



VERBAL PRESENTATION ABSTRACTS

(Alpha by Title)

As of 9-11-19

Title: A Cluster Randomised Controlled Trial of an Infant Food Hygiene Intervention in Peri-Urban Kisumu, Kenya

Jane Mumma, Great Lakes University of Kisumu

Background: Enteric infections have been associated with early growth shortfalls and cognitive development impairment in young children, especially in low and middle- income countries. Children may be exposed to enteric infections indirectly from ingesting food contaminated with enteric pathogens. Infant and child food is an important pathway for contamination often neglected by traditional WASH interventions. The aim of this study was to evaluate the impact of a novel food hygiene intervention on prevalence of specific enteropathogens and diarrhoea among infants at 37 weeks of age, living in a peri-urban community of Kisumu Kenya. Methods: We conducted a randomised controlled trial of a novel infant food hygiene intervention. This local appropriate intervention was designed based on the findings of formative behavioural and microbiological research. The intervention targeted four behaviours among caregivers 1) hand washing with soap before infant food preparation and feeding, 2) bringing all infant food to the boil before feeding, including reheated foods, 3) storing all infant food in sealed containers and 4) reserving specific feeding utensils for the infant and keeping these separate and clean. We assessed the effect of the intervention on food contamination by randomly assigning fifty clusters, representing the catchment areas of community health volunteers, to intervention or control groups. A total of 750 children were recruited on a rolling basis at 22 weeks of age and followed for 15 weeks. Data was collected using survey questionnaires and structured observation. Stool and food samples were collected for enteropathogen and fecal contamination analysis, respectively. The primary outcomes were identifying the presence, concentration, and diversity of specific enteropathogens known to cause childhood diarrhoea in low income settings. A bacterial indicator of fecal contamination (*Enterococcus*) was isolated and enumerated according to EPA Protocol 1600. Concentrations were estimated by comparison of cycle thresholds against standard curves for each reference of interest. The following taxa were detected and quantified using quantitative real-time polymerase chain reaction using Customized Taqman Array Cards on a ViiA7 thermocycler (Life Technologies, USA): 1) bacteria (*Shigella*/*EIEC* plasmid, *EAEC_aaic*, *EAEC_aata*, *EPEC_eae*, *EPEC_bfpa*, *ETEC_LY*, *ETEC_STp_STh*, *EHEC* *Escherichia coli* 0157, *Aeromonas*, *Vibrio cholerae*, *Campylobacter* *jejunii*/*C. coli*, *Clostridium* *difficile*, and *Salmonella enterica*), 2) viruses (*Adenovirus* 40/41, *Adenovirus* Hexon, *Norovirus* GI, *Norovirus* GII, and *Rotavirus*) and 3) protozoa (*Cryptosporidium* 18s, and *Giardia* assemblage A & B). Results: A full analysis of the trial results will be completed by June 2019. Our preliminary results showed a mean difference between groups of one or more enteric infections in exposed children, concentration of individual pathogens and the different pathogens present, as well as the level of infant food contamination. Conclusion: To our knowledge, this is the first randomized controlled trial to assess the effect of an infant food hygiene intervention on enteric infections among a high burden low-income urban setting. Our study adds to a growing literature suggesting that food is a key exposure route for gastro-intestinal disease in young children and that, low cost interventions targeting food hygiene behaviours are promising.

Title: A Combined WASH and Complementary Food Hygiene Intervention to Reduce Diarrhoeal Disease in Rural Malawi

Tracy Morse, University of Strathclyde, Kondwani Chidziwisano, Elizabeth Tilley, Rossanie Malolo, Janelisa Musaya

Diarrhoeal disease continues to be the second leading cause of death in children under five, with approximately 700,000 deaths worldwide annually. It is estimated that 50% of these deaths occur in Africa, and 72% occur in the first two years of life, resulting in a higher mortality rate in children than HIV, tuberculosis and malaria combined. However, recent WASH intervention studies in Kenya and Zimbabwe have reported no impact on diarrhoeal disease in children under five. We designed and implemented a theory-based complementary food hygiene and WASH intervention in rural Malawi and evaluated its impact on diarrhoeal disease in children under the age of five years. The "Hygienic Family" intervention was informed by formative research, grounded in the RANAS (Risk, Attitude, Norms, Ability and Self – regulation) Model, and aimed to ensure inclusion of all family members in an effort to support the concept of whole community improvements versus individualism. The study was implemented as a before and after trial with a control and two treatment arms to measure the relative impact of: (1) a food hygiene intervention (treatment group 1: n=400) relative to a WASH + food hygiene intervention (treatment group 2: n=400), and (2) each intervention relative to the control group (n=200). Treatment group 1 (T1) received training on hand washing with soap and food hygiene, while treatment group 2 (T2) received the same two modules along with training on feces management and water management. The interventions were delivered for 9 months by caregivers at cluster meetings and household visits. Diarrhoeal disease was measured as the primary outcome of interest. This was measured through self reporting (diarrhoeal disease in the two weeks prior) at baseline, midline and end line. Baseline reported an overall rate of 44% diarrhoea (T1=45%; T2=45%; C=43%) which was in line with national rates for children <12 months (41%). Midline measurements were taken at the completion of the handwashing with soap and food hygiene modules and saw a significant reduction in treatment groups (T1=14%; T2=16%) versus the control (C=27%) which was again in line with national rates for children <24 months (29%). This was repeated in end line results following completion of WASH modules in T2 (T1=6%; T2=5%; C=16%; national=14%). In order to better understand how and why each intervention was effective, additional analysis using a difference-in-differences approach to isolate the impact of covariates such as vaccination completion, breastfeeding, intervention compliance, is underway. These

preliminary results indicate that there was a significant reduction in diarrhoeal disease in all treated households, with no significant difference between the two treatment areas. As such, the primary reduction in diarrhoea appears to be associated with improvements in hand washing with soap and food hygiene and there is no additional benefit derived from household faeces or water management.

Title: A Multi-Pathogen Behavioral Exposure Model for Young Children Playing in Public Spaces in Developing Communities

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Enteric pathogen infections cause high rates of morbidity and death in children under five years of age (<5 years) throughout developing communities globally, despite improvements in WASH conditions in households. Household WASH interventions may have had minimal success on disease outcomes due to a failure to improve the hygiene of public spaces where children spend much of their time playing. Public spaces are contaminated with animal and human feces, presenting a risk of multi-pathogen exposure. Increased frequency of unsafe exposure behaviors and increased spatial roaming across public areas heightens the probability of child exposure to multiple pathogens. However, the cumulative amount of enteric pathogen exposure per child per time exposed to public areas is unknown. We model the exposure routes of enteric pathogens to children <5 years related to their time spent in public areas of their communities. Water and soil samples were collected around residential public sites in Corail, Haiti. Samples were analyzed using quantitative Polymerase Chain Reaction (qPCR) methods and *E. coli* culture assays to obtain microbial presence and concentration data. In addition, enumerators observed the same public areas for three-hour time periods, watching individual children for up to 30 minutes at a time to quantify the individual and within-group frequency of behaviors impacting exposure (i.e. hand washing, geophagia, hand to mouth contact, animal contact, etc.). This data serves as inputs into a Bayesian statistical model to evaluate pathogen dose and multi-pathogen exposure of a child per time spent playing in a public space. This model incorporates the interactions between presence and concentrations of different pathogens by utilizing a Probit model for presence/absence data and a normal hurdle model for pathogen concentration data. Preliminary analysis depicts a community ripe with exposure potential and children actively engaging in risky behaviors. Of the 84 soil samples, 44 were positive for Enterotoxigenic *E. coli*, 39 for Enteropathogenic *E. coli*, 28 for *Aeromonas*, and 46 for *Vibrio cholera*. Of 4 surface water samples, all were positive for *Aeromonas*, 3 for *Vibrio cholera*, and 2 for *Cryptosporidium*. Nearly all samples contaminated with one fecal pathogen were contaminated with multiple pathogens, proving the need for a multi-pathogen modeling approach. Nearly all sites, including 27 sites containing latrines and human excreta, had children <5 years of age present. During the behavioral observations, 365 children were observed, with 59 being infants in diapers. Many alarming behaviors were observed, including geophagia, hand to mouth contact, and animal contact. The multi-pathogen exposure model is integrating this environmental and behavioral data to estimate pathogen exposure per time in public child play areas, and the potential impact of increasing sanitation coverage on child exposure to pathogens to target interventions in public spaces to increase the impact and success of WASH interventions.

Title: A Prospective Cohort Study of the Relationship between the Gut Microbiota, Enteropathy, and Child Growth

Jamie Perin, Johns Hopkins University, Christine Marie George

Background: There is a growing body of literature demonstrating an association between environmental enteropathy (EE) and stunting in young children. This condition is defined by reduced intestinal barrier function, and increased inflammation resulting in low nutrient absorption. Microbial communities in the child gut are thought to play an important role in this condition, although the relationship is poorly understood. In this study we investigated the associations between gut microbial communities, EE, and prospective child growth among children in rural Mirzapur, Bangladesh. Methods: We examined four fecal markers of EE (alpha-1-antitrypsin, calprotectin, myeloperoxidase, and neopterin) and anthropometric measures from a cohort of 68 children. We sequenced the 16S rRNA gene of bacterial DNA from stool, and used the resulting sequences to estimate amplicon sequence variants (ASV). We then age-matched children with poor growth to children with normal growth within one month based on the WHO child growth standards, and compared the change in abundance and diversity of ASV over time. Children had a mean baseline age of 17 months and there was a stool sample from each child at baseline and the 18 month follow-up. Using tertiles of standardized anthropometry and the four fecal markers of EE, we compiled child pairs to compare ASV identity and diversity by child growth. Results: We observed increases in *Streptococcus* and *Escherichia/Shigella* among children with elevated alpha-1-antitrypsin compared to controls (3% increase versus 12% decrease, $p=0.008$ and 4% increase versus no change, $p=0.042$, respectively). There was also higher Proteobacteria among children with poor growth (bottom tertile of height for age z-scores) than among controls, (31% versus 12%, $p=0.015$). In addition, we observed increased Proteobacteria presence among children with elevated calprotectin compared to controls (15% increase versus 13% decrease, $p=0.007$). Diversity in ASV was also lower among children with poor growth at study enrollment. Conclusion: Different elevated fecal markers of environmental enteropathy were associated with increased i) *Escherichia/Shigella*, ii) *Streptococcus* or iii) Proteobacteria. Poor child growth was associated with increased Proteobacteria. These findings indicate these microbes and low diversity may play an important role in the pathway between environmental enteropathy and impaired growth.

Title: A Root - Lactic Acid Bacteria Based Method for the Removal of Enteric Pathogens from Wastewater

Walter Chingwaru, Bindura University of Science Education, Richwell Alufasi, Tatenda Jambo

The population of Southern Africa is frequently affected by erratic outbreaks of diarrhoea. In the wake of Cyclone Idai, at least 3,500 cases of cholera were recorded in Mozambique alone. Countries in the region are also affected by other forms of gastroenteritis including typhoid fever. Our ongoing research seeks to establish a bioremediation tool to remove diarrhoeal pathogens from wastewaters that continue to expose citizens to diarrhoea. Bioremediation is widely praised as a sustainable and cheap way to treat wastewaters particularly in resource limited settings. We tested the removal of strains of *Escherichia coli* O157:H7, *Salmonella typhi* and *Shigella* spp. within the rhizosphere of selected macrophytes – relying on interactions between roots and lactic acid bacteria (LAB). Removal of the pathogens was determined relying on the following methods: (i) cidal / static activities of the LAB using the well diffusion assay, (ii) internalisation of pathogens by plants, and (iii) putative antimicrobial activities of root exudates. Our

selected LAB showed high antimicrobial activities against the pathogens (MIC of cell free supernatants $\geq 0.02\text{mg/ml}$ / zone of inhibition $\geq 12\text{mm}$ - comparable to that of streptomycin $\geq 15\text{mm}$). Co-culture of pathogens and LABs within the rhizosphere yielded significant and synergistic reductions in pathogen load ($p < 0.05$) with greater survival of LABs than pathogens. Given the high cidal / static effects of the root - LAB interactions in wastewater, studies are underway to determine the mechanisms by which pathogens are removed within rhizosphere of the selected plants. The method is seen as having potential for use as a cost effective and ecologically acceptable method to sanitise wastewaters of enteropathogens in resource limited settings.

Title: A Systematic Approach to Investigate the Complex Casual Variables to Child Stunting in Guatemala

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Child stunting, or low height-for-age, is a chronic health metric selected as an indicator for Sustainable Development Goal 2.2. Stunted children are at increased risk of morbidity, mortality, and poor cognitive function during childhood and into adulthood. Environmental determinants of child stunting are complex and multilayered, including components such as water, sanitation and hygiene (WaSH) and nutrition, among others. Guatemala is ranked 6th worst in the world for child stunting, with 46% of all children under the age of five stunted. To understand the systems in which child stunting persists, holistic and systematic approaches must be deployed. Our objectives included 1) understand the complex and multilayered associations between variables at the macro-level using exploratory network analysis and cluster analysis, 2) identify local community and national priorities among these variables through semi-structured interviews, 3) assess hypothesized causal pathways attributed to child stunting using structural equation modeling, and 4) investigate specific mediating interactions via an fecal microbiome analysis. First, semi-structured interviews with local and national experts were used in conjunction with a network and cluster analysis between variables measured in national datasets to identify specific hypotheses describing causal relationships between variables related with child stunting. The data suggests that pathogen exposure via poor WaSH, fungal toxin (aflatoxin) exposure from maize diets, low micronutrient consumption, and baby swaddling for the first year of life were associated with child stunting. Next, these results were incorporated into a set of hypothesized structural equation models (SEMs). The three SEMs included unique sets of variables informed by the prior steps hypothesized to directly affect 1) child stunting, 2) fungal toxin exposure, and 3) pathogen exposure; controlling for their respective mediating variables. Surveys were randomly administered by local translators to mothers of children under five years of age in northwest Guatemala (October 2016, $n=378$ and February 2017, $n=295$). The data suggested that higher fungal toxin exposure and more time spent playing on the ground was associated with lower child height-for-age (i.e. higher child stunting). Furthermore, lower levels of fungal toxins in household maize were associated with proper selection habits of maize at the market and buyers paying more for better quality maize from subsistence farmers. Finally, lower levels of diarrheal occurrences were associated with proper water treatment. To investigate further, the potential interaction between fungal toxin exposure, diarrhea and child stunting, a fecal microbiome analysis was conducted on a subset of children. Fecal samples were collected from 35 children between three months and three years of age. Data collected from the children included contaminated maize consumption, diarrhea recall, anthropometric measures, and dietary recall. The data suggested there were significant differences between intestinal microbiomes of children who were taller versus shorter and children who had diarrhea versus those that did not. Finally, children who consumed high levels of aflatoxins had 24-times higher odds of having a dysbiotic intestinal microbiome. The study identified water quality, fungal toxins in maize, and pathogen exposure from the ground as potential mechanisms of poor child growth, partly associated with a dysbiotic intestinal microbiome.

Title: An Enhanced Rotational Cleaning System Among Shared Toilet Users in Lusaka, Zambia

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Background: In high density peri-urban areas, maintaining hygienic sanitation facilities among multiple users is extremely difficult. The Indaba Yama Landlords intervention aimed to improve the quality of shared sanitation by encouraging four improvements to a toilet, which included a cleaning rotational system among landlords and tenants living together on a plot. We assessed the uptake of the rota and its effect on toilet cleanliness and conflict among users; and explored the experiences of landlords implementing the cleaning rota system. Methods: We conducted a randomised control trial with 1085 landlords randomly assigned 1:1 to intervention and control in Bauleni Compound, Lusaka. Using the Behaviour Centred Design (BCD) approach, the intervention aimed to encourage landlords in the intervention arm to introduce a one week cleaning rota through cooperative plot meetings with their tenants. They received a physical object - the Pamodzi Rota - to place on the front door of the household responsible for cleaning the toilet at any given time. Uptake of the rota, rota duration and effect on toilet cleanliness and conflict reduction was measured one month before start and four months after intervention. Post-intervention, we held twelve (12) in-depth interviews and two (2) focus group discussions with landlords to understand their experiences with using the rota system and their collective views on the feasibility of implementing the Pamodzi Rota respectively. Findings: Plot size constituted a median of 3 doors (IQR= 2-4) and 10 tenants (IQR= 6-16). Based on the end-line survey with 474 intervention and 454 control landlords, the intervention was associated with improvements in the prevalence of cleaning rotas (relative risk 1.16, 95% CI 1.05–1.30; $p=0.001$) and an overall uptake of weekly rotas (7.7%). Weekly rotas were significantly associated with conflict reduction compared to absence of rotas (29% vs 15.9%, $p<.001$) and less then weekly rotas (19.9.%). There was no effect of weekly rotas on toilet cleanliness. Interviews revealed that the Pamodzi Rota created order, made managing a rota system easy for landlords and served as a useful reminder for households whose turn it was to clean the toilet. On some plots, landlords assumed the authority of assigning the Pamodzi Rota because tenants couldn't agree among themselves while on other plots, tenants were responsible for passing on the Pamodzi Rota to the next household. Collective views from the FGDs showed that a weekly rota reduced "finger pointing" on whose turn it was to clean the toilet in comparison to a daily rota. Additionally, sit down meetings increased the sense of responsibility among plot households to clean the toilet. However, single male tenants were reported to be the least cooperative with the cleaning rota. Conclusion: A longer rota cleaning system along with a physical reminder makes it easy to manage toilet cleaning and promote cooperation among shared sanitation users.

Title: An Evidence-Driven Approach to Establishing Prices for Pit Emptying Services by Vacuum Truck Operators

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Background: One main reason households in Benin underutilize pit emptying services is its high cost. Consequently, households have seen an increase in unemptied full pits and are exposed to serious health risks. According to the diagnostic report, EDE 2016, carried out under the SPFSM funded by BMGF, only 38% of households empty their pits. In response, PSI leveraged its social franchising expertise to develop the emptying services business model, "VIDANGE MIMIN," funded by USAID's Sanitation Service Delivery (SSD) project, to provide affordable, high-quality services. However, during the bid commitment phase with pre-qualified vacuum truck operators (VTOs), differences arose in the standard price for emptying services. Intervention: Thus, PSI and their local affiliate, ABMS, conducted a "mystery shopper" survey to estimate prices at which emptying services are provided. Survey agents, as regular clients, met and negotiated with business providers, representatives, and drivers to collect data on prices practiced by market operators. Distance to the household of the place of removal was also considered. The survey was conducted in January 2018 in East Cotonou (before the bridge: Akpakpa) and West Cotonou (after the Tokpa bridge to Ménomintin) since Cotonou is SSD's intervention area and the main commune where emptying structures operate. Survey agents were assigned to different emptying service delivery sites and their parking sites. 22 emptying structures were randomly selected from the list of those (40) that officially submitted to be ABMS partners. 20 other emptying structures that did not submit files located within the areas in which agents were distributed were also selected. Truck drivers were randomly selected by the survey agents as they navigated their assigned areas. Results: 20 business providers and 23 representatives or truck drivers were surveyed. 72% of final prices for emptying 6m³ were between 35,000 FCFA (~\$59.95) and 40,000 FCFA (~\$68.52). Final prices by business providers were higher. Seven business providers fixed prices between 41,000 FCFA (\$70.23) and 45,000 FCFA (~\$77.08), while only two managers and no driver solicited the same price range. 67% of final prices for emptying 12m³ were between 70,000 FCFA (~\$119.91) and 80,000 FCFA (~\$137.04). Similarly, business providers set higher prices. Four set prices above 80,000 FCFA (~\$137.04), while only one manager priced in that same range. Using this data, the SSD team negotiated with the Union of Professional Sanitation Structures Benin (USPAB) the official price for emptying 6m³ of sludge from 45,000 FCFA (~\$77.08) to 40,000 FCFA (~\$68.52) and 12m³ from 90,000 FCFA (~\$154.17) to 80,000 FCFA (~\$137.04), each a reduction of 11%. All 35 pre-qualified VTOs signed the partnership agreement for the supply of "VIDANGE MIMIN" services. Conclusion: The "mystery shopper" survey showed that prices vary according to the type of emptying service provider. Owners and emptying truck drivers charge lower prices than business providers. Drivers tended to reduce the cost after negotiation due to, according to them, stiff market competition. Distance had virtually no impact on the price charged by the service providers, although some drivers required households to bear fuel cost.

