe management of stored water by vendors, provision of adequate sanitation and hygiene facilities to ensure hand hygiene, covering and containing ready to eat foods, use of clean utensils for serving high risk foods, effective cleaning of the environment, management and containment of waste. A total of 243 samples were collected from 4 urban markets in Blantyre, including 70 water and drain samples. ESBL contamination was detected in food (26.1%), vendor environments (32.5%), source water (9.5%), vendor water (42.1%), drain water (76.2%) and river water (58.3%) samples. Of the 70 samples processed using the IDEXX Colilert Quanti-tray method, all were positive for the presence of total coliforms, and 93% (n=65) were above the lower LOD for E. coli, (1 MPN/100ml).

Conclusion
Public markets provide a conducive environment for the contamination of produce and ready to eat foods, which may be contributing to the high burden of food borne illness in LMICs. Human behaviours in markets contributed to the contamination of both the market environment and food products. Future interventions should target critical control points within these markets, addressing both infrastructure and behavioural challenges.

Understanding Wash-Climate Change Vulnerability of Rural Households in Cambodia

Presenter: Rana Abdel Sattar, iDE (International Development Enterprises)

Additional Authors: Tyler Kozole, Veasna Toeur, Chris Nicoletti, Six Degrees Bristol University

Introduction
It is estimated that over 25% of the population in Cambodia is affected by challenging environments that experience floods, high ground water, and other barriers to effective sanitation and fecal sludge management (FSM). Rural households living in these environments are more vulnerable to climate change and have limited capacity to resist, cope with and recover from climate hazards. With the mission to improve access to safe sanitation in rural Cambodia, iDE Cambodia's Sanitation Marketing Scale-up (SMSU) Program uses two evidence-based research studies to gain a deeper understanding of households' challenges associated with living in climate vulnerable areas and evaluate how program activities could impact households' resilience to climate change shocks. In particular, iDE explores how climate vulnerability is linked to latrine functionality, FSM practices, poverty status, and latrine abandonment.

Methodology
One study looks at the FSM survey, conducted in collaboration with the University of Colorado, Boulder, reaching 1,472 latrine-owning rural households. The data included frequency of latrine overflow/malfunction during the rainy season, frequency of latrine pits filling up, and unsafe FSM practices such as releasing fecal sludge into the open environment (e.g., opening the pit lid during a flood, piercing the pit). In collaboration with Six Degrees Bristol University scholars, another study uses iDE's program sales data and latrine count survey data collected on a bi-annual basis since 2009 to roughly 200,000 households within all rural provinces of Cambodia where SMSU has been operating. This data includes targeted subsidy sales to government identified poor households, sanitation coverage, and latrine abandonment rates.

Both studies use a similar analysis approach. Using GIS mapping, iDE's data is compared against climate vulnerability maps associated with major natural hazards in Cambodia including flood, strom, and drought to assess the different thresholds of climate change vulnerability. Additionally, logistic regression models are used to better understand the isolated effect of living in climate vulnerable areas and test statistical data correlation and significance.

Preliminary Findings

Climate vulnerable households that lived within the major flood zone were more likely to have had a non-functional latrine during the rainy season [r(1,472) =.07 , p < .01] and were more likely to have a pit fill up [r(1,472) =.05 , p < .05]. Additionally, we found statistically significant differences in unsafe FSM intentions between climate vulnerable households and non-climate vulnerable households [t(1,472) = .03, p < .10]. We also see significantly more households with pierced pits [t(1,472) = .04, p < .05]. Interestingly, we did not see a greater proportion of poor households in flood-prone areas. We also found an even split of targeted subsidy sales to poor households between climate vulnerable and non-climate vulnerable areas. This suggests that poverty status is not likely linked to living in climate vulnerable areas and that iDE's targeted subsidy system has limitations in reaching the most climate vulnerable households. Overall, there is a correlation between living in climate vulnerable areas and high latrine abandonment rates at the provincial level. This link will be further studied and validated at the district and commune levels. Additional data analysis is planned to understand if improving rural households' resilience to climate change is linked to providing targeted subsidies to poor households that cannot afford sanitation products at market price, and providing affordable, desirable, and reliable sanitation products that promote continuous use and reduce latrine abandonment rates.