Title: Assessing Impacts of Commercial Hog Operations on Surface Water Quality

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Prior research suggests associations between commercial swine operations (CSOs) and the presence of antibiotic-resistant fecal indicator bacteria in surface waters, however, well-designed systematic research has not been done to understand how differences in CSO geography and watershed land use effect this prevalence. This longitudinal, landscape-scale watershed study evaluated how precipitation and land use affected the prevalence of antibiotic-resistant *E. coli* and microbial source tracking (MST) markers in watersheds with and without varied influence from CSOs. Surface waters were collected eight times in small watersheds with (n=13) and without (n=9) CSOs upstream of sampling locations between August 2016 and August 2017 resulting in 194 samples. Impacts of CSOs were hypothesized to be dependent on the distance of the CSO to sampling location and thus samples were collected from watersheds with CSOs varying between 0 and 3200 m downstream of sprayfields. We observed significantly higher (p<0.001) mean concentrations of *E. coli* at swine sites (1,284 CFU/100 ml, 95% confidence interval (CI): 625-1,944) compared to background sites (687 CFU/100 ml, CI: 263-1,111) with swine samples exceeding the EPA recommendation for recreational waters more often than background samples (73% vs. 42%, risk ratio: 1.74, CI: 1.30 – 2.33, p<0.001). Additionally, *E. coli* isolates were tested for antibiotic resistance to 12 antibiotics from 9 antibiotic classes using the Kirby-Bauer disc diffusion method and resistance was classified using CLSI guidelines. Resistance was observed to 1, 2, and 3 classes of antibiotics significantly more often (p<0.05) at swine sites (n=556 isolates) compared to background sites (n=356 isolates). Finally, we found similar (p=0.12) low mean concentrations of human MST marker, HF183, at swine sites (1.6 copies/uL, CI: 1.2-2.1) compared to background sites (1.5 copies/uL, CI: 0.69-2.2), but found significantly higher (p=0.003) mean concentrations of the swine MST marker, pig2bac, at swine sites (283 copies/uL, CI: 0-836) compared to background sites (0.76 copies/uL, CI: 0.68-0.84). These results indicate that watersheds with CSOs can be associated with higher prevalence of antibiotic-resistant *E. coli* and presence of the swine-specific MST marker, pig2bac. We will present results from a multivariate regression modeling prevalence of *E. coli*, antibiotic resistant *E. coli*, and MST markers by incorporating precipitation variables, watershed variables such as percent wetland, and CSO geography variables such as distance from sprayfields to sampling location.

Title: Assessing Menstrual Hygiene Management (MHM) among Female Students in Pastoral Regions of Ethiopia

Nikita Salgaonkar, Nga K. Nguyen, Kathrin Tegenfeldt, Michael Blair, AECOM

Poor menstrual health management (MHM) practices can negatively impact young girls' abilities to attend school, manage their health, and may reduce women's overall economic potential. This rings true in Ethiopia, particularly in rural communities affected by drought. Women and girls living in some of the most arid and remote areas in the country are particularly challenged in their ability to hygienically manage their menses. Although research on MHM has been conducted in other areas of Ethiopia; to date, it has been limited in pastoral areas. The USAID Lowland WASH Activity conducted a mixed methods study comprised of household surveys and qualitative interviews to understand challenges and opportunities for improved MHM among female students. The sampling included students aged 14-19 from 12 schools within Debub Ari, Bena Tsemay and Male districts in the South Omo Zone of the Southern Nations, Nationalities, and Peoples region (SNNPR). The study sought to:

- Understand the enabling environment, including physical barriers inhibiting adolescent girls from practicing safe and dignified MHM in schools;
- Uncover the cultural taboos surrounding MHM in remote, rural and pastoral communities;
- Assess the supply chains and market economy for reusable and factory-made sanitary pads; and
- Propose solutions to facilitate WASH programming in schools for improved MHM practices.

Results from this assessment were analyzed using Elephant, Rider, and Path and SaniFOAM behavior change frameworks to provide a systemic and simplified illustration of the key barriers effecting MHM, which include:

- Insufficient knowledge of the menstrual cycle and lack of familiarity with various types of products used for MHM among students;
- Significant misconceptions and taboos related to menstruation that affect women's abilities to fully participate in community activities;
- Very poor sanitation infrastructure including lack of clean and sex-segregated toilets at schools and home to adequately manage menses with safety, dignity and privacy;
- Strong preferences for commercial pads over home-made pads although commercial pads were largely unaffordable;
- Inconsistent supply of sanitary pads in the local markets, unsustainable supply chain of MHM products and low level of MHM business initiatives.

As a result of the above, school absenteeism due to menstruation was found to be high, with 34% of female students reporting missing school due to their most recent menstruation. This demonstrates the lack of informational, social and financial support for female school-aged children and their parents in relation to menstruation and proper MHM. The study findings are similar to research carried out in non-pastoralist areas of Ethiopia by SNV, UNICEF and PSI.

Title: Association Between Ambient Temperature and Childhood Diarrhea at Varying Levels of Piped Water and Sewerage Access, Pre- and Post-Rotavirus Vaccination, Peru 2005-2015

Miranda Delahoy, Emory University, GeoHealth Peru Climate Research Group, Thomas Clasen, Benjamin Lopman, Kyle Steenland, Karen Levy

Global temperatures are projected to rise by $\geq 2^{\circ}\text{C}$ by the end of the century, with expected impacts on infectious disease incidence, including diarrheal disease. Prior research has shown a positive association between air temperature and all-cause diarrhea; however, rotavirus incidence is negatively associated with temperature in the tropics. Establishing historic relationships between temperature and childhood diarrhea is important to inform future vulnerability under projected climate change scenarios. We estimated the relationship between ambient temperature and the rate of clinic visits for diarrhea in children in Peru from 2005-2015, examining whether this relationship was modified by the national introduction of rotavirus vaccination in 2009. We utilized a spatially-detailed national dataset to examine the incidence of weekly clinic visits for diarrhea in children under five years old across the 195 Peruvian provinces. Diarrhea data were obtained from weekly surveillance reports collected by the Peruvian Ministry of Health. The Peruvian National Meteorology and Hydrology Service provided temperature data at 0.1° gridded spatial resolution for the country of Peru, interpolated from air temperature monitors and remote-sensed data. We created a weekly estimate of the mean daily high temperature for each province. We used negative binomial regression to examine the association between temperature and the diarrhea rate, using a distributed lag model to account for the temperature the week of the diarrhea cases, as well as the temperature in each of the prior three weeks. We controlled for secular trend, El Niño events, and the dry vs. wet season. We evaluated whether rotavirus vaccination modified the temperature-diarrhea relationship, considering the “pre-(rotavirus) vaccine” (2005-2009) and “post-vaccine” (2010-2015) eras. The childhood diarrhea rate was 29 annual clinic visits per 100 children in 2005 and declined throughout the study period. We found a significant positive association between diarrhea and temperature (degrees Celsius) the same week diarrhea cases were reported (incidence rate ratio (IRR): 1.03, 95% confidence interval (CI): 1.02-1.03), as well as the previous week (IRR: 1.01, 95% CI: 1.01-1.01); other lagged temperatures were not significant and not retained in the model. Controlling for secular trend, dry season, and temperature, periods with moderate/strong El Niño events had higher diarrhea incidences (IRR: 1.04, 95% CI: 1.03-1.05). The temperature-diarrhea relationship was significantly modified by rotavirus vaccination. In the pre-vaccine era, each 1°C increase in temperature was associated with an approximately 2.2% higher diarrhea incidence that week, whereas in the post-vaccine era the incidence was approximately 3.0% higher. Despite low temperature variability in several provinces of Peru, we found a small, but significantly higher rate of childhood clinic visits for diarrhea at higher temperatures; furthermore, moderate/strong El Niño events were significantly associated with higher diarrhea rates, controlling for temperature. The relationship between temperature and diarrhea was stronger in the rotavirus vaccine era, potentially reflecting a decrease in an etiology of diarrhea known to be associated with cooler temperatures. Given the high baseline morbidity for childhood diarrhea, even these small increases may translate into a substantially increased burden of childhood diarrhea under future climate scenarios, in the absence of diarrhea mitigation strategies.

Title: Association Between Gastrointestinal Disease in Children and Wastewater Agricultural Irrigation in Valle del Mezquital, Mexico

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Background: Wastewater reuse for agriculture has intensified over the years due to increases in urbanization coupled with high prices for fertilizers. In the Valle del Mezquital, Hidalgo, wastewater from the Metropolitan Area of Mexico City is used for agricultural irrigation. Human and animal pathogens are continuously high in wastewater, potentially putting farmers and their families at risk. Moderate and severe episodes of diarrhea constitute a substantial part of total diarrhea and mortality among children under five years of age. The Atotonilco Wastewater Treatment Plant began partially treating the wastewater in May 2017, providing treated water to some irrigation districts of the Valle del Mezquital. Methods: We conducted a longitudinal study from November 2016 to November 2017 following 880 children under five years old. During this period, three visits were made: recruitment (November 2016-April 2017), first follow-up (May-July 2017), and second follow-up (August-November 2017). We administered three questionnaires by interviewing the primary caregiver of children to obtain information about diarrheal disease in children under

five years old, use of water in the household, hygiene practices, and participation in agriculture. We also conducted anthropometric measurements of the children. Using multivariate logistic regression models with fixed and random effects, we estimated the Odds Ratio (OR) of presenting diarrhea and the 95% confidence interval (95% CI). Results: Children under five years old living in zones that irrigated crops with wastewater (zones A and B) had 2.0 times the odds of diarrheal disease compared to zone C (CI 95% 1.27 – 3.1). Compared to Zone C, Zone B had 2.3 times the odds of diarrheal disease (95% CI 1.41 - 3.84), followed by zone A (OR = 1.72 times, 95% CI 1.04 - 2.86), after adjusting for age, sex, presence of chickens, and access to sewerage in households. Likewise, it was observed that the odds of diarrhea in children under five increased in the presence of chickens (OR = 1.74, 95% CI 1.18 - 2.57) and decreased with access to sewerage in households (OR = 0.50, 95% CI 0.27 - 0.93). Conclusions: Our results suggest that exposure to wastewater used for irrigation, with or without treatment, contributes to the presence of diarrheal disease in children under five years of Valle del Mezquital.

Title: Can Social Motivators Improve Children’s Handwashing Behavior? RCT Evidence from Primary Schools in the Philippines

Jeffery McManus, IDinsight, Meg Battle, Clément Bisserbe, Haijing Crystal Huang, Qayam Jetha, Lilian Lehmann

Background: Generating sustained improvements in handwashing behavior is an enduring public health challenge. Whereas many interventions focus on closing knowledge and accessibility gaps, a relatively new approach uses motivators rooted in social psychology, such as peer affiliation and disgust, to promote handwashing. We provide evidence from two of the first large-scale evaluations of a school-based program – the HiFive for HySan (‘HiFive’) program, implemented by the Philippines Department of Education and supported by UNICEF and the International WaterCentre - which uses social motivators to improve handwashing rates. The intervention involved teacher training, monitoring, and support to conduct classroom activities using behavioral messaging to promote student handwashing at critical times. Methods: We evaluated two consecutive iterations of the HiFive program and are currently designing an evaluation of a new program that builds on the previous pilots. In year 1, we conducted a clustered RCT across 196 schools in the Philippines. To assess the impact of the program we observed 5,296 instances of handwashing opportunities, surveyed 4,295 students, and inspected 4,187 handwashing facilities. In year 2, the HiFive program design and implementation was updated based on results from the previous year’s evaluation and rolled out in the previous year’s control group. We assessed the impact of the revised program using data from 2,364 observations of handwashing opportunities, 1,356 student surveys, 834 facility inspections, and 236 teacher interviews. A new program and evaluation in 150 schools are currently being designed based on these results. Results: Rates of student handwashing are strikingly low. In control schools, students were observed washing their hands with soap after using the toilet only 2.5% of the time. In year 1, HiFive led to a 3.7 percentage point increase in handwashing ($p < 0.01$) and in year 2, HiFive led to a 5.1 pp increase ($p < 0.01$). However, the program had limited impact on the social motivators targeted by the program, suggesting that the marginal improvements in handwashing rates may have been primarily driven by small but statistically significant increases in the (already high) availability of soap and student knowledge about the importance of handwashing. Conclusion: Despite access to functional hand-washing facilities and high levels of knowledge of good hand-washing practices, many children still do not wash their hands with soap after using the toilet. The HiFive intervention, based on classroom activities that trigger social motivators, led to statistically significant but relatively small improvements in handwashing rates. In light of these findings, we are collaborating with UNICEF to design and evaluate a new program that will use behavioral nudges to improve handwashing rates.

Title: Capacity-Building for Improved WASH Governance through Tracking and Analysis of Decentralised Budgets and Financial Systems

Ruchika Shiva, International Water and Sanitation Centre (IRC), Trisha Agarwala, Subrat Das, V.R. Raman

India is a signatory to the UN Mandate on the Right to Water 2010. While toilet construction and promotion has been a priority during the past decade, focus on provisioning safe drinking water and environmental sanitation services has been consistently poor. Public provisioning in water and sanitation in India has always remained very low, at less than 1 percent of the GDP. Further, governance and management of WASH services remain a major challenge at the provincial and district levels, coupled with huge unspent balances in the sector budgets. Budgets and expenditures are critical policy processes, and analysing these can highlight the commitments and priorities of the government. Budgets help to assess the ‘gaps’ in planning and implementation, and suggest corrective actions. In India, devolution of power and funds (especially since the 14th Finance Commission in 2015) for water and sanitation has necessitated that local governments be able to understand the processes of WASH planning, fund allocation and utilisation. In this regard, Watershed partners along with WaterAid India and its partners launched an initiative to build capacities of CSOs (including local government) around institutional arrangements, programmatic priorities, financial allocation and utilisation, towards improving WASH services in select districts in two states (Bihar and Odisha) of India. As part of the study, WASH budgets and expenditure were tracked from national, state, district, sub-district and local government level, for rural water and sanitation programmes, deploying the LCCA framework as a way to understand the same. The purpose of the study was:

- To involve relevant CSOs in the budget tracking and analysis process, thereby building their capacities to understand the institutions and budgetary flows with respect to water and sanitation.
- To capture the challenges faced by CSOs in the process
- To assess the priorities and trends in the budgetary allocations and expenditure in Water and Sanitation services at various levels of the government.
- To understand the expenditures with respect to the four key cost components of LCCA - Capital expenditure, Capital maintenance expenditure, Cost of Capital, Operating and minor maintenance expenditure, Expenditure on direct support, and, Expenditure on indirect support
- To provide solutions to strengthen WASH budget and expenditure processes.

Initial analysis shows that while there has been a significant increase in the central government’s budgetary allocations for toilet construction (under the ‘Swachh Bharat Mission’), that for drinking water and other environmental sanitation measures have remained suboptimal. However, in both the states the state governments have allocated a fair amount of their own resources towards the provision of drinking water, in addition to the untied

funds available under the 14th finance commission. While budget expenditures show considerable increase in terms of absolute amounts, they underline the critical need for institution and systems strengthening to ensure that such allocations and utilisation result in improved WASH services and environmental health. The proposed paper will further detail out the processes deployed under this study, and the critical learnings emerged out of it for public finance and governance for the WASH in India and elsewhere.

Title: Cassava, Cyanide and Drinking Water or the Consideration of Productive Uses in the Design of Water and Sanitation Infrastructures
Gaëtan Bonne, French Red Cross, Jean-Marc LeBlanc

In 2014, the Ministry of Hydraulics of Republic of Congo delegated to the French Red Cross the project management for the realization of two drinking water infrastructures in the villages of Ingah and Imvouba. These villages are located on the Plateau of Mbé that culminates at 800m and has annual rainfall up to 1,800mm. People practice rainwater harvesting for the various daily uses, namely drink use, domestic use and productive use. As Geology is composed of permeable layers, the supply via groundwater requires the realization of expensive infrastructures, with a favorable area to capture water at 250m depth. The cost of these infrastructures requires special attention at the level of design studies to ensure the viability of investments. A study at the household level has been undertaken to know the volumes induced by all the different uses of water in the design calculations. A qualitative and quantitative survey have been carried out on a representative sample of 107 households to refine the knowledge of volumes consumed and their use in order to be able to consider them. The study of the uses of water, and in particular productive one, has shown that large quantity of water are reserved for the processing of the bitter cassava (*Manihot esculenta*), the main source of carbohydrates in the diet. The results show that 90% of households practice processing of cassava and that the daily average volumes consumed are 42.5 liters per person per day. 52% of this volume is used for productive use, in our case the processing of cassava. This practical case demonstrates the importance of considering all the uses of water in the design of the drinking water infrastructures, and in particular productive uses because of the risk of not responding correctly to the needs of the populations. The lack of consideration of productive uses would have led to under-size the infrastructures and as result, led to a lack of available water and a stress for the populations that could generates tensions, and jeopardizing the viability of drinking water infrastructures. In addition, it is also important to take into account the different uses in the implementation of action to limit the impacts of wastewater discharges. Cassava contains cyanide compounds (toxic cyanogenic glycosides) and the processing includes steps to reduce the concentration of these compounds in the final product. These contaminated waste and effluent are discharged into the environment and causes contamination of soil and groundwater. In an aquifer at about 105m depth, hydrogen cyanide concentrations seven times higher than the WHO drinking water standards have been measured. Chimie Sans Frontière and the French Red Cross are studying the possibility of carrying out additional researches to better characterize the pollution. A reflection should be undertaken on the control of effluent and other contaminated waste resulting from the transformation process. The sensitization of the households on the problematic of the contamination could make accept an evolution of the practices.

Title: Child Feces Management and Fecal Contamination: Evidence from a Cross-Sectional Study in Rural Odisha, India
Valerie Bauza, Emory University, Fiona Majorin, Parimita Routray, Gloria D. Sclar, Bethany Caruso, Thomas Clasen

Background: Many rural Indian households do not dispose of their young children's feces in a latrine, even when one is used by household adults. While safe management of children's feces is likely critical for reducing fecal contamination exposure, the effectiveness of different child feces management practices in reducing fecal contamination is not well understood, yet has implications for the potential benefits of child feces interventions. Methods: We conducted a cross-sectional study of households with children <6 years in rural Odisha, India, using a combination of household surveys (188 households), environmental sample analysis for *E. coli* (373 samples for 78 child defecation events), and unstructured observation techniques (33 households) to capture information on potential fecal contamination along the entire child feces exposure pathway: child defecation area, feces handling and disposal, tool cleaning, anal cleansing, and handwashing. For environmental sampling, we developed a novel sampling strategy that involved collecting samples at the time and point of child defecation to capture activity-level fecal contamination for child feces management activities. The study was supplemental to an ongoing intervention trial that included the distribution of potties and scoops for safe child feces management. Results: Sample analysis provided empirical evidence that current methods widely used for child defecation and feces handling are not effective at preventing fecal contamination of the ground/floor or hands. Defecating on the floor or ground, which was practiced by 63.7% of children <6 years, was found to increase the level of *E. coli* contamination on finished floor ($p < 0.001$) or earthen ground surfaces ($p = 0.008$) after feces was removed, even if paper was laid down prior to defecation. Waste paper was the most common tool used by caregivers to pick up children's feces for disposal. Sampling revealed that use of unsafe tools (e.g., paper, plastic bag, straw/hay) increased contamination on hands after feces handling ($p < 0.0001$), whereas the use of safe tools (e.g., potty, hoe, scoop) did not increase hand contamination ($p = 0.54$). The most common feces disposal location for child <6 years was throwing feces into an open field, which unstructured observation noted was usually close to the house. Although several households owned scoops or potties for child feces, use was low and we identified a number of shortcomings with these typical CFM hardware interventions that we will present, along with recommendations for hardware intervention improvements. Finally, this presentation will also share insights about other sources of contamination along the child feces management chain that were investigated, including defecation area or tool cleaning, child anal cleansing, and caregiver handwashing. Conclusions: Current practices and tools used for managing child feces in this setting were inadequate at preventing fecal contamination of the environment. Scoops and potties were associated with lower caregiver hand contamination after feces disposal, but had low use. Our results demonstrate the need for innovative child feces management interventions that address the many points of potential contamination exposure – including but not exclusive to disposal – to comprehensively account for defecation, feces handling, and cleaning activities to reduce contamination in the environment and on caregivers' hands.

Title: Child Feces Management and Fecal Contamination of Hands and Stored Drinking Water in Rural Bangladesh

Mahfuza Islam, International Centre for Diarrhoeal Diseases Research, Bangladesh (icddr,b), Ayse Ercumen, Mahbubur Rahman, Benjamin F. Arnold, Stephen P. Luby, John M. Colford, Jr.

Background: Fecal-oral infections can be transmitted via contaminated hands, drinking water, food, soil, fomites and vectors. Child open defecation is common in low-income countries and can increase the risk of fecal exposure in the domestic environment, especially for young children who have frequent hand contact with feces or soil contaminated by feces. This study, among households with children <5 years in rural Bangladesh, aimed to assess the association between reported child defecation and child feces disposal practices and (1) *E. coli* contamination of child and caregiver hands and stored drinking water and (2) observed cleanliness of caregiver and child hands. Methods: We visited 360 households with a child <5 years approximately quarterly, for a total of 8 visits over 2.5 years between June 2014 and December 2016. At each visit, field workers recorded caregiver-reported defecation and feces disposal practices for children <5 years and examined caregiver and child hands (fingernails, finger pads and palms of each hand) for visible dirt using a three-point scale (visible dirt particles, unclean appearance, clean). We also collected child and caregiver hand rinses and stored drinking water samples from each household at each visit to enumerate *E. coli*. We assessed how reported child feces management practices are associated with *E. coli* presence/levels and observed hand cleanliness using generalized linear models (GLM) with a binomial error distribution and log-link for binary outcomes and with a Gaussian error distribution for log-transformed *E. coli* counts, with robust standard errors to account for geographical clustering of study participants. Results: Safe defecation (in latrine/potty) and safe feces disposal (in latrine) for the last child defecation event was reported by 21% (n=548) and 23% (n=607) of households, respectively. *E. coli* was detected in 75% (n=1988) of caregiver and 75% (n=1963) of child hand rinses and 81% (n=1870) of stored water samples. Visible dirt was observed on 67% (n=1775) of child and 79% (n=2083) of caregiver hands. In multivariable analyses controlling for child age, household wealth and mother's education, we found that *E. coli* prevalence on child hands was higher in households reporting unsafe child defecation (PR: 1.12, 1.04-1.20) and unsafe child feces disposal (PR: 1.11, 1.02-1.21). *E. coli* prevalence in stored drinking water was also significantly higher among households reporting unsafe child defecation (PR: 1.12, 1.03-1.21) and unsafe child feces disposal (PR: 1.10, 1.03-1.18). Effects on *E. coli* levels were similar. Unsafe defecation and feces disposal were significantly associated with higher prevalence of visible dirt on child hands. Conclusion: Unsafe child defecation and child feces disposal was reported by the majority of households in a rural Bangladeshi setting with widespread access to on-site sanitation. These practices were associated with increased *E. coli* contamination of child hands and stored drinking water and increased likelihood of visible dirt on child hands. Our findings suggest that poor child feces management may be an important source of fecal exposure for young children. Studies should assess if targeted interventions to improve child feces management practices reduce fecal contamination in the domestic environment and child diarrhea.

Title: Child Mouthing of Contaminated Fomites and Animal Contact is Associated with Diarrhea and Stunting (REDUCE Program)

Christine Marie George, Johns Hopkins Bloomberg School of Public Health

Background: Undernutrition is the underlying cause of death of over half of young children worldwide. Furthermore, diarrhea is a leading cause of death in young children globally, causing an estimated 500,000 deaths annually. Exploratory play behavior is important for motor and cognitive development in young children. However this behavior also presents an exposure route to fecal pathogens for susceptible pediatric populations. In many low and middle income countries, infants and young children frequently come into contact with animal and human feces and contaminated soil while crawling and playing outdoors. Methods: We are currently conducting a prospective cohort study of 515 children under 5 years of age in Walungu Territory of South Kivu in the Democratic Republic of the Congo. Child mouthing of soil and objects is assessed by five hour structured observation, and contact with domestic animals is assessed by caregiver reports. Spot checks are also performed where research staff observe if there are signs of open defecation or flying toilets on the household compound. These activities along with height and weight measurements are collected at baseline and at a 6 month follow-up. In this abstract we present the findings from baseline. The 6 month follow-up visits will be completed for all households in May 2019. Results: Fifty percent of children were observed putting soil in their mouth, and 90% of children were observed mouthing a visibly dirty object during structured observation. Caregivers reported that 42% of children touched chickens, 36% touched guinea pigs, and 20% touched rabbits in the last week. Children observed putting soil in their mouth had a significantly higher odds of stunting (Odds Ratio (OR): 1.72 (95% Confidence Interval (CI): 1.06, 2.82)). Children observed putting a visibly dirty object in their mouth had a significantly higher odds of diarrhea (OR: 4.97 (95% CI: 1.17, 21.04)). Children that were reported to have touched chickens had a significantly higher odds of diarrhea (OR: 1.76 (95% CI: 1.06, 2.92)). In addition, children in households with signs of open defecation or flying toilets were at significantly higher odds of being wasted (OR: 2.87 (95% CI: 1.02, 8.04)). Conclusion: Child mouthing of soil and visibly dirty objects and contact with chickens was associated with stunting and diarrhea in rural Democratic Republic of the Congo. These findings are being used to design an evidence-based Baby water, sanitation, and hygiene intervention to target these identified risk factors in the upcoming REDUCE trial. Interventions that focus on clean child play spaces are urgently needed to reduce pediatric exposure to fecal pathogens.

Title: Child Mouthing of Contaminated Fomites in an Urban Setting in Bangladesh (CHoBI7 Program)

Tahmina Parvin, Johns Hopkins University, Christine Marie George

Background: There are estimated to be 155 million children stunted globally. There is a growing body of literature indicating an association between stunting and environmental enteropathy (EE), a disorder thought to be caused by repeated exposures to enteric pathogens. EE is defined by abnormal intestinal morphology, reduced intestinal barrier function, and increased inflammation. Exploratory play behavior is important for motor and cognitive development in young children. However this behavior also presents an exposure route to fecal pathogens for susceptible pediatric populations. The objective of our study was to investigate exposure routes to fecal pathogen for young children. Methods: We conducted five-hour structured observation of 378 children under 5 years of age in Dhaka, Bangladesh to investigate child mouthing behaviors. Child mouthing behavior

was also assessed by caregiver reports for 835 children under 5 years. In a separate sub-study, a total of 112 soil and surface samples were collected from households with a child under 5 years of age to measure *Escherichia coli*. Soil samples were collected from spaces where children were observed playing, and surface samples were collected of objects children put in their mouth during structured observation. Results: The mean age was 23 months; and 45% (n=171) of children were female. Overall, 76% (n=285) of children were observed mouthing soil, objects with visible soil, or food with visible soil during the structured observation period. Sixty-one percent (n=233) of children were observed mouthing objects with visible soil, 33% (n=123) of children were observed mouthing food with visible soil, and 21% (n=79) of children were observed mouthing soil directly. Ninety-one percent (n=760) of caregivers reported their child mouthed dirty objects in the past week (compared to 61% observed). Sixty-six percent (n=552) of caregivers reported their child mouthed soil in the past week (compared to 21% observed). All soil samples had detectable *E. coli*, and the median concentration of *E. coli* in soil was 134.6 colony forming unit (CFU)/g (N=46). Thirty five percent (N=66) of surface samples had detectable *E. coli*. Balls were the most commonly contaminated item. Conclusion: These findings demonstrate that child mouthing of contaminated fomites is high in our urban setting in Bangladesh. Interventions are urgently needed to protect young children from fecal pathogens in their play spaces.

Title: Community Perceptions and Implementation Fidelity of a Multi-Level Behavior Change Sanitation Intervention in Odisha, India

Gloria Sclar, Emory University, Valerie Bauza, Apurva Ghugey, Munmun DasMohapatra, Thomas F. Clasen, Hans-Joachim Mosler

Background: India has a long history of government programs to fight open defecation, which have mainly focused on emphasizing latrine construction to increase latrine use uptake. Odisha has one of the lowest rates of individual household latrine coverage in India and research has shown that households owning latrines do not necessarily use them. Cost-effective and culturally appropriate interventions targeting behavioral barriers are necessary to bridge the gap between latrine ownership and use. Understanding of how communities perceive behavior change interventions is needed to optimize effectiveness. This qualitative study broadly examined general perceptions of how communities view sanitation interventions in Odisha, and specifically investigated community perceptions and spillover of Sundara Grama, a multi-level behavior change intervention in Odisha, India which aimed to increase latrine use. Methods: Sixteen sex-segregated focus group discussions, eight with women (n=72) and eight with men (n=80), were held in six rural villages. Three villages received the intervention, and three did not. General perceptions of sanitation interventions were assessed in all six villages, perceptions of Sundara Grama were assessed in the three villages that received the intervention, and spillover was evaluated in two villages that did not receive the intervention but were in close proximity to those that did. Data were analyzed using thematic analysis. Results: Sundara Grama was largely well-received, but certain barriers prevented some from experiencing the intervention as intended. Certain groups were missed during recruitment, possibly because they were women, or from a lower caste. Unclear messaging occasionally led to misunderstandings of the purpose of the transect walk, and may have encouraged villagers to punish open defecators. Internal conflicts and divisions made it difficult for communities to work together toward a common sanitation goal. On the other hand, the intervention may have boosted community self-efficacy toward village cleanliness, though not necessarily latrine usage. Communities were already familiar with sanitation messaging, but they were often reluctant to actively encourage members to use a latrine. This was because they could not provide latrines to others and they considered sanitation a personal decision. Because of this, participants expected outsiders to initiate and support sanitation efforts. Intervention spillover into control villages depended on the relations between the villages. When relationships between and within the paired villages were good, the control village knew about the intervention. When a high amount of conflict was reported in the village pair, control village did not know about the intervention. Conclusions: Post-intervention qualitative work in communities can bring insight to the intervention delivery and explain endline results. Implementers of community interventions in Odisha should consider the different groups, and divisions in a village, intentionally targeting those most likely to be excluded, such as women and lower castes. Future sanitation interventions aimed at producing collective action should first assess underlying social divisions and cultural norms about sanitation. By integrating activities to strengthen collective efficacy into the intervention, communities may become more empowered to act. In a similar way, integrating relationship-building activities and encouraging inter-village cooperation should increase spillover to nearby villages.

Title: Comparison of SaniPath Exposure Assessments in Low-Income Urban Areas in Eight Countries

Wolfgang Mairinger, Emory University Yuke Wang, Suraja Raj, Habib Yakubu, Casey Siesel, Christine Moe,

The SaniPath exposure assessment tool compares risks of exposure to fecal contamination in urban environments across multiple exposure pathways. The tool has been deployed in 39 neighborhoods in 8 cities: Accra, Ghana, Vellore, India; Maputo, Mozambique; Siem Reap, Cambodia; Dhaka, Bangladesh; Atlanta, United States; Lusaka, Zambia; and Kampala, Uganda. Ten exposure pathways were investigated (open drains, ocean water, surface water, floodwater, public latrines, soil, bathing water, raw produce, drinking water, and street food) through behavior surveys and environmental sample analyses. Exposure was expressed as monthly dose (average amount of fecal contamination ingested as measured by *E. coli* colony-forming units [CFU]) and the percent of population exposed to fecal contamination for each pathway. Magnitude of fecal contamination, frequency of exposure behavior, and estimated fecal exposures were compared across pathways, neighborhoods and cities. The most common dominant exposure pathways for adults were raw produce, open drains, and street food and for children were open drains, produce, and floodwater. For produce, the dose was usually very high (>106 CFU/month), and a large percent of the population was exposed (>80%). For street food, average *E. coli* concentration ranged from 101.3 CFU/serving in one neighborhood in Lusaka, Zambia to 105.5 CFU/serving in one neighborhood in Dhaka, Bangladesh. Exposure to open drains resulted in high doses (>104 CFU/month), but the population exposed varied (5%-92%) even within the same city. Exposure to fecal contamination via floodwater, usually affected a high percent of population (>80%) but had variable doses (102.5-1010 CFU/month). Both dose and percent of population exposed varied for public latrines and municipal piped water. This information can help city governments choose effective interventions to reduce the risk of exposure to fecal contamination. Widespread risks from contaminated produce and street food within and across cities underscore the link between excreta management and food safety and need for global action.

Title: Comparison of Stool Collection Methods for Microbiome Research

Kelly McCain, Rollins School of Public Health, Emory University, Karen Levy

Stool collection methods and storage reagents for studies evaluating the relationship between the human microbiome and human health have focused on studies conducted in high-income settings. In many low-income settings, there is not access to optimal transport and storage methods of stool samples, making it logistically challenging to collect and analyze stool samples within an acceptable amount of time. We conducted a study comparing different stool collection methods that have the potential to be used in remote settings due to their ease of use and stability of storage. All use a lysis buffer solution and do not require a cold chain, reducing logistical sample transport difficulties. We compared raw stool with no preservatives frozen at -80° C with samples collected using kits provided by: uBiome, a direct-to-consumer microbiome analysis kit, and Zymo's DNA/RNA Shield Fecal Collection Tube and Swab and the OMNIgene GUT kit, both temperature-stable stool collection kits. We collected stool samples from 12 children under two years of age living in Atlanta, Georgia. We collected two field replicates for each collection method, and for two children, we spiked the samples with norovirus and rotavirus. We extracted stool samples manually using the RNeasy PowerMicrobiome kit and automated on the QIAcube with the QIAamp 96 Virus QIAcube HT Kit. Additionally, we compared swabs taken directly from the child's rectum compared to swabs of fecal material from the child's diaper. Extracted samples were analyzed using a Nanodrop to quantify DNA, 16S amplicon sequencing to assess alpha and beta diversity and microbial composition, Taq Man Array Card (TAC) to quantify pathogens, and quantitative PCR to target rotavirus and norovirus. Laboratory analyses are underway and are expected to be completed by May 2019. We will compare the lab results of each stool collection method to raw frozen stool with no preservatives, which is considered the gold standard, and analyze the stability, reproducibility, sensitivity, and specificity of each. We expect that uBiome will be comparable to both Zymo methods as well as OMNIgene GUT but will potentially capture less diversity than the raw frozen stool. We also expect differences between rectal and diaper swabs. Stool collection methods that provide sensitive and specific results in downstream analyses are essential, and the results of this study will inform future microbiome research. Fulfillment of the pilot study objectives will lay essential groundwork for ongoing studies in our and other research groups by ensuring selection of an optimal fecal collection, storage, and transport approach. The results from this study will inform future research studies in low-income settings without access to optimal biological sample transport and storage conditions.

Title: Compromised Water Quality in Colonias of Nueces County, Texas: A Vicious Cycle

Lewis Stetson Rowles, Environmental Engineering University of Texas at Austin, Areeb I. Hossain, Desmond F. Lawler, Mary Jo Kirisits, Isabel Araiza, Navid B. Saleh

Colonias are self-built neighborhoods of mostly low-income families that lack basic infrastructure. While some funding from the state government has built roads and provided electricity, water and sewage systems are still lacking for many of the estimated 400,000 colonias residents in Texas. Of those that do have tap water, the supply is either inadequate or of questionable quality. Some colonias residents have access only to off-the-grid water supplies, and residents collect their water from community wells, or, if fortunate, from a personal well. Many of these wells are self-built and therefore shallow. In Nueces County, the groundwater in several colonias has been reported to contain arsenic, while poor sanitation practices (i.e., self-built septic systems) and heavy rainfall events in the region compromise the microbial quality of the groundwater. The naturally occurring arsenic in the aquifer and microbial contaminants from flooding events mean that the only available drinking water source in these colonias is contaminated throughout the year. In this research, datasets on water quality in nine colonias in Nueces County were collected both in wet (after a major rain/flooding event) and dry (no significant rainfall for four weeks) periods. The water quality analyses included traditional microbial quality assessment (total coliforms, *Escherichia coli*, and heterotrophs), pH, hardness, total dissolved solids, and a suite of metals that are relevant to human health (e.g., arsenic and lead). Microbial community analyses also were completed on select samples to assess the shifts in microbial ecology between wet and dry periods. Results reveal that water quality varies based on environmental conditions and presents a serious risk to human health. Water sampled during the wet period had extensive microbial contamination with elevated heterotrophs and total coliforms, and *E. coli* was identified in some samples. In the dry period, water from a number of colonias exhibited elevated levels of arsenic (above United States Environmental Protection Agency's Maximum Contaminant Level of 10 µg/L). This study is one of the first to systematically investigate water quality in Texas colonias, and the results highlight how water quality in these communities is compromised year-round, going between microbial contamination in wet events and arsenic contamination in dry events.

Title: Coordinated and Effective Capacity Development Services for Emptiers using the Emptying Service Competency Framework

Kelly James, Centre for Affordable Water and Sanitation Technology (CAWST), Laura Kohler, Taya Raine

Despite their central importance to ensuring the safe management of non-sewered sanitation, emptying service professionals are often underserved by capacity development programs and initiatives. CAWST conducted interviews in 10 African countries and found that existing capacity development initiatives for emptiers often face a number of challenges to supporting scaled up high quality emptying services. These challenges include:

1. limited coordination amongst existing capacity service providers and initiatives;
2. limited documentation and dissemination of lessons learned from successful interventions;
3. the sporadic or project based nature of capacity development interventions for emptiers;
4. and the heavy emphasis on very specific, often technical, aspects of emptying service delivery.

In order to respond to these challenges, CAWST developed a Emptying Service Competency Framework. Competency frameworks can be used as a tool to compare service performance against defined standards for what constitutes a high quality and integrated emptying service, identify potential areas for professional development, and as a tool for structuring and coordinating capacity development activities in order to avoid gaps and overlaps. In 2018, CAWST hosted two workshops with representatives from city level and national emptiers associations as well as from the

PanAfrican Sanitation Actors Network (PASA). These workshops used a series of structured activities and discussions in order to; 1) articulate the components and characteristics of a high quality emptying service, 2) understand common challenges faced by emptiers, and finally 3) to map the competencies (knowledge, skills, and attitudes) required to deliver a quality service. Following the development of this competency framework, CAWST brought together representatives from municipalities, utilities, and capacity development providers to obtain feedback and to host structured reflections on how this tool can be used to support both the effective integration of emptying services into the sanitation service chain, as well as the improvement of emptying service delivery. This session will share reflections and lessons from the competency framework development process. This will be followed by a discussion of opportunities for using competency frameworks to support the improvement of capacity development services for sanitation actors.

Title: Cost-Effectiveness Analysis of a Sanitation Intervention with a Quality of Life Measure as the Outcome

Ian Ross, London School of Hygiene & Tropical Medicine (LSHTM), Oliver Cumming, Robert Dreibelbis, Zaida Adriano, Guilia Greco

Background: Cost-effectiveness analysis (CEA) of health interventions usually include averted cases or disability-adjusted life years as the outcome. However, sanitation interventions have broader outcomes beyond infectious disease (such as privacy, dignity and comfort) which are often valued above health benefits by users. No quantitative metric exists to capture these outcomes, and they are ignored in economic evaluations, whether cost-benefit analysis or cost-effectiveness analysis. This may harm allocative efficiency when comparing sanitation interventions. It may also harm equity if these outcomes are valued differently by gender and social status. Methods: This quantitative study undertaken in 2019 aimed to estimate the cost-effectiveness of an urban sanitation intervention, using a novel quality of life measure as the outcome. Data was collected from 400 participants recruited from intervention and control the compounds enrolled in the Maputo Sanitation trial (MapSan) which were matched at baseline. Intervention compound users had access to well-built pour-flush toilets, while control compound users had access to unsafe 'traditional' pit latrines. This effect estimate from a cross-sectional evaluation of the intervention on SanQoL was used in a cost-effectiveness analysis. Attributes in the SanQoL measure were valued (weighted) using a ranking exercise carried out with all 400 respondents. Incremental costs were estimated drawing on implementer records (for capital costs) and a separate 2018 household survey of intervention and control households (for recurrent costs). Results: Analysis is currently underway, with results expected in June 2019. Estimates of the following outcomes will be reported: Incremental economic cost of the pour-flush toilet service over an unimproved pit latrine

- Incremental effect of the intervention on the SanQoL measure.
- Incremental cost-effectiveness ratio, namely US\$ per point increase in SanQoL.

Probabilistic sensitivity analysis using Monte Carlo simulation will be used to characterise uncertainty.

Conclusions: There are many possible applications of a SanQoL measure, if future work supports generalisability beyond this setting. The primary intended application is in allowing economic evaluations to measure and value the non-disease outcomes affected by sanitation interventions. This would help improve allocative efficiency within the sanitation sector. The measure could also be used to explore heterogeneity in valuation of SanQoL attributes in different settings, so as to improve the messaging of behaviour change and sanitation marketing programmes.

Title: Development and Reliability of a Novel Personal Hygiene Metric: Implications for Holistic WASH Program Evaluation

Maryann Delea, Emory University & The University of Pennsylvania, Jedidiah Snyder, Mulat Woreta, Kassahun Zewudie, Matthew Freeman

Background: Evidence suggests that inadequate personal hygiene, including poor facial and hand cleanliness, is associated with several infectious diseases, including some neglected tropical diseases. Current methods employed to assess personal hygiene are limited with regard to their granularity (qualitative, binary data), objectivity, and validity. These metrics may not be nuanced enough to detect incremental changes in personal hygiene behaviors, which limits assessments of dose-response relationships and the type of evidence available for evaluating the effectiveness of behavior change interventions on behavioral outcomes and downstream health impacts. The aim of this research study was to develop a novel objective metric that generates nuanced, quantitative data on facial and hand cleanliness and evaluate its inter-rater reliability. Methods: Using color theory principles, we created and tested a novel, standardized brown scale, which depicts a continuum of color along a specific RGB color model array. We used this scale to obtain quantitative measures of personal hygiene. Enumerators first obtained data on qualitative facial and hand cleanliness metrics (e.g., presence/absence of nasal and ocular discharge, dirt or debris under finger nails or on finger pads and palms of each hand, amongst others). Field supervisors collected data on a validation sample that reflected approximately 10% of observations from each study cluster. Enumerators then used our novel hygiene metric to collect non-blinded quantitative facial and hand cleanliness data. To obtain these quantitative data, enumerators used pre-moistened, sterile gauze pads to wipe the skin along the eyes and hands (separately) of index children, using a standardized method to do so. Enumerators then compared the color of the darkest point within the darkest half-inch of the gauze pad against our novel color scale to rate the cleanliness of the index child's face and hands. All cleanliness wipes were rated by one master rater blinded to the conditions of the child and household. A sub-set of wipes were assessed by two additional blinded raters. Computer-automated ratings were obtained, through the use of densitometry, on this sub-set as well. We compared inter-rater reliability between three sets of raters: 1) non-blinded raters (i.e., enumerators) and a master rater blinded to the conditions of the household and child children; 2) three blinded raters; and 3) blinded and computer raters (i.e., automated scoring via densitometry). Results: Inter-rater reliability between various rating pairs was high, and ranged from 0.90 (95% CI: 0.89, 0.91) to 0.99 (95% CI: 0.994, 0.996) for facial cleanliness, and 0.96 (95% CI: 0.82, 1.00) to 0.99 (95% CI: 0.989, 0.994) for hand cleanliness.