Wider Implications

This study is meant to provide a better overall understanding of the impact of climate change on sanitation in order to enable iDE to develop sharper strategies to address SDG 6.2. By identifying and classifying climate vulnerable environments, then comparing households' socioeconomic standings and behaviors within and between them, iDE can prioritize and market customized sanitation solutions to those who are most vulnerable. For example, findings found that with increased frequency and intensity of climate change hazards across iDE's operational areas, we can expect to see increased challenges with dysfunctional latrines which will amplify the use of unsafe FSM practices. To reduce households' climate vulnerability, these associated unsafe FSM behaviors can be targeted and mitigated. In addition, this study evaluates how increasing latrine coverage of affordable, desirable, and reliable sanitation products and providing targeted subsidies to poor households could impact households' resilience to climate change shocks. This case study presents learnings as well as a methodology that can be used or adopted by WASH practitioners and researchers to target climate vulnerable areas and monitor and evaluate program impacts on WASH climate change resilience.

Using Urban Utility Data to Improve Service Delivery and Inform National SDG Monitoring in Haiti

Presenter: Myriame Dorfeuille, Directrice de l'Observatoire National de l'Eau Potable et d'Assainissement

Additional Authors: John Feighery, Daniel O'Neil, Annie Feighery, Heather Skilling, Brian Jensen

Piped water networks managed by well-regulated public utilities are the most efficient means to deliver safely managed water services in urban areas, but service providers in low-income countries face many challenges arising from a downward spiral of lack of investment, leading to poor service quality and unwillingness on the part of users to pay fees. Nowhere has this "spiral of decline" been more apparent than in Haiti, where most utilities provided only sporadic service and relied on international donors to fund the little maintenance that was being done. As a result, urban residents resorted to obtaining water from either unprotected wells or surface water or purchasing expensive trucked or bottled water.

Studies of utilities who experienced a turnaround from these conditions of poor performance and inadequate revenues have repeatedly shown that a data-driven approach is required, with improvements to management information systems one of the first steps taken. However, documented experience of such turnarounds is still rare in low-resource countries. While there is increasing recognition of the importance of a shared information and accountability platform for building the capability of WASH sector institutions, there are few studies reporting on specific actions and enabling factors that lead to the development of sustainable sector information systems. In this study, we report on a 3-year process undertaken by the Haiti Water and Sanitation Authority (DINEPA), the USAID Haiti Water and Sanitation Project, and other development partners to design and build a utility management system that has resulted in data-driven actions to increase coverage and revenue from the targeted urban water utilities.

The development of the utility management platform followed a problem-driven iterative process that began with collecting feedback from diverse stakeholders, prioritizing information needs, assessing the landscape of available solutions, and then implementing field deployments of the data collection, approvals, and visualizations built using the free and open access mWater data management platform. Specific strategies that we tested to increase the use of data for decision-making included agreement on a set of 10 key monthly performance indicators for all utilities, the provision of a local data expert to provide on-call technical support and regular onsite trainings, and monthly meetings held by each utility in which key indicators are reviewed and targets are set and updated.

Outcomes of this approach include the decision by DINEPA to scale up from the 5 utilities initially supported by USAID to all 26 utilities using DINEPA's in-house training capacity, alignment by other donors and development partners in the sector around building a more general WASH sector information system on the same platform, and increases in both numbers of subscribers and revenue collection efficiency that the utilities attribute to the focus on data and performance metrics. We present an analysis of specific factors that were cited by stakeholders in key informant interviews as having contributed to successful scale up and use of the data system and review key performance indicator trends in the context of specific management actions taken by each utility in response to data.