Conclusions: Our novel personal hygiene metric allows for objective and quantifiable assessments of personal hygiene. Therefore, this novel metric may serve as a better program monitoring indicator for the uptake of improved hygiene behaviors than existing metrics.

Title: Disinfection By-Product Formation in Drinking Water Systems Using a Unique Chlorine-Based Disinfection Agent, Trichloroisocyanuric Acid

Megan Lindmark, University of Iowa, Craig Just

Background: Disinfection by-products (DBPs), typically formed when chlorine-based disinfectants react with natural organic matter in source water, pose a significant long-term public health threat. However, in resource-constrained communities in developing countries, the threat of DBPs is largely ignored since the immediate risk of waterborne illness is high and the local capacity to dose chlorine with precision is low. Based on water chemistry, we hypothesize that trichloroisocyanuric acid (TCCA) will provide a more stable chlorine residual and a decreased DBP formation potential compared to a free chlorine only disinfection approach. If this hypothesis is true, for a variety of water chemistries and temperatures, TCCA would be a favored alternative to free chlorine only disinfection in developing countries. TCCA usage for drinking water disinfection is increasing, particularly in developing countries where it is often available as a high chlorine-content, stable tablet. For example, over 750 communities in rural Nicaragua, through partnerships with EOS International, are operating simple, in-line chlorinators that use TCCA to disinfect spring-fed community drinking water systems. Therefore, understanding the impact of different disinfection agent choices on DBP formation is critical for both short- and long-term public health in countries like Nicaragua.

Methods: To compare DBP formation between TCCA and calcium hypochlorite 250 ml reactors were dosed with disinfectants to reach a total chlorine concentration of 1, 5, or 10 mg/L. Reactors were run in triplicate resulting in 9 reactors for each disinfectant and 18 total reactors. Each reactor also contained 5mg/L Sewanee River natural organic matter to mimic natural source water. The pH in each reactor was maintained 7 through the addition of (WHAT KIND) buffer. Reactors was sampled after a contact time of 1-hour for trihalomethanes and haloacetic acids. Results: Only chloroform was detected of the trihalomethane DBP group, which was detected above the quantification limit but below the maximum contaminant limit in all 18 reactors. Chloroacetic acid, dichloroacetic acid, and trichloroacetic acid were also detected above the quantification limit but below the maximum contaminant limit in all 18 reactors. Because the same trihalomethanes and haloacetic acids were detected in all 18 samples, analyses were completed on total trihalomethanes and total haloacetic acids (the sum of the respective individual concentrations for each disinfection by product within each sample). On average, trihalomethane concentrations and haloacetic acid concentrations were lower at each total chlorine concentration for reactors dosed with TCCA when compared to those dosed with Calcium hypochlorite. Conclusion and Implications: Our results echo those generated by a similar study completed by the EPA; however, they also suggest there may be a more distinct difference in DBP formation between the two than previously suggested. Our results show that TCCA has the potential to form fewer DBPs than other more traditional chlorine-based disinfectants. However, more rigorous testing on a variety of source water chemistries will be required to validate that these results will hold true for many drinking water treatment scenarios.

Title: Disparities in Municipal Water Service Access Increase Risk of Elevated Blood Lead in Children

Jacqueline MacDonald Gibson, Indiana University, Allison Clonch, Mike Fisher, Phil Cook, John MacDonald

The water crisis in Flint, Michigan, raised awareness of potential racial disparities in exposure to lead in drinking water. This study examines the impact of disparities in access to treated municipal drinking water in peri-urban areas on children's blood lead levels. We hypothesized that lack of access to a regulated municipal water system in peri-urban areas increases the lead concentration in children's household drinking water and is thus associated with elevated childhood blood lead levels. To test this hypothesis, we built a curated database including blood lead measurements from 34,314 children in Wake County, North Carolina, collected between 2002 and 2017; household water source (private well or regulated community water system) for each child; demographic characteristics; and household and neighborhood attributes. We found that children in peri-urban areas lacking connections to nearby municipal water supplies had 35% ($p < 0.0001$) increased odds of detectable lead in their blood. In addition, they had 21% ($p < 0.05$) increased odds of having blood lead levels above the 5 $\mu\text{g}/\text{dL}$ threshold for elevated blood lead established by the U.S. Centers for Disease Control and Prevention. These findings support the need for interventions—potentially including connections to nearby community water systems—to mitigate the impacts associated with exposure to lead in drinking water in peri-urban areas relying on private wells.

Title: District-Wide WASH Coverage Surveys in Healthcare Facilities: A Roadmap to SDG6 in Four African Countries

Victoria Trinies, Centers for Disease Control and Prevention (CDC) Foundation, Hammad Ncho, Geoffrey Masyongo, Patrick Munywoki, Alice Ouma, Godfrey Bigogo

Background: The UN Secretary General recently noted that deficient WASH coverage in healthcare facilities (HCF) in low- and middle-income countries is a crisis requiring urgent action. WHO and UNICEF launched a global initiative to achieve full WASH coverage in HCFs by 2030 as part of SDG6. A recent assessment of WASH coverage in HCFs estimated that 50% lacked an improved water source on premises, 33% lacked improved sanitation on premises, and 39% lacked soap for handwashing. In 2018, to support a project aiming to achieve SDG6 in public sector HCFs, we conducted baseline assessments in HCFs in six largely rural districts in Mali (1), Uganda (1), Ghana (1), and Ethiopia (3) to develop meaningful indicators of WASH coverage, determine detailed coverage deficiencies, and guide partners toward successful WASH implementation. Methods: Between May and August 2018, we partnered with implementing organizations to assess a convenience sample of public HCFs that provide primary care, using a CDC-developed survey tool that included an interview with HCF management and comprehensive direct WASH observations. Indicators were derived from SDG Joint Monitoring Program (JMP) basic service levels, WHO's WASH FIT tool, and country-specific standards where applicable. Water samples collected from the main water source and up to two drinking water points were tested for total and free chlorine residual using a HACH colorimeter and Escherichia coli contamination using the Aquagenx compartment bag test. Results: We assessed 10 HCFs in Mali, 30 in Uganda, 25 in Ethiopia, and 7 in Ghana. Across these HCFs, median monthly outpatient visits ranged from 309 to 1,020. Across project countries, JMP basic service level for water (improved water source on premises) was met in 61% of HCFs (range: 44%-100%). However, 60% of source water samples and 27% of drinking water samples had detectable *E. coli*, and drinking water stations with water

were available in 4% of patient care areas (range: 2%-9%). No HCFs met JMP basic service levels for sanitation (improved, usable sanitation facilities, with at least one toilet dedicated for staff, one for menstrual hygiene management, and one for mobility-limited persons). However, at least one usable, improved toilet was accessible by patients in 61% of HCFs (range: 52%-100%). Only Mali (10%) had any healthcare facilities that met JMP basic service levels for hand hygiene (at least one functional handwashing station with soap and water within a randomly selected patient care area and within 5 meters of toilets). However, across districts within project countries, appropriate handwashing stations with soap and water were available at 26% of total patient care areas (range: 24%-49%). Conclusions: The percentage of these rural primary care HCFs that met JMP basic service levels was low. Our coverage data revealed important gaps in WASH service delivery in our target districts, such as water quality and coverage of handwashing stations across patient care areas, which the JMP framework does not capture. When developing a roadmap for achieving SDG 6, countries should conduct detailed assessments of WASH coverage to fully understand HCF WASH status and accurately prioritize areas of need.

Title: Do Toilets Keep Kids in School? Statistically Linking School Sanitation and Enrollment in LMIC

Leigh Hamlet, University of Washington, Jessica Kaminsky

It is generally held that providing sanitation facilities in schools enhances children's educational experiences, yet there is a deficit of quantitative evidence to support this claim. Given that girls lag behind in education and—particularly pubescent-age girls—bear the greatest burdens related to poor sanitation conditions, the school sanitation experience of boys remains largely unexplored. As such, we investigate the differential impact of sanitation infrastructure on educational participation of both boys and girls in primary and secondary schools within low-income settings. Toward this end, we employ country-level longitudinal data of low-income nations from the new Joint Monitoring Programme (JMP) WaSH-in-schools database and sixteen years (2000-2016) of World Bank enrollment data. We use a linear mixed model to associate school sanitation services and educational participation. Preliminary results suggest that the provision of facilities matters independent of gender and does not differentially impact the enrollment of primary and secondary female students. For older students, regardless of gender, the quality of a facility impacts participation more than simply the provision of a facility. To generate more reliable inferences from the limited dataset on school sanitation services in low-income countries, we will employ a multiple imputation approach and compare the results with those of the original model. We will also discuss the use of multiple imputation and our overall statistical approach for other WaSH service country-level datasets with high missingness. With this study, we hope to expand the discourse of school sanitation to consider not only pubescent-age females but all students, in accord with the aim of universal education. Further, we statistically corroborate the widely held belief that the mere construction of facilities is not enough to improve educational participation, which imports the need for high-quality global infrastructural standards for the achievement of school- and gender-related development goals. Overall, we provide one of the first analyses of the new JMP school sanitation dataset and begin to more quantitatively value and appraise the current global monitoring of school sanitation services.

Title: Drinking Water Quality and Source Selection in Central Appalachia

Hannah Patton, Virginia Tech Biological Systems Engineering Department, Dr. Leigh-Anne Krometis, Dr. Emily Sarver, Ethan Smith

Past research efforts have elucidated that there are rural residents of Central Appalachia that collect their drinking water from roadside “spout” springs, despite having access to in-home piped point-of-use (POU) water. These residents have cited perception, availability, and water quality concerns, among others, as their primary reason for visiting roadside springs, a behavior that can often entail hours of effort multiple times a week. This research effort builds upon an ongoing spring water quality monitoring study that observes that unprotected and unregulated roadside springs are frequently contaminated by fecal indicator bacteria such as *E. coli*. Through a household study, the present effort aims to directly compare spring and piped in-home POU water in order to: 1) describe any differences in potential waterborne exposure; and 2) further explore household motivations for spring water collection. Households were recruited from communities surrounding springs in three states (Kentucky, Virginia, West Virginia). Water samples were collected from both participating households and nearby frequented roadside springs and were analyzed for fecal indicator bacteria, metals, and nutrients. Although the sampling campaign is continuing through this spring, current results indicate that while most springs are contaminated by *E. coli*, household water samples have violated Safe Drinking Water Act (SDWA) standards for aluminum, iron, manganese, and in some cases, total coliform. Springs are not always necessarily of poorer water quality, as some homes dependent on municipal water were in violation of multiple SDWA standards. Present findings may reflect issues with aging premise plumbing or public infrastructure. In addition to providing water samples, participants completed a short survey to inventory their perceptions of their household drinking water specifically. The majority of participants indicated water palatability and/or perception (e.g. color, smell, and taste) as motivators for distrust in their in-home water source, as well as fears for their family's health. Household POU water quality and spring water quality varied in SDWA compliance within each community and at each participant's home. Interventions designed to minimize risk of infectious waterborne disease or metals exposure therefore would be most effective when devised on a house-by-house basis that addresses site-specific plumbing and water source issues.

Title: Drivers and Barriers Affecting Water Source Choice in Kibera, Kenya

Victoria Trinies, Centers for Disease Control and Prevention (CDC), Hammad Ncho, Geoffrey Masyongo, Patrick Munywoki, Alice Ouma, Godfrey Bigogo

Background: Kibera is a large, densely populated informal settlement in Nairobi, Kenya, with no formal access to municipal water systems. Residents typically buy water from private vendors who use unregulated networks of hoses and pipes connected to distant municipal supplies. These networks are often leaky and run through unsanitary environments. In 2016, Shining Hope for Communities (SHOFCO), a local non-governmental organization, introduced a novel system distributing filtered and chlorinated borehole well water to kiosks using aerial piping. As part of an evaluation of the safety, acceptability, and health impact of this system, we conducted focus group discussions to examine drivers and barriers affecting water

source choice in Kibera. Methods: We identified participants through the Population-based Infectious Disease Surveillance (PBIDS) platform in Kibera. We conducted four focus groups with residents reporting SHOFKO kiosks as their primary source of household drinking water and four with residents reporting other (non-SHOFKO) primary drinking water sources. Each group included 6-8 participants. Trained facilitators led the discussions using semi-structured guides that covered water usage practices, perception of water sources, and facilitators and challenges to water usage. Transcripts were translated to English and analyzed in MaxQDA 2018 using a priori codes developed from interview guides and refined using a grounded theory approach to identify themes within the data. Results: Participants in both groups used water from a variety of sources and reported similar drivers and barriers affecting water source choice. A key driver across both groups was water quality, including taste, cleanliness, and perceived safety. Participants felt that the piping for non-SHOFKO water was often inadequate and led to water being unsafe and visually dirty. Participants reported feeling that SHOFKO water was safer than other sources because it was treated with chlorine and the aerial distribution pipes prevented contamination; however, many said that SHOFKO water had a “salty” taste and preferred water from other sources for drinking. Another key driver for water source choice was convenience of access, including proximity, wait time, and operating hours. Proximity was the primary factor for some non-SHOFKO users in their choice of water supply, as they had only one (non-SHOFKO) vendor near their homes. Maintenance of tanks and cleanliness of the environment around the water kiosks was also important to participants, as was good customer service including attendant friendliness, credit arrangements, and benefits such as onsite laundry space or free water giveaways. One difference between the groups was that SHOFKO users frequently chose SHOFKO water because it was less expensive than other options. However, due to the perceived salty taste, many participants in the SHOFKO users group reported using SHOFKO water primarily for cleaning. Conclusions: Kibera residents are motivated to select their water supply by many factors including water quality, convenience, price, and kiosk attributes. In some cases, drivers such as taste or accessibility may influence people to purchase drinking water from sources that are at greater risk of microbiological contamination. Understanding the range of drivers in this context is important to optimize the health impact of clean water interventions.

Title: *E. coli* in Soil, Food, Hand, Water, and Surfaces Samples in the Democratic Republic of Congo

Patrick Mirindi, Johns Hopkins University, Christine Marie George

Background: In low income countries, gastrointestinal disease is responsible for 500,000 deaths of children under 5 years annually. While drinking water and poor sanitation constitutes a major source of fecal contamination and diarrheal disease in resource-limited contexts, large scale WASH intervention trials that included water treatment and improved sanitation did not show expected improvements in child health. This has highlighted the need to identify unique exposure pathways to fecal pathogen for pediatric populations. The objective of our study was to investigate potential fecal exposure pathways for children under five years living in Walungu Territory, in South Kivu, Democratic Republic of Congo. These findings are being used to develop evidence-based interventions for this population. Methods: A total of 649 soil, food, hand, water, and surface samples were collected from households with a child under 5 years of age in an ongoing prospective cohort study. Soil samples were collected from spaces where children were observed playing and surface samples were collected of objects children were observed putting in their mouth. Hand rinse samples were collected from children under 5 years of age and their household members. Food given to children under 5 years of age in the home was also collected. All samples were analyzed using the IDEXX Quanti-Tray System (Colilert-18 media; IDEXX Laboratories, Inc., Westbrook, ME) to enumerate *Escherichia coli* using the most probable number (MPN) method. Results: Seventy eight percent of soil samples had detectable *E. coli* (118/152), with a geometric mean of 210 *E. coli*/per gram dry weight. Thirty five percent of surface samples had detectable *E. coli* (22/62). A bottle or jar was the most commonly contaminated item children were observed putting in their mouths. Forty eight percent of food samples had detectable *E. coli* (16/33), with a geometric mean of 156 *E. coli*/per gram of dry food. Meat, sweet potatoes, and beans were the mostly commonly contaminated food items. Sixty four percent of children under 5 years had detectable *E. coli* (96/150) on their hands, compared to 57% (45/79) of individuals 5 years of age or older. Seventy two percent of stored water samples (67/93) had detectable *E. coli* with a geometric mean of 210 *E. coli*/per 100 ml. Source water had lower contamination with 39% (31/80) having detectable *E. coli* with a geometric mean of 16 *E. coli*/per 100 mL. Conclusion: These results highlight the need for WASH interventions to reduce child contact with contaminated surfaces, improved food hygiene, and promotion of handwashing with soap. Furthermore stored water drinking water appears to be a major source of fecal contamination in the household that should be targeted through water treatment interventions. Funding: This study was funded by the USAID Food for Peace Office.

Title: Effect of an mHealth Intervention with no Interpersonal or Material Components on Handwashing with Soap

Anila Gopal, Unilever, James B. Tidwell, Esha Sheth, Arathi Unni, Myriam Sidibe

Poor handwashing behavior is a major cause of morbidity and mortality globally, but many handwashing promotion interventions have failed to change behavior, with a lack of contact frequency often a challenge. On the other hand, the few successful programs have often been expensive and difficult to scale. Mobile phone-based interventions have the possibility of being scalable and reaching large sections of the population, with more than 800 million regular mobile phone users in India alone, particularly when done based on sustainable funding sources. We evaluated a branded mobile phone-based intervention targeting mothers to increase the frequency of handwashing with soap, which provided no materials to participants and no in-person education or other intervention components, the first evaluation of such a program of which we are aware. New mothers (n=598) and mothers of 4-7 year old children (n=501) were randomly allocated to the treatment or control arm. Mothers in the treatment arm received mobile phone messages twice a week for 8 weeks (mothers who recently gave birth, or “new mothers”) or 4 weeks (mothers of 4-7 year-olds). Messages were creatively rendered through stories involving a fictionalized local doctor who represented an authority figure and was well versed in local health beliefs. Messages were about 90 seconds long and included a jingle to identify and brand the campaign, a dialogue between the doctor and a mother, and then a summary and sign off directed back to the caller. The overall tone of the campaign was one of a warm, caring doctor communicating informative and encouraging messages to link the target behaviors to a mother’s desire to nurture her child. Messages to general mothers were about hygiene topics, while messages to new mothers included more general maternal health messages as well. All participants were surveyed two weeks after the end of the program using sticker diaries to mask the intent of the self-reported measure. Differences in the rates of

handwashing with soap on key occasions were calculated by comparing treatment versus control using log binomial regressions. New mothers in the control were slightly more likely to wash their hands with soap on key occasions (49.6%) than general mothers (46.7%). New mothers (adj-RR: 1.04, $p=0.035$) and general mothers (RR: 1.07, $p=0.007$) receiving the intervention were more likely to wash their hands with soap on key occasions than those in the control group. These interventions were associated with significantly greater handwashing with soap. Though the magnitude of the intervention effects was small, the potential reach and low cost have major implications for handwashing behavior change at scale and for the feasibility of branded messaging to have a large public health impact.

Title: Effectiveness of SMS Messaging for Diarrhoea Measurement: A Factorial Cross-Over Randomised Controlled Trial

Ryan Rego, The University of Warwick, Samuel Watson, Philbert Ishengoma, Philemon Langat, Pireh Otieno, Richard Lilford

Despite the importance of generating information on diarrhoea epidemiology in developing contexts, collecting data on diarrhoea epidemiology has proven difficult in such settings. The standard method of estimating diarrhoea epidemiology is to ask carers if a child has had diarrhoea over some pre-determined period, typically ranging from 24 hours to 30 days – with the most common being two weeks. These data are routinely collected through in-person surveys, a costly and time-consuming process that is particularly challenging when done at large scale. A significant need for cost-effective diarrhoea measurement at a large scale exists in the Lake Victoria region of Eastern Africa – where the Lake Victoria Water and Sanitation Project (LVWATSAN) has worked for over a decade on improving water and sanitation infrastructure, and the management of Lake Victoria. In settings like this and across developing contexts, mobile phone ownership is commonplace (at 75% among adults in Tanzania) – and may thusly represent a cost-effective tool for infant diarrhoea surveillance, a method which has been successfully used in the measurement of other diseases. This study aims to pilot the use of SMS text message surveys for diarrhoea measurement in the evaluation of the LVWATSAN project in Mwanza, Tanzania. The study is an individual-level factorial cross-over randomised controlled trial of SMS surveys for measuring diarrhoea among under five slum-dwellers in Mwanza, Tanzania. The trial is evaluating the following survey conditions: (1) daily recall for two weeks versus one-off two-week recall, (2) a multi-level questionnaire compared to a single response questionnaire, and (3) the provision of an incentive to survey participation in addition to reimbursement. We will randomly select households with weaned children under five from community lists provided by community leaders, and recruit and enrol 150 consenting households. The households will be randomised into one of eight treatment groups, with each group crossing-over between all combinations of the three treatments in a random differing order. Additionally, semi-structured interviews will take place to determine attitudes towards the new measurement strategy. Quantitative data will be analysed using mixed-effects modelling methods - taking into account time, treatment statuses, interactions between treatment statuses, and individual-level effects. Bivariate and univariate analyses will also be conducted. Qualitative data will be coded, analysed, and reported through summary text and select quotes. The primary outcome of this study is the response rates relative to each intervention. Secondary outcomes are as follow: 1) examining how response rates vary over time; and 2) determining feasibility and attitudes towards mobile phones for surveying. Results from this study will primarily be used to inform future monitoring and evaluation and programming work on WASH in slums, as well as informing future studies – particularly a full-scale study on the LVWATSAN project. Data collection for this study has begun in April 2019, concluding in July 2019.

Title: Effectiveness of Sundara Grama, A Behavior Change Intervention to Increase Latrine Use in Rural India

Bethany Caruso, Hubert Department of Global Health, Emory University, Gloria Sclar, Parimita Routray, Corey Nagel, Fiona Majorin, Thomas Clasen

Background: Sustainable Development target 6.2 aims to end open defecation by 2030. In India, where 60% of those practicing open defecation reside, the government claims to have built over 92.5 million household latrines under the Swachh Bharat Mission (SBM). Yet, numerous studies demonstrate that latrine ownership does not equate to use. To increase latrine use in rural Odisha, India, we developed a low-cost behaviour change intervention, known as Sundara Grama (“Beautiful Village”), based on formative research and behavioral theory, and subsequently evaluated the intervention’s effectiveness. This presentation will share details of the Sundara Grama intervention, the impact evaluation design, and findings from the impact and process evaluation. Methods: We conducted a cluster randomized controlled trial (CRT) in 66 villages (33 intervention, 33 control) in rural Odisha, India. The primary outcomes were reported latrine use and safe disposal of child feces, assessed among all latrine-owning households in each village. Secondary outcomes of interest included behavioral drivers of latrine use and child feces disposal. A process evaluation of all intervention activities was conducted in all 33 treatment villages to determine if the intervention was delivered as designed and reached the intended target populations. Qualitative research was conducted in six non-trial villages shortly after intervention implementation to assess community perceptions of the intervention and spillover in non-treatment villages, and again post-endline to gain insights about the intervention’s influence on behavior. Findings: Latrine use data from 13,406 individuals over age 5 was collected at both baseline and endline (Intervention: 6,544, Control: 6,862). Our intention to treat (ITT) analysis revealed an increase in reported latrine use among individuals age 5 and older of 6.4% (95% CI 2.0%-10.7%, $p=0.004$) in the intervention group at endline after accounting for the increase in latrine use observed in the control group. Child feces disposal data from 406 children under age 5 was collected at both baseline and endline (Intervention: 199, Control: 207). Our ITT analysis revealed an increase in reported safe disposal of child faeces of 20.4% (95% CI 11.7%-29.2%, $p<0.001$) in the intervention group at endline after accounting for the increase in safe disposal of child faeces observed in the control group. The process evaluation revealed that the intervention activities were delivered with high fidelity overall, but future iterations of Sundara Grama should modify activities to better reach women. Conclusions: The Sundara Grama intervention succeeded in changing latrine use and safe child feces disposal behaviour in the intervention villages compared to the controls. The in-depth process evaluation and integrated qualitative research were critical to the evaluation, specifically highlighting opportunities for improving the intervention and lessons for like interventions in the future. The Government of India has yet to prioritize efforts around safe child feces disposal; our findings demonstrate that this behaviour is changeable and should be a priority in the post-SBM era and in other future sanitation and health campaigns.

Title: Effectiveness of the Three Water Trucking Interventions in Humanitarian Emergencies

Mustafa Sikder, Tufts University, Gabrielle String, Daniele Lantagne

Background: In 2017-2018, nearly 730,000 Myanmar refugees arrived in Cox's Bazar, Bangladesh and settled in 27 camps. The Government of Bangladesh and humanitarian responders are supporting the camps by supplying safe water. Chlorination at the source was adopted by multiple responders, and different implementation models were used depending on source water quality and available water treatment technology. The aim of this research is to evaluate the effectiveness of three different water chlorination interventions in Cox's Bazar. Methods: We applied a mixed-methods protocol for the evaluations, including chlorination point structured observations; key informant interviews (KII); household surveys; focus group discussions (FG); and, water quality sampling. We used water quality and reported acceptability to evaluate the programs. We will apply appropriate statistical tests to compare the results among evaluations and study associations between water quality and other variables. Results: We have completed evaluations of a bucket chlorination intervention (August 2018) and an in-line chlorination intervention (December 2018). We will evaluate a centrally chlorinated piped network system in April 2019. In the bucket chlorination intervention, responders trained and equipped chlorination agents to prepare and dose chlorine solution into beneficiaries' containers after collection of water from ringwells. We observed nine chlorination points, conducted 10 KIIs, and led four FGs; enumerators surveyed 148 households. Chlorine concentration in the stock solutions varied 0.07-0.34%. Stratified by chlorination point, the mean household free chlorine residual (FCR) 30 minutes post-treatment varied 0.1-0.5 mg/L, with 28% of households having no detectable FCR. Furthermore, 73% of households had <10 *E. coli*/CFU/100mL. Most beneficiaries believed the chlorination intervention made water safe (85%). Overall, the program treated poor quality source water at no cost to users. Recommendations included increasing the concentration of stock solution to meet the minimum standard (1%), providing protective equipment to the staff, using opaque bottles to store chlorine, and to prepare solution regularly. In the in-line chlorination intervention, responders installed automated chlorination devices at handpump spouts in two camps. We observed nine in-line chlorination points, conducted two KIIs, and led two FGs; enumerators surveyed 180 households. At the chlorination points, FCR varied <0.05 -3.78 mg/L and *E. coli* were 2-14 CFU/100mL (median <5). Stratified by chlorination point, the mean household FCR 30 minutes post-treatment varied 0.0-0.4 mg/L, with 63% of households having no detectable FCR. However, 91% of households had <10 *E. coli*/CFU/100mL. Many users believed the chlorination made the water safe (62%). While the program successfully treated water, the in-line chlorination devices were not adjustable to varying chlorine demand. Key recommendations were to replace the devices with adjustable ones and regularly monitor household water quality to determine chlorine dosage. Conclusions: Despite varying modalities, both interventions generally reduced the *E. coli* to <10 CFU/100ml and had high acceptance rates, but struggled to maintain FCR >0.2 mg/L. While the objective of the interventions was to provide safe water to the refugees, the chlorination interventions required different technological, programmatic, and user sensitization preparations. Comparisons of the interventions will help responders make informed decisions in selecting appropriate technology for the camps.

Title: Efficacy of Jerrycan Disinfection Methods

Marta Domini, Tufts University, Gabrielle String, Hanaa Badr, Anthonia Ogudipe, Marlene Wolfe, Daniele Lantagne

Jerrycans are commonly distributed in humanitarian emergencies for safe water storage; they have small openings to help prevent recontamination of water and are typically made of high density polyethylene. Jerrycans can act as a microbial reservoir for pathogens: a biofilm can form on interior surfaces and shed microorganisms which may lead to recontamination of drinking water and deterioration of disinfectant residual. Jerrycan recipients report using rocks/sand, bleaching powder, and/or other local materials to clean jerrycans via shaking. The impact of local cleaning techniques on the development of biofilms in jerrycans had not previously been studied in large-scale. In the laboratory, 72 jerrycans (5 L) containing *Escherichia coli* spiked water were kept at 35°C for 3 months. Jerrycans were stratified by: treated/not treated with regular Aquatabs addition; 5 or 50 NTU turbidity water; and, six cleaning methods: 0.5% NaOCl; pebbles; sand; 0.5% NaOCl and pebbles; 0.5% NaOCl and sand; and, none. Each combination (e.g. "Aquatabs-treated/50 NTU/pebbles") was tested in triplicate. Jerrycans were cleaned and filled with new *E. coli* spiked water every day (Month 1), every other day (Month 2), and once a week (Month 3). Every day, FCR was measured at 1, 4, and 22 hours after water addition. Every week, *E. coli* in water was measured via membrane filtration. Every month, one jerry can per combination was destructed, and 2 cm² coupon samples were cut from the bottom and middle surfaces. After cutting, culturable *E. coli* were enumerated and biofilms were imaged by epifluorescence microscopy. We found FCR <0.1 mg/L in all jerrycans not treated with Aquatabs, even when cleaned with NaOCl. Non-Aquatab-treated jerrycans averaged >105 CFU/100mL *E. coli*; with higher concentrations at 22 hours and in 50 NTU containers, regardless of cleaning method. The average FCR decayed from month 1 to 3 in both 5 NTU (1.18 to 0.55 mg/L) and 50 NTU (0.38 to 0.07 mg/L) in Aquatabs treated jerrycans. *E. coli* results in containers treated with Aquatabs averaged <103 CFU/100ml, with concentrations under the detectable limit after 22 hours and in 5 NTU containers. We found *E. coli* biofilms were not present in: all 5 NTU Aquatabs-treated jerrycans; most 50 NTU Aquatabs-treated jerrycans, most 5 NTU no-Aquatabs jerrycans cleaned with "NaOCl" or "NaOCl and sand/pebbles", and most 50 NTU no-Aquatabs jerrycans cleaned with "NaOCl and sand/pebbles." This is consistent with *E. coli* coupon enumeration, which found the highest concentration of *E. coli* and the greatest biofilm structure density in untreated jerrycans cleaned with pebbles only and sand only, and in controls. Please note biofilm structure density increased from Month 1-3 in these samples. Bottom surfaces of untreated jerrycans typically had the most *E. coli* across all months. We found biofilms developed rapidly in jerrycans without regular Aquatabs treatment; chlorine combined with abrasives inhibited biofilm development across all test combinations; and, bottom surfaces were the most challenging to clean. We propose best practices for household cleaning of jerrycans based on these results.

Title: Environmental Monitoring of Antibiotic Resistant Bacteria with Long-Read Sequencing in Boston and India

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The spread of antimicrobial resistance (AMR) is a critical threat to human health. AMR infections are more prone to treatment failure, which in turn increases mortality rates and healthcare costs. Risk of exposure to AMR bacteria may be increased in settings with inadequate water and sanitation infrastructure. However, variation in the prevalence and concentration of AMR bacteria in environmental reservoirs is not well understood, in part because there are limited standardized techniques for environmental monitoring of antimicrobial resistant bacteria. We used the Nanopore MinION, Illumina HiSeq, and qPCR to identify AMRG and MGEs in wastewater, river water, and hospital effluent samples from Boston, USA and Vellore, India. Our primary objectives were: 1) to compare the performance of the MinION to qPCR and HiSeq at detecting AMRGs and enteric pathogens; and 2) to compare the prevalence and diversity of AMRGs, MGEs, and their microbial hosts across locations. Six samples were collected from the greater Boston area (n=1 hospital effluent; n=3 wastewater; n=2 river) and the city of Vellore (n=1 hospital effluent; n=2 wastewater; n=3 river). DNA was extracted and analyzed by the MinION (1D ligation), HiSeq (PE150), a qPCR AMR Array Card (87 targets), and a qPCR TAC Pathogen Array Card (33 targets). Outputs were compared across devices and across locations. Our findings suggest that metagenomic MinION and HiSeq results were similar in estimating microbial and AMR gene (AMRG) abundances and suggested increased diversity in Vellore versus Boston. Concordance between the MinION and qPCR detecting the same AMRG and enteric pathogen gene targets was 68% and 64%, respectively. Leveraging the long-read data, results from the MinION identified that across all samples 45% of AMRGs (45% in Boston, 44% in Vellore) were on chromosomes and 33% of AMRGs (31% in Boston, 35% in Vellore) were on plasmids (22% were unknown). While AMRG profiles among chromosomes were similar to plasmids, there were exceptions. For example, in Boston river samples, 90% of sulphonamide AMRGs were found on plasmids. Further investigation of chromosome-based AMRGs suggested significant differences in microbial hosts across geographic locations (AR Enterobacteriaceae dominated Vellore while AR Moraxellaceae dominated Boston). Among DNA reads classified as *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* spp., the ratio of AMR reads to total reads in a given taxon was highest in Vellore versus Boston, and highest in the hospital effluent versus other sample locations in both field sites. Finally, further assessment of AR *K. pneumoniae* and AR *E. coli* suggested MGE presence (related to horizontal gene transfer) was highest in wastewater, followed by hospitals, then rivers. This study demonstrated MinION outputs were similar to HiSeq but struggled with specific qPCR targets. Additionally, there was a higher diversity of AMRGs in Vellore compared to Boston, and that AMR genes were more likely to be identified on plasmids in Vellore than in Boston. The data also suggest AMRG profiles can be similar between chromosomes and plasmids. Lastly, chromosome-based AMRGs were most prevalent in hospital effluent while AMRG-related MGEs were most prevalent in wastewater.

Title: Equity in Water Safety Planning in Nepal

Giri Khatri, IHE Delft. Giuliana Ferrero

Sustainable Development Goal (SDG) 6, target 6.1, focuses on achieving equitable and universal access to safe drinking water by 2030. Water Safety Plans (WSPs) represent a comprehensive risk assessment and risk management approach that encompass all steps in water supply from catchment to consumers, with the goal of ensuring safe drinking-water. WSP implementation can contribute to equitable outcomes of safe drinking water delivered to consumers, irrespective of their gender or socio-economic status. This study explored how equity is incorporated in the WSP process from its inception to continuous implementation, highlighting the procedural aspects, equity impacts and application of monitoring tools and indicators. The methodology used is qualitative case study approach. The study was performed in four selected water supply schemes in Kavre, Tanahaun and Kaski districts of Nepal. In two of the systems, the equity component was explicitly integrated in WSPs during pilot training projects led by the WHO and the Department of Water Supply and Sewerage (DWSS) under Ministry of Water Supply and Sanitation. In two of the systems, the equity component was not explicitly included. Empirical data was collected through documents review, semi-structured interviews with key stakeholders (e.g., facilitators, water users committees, and users), focus group discussions and field observations. From the analysis it emerged that the degree of representation and participation of women and other marginalized groups in WSP teams varies in different locations. In one of the case study locations, women and marginalized groups as well as health workers and school teachers are well represented in the WSP team. Whereas in another water supply scheme, where equity was explicitly considered while selecting the WSP team members, the representation of marginalized and low caste groups can be considered fictitious, since those representatives do not have any power in decision-making. The Nepalese national policies of having women and marginalized communities represented in committees and included in capacity development training had a certain influence on inclusiveness in water safety planning, however, does not guarantee the decision-making power. Yet, with regard to monitoring, the tools and indicators designed to assess equity in WSPs are not generally used, due to their complexity and lack of accountability mechanisms. The participation of women and disadvantaged groups in water users committees can positively influence the outcomes of WSPs. However, in a deeply unequal society the power of representatives from these groups in decision-making is still limited. Regular follow-up and monitoring after capacity development training of water users committees and WSP teams is critical. The newly established local governments are main bodies to oversee rural water supply services and may be the preferred option for supporting and monitoring equity in WSP implementation. Finally, it is recommended to simplify monitoring tools and indicators in collaboration with local WSP teams and water users committees.

Title: Estimating Economic Benefits of Market-Based Sanitation Programs: Design and Application of a Novel Model

Geoff Revell, WaterSHED, Bart Robertson

Background. WaterSHED implemented the Hands-Off sanitation marketing program (2011-2017) in rural Cambodia. The program supports small businesses to produce low cost, improved latrines by providing technical skills training and business professionalization training. The model was developed to compare the market of interest (MOI) between a 'program scenario' and a theoretical scenario in which the program does not exist (DNE scenario). In this case, the model is applied to compare costs and benefits of the Hands-Off program to a DNE scenario. Methodology: The

MOI is defined by three dimensions: the product/service (latrines), target market, and time period. The total market value (TMV) is the product of the quantity of latrines sold and their market price (including retail mark-up, sales commission, shipping, installation). Total sanitation benefit (TSB) is economic impact due to labor productivity gains and time savings as a result of owning or having access to a latrine. TMV is equal to the total cost to the economy to produce latrines, while the TSB is the total benefit generated by latrines. The ratio TMV:TSB can be thought of as the MOI's efficiency ratio or how efficiently it converts inputs into outputs. The market's value added to the economy can be calculated by subtracting TMV from TSB. Data sources for the DNE scenario included costing, coverage, and health surveys completed prior to the start of the Hands-Off program; data are adjusted for inflation over the program period. Results: In the program scenario, latrine sales more than doubled, costs to consumers were 53% lower, and TMV increased by \$8.6 million. Under the program, there was an additional \$1.9 million in profits to latrine producers and \$2.9 million in wages to the labor they hire. In the DNE scenario, every dollar a household invests in a latrine would contribute \$1.65 to the economy due to improved health outcomes and time savings. In the program scenario, every dollar a household invests contributed \$3.03 to the economy. Finally, in the DNE scenario, the MOI would have contributed \$50 million to Cambodia's economy over a seven-year period. Under the Hands-Off program, the MOI contributed \$166.4 million over the same period. Discussion: By comparing these two scenarios the model elucidates how the program has transformed the MOI and how this impacts the wider economy. The program led to 'lean' market growth whereby the increase in TMV was driven by increases in sales, while the market price per unit decreased. The model was also used to compare the Hands-Off program with a subsidy-based sanitation program; the results strongly favor the Hands-Off program and demonstrate the model's utility for decision-making across multiple program approaches.

Title: Estimating the Burden of Waterborne Disease in the United States

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Background: The routine treatment of drinking water is one of the greatest US public health achievements of the twentieth century and provides a safe, reliable water supply. Treated water is used in many complex ways that can affect disease transmission. Waterborne disease and outbreaks continue to occur in the United States and are associated with a variety of water sources (drinking, recreational, environmental) and exposure routes (ingestion, contact, inhalation). We have recently completed an estimate of the burden of waterborne disease in the United States, measured through numbers of illnesses, emergency department (ED) visits, hospitalizations, deaths, and associated costs, which will direct prevention activities and set public health goals. Methods: We chose 17 waterborne diseases for which surveillance data, billing data, or literature estimates indicated domestic waterborne transmission was plausible, substantial burden of illness or death was likely, and data were available. Where possible, we classified diseases as primarily enteric (campylobacteriosis, cryptosporidiosis, giardiasis, norovirus infection, salmonellosis, and shigellosis) or primarily respiratory (Legionnaires' disease, nontuberculous mycobacteria [NTM] infection, and *Pseudomonas pneumonia*). Adapting previously developed methods, we used a series of disease-specific multipliers to adjust the reported/documented number of cases of each disease for under-reporting, under-diagnosis, proportion domestically acquired, and proportion transmitted via water to generate point estimates with 95% credible intervals (CrI). Sources for multipliers included surveillance data, population studies, and expert judgment when no other data were available. We estimated the number of illnesses, ED visits, hospitalizations, and deaths, and the costs of ED visits and hospitalizations due to waterborne disease transmitted in the United States in 2014. Results: An estimated 7.2 million waterborne illnesses (CrI 3.9–12.0 million) from the selected diseases occur annually, including 600,000 (CrI 365,000–865,000) ED visits, 120,000 (CrI 85,000–150,000) hospitalizations, and 6,500 deaths (CrI 4,300–8,900) deaths, incurring US\$3.2 billion (2014 dollars) in direct healthcare costs. Otitis externa and norovirus infection were the most common illnesses. Hospitalizations and deaths were predominantly caused by environmental pathogens that are commonly associated with biofilm in plumbing systems (NTM, *Pseudomonas*, *Legionella*) costing US\$2 billion annually. Conclusions: Millions of domestically-acquired waterborne illnesses from these 17 infections occur in the United States each year, and incur billions of dollars in healthcare costs. This analysis highlights the roles of enteric and environmental pathogens in waterborne disease in the United States.

Title: Evidence Based Planning for Effective FSM in Two Town Panchayats in Tamil Nadu, India

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Emerging evidence in India and elsewhere indicates a high incidence of wide variation in design and construction of on-site systems (OSS), and mis-reporting of these types – this has implications for the entire sanitation chain. The objectives of this study was to understand the types of OSS (including dimensions, materials, porosity, access) and de-sludging practices in two small towns in India with a view for better planning (develop containment improvement plan, establish de-sludging frequency and estimate Fecal Sludge (FS) (treatment capacity requirement) and implementation.

Methodology and Findings: IIHS is working with the Government of Tamil Nadu to implement full chain of fecal sludge management in, Periyanaickenpalayam (PNP) and Narasimhanaickenpalayam (NNP) Town Panchayats in Tamil Nadu, India, with a population of 25,930 and 17,858 respectively (Census India, 2011). A census survey of households and establishment along with spatial mapping was conducted in the year 2017. The survey revealed both wide variations in design and constructions practices for OSS, as well a high likelihood of variations. In response to a question on type of OSS, around 91% of households in PNP and 76% in NNP reported that their toilets were connected to septic tanks. However, a series of discrete questions were also asked regarding material/ porosity of base and walls, and presence of baffle walls. Analysis of these discrete questions revealed that a mere 1% of households were found to have septic tanks built according to standards. None of the septic tanks were connected to a soak-away. In comparison, Census of India (which is widely used as basis for FSM planning) reports that 68% of households were connected to septic tanks. These on-site systems function either as single pits or holding tanks. The estimated average volume of these containment structures was 17m³ in both locations (these are being triangulated through interviews with masons as well as observations). Consistent with the large containment structures, de-sludging practice was reported to be low in both the towns. Only 6% of the households reported de-sludging their

containments ever, and a quarter reported emptying only once. Accessibility to the containment structures were observed to be poor. Less than one-third of the OSS (29%) were accessible through a manhole or a pipe with cover. For the rest, the slab had to be broken for de-sludging. Based on findings, an appropriate containment improvement plan, appropriate de-sludging (scheduled for holding tanks, and demand based for pits) and treatment facilities are being designed. Wider Implications for Research and Practice: Current Fecal Sludge Management interventions are based on the assumptions that on-site systems are built according to specifications. This could lead to various planning and implementation errors like wrong estimation of de-sludging frequencies and/ or over-designing treatment facilities. Further, non-standard design affects environmental safety e.g. septic tanks are often recommended for dense settlements- but these are not built properly, then risk of water contamination increases. Also, this has implications on what is counted as 'safely managed' for SDG 6. The study illustrates a need for more and robust evidence for this issue as well as need to consider this in planning and implementation.