Wastewater SARS Public Health Environmental Response (W-Sphere) Global Data Center

Presenter: Colleen Naughton, University of California Merced

Additional Authors: Dr. Joan Rose (Michigan State University), Dr. Gertjan Medema (KWR Water Research Institute), Vajra Allan (PATH), Panagis Katsivelis (Venthic Technologies), Krystin Kadonsky (UC Merced grad student)

Over a year since the declaration of the global coronavirus disease 2019 (COVID-19) pandemic there have been over 153 million cases and 3.2 million deaths. Using methods to track community spread of other viruses such as poliovirus, environmental virologists and those in the wastewater based epidemiology (WBE) field quickly adapted their existing methods to detect SARS-CoV-2 RNA in wastewater. Unlike COVID-19 case and mortality data, there was not a global dashboard to track wastewater monitoring of SARS-CoV-2 RNA worldwide. We first created COVIDPoops19, a global dashboard for wastewater monitoring of SARS-CoV-2, that has grown into a global data center. Objectives of this presentation are to exchange best practices, data visualization, case studies, and analysis of a global data center for SARS-CoV-2 in wastewater surveillance to build current and future resilience to global pathogens.

Methods for the COVIDPoops19 ArcGIS online dashboard included google form submission of direct sampling of wastewater for SARS-CoV-2 in several countries and stakeholder engagement, literature review, social media and news key-word searches, and attendance at online wastewater surveillance webinars worldwide. After a year of data tracking, wastewater surveillance for SARS-CoV-2 is conducted in over 53 countries, 2,082 sites, and 248 universities/institutions. A small subset (75) of those monitoring for SARS-CoV-2 in wastewater that provide their data publicly and only thirteen provide limited downloadable data. Of the 53 that are conducting wastewater monitoring: 35 (65%) are in high-income countries, 11 (20%) are upper middle income, 8 (15%) are lower middle income, and 0% are low income countries.

COVIDPoops19 is informing a global data center W-SPHERE global data center (Wastewater SARS Public Health Environmental REsponse) using open data from individual country/city wastewater dashboards and solicited data submissions and agreements from the research community. The mission of W-SPHERE is to advance environmental surveillance of sewage to inform local and global efforts for monitoring and supporting public health measures to combat COVID-19. We use ArcGIS online dashboards for data visualization, case studies, and employ geospatial and statistical tools for data normalization, comparison, and analysis.

We collected a number of compelling case studies of wastewater surveillance for SARS-CoV-2. Wastewater surveillance has been effective as an early warning system of COVID-19 cases and even estimated COVID-19 cases in university dorms such as at University of Arizona. Australia has really integrated wastewater surveillance to keep their case count near zero, using it to trigger both asymptomatic and symptomatic COVID-19 testing of individuals and border closures. There are a growing number of areas using wastewater surveillance at correctional facilities, nursing homes, and K-12 schools.

Wastewater surveillance has been a powerful tool to build resilience to the COVID-19 pandemic. However, there is a severe lack of use in low-income countries, limited data sharing publicly and challenges in analysis of the data to communicate to public health officials for

decision making. We have provided a global data center and standards to build resilience beyond COVID-19 in the face of climate change and increased pathogens in the environment.

Water Insecurity and Psychological Distress Among Impoverished Ghanaian Households

Presenter: Elijah Watson, Northwestern University

Additional Authors: Hilary J. Bethancourt, Andre Nickow, Sera L. Young

Low water availability and inadequate water infrastructure negatively impact health and well-being, but limited research has empirically assessed the relationship between experiences of water insecurity and well-being. Experiential measures of water access, use, and stability may be more informative because they are more proximal to outcomes of public health significance. Therefore, we quantified experiences of household water insecurity in economically disadvantaged households in Ghana, and explored their relationship with psychological distress among male and female household heads.