Title: Faces, Fingers, Fomites & Flies: What do we Know about Human Behaviour and Trachoma Transmission?

Katie Greenland, London School of Hygiene & Tropical Medicine (LSHTM), Alexandra Czerniewska, Anna Last, Allie Robinson, Aalbertus Versteeg, Matthew Burton

Trachoma is the commonest infectious cause of blindness globally, affecting some of the world's poorest communities. Trachoma is caused by repeated ocular infection with the bacterium *Chlamydia trachomatis* (Ct). Trachoma control requires implementation of the WHO-endorsed SAFE strategy: Surgery for trichiasis; Antibiotics to treat infection; Facial cleanliness and Environmental hygiene to reduce transmission. Although SAFE has been successful in reducing disease burden in many areas of the world, there is evidence that for hyperendemic regions, particularly in Ethiopia, implementation of SAFE does not have the anticipated impact on infection and disease. F&E measures aim to suppress Ct transmission, but it is unknown which, if any, of these measures are effective under programmatic conditions. This is largely because our understanding of Ct transmission within endemic communities is limited, which makes it hard to focus F&E interventions. The Stronger-SAFE project aims to improve understanding of Ct transmission and subsequently develop and test an evidence-based intervention package to interrupt transmission. We first sought to investigate the relative importance of potential transmission routes of Ct and explore behavioural and environmental determinants of transmission. Data were collected in rural areas of Shashemene Woreda in the West Arsi Zone of Oromia, Ethiopia in 2018. We surveyed 250 households, collecting 5804 ocular and non-ocular swabs, capturing flies and recording data on potential risk factors. Ct was recovered from 29 of 785 non-ocular swabs collected from faces (n=13), hands (n=5), clothing (n=10) and bed linen (n=1). Ct was not found on any household objects, or any swabs from ocular-negative households. Overall, 11.2% of 303 flies were Ct-positive. We observed nine households with at least one child aged 1-9 with clinical signs of trachoma for 27-hour periods at three times of year, recording all water use and hygiene practices. Both actual and perceived household-level water availability varied by season. Hand and face washing were uncommon in any season and soap use was infrequent. Only one in three surveyed households had soap and just 27 (11.3%) reported that their children use soap for face washing. Finally, we enrolled 83 children aged 1-9 into a small microbiological study into the effectiveness of face washing practices for removal of Ct. Face washing with soap was found to be more effective at removing ocular discharge than face washing with water only (post-wash prevalence of ocular discharge = 11.1% vs 73.3%, p=0.003). Our finding that the skin of the face and hands are the non-ocular locations most frequently positive for Ct supports the notion that the skin plays a key role in Ct transmission. Coupled with the observed infrequency of face washing and demonstrated importance of soap in removing ocular discharge, it is appropriate to focus our intervention on reducing the load of Ct on the faces (and hands) of people in closest contact with children aged 1-9 who harbour the greatest burden of infection. Fly control may also prove to be important and is also prioritised during intervention development.

Title: Facilitators and Barriers to Sustained WASH Behaviors for Household Members of Diarrhea Patients (CHoBI7 Program)

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Background: In Bangladesh, diarrhea is a top reason for seeking hospital-based care. Access to a safe domestic water source and handwashing with soap are demonstrated to reduce the burden of diarrheal disease, however, sustained behavior change is important to ensure the success of these interventions. The Cholera Hospital-Based Intervention for 7 days (CHoBI7) is a water treatment and handwashing with soap intervention that leverages the time patients and caregivers spend in the health facility for WASH intervention delivery. The intervention package, delivered at the patient's bedside, includes a pictorial module on diarrhea transmission, a handwashing station (covered bucket with tap), soapy water bottle, covered drinking water vessel with tap, and chlorine tablets for water treatment. In a previous RCT, CHoBI7 significantly increased WASH behaviors that were sustained to our 12-month follow-up visits among cholera patient households. In our most recent RCT of a scalable design of CHoBI7, the intervention significantly reduced pediatric diarrhea in diarrhea patient households. Methods: We conducted in-depth interviews with intervention households 7-12 months post-enrollment to identify facilitators and barriers, preferences, and experiences with CHoBI7-promoted hardware and behavioral recommendations. We purposefully selected households no longer using CHoBI7 hardware and households still using either a soapy water bottle, handwashing station, or drinking water vessel in order to better understand factors that may contribute to sustained use of CHoBI7 hardware. Systematic debriefing was conducted after each interview and findings were summarized thematically for each intervention component. Findings: Households not using a soapy water bottle reported that keeping young children from playing with and spilling the soapy water was a key barrier to continued use. Some households stored the soapy water at an elevated height in order to overcome this barrier, while other households switched to bar or liquid soap. Unrestricted access to a gas supply and existing habits facilitated boiling drinking water, while a limited gas supply, concern for injury, and perceiving source water as safe were reasons for not boiling water as recommended. One facilitator for continued use of the handwashing station was dislike of the household's prior handwashing system (e.g. communal water pump). In households no longer using the handwashing station or drinking water vessel, some households had shifted homes and had left their hardware with other family members. Other reasons for not using hardware included young children spilling water from the buckets, limited space in the household, or not being able to replace

lost or broken hardware. Additional behavior change communication was provided to households based on interview findings (e.g. recommending households elevate the soapy water bottle out of reach of children). Conclusions: Interviews with intervention households identified facilitators and barriers to sustained use of hardware and behavioral recommendations, highlighting opportunities to provide additional support to enrolled households. Interventions seeking to achieve long-term WASH behavior change should consider providing households with support during disrupting events (e.g. moving) and with developing child-friendly modifications to intervention components, and with guidance on navigating market availability of promoted technology.

Title: Fecal Contamination of the Environment and Child Health: A Systematic Review and Meta-Analysis Using Individual Participant Data
Frederick Goddard, Emory University, Amy J Pickering, Ayse Ercumen, Joe Brown, Howard H Chang, Thomas F Clasen

Background: Water, sanitation and hygiene (WaSH) interventions have historically sought to improve child health by interrupting fecal-oral transmission of enteric pathogens. However, recently published evaluations of large WaSH trials have shown mixed results on diarrhea and growth, raising questions about the extent to which fecal contamination needs to be reduced in the environment to impact child health. To design more effective interventions, there is a need to better understand the associations between fecal contamination and child health and how those differ along various fecal-oral transmission pathways. Methods: We systematically identified studies that quantified household-level FIB concentrations in environmental samples or fly densities, and individual-level reported diarrhea or growth. Eligible studies were limited to children <5 years in low- and middle-income settings. We obtained raw individual participant data from eligible studies and matched household-level fecal contamination to individual-level health data. We used multilevel generalized mixed effects models to estimate the odds ratio for diarrhea and the change in height-for-age Z (HAZ) scores associated with a 1-log increase in fecal contamination along individual fecal-oral transmission pathways. Results: We obtained data from 17 eligible studies, totaling over 48,000 data points on reported diarrhea and over 24,000 growth measures, spread across four transmission pathways: drinking water, child hands, flies and fomites (sentinel toys). We found increases in the odds of diarrhea with a 1-log increase in fecal contamination in water, hands and on fomites, although this finding was not statistically significant for fomites. Children exposed to higher levels of fecal contamination in water, hands and fomites also had reduced HAZ scores, but these findings were only statistically significant in water. We did not see an association between fly densities and either diarrhea or growth. Conclusions: Our findings indicate that fecal contamination in the domestic environment is associated with child diarrhea and growth. Interventions that failed to yield health benefits may not have sufficiently interrupted fecal-oral transmission. Our mixed findings by pathway suggest that fecal contamination along proximal pathways (water and hands) is more strongly associated with child health than contamination along distal pathways in the broader domestic environment.

Title: Field-trial of an automated chlorinator at shared water points in a Rohingya camp, Cox's-Bazar, Bangladesh
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Capacity of an automated-chlorinator to effectively treat shallow-tubewell-water, ensuring that chlorine residual is present in containers used by the household and not just from immediately chlorinated water is critical to examine in emergency-settings. Point-of-use water treatments with chlorine are widely used in emergency responses because of chlorine availability, cost-effectiveness, and residual protection in stored water. Despite considerable benefits, chlorination programmes in emergencies remain challenging because of no/lack of standard recommendation for dosing/residual chlorine levels, lack of appropriate chlorination technologies, and limited research in these settings. We conducted a small-scale field-trial to assess accuracy, consistency, and acceptability of an automated chlorinator "Zimba" in a Rohingya-camp, Cox's-Bazar. From August-September 2018, we selected two shallow tubewells (accessed by >100 households each) and enrolled 20 households (10 accessing each tubewell) to participate in household surveys. At baseline, fieldworkers tested iron, turbidity, free and total chlorine from tubewell and household stored-water using digital field-test kits. An important advantage of Zimba is that it can be adapted to typical tubewells rather than needing specialist engineering. The Zimba was installed at two tubewells dosing with ~2.62% NaOCl. During follow-up visits, fieldworkers tested free and total chlorine, turbidity, and iron concentration from Zimba water immediately after chlorination (N=337), household stored-water (N=133), and chlorinated stored-water that the fieldworkers placed in households in safe storage containers (N=33). Endline surveys were conducted with the same households after 8-weeks of intervention. To understand the acceptability of Zimba and chlorine smell/taste perceptions among users, we conducted 10 in-depth interviews with the mothers/caregivers from the households. At baseline, mean turbidity was 2.5 NTU, chlorine residual 0.10 ppm, and iron concentration 2.0 mg/L in household stored-water. After introducing Zimba, free chlorine >0.2 mg/L was detected in all Zimba water samples collected immediately after chlorination (100%, mean=2.12 mg/L, SD=1.12), in 24% of household stored water (mean=0.39, SD=0.90), and in 94% of household stored safe storage container water (mean=1.4 mg/L, SD 0.9). During endline only 25% of respondents complained about chlorine smell/taste in the water and 80% were satisfied with the water treatment system. In-depth interviews suggested that most households (7 out-of 10) detected a strong smell of chlorine at the initial stage of Zimba installation but became habituated with the smell after few-weeks. Some households (3 out-of 10) mentioned that they had to wait in a long queue to collect Zimba treated water. One household mentioned that the increased height of the tubewell made it difficult to pump water. More than half of the interviewee households complained that it was difficult to draw small amounts of water (i.e. for 2-3 L jugs) and took a long time. The Zimba chlorine dispensers provided accurate and consistent residual free chlorine >0.2 mg/L immediately after treatment and when kept in a safe storage container, but not when stored in the household's own containers. Our study suggested that Zimba has potential as a water treatment technology for humanitarian settings. Future research should explore the reasons for low-chlorine concentration in household stored water for effective water treatment, and impact on water contamination.

Title: Findings from the Implementation of the First Cross-Culturally Validated Household Water Insecurity Experiences (HWISE) Scale in Zambia and Democratic Republic of Congo

Sera Young, Northwestern University, Jaynie Whinnery, Joshua D. Miller, Chad Staddon, HWISE Research Coordination Network

Introduction: Water insecurity, the inability to access and benefit from affordable, adequate, reliable, and safe water for wellbeing, has manifold adverse effects on physical and mental health, and is a major contributor to the global burden of disease. Although the need for water is universal and its safe access is considered a critical Sustainable Development Goal (SDG 6.1), there is no metric for assessing experiences of water insecurity in a cross-culturally valid way. This measurement gap presents numerous challenges for monitoring and evaluating progress towards water security. Methods: To develop and test such a measure, we formed the Household Water InSecurity Experiences (HWISE) Consortium (<http://hwise.org>). Cross-sectional surveys were implemented in 8,127 households across 28 sites in 23 low- and middle-income countries. Data collected included 32 items on water insecurity in the prior month; socio-demographics; water acquisition, use, and storage; household food insecurity; and perceived stress. We retained water insecurity items that were salient and applicable across all sites. We used classical test and item response theories to assess dimensionality, reliability, equivalence, and validity. Ultimately, 12 items about experiences of water insecurity were retained. This 12-item scale was then implemented by Oxfam GB in an ex-post impact evaluation of an intervention designed to improve the provision and sustainable management of WASH services in three urban, cholera-prone compounds in Lusaka, Zambia. Results: Oxfam integrated the 12-item HWISE Scale into an existing evaluation framework. We validated the scale based on data from 1014 household interviews conducted by an external consulting team as follows: (1) Chronbach's alpha was 0.96, (2) water collection time was significantly correlated with increased water insecurity (r [correlation coefficient] = 0.10, $p < 0.01$), such that every one-point increase in the HWISE Scale was associated with 10 additional minutes spent collecting water, (3) increased disruption caused by drought or flooding was significantly associated with increased water insecurity ($r = -0.51$, $p < 0.01$), and (4) several well-being measures were significantly correlated with water insecurity, such that (a) those who were more water insecure were more likely to report fever ($r = 0.12$, $p < 0.05$) and more likely to report feeling so unwell that it interrupted their normal daily activities ($r = 0.12$, $p < 0.01$) and (b) those who were less water insecure were more likely to rate their health better overall ($r = -0.21$, $p < 0.01$) and report that the 2018 cholera outbreak affected their household less in comparison to previous outbreaks ($r = -0.17$, $p < 0.01$). Conclusions: The HWISE Scale measures universal experiences of household water insecurity across low- and middle-income countries. The scale provides valuable data for monitoring and evaluation of water-related programs. In sum, the development of the HWISE Scale ushers in the ability to quantify the prevalence, causes, and consequences of household water insecurity, and can contribute an evidence base for clinical, public health, and policy recommendations regarding water. Oxfam plans to expand the use of the scale for monitoring and measuring impact in other settings and has incorporated HWISE into a household-level multidimensional index for Sustainable Water and Sanitation.

Title: Formative Research for Development of Evidence-Based Baby-WASH Interventions to Reduce Exposure to Fecal Pathogens (REDUCE Program)

Jennifer Kuhl, Johns Hopkins University, Christine Marie George

Background: Findings from large scale WASH intervention trials focused on "F diagram" fecal exposure pathways have not shown expected improvements on child health. This has highlighted the need for further research identifying the unique exposure pathways to fecal pathogens for pediatric populations, and WASH interventions tailored to young children. The REDUCE study focuses on identifying exposure pathways to fecal pathogens that are significant contributors to morbidity for young children in the Democratic Republic of the Congo (DRC), and on developing and evaluating scalable interventions to reduce fecal contamination from these pathways. Our recent cohort study found unsafe feces disposal, child mouthing of contaminated fomites, and contact with animals to be associated with diarrhea and stunting among young children. Methods: A theory and evidence-based approach was used to design our Baby WASH intervention program. Formative research for intervention development included 31 semi-structured interviews and 6 focus group discussions with caregivers of young children, community leaders, and health workers to explore practices and perceptions of WASH behaviors and preferences for intervention delivery. The contextual, psychosocial, and technological factors driving safe feces disposal, caregivers stopping children from mouthing contaminated fomites, and child contact with animals identified during qualitative research were analyzed using the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework. Intervention development focused on targeting these multilevel multidimensional factors driving the recommended WASH behaviors. Results: Lack of adequate child supervision because of parents working outside of the home, and lack of clean child play spaces were factors driving caregivers' ability to stop children from mouthing contaminated fomites. Rice bags and plastic flooring being used as a playmat for young children emerged as a locally sourced material to prevent children from touching and ingesting dirt. Fear of theft, lack of resources to separate animals and children, and a long generational history of living with animals were factors driving the high contact observed between children and small animals. Locally sourced hutches for small animals were recommended to separate children from animals. Pictorial modules were also developed to target the contextual, psychosocial, and technological factors identified through qualitative research. Pilot-testing of these Baby WASH interventions in 50 households is ongoing. Conclusion: This study presents a theory and evidence based approach for the development of a Baby WASH intervention.

Title: Formative Research for the Design of a Baby WASH Mobile Health Program (CHoBI7 mHealth Program)

Shwapon Biswas, Johns Hopkins University, International Centre for Diarrhoeal Diseases Research, Bangladesh (icddr,b), Christine Marie George

Background: Mobile health (mHealth) programs present a promising low cost scalable approach to increase WASH practices and reduce pediatric diarrheal diseases. Our recent randomized controlled of the CHoBI7 (Cholera –Hospital-Based-Intervention-for 7-Days) mHealth program delivered to diarrhea patients and their family members which focused on promoting handwashing with soap and water treatment lead to significant increases in these behaviors and significant reductions in pediatric diarrhea. Building on this work, the current USAID funded study aims to develop three Baby WASH mHealth modules targeting safe child feces disposal, improved food hygiene, and safe child mouthing practices. Methods: A theory and evidence-based approach using qualitative research methods was implemented to design this Baby WASH mHealth program in urban Dhaka,

Bangladesh. Formative research for the development of the mHealth program included five focus group discussions, 21 semi-structured interviews, six mHealth workshops, and a pilot study of 50 households of the developed mHealth program. The contextual, psychosocial, and technological factors driving safe child feces disposal, improved food hygiene, and safe child mouthing behaviors were analyzed using the Integrated Behavioral Model for Water, Sanitation and Hygiene (IBM-WASH) framework. Intervention development focused on targeting S1 drivers of behavior change (relatively automatic, cue-driven drivers) to promote these three key hygiene behavior practices and to reduce diarrheal diseases in young children. Results: Self-efficacy to dispose of child feces safely, existing household and community habits, perceived disease risk, availability of child potties, and life stages changes were drivers of safe child feces disposal behaviors. Gender roles, hot and cold weather, access to soap, fly covers, and gas supply, perceptions that storing food in a food rack (miscel) alone was sufficient to keep food safe, and the availability of a refrigerator were drivers of safe food hygiene behaviors. Caregivers mentioned that their child were always playing outside and that it was difficult to control what they put in their mouth during play. Descriptive norms around child mouthing behaviors, parents working outside of the home, lack of adequate support for supervision, lack of availability of clean play spaces, and elders perceiving that eating soil was good for child health were drivers of safe child mouthing behavior. Mobile messages were developed that leveraged context changes, highlighted descriptive and localized norms around key behaviors, piggybacked on existing behaviors, and managed physical availability of enabling technology. Dr. Chobi, the sender of program messages, was considered a credible source of public health information and well received by participants. Conclusion: This study presents a theory and evidence-based approach for intervention development that can be implemented for the development of future Baby WASH mHealth programs in low resource settings.

Title: Geotextiles - Low Cost Dewatering Technique in the Initial Step of Fecal Sludge Treatment

Naomi Korir, Sanivation, Kate Bohnert, Catherine Berner

Dewatering has always been one of the biggest challenges for fecal sludge treatment and reuse. Existing processes are either expensive and technically complicated, or require large amounts of land and time to reach >30% total solids from traditional septic tank or pit latrine sludge. One promising option that has yet to be evaluated at scale are geotextiles. Geotextiles have shown lasting success in other industries, (wastewater treatment, geotechnical engineering, landfill design, etc), but have never been used for fecal sludge dewatering. In designing their new feces to fuel factory, Sanivation needed a technology that provided high total solids at minimum time, space, and operational costs. Comparing current dewatering options such as settling tanks and various mechanical dryers Sanivation concluded that geofabrics are the most cost effective option for land and time limited dewatering. Lab trials were conducted first to understand process potential. Using locally sourced polymer Sanivation demonstrated that sludge from exhauster trucks with initial TS of <0.5% reached and average of 18% TS in 1 day, 35% TS in 4 days, and 60% TS in 8 days in an indoor evaluation. Because geotubes have never been used before for fecal sludge processing, there has been concern about lifetime and reusability. It has been determined, along with geotextile producer Huesker, that geofabrics could be reused for a lifespan of over two years rather than the traditional method of cutting and disposing after every use. Sanivation's factory in Naivasha, Kenya is designed to process approximately 30 tons/day of exhauster truck waste (from pit latrines and septic tanks) at income solids of <5% Total Solids (TS). To increase TS to greater than 30% only requires 92m² of geotextile fabric, providing a factory capacity of producing over 5 tons/day of dewatered sludge. Costs for the system to dewater the 600 tons of FS per month are roughly \$12,000 in CapX (\$5,000 for fabric + shipping, \$7,000 for metal holding rack construction) and estimated \$840/month operational costs (\$1.4/ton of FS- \$1 for polymer, \$0.20 for labor, and \$0.20 for fabric repair). These costs at such a small footprint (less than 3 m²/ton dewatered per day) make geotextiles the most promising dewatering technology for FS processing. This technology will be incorporated into Sanivation's daily operation in the production of over 100 tons/month of non carbonized briquettes by September of 2019. Further data on operational costs and logistics will be shared at UNC WASH in October of 2019. Sanivation will be expanding the current factory in 2019/2020 and will utilize geotextiles to treat >3,000 tons of FS/month.

Title: "Got Worms? Thank Your Neighbor! Herd Protection against Soil-Transmitted Helminths."

Per Ljung, Thrive Networks / East Meets West

Soil transmitted helminths (STH)—primarily roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), and hookworms (*Necator americanus* and *Ancylostoma duodenale*)—are endemic throughout the developing world, affecting more than one billion individuals. The key weapon in the battle against STH infection is preventive chemotherapy in the form of mass drug administration (MDA), mainly targeted at school children. Unfortunately, present drugs do not completely eliminate the worms and, more importantly, do not prevent reinfection, which can be rapid (Campbell et al. 2018). Thus, there is a growing awareness that MDA programs need to be complemented by water, sanitation and hygiene interventions. Systematic reviews have demonstrated that various WASH interventions reduce the incidence of STH infections (Ziegelbauer et al. 2012, Strunz et al. 2014). However, virtually all studies have examined individual and household behavior and assets with little attention paid to externalities and neighborhood effects. Within the framework of a major deworming program, we randomly selected 100 primary schools in Phu Tho province in northern Vietnam. All students in 3rd and 4th grade in the fall of 2017 filled in simple KAP surveys and were asked to provide stool samples. Sixty-one percent of the students (i.e. 9,600) provided samples that were analyzed following the Kato-Katz methodology. Shortly thereafter, the students were given one dose of mebendazole. This process was repeated 12 months later. In addition, we randomly selected 2,900 parent households for a KAP survey undertaken in early 2018. The probability that a child would be infected with *A. lumbricoides* or *T. Trichiura* was expressed as a function of individual behavior (such as wearing shoes, washing hands and defecation practices), household characteristics (including use of human feces as fertilizer and open defecation) and local environmental conditions. The latter variables include a rough classification of the area (urban/rural and mountainous/plain) and an estimate of the infectious reservoir which depends on neighbors' worm loads or infection rates as well as defecation and farming practices (i.e. use of feces as fertilizer). Household income and education level of the mother (or father) significantly reduce the STH infection risk. Effects of other household and individual variables (such as handwashing with soap) are not statistically significant. However,

neighborhood factors such as prevalence of open defecation and use of feces as fertilizer in the local area significantly increase infection rates and worm loads.

Title: Hand Contamination with Pathogenic, Zoonotic, and Antimicrobial Resistant Bacteria among Caregivers Residing with Domestic Animals

Marlene Wolfe, Stanford University, Karin Gallandat, Daniele Lantagne, Amy J Pickering

Introduction: Exposure to zoonotic pathogens and antibiotic resistant bacteria is a growing concern in low-income domestic settings, and the use of antibiotics in animal feed is expected to increase by 82% in India by 2030. This trend is likely to intensify environmental transmission of antimicrobial resistant bacteria. The goals of this study were to 1) identify whether hands of caregivers living in close proximity to animals are associated with animal fecal contamination and pathogens, and 2) to investigate whether hands are a likely transmission pathway for pathogenic, zoonotic, and antimicrobial resistant bacteria among using complementary methods: culture-based, PCR, and long-read genomic sequencing. Methods: We conducted a survey on animal care and presence in households and collected hand rinse samples from 108 caregivers of young children in a rural community in Maharashtra, India. We cultured *E. coli* and total coliform from hand sample rinsate and extracted and analyzed DNA from cultured biomass to identify *E. coli* virulence genes (ECVG) by multiplex PCR and bacterial pathogens and antimicrobial resistance genes (ARG) among viable bacteria by untargeted long-read genomic sequencing. We analyzed DNA directly from rinsate to identify a host-associated genetic marker (BacCow) specific to animal feces in the study area using quantitative PCR. Associations with cultured *E. coli*, ECVG, and BacCow were estimated using generalized linear models. Sequencing data was mapped to bacterial genomes in RefSeq using Centrifuge and to ARG in the ResFinder database using Minimap2. Results: Ruminants were present in 67% of compounds and poultry in 44%. *E. coli*, ECVG, and BacCow, were identified in 78%, 29%, and 97% of hand rinse samples respectively. Providing animal care was positively associated with cultured *E. coli* and the presence of any ECVG, animal presence was positively associated with BacCow, and the log₁₀ number of animals was negatively associated with any ECVG and animal-associated ECVG. We found no association between BacCow and ECVG. Long-read genomic sequencing identified 28 species of pathogenic bacteria, including zoonotic species such as enterotoxigenic *E. coli*, non-Typhoidal Salmonella spp., and Campylobacter spp. We also identified 106 distinct ARGs, the majority associated with resistance to β -lactam antibiotics. ARGs were found within zoonotic pathogens, including non-Typhoidal Salmonella spp. and Klebsiella pneumoniae, among others. Discussion: Animal fecal contamination on caregiver hands was almost universal, and long-read sequencing results suggest that hands are carriers of important pathogenic bacteria and ARGs. However, the association between animal exposure and pathogens was inconsistent: participating in animal management was associated with a risk of ECVG on hands, however, the presence of more animals in the household showed the opposite association. To our knowledge, this is the first study to conduct long-read sequencing of viable bacteria from caregiver hand samples in a low-income context, allowing us to probe for hundreds of bacterial pathogens and ARGs. We suggest that future research should consider sequencing viable bacteria on hands to identify pathogens and ARGs in combination with observation of contact with animals and animal feces to inform exposure risk assessments.

Title: Heavy Rainfall and Diarrheal Disease Epidemiology within Urban-Rural Contexts

Aniruddha Deshpande, IHME, University of Washington,

Diarrheal diseases are a major cause of deaths among children under 5 years of age, causing over 590,000 deaths in 2017. Furthermore, a disproportionate amount of this burden is in low and middle income countries. Climate change is an increasing public health concern, particularly in low and middle income countries where many vulnerable populations reside. Through changes in rainfall patterns, climate change could alter the epidemiology of waterborne enteric pathogens exacerbating the burden of diarrheal diseases in vulnerable populations, especially in tropical areas. To further understand the implications of changes in rainfall patterns, we analyzed cases of diarrheal disease in relation to rainfall patterns, contextualized within urban versus rural environments. We utilized data on 33,927 cases of diarrhea from all Ministry of Health facilities in Esmeraldas Province, Ecuador across a 24-month period from 2013 to 2014. Combining the case data with daily rainfall estimates from satellite measurements from the Tropical Rainfall Measuring (TRMM) Mission, we were able to assess the complex relationship between rainfall and incidence of diarrheal diseases using Poisson regression. In particular, we assessed the relationship between heavy rainfall events (HREs) and diarrheal disease incidence, and how it is modified by antecedent rainfall conditions and the urban-rural environment. Dry antecedent conditions compared with wet conditions were significantly associated with increased incidence of diarrhea in urban areas. This effect was further pronounced, as HREs occurring following dry conditions were associated with an incidence rate ratios up to 1.35 (95% Confidence Interval: 1.14 – 1.60) compared to dry conditions without HREs. There was no statistically significant association observed between HREs and diarrhea incidence in rural areas. The observed phenomena could be driven by a flushing effect of HREs following dry periods, resulting in increased contamination in urban areas with more impervious sources. These findings suggest the increased frequency of extreme weather events such as HREs under climate projections, and the rapid pace of urbanization in many low and middle income countries may increase the burden of diarrheal diseases, unless interventions are implemented addressing this mechanism.

Title: Household Water Quality in the US Virgin Islands: Understanding Risks in Cisterns

Gouthami Rao, Centers for Disease Control and Prevention (CDC), Jennifer Murphy, Jonathan Yoder, Brett Ellis, Amy Kahler, Lee Voth-Gaeddert

In the United States Virgin Islands (USVI; population 106,405, US Census 2010), 95% of households collect and store rainwater in cisterns with a storage capacity ranging from 4000 to 40,000 gallons. Furthermore, recent data suggests 17% of households in USVI use untreated cistern water as a source of drinking water. Hurricanes Irma and Maria brought additional attention to the potential health risks associated with household cistern water use in both emergency and non-emergency situations. Waterborne pathogen exposure is a critical, acute issue. Currently, there is limited evidence-based guidance available for households on cistern water use and management. In collaboration with the USVI Department of Health

(DOH) and partners, we aim to develop guidance for household cistern water use and management in USVI to reduce risk of waterborne disease exposure. The team is conducting a two-stage data collection campaign, which includes a 25 household pilot study and a full study representative of the territorial population across all islands. Recommendations will be developed and disseminated across the territory by the USVI DOH and associated partners for risk mitigation. The pilot study has been completed and results are reported below. The full study is planned for summer 2019. The pilot study was completed in February 2019 and included households from St. Croix (n=19), St. Thomas (n=4), and St. John (n=2). Data collection included a brief questionnaire and water sampling. Questionnaire data included information on cistern and water use and management practices. Grab samples were collected from a kitchen tap and directly from the cistern and tested for physicochemical water quality parameters, total coliforms, and *E. coli*. A sub-set (n=10) of the grab samples were tested for meropenem-resistant and non-resistant *Pseudomonas*. Dead-end ultrafiltration (DEUF) was used to filter 100 L of cistern water onsite. Recovered DEUF concentrates will be analyzed for bacterial and protozoan waterborne pathogens (*Salmonella*, *Giardia*, *Cryptosporidium*, *Naegleria fowleri*, *Leptospira*, and *Legionella*) and a human fecal marker (HF183). Total coliforms were detected in 87.5% (n=21) of bulk cistern water samples, while 64% (n=16) of kitchen tap samples were positive for total coliforms. *E. coli* was detected in 66% (n=16) of cistern water samples and in 32% (n=8) of kitchen tap samples. *Pseudomonas* was detected in 90% (n=9) of cistern water samples and 20% (n=2) of the *Pseudomonas* detections were meropenem-resistant. While 48% (n=12) of households reported using the cistern as their primary source of drinking water, one reported not treating the water before consumption. Reported and observed water treatment techniques included chlorine dosing, sediment filters, carbon point-of-use filters, boiling, and inline multi-stage treatment. Among households who reported treating and then drinking their cistern water (n=12), half were not correctly following EPA guidelines for drinking water treatment. Results from the pilot study suggest the prevalence of pathogens in USVI cisterns may be high, while there may also be potential opportunities for improving cistern and water management practices for the removal of microbial contaminants. The full study will provide additional representative data to inform improved recommendations for household cistern use and water management.

Title: How to Support Governments Monitor Safely Managed WASH Services

Ethel Mendez Castillo, Akvo

The move from MDGs to SDGs requires more targeted and interconnected data collection. While the MDG era data determined whether a water source should be considered improved or unimproved, SDG data goes beyond to incorporate water quality information. In order to determine whether a water source is safely managed, governments need to shift thinking towards integrating new and different data sources that include water quality information. This session, co-presented by UNICEF and Akvo, presents the argument: it is possible to design data processes that harness collaboration between data collectors. It is possible to ensure the robust monitoring of safely managed water sources. The focus is on lessons learnt from work with governments across Oceania and Africa, and different regional approaches employed while advancing from MDG's to SDG. It will be an interactive look at how we can better design data collection processes to allow for better merging and presentation of results for holistic and realistic views of WASH statuses. The outcome of the session is participants with real exposure to processes that allow them to monitor safely managed water sources.

Agenda:

1. Present key projects from the field that have taken different approaches to using and sharing data
2. Workshop session from the room: What are the challenges that are being faced in moving towards safely managed water quality?

Title: Human Waste of Time - Valuing Open Defecation Time Savings

Ian Ross, London School of Hygiene & Tropical Medicine (LSHTM), Giulia Greco, Oliver Cumming, Catherine Pitt

Background: Cost-benefit analysis (CBA) is the most commonly-used methodology for evaluating the economic performance of rural sanitation programmes. However, widely-cited studies aimed at global audiences have divergent results. These differences are largely driven by how time savings from avoided open defecation are estimated and valued. Of the two most-cited studies, one used very high estimates and valuations of time saved, and the other very low, reflected in the relative contributions of time savings to their respective CBA results. The aim of this study is to explore how valuation of time savings influences the results of economic evaluations, and to make recommendations for the characterisation of related uncertainty in future studies. Methods: With data for 2,000 people practicing open defecation from five Indian states, we estimate the distribution of travel time for open defecation. Using distributions of rural wages for agricultural and non-agricultural occupations in the same states, we estimate the economic value of this travel time with a Monte Carlo simulation. We also investigate gender differences in travel time, and explore the effect of applying actual (unequal) gender-specific wages or an equal wage. Results: We find that, in this rural Indian setting, the median daily travel time for rural people who practise open defecation was 40 minutes (with inter-quartile range 20 to 60 minutes). We propose that an appropriate base case value of time saved from avoided open defecation in this setting is around US\$ 0.20 per hour. We identify that US\$ 0.10 and US\$0.30 per hour would be appropriate lower and upper bounds for sensitivity analysis. At base case parameter values, there could be an annual saving of \$US 25 billion if all Indians practising open defecation in 2015 switched to using a household toilet. According to Indian government figures, many of these benefits will have been reaped by the Swachh Bharat Mission, though questions remain about the sustainability and equity of its achievements. Conclusions: Based on our results, we make recommendations for the measurement and valuation of time savings in future economic evaluations of sanitation programmes. We also make broader recommendations for valuing 'wasted' time in other sectors. Specifically, we propose approaches to valuation of time to be considered as base case, lower bound and upper bound, and for the characterisation of uncertainty in economic evaluation results. In this Indian setting, the base case results are mid-way in the range of previous estimates in the literature. These approaches can help future studies characterise uncertainty, in support of improving allocative efficiency.

Title: Identifying Psychosocial Determinants of WASH Behaviors for the Development of Evidence-Based Baby WASH Interventions

Ron Saxton, Johns Hopkins School of Public Health, Christine Marie George

Background: There is growing evidence demonstrating theory-based interventions yield greater behavior change than those based on health education alone. Study Design: To develop theory and evidence-based behavior change techniques for a Baby WASH intervention, we examined psychosocial factors associated with caregiver WASH behaviors in an ongoing USAID Office for Food for Peace funded cohort study in South Kivu, Democratic Republic of Congo. Caregivers of children <5 years (N=385) answered a 54-item psychosocial factor questionnaire derived from the IBM-WASH, and RANAS models. The following WASH behaviors were assessed by 5-hour structured observation: 1) handwashing with soap; 2) stopping children from mouthing fomites and food with visible dirt; and 3) water treatment (caregiver report). Because directional hypotheses were tested, 90% confidence intervals were estimated. Results: Caregivers that strongly agreed that their child under 2 years contracting diarrhea would severely impact their life(perceived severity) were significantly more likely to stop their child from putting visibly dirty food in their mouth (OR: 3.20; 90%CI: 1.03-9.93). Caregivers that strongly agreed that their child was at high risk of diarrhea (perceived susceptibility) were significantly more likely to wash their hands with soap at stool and food related events (OR: 3.30; 90%CI: 1.28-8.47). Caregivers that strongly agreed that if hands were visibly clean then there were no germs on them (dirt reactivity) were significantly less likely to wash their hands with soap (OR: 0.48; 90%CI: 0.99-0.23). Caregivers that strongly agreed that it was hard to find wood or charcoal (barriers) were significantly less likely to boil their water (OR: 0.29; 90%CI: 0.87-0.09). Caregivers that strongly agreed that visitors would respect them more if they provided boiled water for drinking (injunctive norms) were significantly more likely to report boiling their water in the past 48 hours (OR: 20.24; 90%CI: 1.28-320.37). Intervention Development: Based on these findings, we developed pictorial modules targeting these psychosocial determinants of WASH behavior. We developed a child mouthing module that emphasizes that children putting dirty objects in their mouth puts them at high risk for diarrhea. This module also encourages caregivers to closely supervise their child when playing outside, and to stop children from putting visibly dirty objects in their mouth. For our handwashing with soap pictorial module, we emphasized that even hands that appear clean can have microbes, and that not washing hands with soap puts children at high risk for diarrhea. We have introduced chlorine tablets as an alternative safe water treatment method that does not require difficult-to-acquire wood or charcoal. Conclusions: This study presents an evidence-based approach for the development of a Baby WASH intervention.

Title: Impact and Cost-Effectiveness of Safe Drinking Water for the Treatment for Severe Acute Malnutrition, Pakistan

Bram Riems, Action Against Hunger USA, Shannon Doocy, Hannah Tappis, Ann Suk, Nicolas Villeminot, Eleanor Rogers

Undernutrition has been shown to lead to increased frequency and duration of diarrhoeal illness whereas diarrhoeal illness impairs weight and height gains, when illness is recurrent or when the child is severely malnourished. In the context of CMAM programmes, where children with uncomplicated SAM are treated at home, access to safe drinking-water is a major concern, as consumption of contaminated water can lead to increased morbidity and mortality risk as well as reduce treatment efficacy. Action Against Hunger and John Hopkins University conducted a cluster-randomized trial in Sindh Province, Pakistan, to evaluate the effectiveness of point-of-use water treatment in improving treatment of children affected by severe acute malnutrition. Point-of-use water treatment has the potential to decrease exposure to diarrhoeal disease pathogens, reduce incidence of diarrhoeal disease and increase the speed of recovery of children with SAM, thereby reducing the length of enrollment in CMAM programmes and overall treatment costs. Eligible CMAM sites were randomized to one of four intervention arms: (i) standard severe acute malnutrition (SAM) treatment in which participants received a water container, (ii) standard SAM treatment plus flocculent-disinfectant water treatment, (iii) standard SAM treatment plus chlorine disinfectant, (iv) standard SAM treatment plus ceramic water filter. Anthropometric data of children aged 6–59 months with SAM (MUAC of <11.5cm) and no medical complications were collected weekly during monitoring visits. Outcome measures were calculated upon exit or after 120 days of enrollment. Use of water treatment products was assessed 4–6 weeks after enrollment. Recovery rates were 16.7 to 22.2% ($p<0.001$) higher among children receiving water treatment compared with the control group and the adjusted odds of recovery were approximately twice as high for those receiving water treatment compared with controls. Differences in recovery rates among intervention groups were not statistically significant. Differences in length of stay and rate of weight gain between all four groups were also not statistically significant. In this site-randomized trial, provision of water treatment products significantly increased nutritional recovery of acutely malnourished children in an outpatient treatment programme. Lower diarrhoea prevalence was associated with increased odds of recovery. However, longitudinal prevalence of diarrhoea was only slightly lower among children in water treatment groups compared with controls. Therefore, the mechanism by which water treatment impacted treatment outcomes remains unclear. A cost and cost-effectiveness study were also conducted to help understand financial and programmatic implications of adding a water treatment component to CMAM interventions. An institutional perspective was adopted for costing, considering the direct and indirect costs incurred by the provider. Combining the cost of SAM treatment and water treatment, an average cost per child was calculated for the combined interventions for each arm. The costs of water treatment alone and the incremental cost-effectiveness of each water treatment intervention were also assessed. This second study found that the average cost per child recovered was lower for both the chlorine disinfectant and flocculant-disinfectant arms than for the control arm, with chlorine disinfection being the most cost-effective. In this setting, adding a drinking water component improved cost-effectiveness.

Title: Impact of an Urban Sanitation Intervention on Fecal Sludge Management in Maputo, Mozambique

Drew Capone, Georgia Institute of Technology, Robert Dreibelis, Oliver Cumming, Jackie Knee, Ian Ross, Joe Brown

Fecal sludge management (FSM), the hygienic emptying, transport, and treatment for reuse or disposal of fecal sludge, is essential to safely managed sanitation. As the unsewered areas of cities in low- and middle-income countries increase in population, there is an increasing need for FSM. We evaluated the impact of an urban sanitation intervention (sanitation infrastructure and development of pit-emptying service providers) on FSM in Maputo, Mozambique by comparing FSM status in intervention and control compounds from the Maputo Sanitation (MapSan) trial 24 months after the intervention. MapSan intervention compounds (clusters of 1 – 40 households, median = 3) received a highly subsidized pour-flush latrine to

septic tank system that replaced an existing shared latrine; control compounds continued using existing latrines. In trial compounds we surveyed compound residents and in compound neighborhoods we surveyed local government officials, performed structured in-depth interviews with hygienic pit-emptying companies, and analyzed available municipal data on FSM in the city. Emptying was more frequent at control compounds as the recent construction of the intervention likely limited the need for emptying services; 6% (15/270) of intervention compounds and 30% (74/247) of controls emptied their on-site sanitation system in the previous year. Among the compounds who had emptied their on-site sanitation system in the previous year, hygienic formal emptying was more common at intervention compounds; 14% (10/74) of control compounds reported using a hygienic service provider compared to 73% (11/15) of intervention compounds. No control compound reported using a pit-emptying company who was equipped as part of intervention, compared to 20% (3/15) of intervention compounds. Multivariable Poisson regression indicated that intervention compounds were 3.8 times (95% CI: 1.4, 10.0) more likely to have used a hygienic pit emptying service provider in the previous year compared to controls. Additionally, most hygienic pit emptying by control compounds occurred at the subset of compounds with pour-flush sanitation technology; intervention compounds were more likely, but not significantly more likely (aRR = 2.0, 95% CI: 0.86, 4.4) to have used a hygienic pit emptying company in the previous year compared to the subset of control compounds with pour-flush facilities. Our results suggest that the urban sanitation intervention, which addressed FSM alongside the provision of onsite infrastructure increased the likelihood of hygienic pit emptying in this setting.