We analyzed cross-sectional data from adult (≥18 years) household heads from the Northern (n = 2,973) and Upper East regions (n = 855) of Ghana who participated in the Ghana Socioeconomic Panel Survey questionnaire. Data were collected in 2019 among households that had been enrolled in a randomized controlled trial to reduce poverty among the ultra-poor from 2011 to 2013. Household water insecurity was measured using the Household Water InSecurity Experiences Scale (HWISE Scale, range 0-36), a cross-culturally validated tool that quantifies the frequency of disruptions in daily activities (e.g., interruption of daily plans or food choice, inability to wash hands, bathe, do laundry) and psychological burden (e.g., worry, anger, stigma) due to problems with water. Psychological distress was measured using the Kessler Psychological Distress Scale (K10, range 10-50). We built mixed effects linear regression models with robust standard errors to test the relationship between household water insecurity (HWISE Scale scores ≥12) and distress, with random intercepts for household. Models adjusted for gender, age, household size, and socioeconomic status (proxied as the log-transformed total value of household assets).

Water insecurity was substantially higher in households in the Northern Region (39.6%; HWISE Scale score mean±SD, 10.2±11.6) than in the Upper East Region (13.7%; 3.6±7.8). In contrast, psychological distress was lower in the Northern Region (20.6±6.6) than in the Upper East Region (K10 score mean±SD: 24.5±6.0). Given that the prevalence of water insecurity was 25.9% lower in the Upper East Region, we assessed if its relationship with distress held across regions by testing for an interaction between water insecurity and region. In the final model, household water insecurity was associated with higher distress scores in the Northern Region where water insecurity was relatively high (b = 3.6; 95% CI: 3.0, 4.1), but with marginally lower distress scores in the Upper East Region, where water insecurity was low (b = -1.2; 95% CI: -2.3, -0.1 P for interaction < 0.05).

Household water insecurity was associated with higher psychological distress among disadvantaged households in the Northern Region of Ghana, where water insecurity is more prevalent. This was not the case in Ghana's Upper East Region, however, where water insecurity was substantially lower and average distress scores were higher. These findings of regional differences suggest that the HWISE scale offers an indicator that is useful for identifying areas in which the psychological burden of experiential water insecurity is higher, and is thus helpful for targeted policies and making decisions about investment in resources.

Water Treatment for Schistosomiasis Control – New Evidence for International Guidelines

Presenter: Laura Braun, London School of Hygiene and Tropical Medicine

Additional Authors: Yasinta Sylivester, Meseret Dessalgene, Safari Kinunghi, Michael Templeton

Schistosomiasis is a neglected tropical disease that affects over 200 million people, primarily in sub-Saharan African. It is acquired through contact with freshwater containing cercariae, the parasite larvae. Schistosomiasis is a disabling disease that disproportionately affects children. It leads to anaemia, organ damage, cancer and eventually death. While praziquantel is an effective treatment for schistosomiasis, it does not prevent reinfection upon contact with contaminated water sources. This leaves millions of people living in endemic regions trapped in frequent reinfection cycles due to reliance on cercaria-contaminated water for daily activities (e.g. laundry, bathing). Water treatment has the potential to help break this reinfection cycle by inactivating cercariae in water, thereby providing communities with safe water and preventing water-based exposure and infection. However, there are insufficient data to devise guidelines on how to inactivate cercariae. We tested the effectiveness of chlorine on Schistosoma mansoni cercariae inactivation under

controlled conditions (pH 6.5, 7.0 or 7.5, and temperature of 20°C or 27°C). Chlorine was dosed at 1, 2 or 3 mg/l and experiments were run up to contact times of 45 minutes, in 5-minute intervals. 100 cercariae were used per experiment, allowing us to assess up to 2-log (approximately 99%) inactivation of cercariae. Experiments were replicated using both laboratory-raised cercariae (UK) and cercariae isolated from the field (Lake Victoria, Tanzania) and again with both fresh (<1 hour old) and aged (6-8h old) cercariae. Results were translated into CT values – a product of the residual chlorine concentration and chlorine contact time necessary to achieve a 2-log inactivation.

Findings indicate that a CT value of 26±4 mg·min/l is required to achieve a 2-log (or 99%) inactivation of S. mansoni cercariae under the most conservative condition tested (pH 7.5, 20°C), which indicates moderate chlorine resistance. Field and lab-cultivated cercariae show similar chlorine sensitivities, and aged cercariae are significantly more sensitive than fresh cercariae. Overall, a CT value of 30 mg·min/l is recommended to disinfect cercaria-infested water, though chlorine residual and contact time may require modifications depending on water quality and operating conditions. A CT value of 30 mg·min/l can be achieved with a chlorine residual of 1 mg/l after a contact time of 30 minutes (or lower doses for longer contact times), for example. In comparison, the WHO recommends a CT value of <1 mg·min/l to inactivate bacteria or 2-30 mg·min/l to inactivate viruses. This chlorination recommendation for inactivating S. mansoni cercariae will be included in the WHO's schistosomiasis factsheet. It can be used by households, water vendors or designers of community-scale water infrastructure (e.g. laundry stations, showers) to treat cercaria-infested water and provide schistosomiasis-endemic communities with safe water facilities, thereby reducing reinfection.

What Can We Learn from Call Center Data in FSM Service Delivery?

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Introduction: Pit Vidura is the sole provider of safe sanitation services for last mile households in dense urban areas of Kigali. It relies on several marketing channels to sell services in poorly serviced low-income areas including door-to-door marketing agents, radio ads, and calls/reminders to repeat customers . Pit Vidura operates a call center that uses a CRM system to streamline and improve marketing and sales strategies, ensure quality customer service and service delivery as well as minimal attrition in the sales pipeline. These improvements are crucial to offer affordable sanitation services while operating a scalable and viable business.

Methods: This research leverages data from the call center to evaluate the effectiveness of various measures that were introduced during the study period between February 2019 and December 2020. We analyzed call center logs and sales data with a focus on the rate of abandoned (missed) calls, conversion rates , and leads-to-customer (LTC) transition times. These key metrics were assessed in relation to the timing of key interventions to identify the respective impact on the business' operations.

Results: Hiring call center agents and extending call center hours significantly reduced abandonment rates (from over 90% to below 10%) and callback times (from over 30 hours to less than 30 minutes) in successive periods of 14 and 5 months. Responsiveness of the call center is essential to grow the customer base to incrementally reduce the number of households turning to improper and unsafe practices. Calls received during after-hours showed the highest conversion rates, 26% above average, and the shortest LTC times, 58% below average, hinting to a high number of urgent customers. Streamlining processes and upscaling the marketing and sales department improved the conversion rate from below 0.6 to over 0.7 empties per new lead between September 2019 and February 2020, and successively decreased LTC times from 13.6 to 3.0 days between the first and last quarters of 2020. LTC times showed a reasonable correlation with high attrition rates: the longer customers wait, the more likely they are to seek services from an informal manual emptier. We found the biggest bottleneck in the customer acquisition process to be "scheduling" making up 55% of the total LTC time. The lag in scheduling may be largely driven by the time required for households to avail the necessary deposit to schedule the empty.

Conclusion: The call center enabled Pit Vidura to systematically collect and evaluate data on the successfulness of customer acquisition strategies. Achieving higher efficiency in the acquisition process is a prerequisite to improve geographic clustering for service delivery, which is crucial for business viability and to offer affordable sanitation to those who need it the most. Therefore, subsequent work should focus on the generation of strategic backlogs in geographic clusters without increasing attrition. To accomplish this, the linkage and integration of GIS mapping and remote monitoring tools into the CRM system with an initial focus on high demand areas are recommended. Additionally, the duration to schedule empties shall be reduced through pre-scheduling and regular follow-ups with customers.