Title: Improving Outcomes for Girls through a Holistic MHM Approach: Evidence from Ghana

Tatiana Reyes Jové, Be Girl, Audrey Anderson, Alberto Wilde, Sarah Goddard

Girls and women face particular needs related to menstrual hygiene management (MHM) in order to access their rights to health, quality education, and full participation in society. Inadequate sanitation facilities and low access to MHM materials and information create significant challenges for girls in attending and engaging in school and other daily activities. Though providing access to improved sanitation facilities has proved beneficial for menstruating students at school, this impact can be broadened by a holistic approach to MHM. This includes MHM materials for girls and education for both girls and boys to ensure girls can understand and manage menstruation in a stigma-free environment. In partnership with the Ghana education service and the social enterprise Be Girl, Global Communities implemented an MHM pilot program to assess the impact of having access to reusable menstrual panties and a menstrual cycle tracking device (the SmartCycle®) accompanied by basic menstruation education. A Be Girl menstrual kit (sustainable, hygienic period panties and a user-friendly SmartCycle® tool) was provided to 1,142 girls and MHM education to 276 boys in schools across four regions, including both rural and urban locations. Baseline and end line surveys were conducted to evaluate the impact of education alone or education and the menstrual kit on school attendance. To determine the impact of providing period protection products compared with education only, a control case study was conducted between two public schools, with one receiving the menstrual kit, and the other receiving MHM education only. The data collected revealed insights into girls' experiences during menstruation and the effect of the provision of MHM materials and information. Results indicate that improved MHM for girls improves both school attendance and concentration. During the baseline, 344 girls missed school during their menses but after receiving the Be Girl products, only 26 of them missed school during their menses. Survey results also indicate that the desire to attend school during menstruation increased as a result of the pilot. Additionally, the boys surveyed demonstrated that increased knowledge about menstruation increases their comfort level around girls, contributing to a more enabling environment for girls to manage menstruation and participate in school. Finally, MHM education had a positive impact on the health knowledge of both boys and girls, as they understood menstruation as a stage of reproductive growth. It is important to continue to assess the impact that improved sanitation and hygiene can have on MHM and girls' participation in school, which has social and economic effects over the life course. The pilot highlights that: 1) MHM education is important for boys and girls in primary and secondary school to reduce harmful social norms and stigma around menstruation; 2) Special messaging should target adults and traditional leaders to reform detrimental norms and taboos; and 3) MHM materials, including Be Girl menstrual kits, should be made available in schools in order to increase girls' capacity to manage menstruation safely and comfortably, thus reducing barriers to accessing a quality education, contributing to socio-economic progress, and making progress toward sustainable development.

Title: In-line Chlorination for Safe Drinking Water for Community-Managed Systems in Rural Nepal

Yoshika Crider, UC Berkeley, Sanjeena Sainju, Rubika Shrestha, Guillaume Clair-Caliot, Ariane Schertenleib, Madan Bhatta

Only 27% of the population of Nepal has safe water access, as defined within the Sustainable Development Goal framework, with notable disparities between population subgroups. For example, 34% of the urban versus 25% of the rural population uses drinking water sources that are categorized as meeting target criteria. Promotion of household-level safe water products has been the primary strategy for provision of safe drinking water in communities without safe water access, however this approach has notable limitations. The daily burden of treatment falls on the household, often to women and girls, and products must be maintained or repurchased, a separate added task for busy, low-income households. As an alternative, system-level treatment technologies may have the potential to reduce this burden on households by treating water before it is collected at the tap. In-line, passive chlorination technologies may be especially appealing for small, rural systems, which often have limited technical and managerial capacity for water system management. Furthermore, residual levels of chlorine protect drinking water from recontamination during distribution and storage, an important benefit where water is intermittently supplied, a common feature of small, piped water systems. Within a larger rural water system improvement project in Nepal, we evaluate the effectiveness of 2 system-level chlorination technologies (Aquatabs Flo (Medentech Corp.) and PurAll 100 (Easol Ltd.)) across 6 small piped water systems (<50 households each) managed by community water user committees. In these remote communities, ceramic household filters have been intensively promoted by a local NGO and are widely used to treat and store drinking water. However, due to factors such as inadequate maintenance and poor product integrity, household water quality still often fails to meet health-based standards and places users at risk for waterborne illness. Through systematic chlorine monitoring and water quality testing, this study evaluates whether in-line chlorination technologies consistently improve water quality within small, rural water systems serving communities with a relatively high baseline knowledge of safe water practices.

Title: Incorporating Equity into the Sanitation Service Chain

Zachary Burt, Athena Infonomics Sharada Prasad CS, Narayan Bilava, Chris Hyun, Arne Panesar, Isha Ray,

Sustainable Development Goal (SDG) 6 has brought increased focus on the 'back-end' of the sanitation value chain, incorporating indicators for 'safely managed' sanitation, rather than just measuring access. SDG 6 has also incorporated equity explicitly as part of the goal; the indicator being adopted for this is the proportion of the population with access to safely managed sanitation. While safely managed sanitation, theoretically, will not burden other residents with exposure, many sanitation systems, and current sanitation system upgrades, do, by simply moving dangerous, untreated wastes from one location to another. Such cases can be better described as sanitation 'movement' rather than sanitation 'management'. Tracking equity in such complicated sanitation systems requires looking at not just access, but also exposure. In order to track inequities in both access and exposure, we conducted a household survey in Hubli-Dharwad, a mid-size (tier II) Indian city of approximately one million people. There is some discrepancy across data sources, but as of 2011, 50-70% of the city was estimated to have private toilets connected to underground sewers, while the rest discharged to open drains, septic tanks, or pits. According to one estimate, 3% of the population practiced open defecation at that time. We conducted 4407 household surveys across all wards in the city. We tracked socio-economic status (SES) for the different types of sanitation access that exist within the city, including on-site (pits and septic tanks), open drains and covered sewers. We also tracked SES at the types of exposure that exist in the city, including contamination of piped water during distribution, groundwater contamination, flooding, living near an open sewer or de facto cesspool, living near an open defecation area and living near a large, open wastewater channel. We tried to also get information on fecal sludge disposal sites, but were not successful. We conducted this survey in the hopes of developing, and then verifying a method that could be implemented using only census data, thus expanding the number of potential users. Exposure happens across the sanitation service chain; it was only natural to express our results in a modified shit-flow diagram. In addition, we created a Sankey diagram of pollution creation and exposure that we are calling the equity-risk-flow diagram, and we created a map of access and exposure across Hubli-Dharwad, aggregated at the ward-level. These tools can potentially be used for impact assessment, planning or advocacy. They are designed to make rough approximations based on easily accessible data and are not meant to be used to quantify risk, but rather quantify and characterize the number of people at risk; this was done with the aim of making something that could easily be adopted by resource-constrained municipalities in low and middle income countries. These tools can assist in making equity a priority for sanitation system upgrades.

Title: Individual and Community Level Factors in Under-Five Children Diarrhea among Agro-Ecological Zones in Southwestern Ethiopia

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Ethiopia is Sub Saharan African country where under five children diarrhea (UFCD) is a major public health problem where the problem persisted due to poor environmental health and low access for basic water sanitation and hygiene (WaSH) services. Though, WaSH related problems are crosscutting in developing countries, investigation of socio-cultural and environmental factors help to design location specific intervention in a given community. This study aimed to examine spatiotemporal variability, detect hotspots areas and identify predictors of UFCD in Bench Maji zone, southwestern Ethiopia. An integrated study design approaches (ISDA) was used to investigate hotspot areas and identify UFCD factors. Firstly, retrospective longitudinal analysis using 90716 cases of ten years diarrhea illness data registered at health institutions of Bench Maji zone Health Management Information System (HMIS) at district level from January 2008 to June 2017. Spatial, space- time and temporal analyses were done using SaTScan version 9.4. In the meantime, spatial autocorrelations, hotspot detection were done using ArcGIS 10.5 software. Secondly, community based cross-sectional data was collected from 826 mothers with under-five children in selected districts during 01 Feb. to 30 April 2018, where multivariable logistic regression model was fitted on STATA 12 to identify UFCD predictors. Annually UFCD cases of 3610 per 100,000 was identified with a relative risk (RR) of 1.6. The highest incidence of UFCD was recorded during dry season and showed an increment from October to February. In spatial terms, risky cluster (RR>1) was detected in the districts of Bero, Maji, Surma, Minit Shasha, Guraferda, Mizan Aman town, and Sheko with non-random distribution. Six most likely clusters were identified as hotspot areas of UFCD. At individual level, child age in months (95% CI for AOR 1.20;1.08-1.36), supplementary feeding age (95% CI for AOR1.75;1.882.89), mothers' occupation (95% CI for AOR 1.75;0.51-0.93), mothers' educational status (95% CI for AOR 1.58;1.10-1.56), mothers' knowledge of diarrhea (95% CI for AOR 1.25;1.44-2.99), absence of hand washing during critical time (95% CI for AOR 0.95;1.69-3.65), and shared residence with domestic animals (95% CI for AOR 1.16;2.85-4.89) whereas, at community level, spatial heterogeneity (95% CI for AOR 1.72; 1.46-2.19), unimproved water sources (95% CI for AOR1.04; 1.11-1.63), and unimproved latrine facility (95% CI for AOR 1.02;1.00-1.71) were identified as major causes of UFCD. Besides, the study indicated attention should be paid during dry season to avoid UFCD catastrophe. Likewise, UFCD risky districts needs targeted interventions to improve WaSH facilities and proper utilization, increase knowledge of mothers and change behavioral aspects of the community.

Title: Integration of Household Water Filters into the Community Based Environmental Health Promotion Programme in Rwanda

Abigail Bradshaw, University of Colorado, Dr. Laura MacDonald, Dr. Evan Thomas

The Community-Based Environmental Health Promotion Programme (CBEHPP) was established in 2009 by the Rwandan Ministry of Health as part of a strategy to reduce diarrheal disease. The program has succeeded in creating a network of Community Health Clubs (CHC) throughout Rwanda, which train and educate families on health-related practices like boiling water. However, a recent cluster randomized control trial in Rusizi District of Rwanda found no significant impact on parameters like microbial water quality or caregiver-reported diarrhea events. In parallel to this trial, a large-scale distribution and education program was conducted in the Western Province of Rwanda where advanced household water filters were distributed to the poorest families, classified by the government as Ubudehe 1 and 2. Evaluation of this program demonstrated that household water filters can reduce diarrhea prevalence in young children and improve drinking water quality. In an effort to address the current gaps in the CBEHPP program, advanced water filters are being incorporated into a subset of the CBEHPP called the Gikuriro Program, led by SNV. The Gikuriro program is an integrated education program that aims to reduce diarrhea and improve adherence to healthy water, sanitation, and hygiene practices. Emory

University, in collaboration with SNV and the University of Colorado Boulder (CU), is carrying out an impact evaluation on the integration of water filters into the Gikuro program. Under the umbrella of this evaluation, Emory is performing a randomized controlled trial on the health impacts of the filters. CU is providing training, planning and programmatic support to SNV with respect to training of CHC facilitators on household education, filter use and maintenance, as well as on distribution of the filters and follow-up support. Additionally, CU is carrying out a process evaluation which will assess the uptake of water filters, determine whether filters are being correctly and consistently used by households, and describe the implementation process related to delivery of filters and adherence to filter use. In March 2019, 30 CHC facilitators from 30 villages in the Rwamagana District were trained, and water filters were distributed to 990 households. Households were eligible to receive the filter if they were members of their village CHC at the time of distribution and had a child under 5 or a pregnant woman as a member of the household. Distribution events included an introduction to filter use and maintenance and were followed by an in-depth training on the filters at follow-up village CHC meetings. In May 2019, CHC facilitators will visit each household to provide follow-up education and training and to collect preliminary data on water practices and filter use. Additionally, in May and August 2019, the CU research team will carry out semi-structured interviews of governmental, non-governmental and community stakeholders as part of the process evaluation. Final verification surveys will be carried out in March 2020. We will present the findings of the May 2019 household surveys and stakeholder interviews and reflect on key challenges faced throughout the implementation.

Title: Intervention Study to Improve Food Hygiene Behaviors in Rural Households of Malawi

Kondwani Chidziwisano, University of Malawi Jurgita Slikenene, Joachim Hans Mosler, Tracy Morse

Introduction: Globally, diarrheal disease accounted for over 90% of foodborne illness in 2010, with over 70% of this burden in Sub-Saharan Africa. However, traditional diarrheal prevention interventions have focused on water, sanitation, and handwashing (WASH), with little integration of food hygiene. In this study, we evaluated the effectiveness of an intervention to improve food hygiene practices among child caregivers in Chikwawa District, rural Malawi.

Methods: Formative research and intervention development was grounded in the RANAS (Risk, Attitude, Norms, Ability and Self – regulation) Model and targeted five key behaviors: 1) cleaning of feeding and cooking utensils, 2) safe utensil storage, 3) reheating of left-over food, 4) feeding of child by the caregiver, and 5) handwashing with soap at critical times. Formative research indicated that norms, ability and self-regulation factors were the primary determinants of selected behaviors; and intervention activities were developed based on the suggested behavior change techniques (BCTs) aligned with these determinants in the RANAS model. We randomly assigned villages to a control or intervention group and targeted caregivers of children aged six months to two years in each arm. The intervention was delivered for 9 months through village meetings and household visits that included demonstrations, games, rewards and songs. Food hygiene behaviors were measured through direct observation of caregivers both before and after the intervention and changes assessed by comparing differences in the population proportion between each group. Results: At end line, direct observations identified a significant increase in 4 of the 5 target behaviors: cleaning utensils (95% vs 70%, $p = 0.008$); keeping utensils in an elevated place (98% vs 16%, $p = 0.000$), reheating of food (24% vs 4%, $p = 0.024$) and handwashing with soap at critical times (46% vs 6%, $p < 0.000$). We also identified significant increases in our measures of perceived norms and perceived ability ($p < 0.000$) related to the target behaviors in the intervention arm, indicating an effective influence of the intervention on behavioral determinants. Conclusion: Despite observing no significant change on how the child was fed (86% vs 88%, $p = 0.77$), our intervention was successful in increasing perceived norms and ability related to food hygiene practices and had a significant impact on handwashing with soap, reheating food, and keeping food preparation and feeding utensils clean. This demonstrates that targeting complementary food hygiene behaviors with context specific BCTs can improve the behavior of child caregivers. Theory-driven behavior change initiatives using contextual and psychosocial factors of behavior change effectively improved food hygiene behaviors in rural Malawi.

Title: Latrine Reconstruction Decisions and Predictors in Flood-Affected Households in Ethiopia

Katherine Chambers, University of Colorado Boulder, Amanda Carrico, Sherri Cook

Sanitation infrastructure currently experiences high rates of failure in resource-limited settings. Exacerbating this issue, this infrastructure is expected to become more vulnerable as extreme precipitation events increase in frequency and intensity. Existing sanitation resilience research has largely focused on infrastructure that can withstand extreme weather events; however, not all resource-limited households will construct or adapt this type of infrastructure, and catastrophic events can destroy even the most resilient infrastructure. Therefore, there needs to be a focus on re-adoption, which is the repair or reconstruction of sanitation infrastructure after damage by a disaster. To this end, a survey was developed to help identify and understand decisions about latrine design and determinants of latrine re-adoption. Data was collected from 502 households, representing about 50% of the population of flood-affected households that had a latrine, in five rural Ethiopian communities from October 2018 – February 2019. Data on a household's previous and current latrines (e.g., cost, construction year, implementing party, expected lifetime, structural qualities) were collected on the three most recent latrines. Households that reconstructed latrines tended to rebuild the same latrine: 70% reconstructed the same slab, and 80% reconstructed the same superstructure. Structural qualities differed between households that did and did not re-adopt: 35% of re-adopters, versus 16% of non-re-adopters, had improved latrines (i.e., concrete slab). Improved latrines may be more resilient to flooding, or households may be more willing to re-adopt if they already had invested in and been accustomed to an improved latrine. Only 5% of households reported attempting to construct a latrine resilient to flooding. Households are continuing to construct vulnerable infrastructure and may be reluctant to change latrine design due to design preferences or financial constraints. Consequently, there is a need to understand additional factors impacting re-adoption decisions. Following flooding, 96% of household latrines needed repair or reconstruction. Only 62% of these households re-adopted (92% reconstructed, 8% repaired) a latrine, resulting in a significant drop in latrine coverage. Despite many household and community similarities (e.g., socio-economic status), the rates of re-adoption ranged from 11% to 93% between communities. Part of this difference may be due to each household's experience with latrine failure, which was not always due to a disaster; for example, of the 75% of households that had reconstructed

their latrine at least once, 15% of failures were not due to flooding. There is a need to understand the impact of multiple types of failure on re-adoption. Social network data (relationships, homophily, latrine history) on at least six social contacts from the household head and spouse were collected. When controlling for income, a household was significantly more likely to re-adopt if a higher proportion of the household head's social contacts also owned a latrine ($p < .05$), which suggests that creating social norms around sanitation may encourage re-adoption. This data is being further analyzed to evaluate additional re-adoption decision trends and predictors following latrine failure. This study's results have implications for sanitation programming in flood-prone areas, providing guidance to predictors of latrine re-adoption and insights to vulnerable populations.

Title: Machine Learning and Spatial Data Analysis Applications in Modeling Risks of PFAS Substances in Private Well Water

Javad Roostaee, UNC Chapel Hill, Jacqueline MacDonald Gibson

During the past year, per- and polyfluoroalkyl substances (PFAS), including GenX, have been detected in more than 75% of 769 private water supply wells located near the Chemours Company Fayetteville Works in North Carolina (NC). GenX concentrations exceeded the NC provisional public health goal of 140 ng/L in nearly 25% of the wells. High geographic variation in PFAS occurrence has been observed. In multiple areas, properties with highly contaminated wells neighbor properties where no PFAS have been detected. The causes of this variation are not understood. A wide variety of factors—from fine-scale geologic heterogeneity to well depth and age to wind direction relative to the Chemours facility—could influence contamination risk. However, the relative importance of such factors and how they interact to influence whether a specific drinking water well will be contaminated are not understood. We will report on a project to develop machine-learned Bayesian network models that can explain the geographic variation and predict contamination risks in wells that have not been tested. Model structure and underlying parameters are being learned from a curated data set combining results from the 769 wells already tested with data retrieved from publicly available sources, including well permits, databases characterizing soil type and hydrogeology, proximity to the Chemours facility, septic tanks, and local climatic data. We are testing multiple supervised algorithms for developing the Bayesian network model structure. Preliminary results show high accuracy, as measured by area under the receiver-operating characteristic (ROC) curve, in predicting which wells are at risk of GenX occurrence above the health-based standard established by North Carolina. These models are expected to yield insights about the factors most influencing the risks of private well contamination with PFAS.

Title: Managing reclaimed water applications using QMRA approach

Rajashree Hajare, CSIR-National Environmental Engineering Research Institute Tedla Mulatu, Lemessa Mekonta, John Butterworth, Joseph Pearce, Laura Brunson

While India tackles its worst water shortage problems, urbanization and population growth adds more stress on its freshwater supply. At the same time, the untreated sewage is dispensed in water bodies which further contaminates water. This puts water quality in danger and introduces health risks to local populace who are exposed directly or indirectly. Water reclamation which refers to use of treated wastewater, is a valued practice today, however, the release guidelines and standards in India are characterized for a limited designated application. Hence, there is a need for a consistent and reliable health-based risk assessment approach to define the best assigned utilization of reclaimed water and degree of treatment to be introduced so as to avoid any adverse impacts on public health. Quantitative microbial risk assessment (QMRA), a risk-based assessment tool which determines the magnitude of acquiring an illness on exposure to pathogenic microorganisms and probability of illness is used as an indicator to designate the best application of reclaimed water. This approach was demonstrated in two cities in India: Delhi and Nagpur; with an overall aim to optimize the choice of treatment for domestic sewage to produce water of fit-for-purpose quality for the end-user. At Delhi, the industrial and domestic wastewater was treated in a conventional STP and treated effluent was used partially for irrigation of ornamental plants and edible crops. Water samples were collected and tested for bacterial indicators and pathogens. Using QMRA, the current risk for use of reclaimed water for edible crops (uncooked) was 1.18×10^{-2} pppy, which is above the WHO stipulated guideline ($\leq 10^{-4}$ pppy). To ensure reuse, low exposure reuse options were explored and in combination with on-site control measure was proposed for reuse for irrigation of fruit plants using sprays, sport fields and silviculture with limited public access. It was suggested only after installation of UV or ozonator; effluent can be used for crop (eaten uncooked) irrigation. At Nagpur, domestic sewage was treated in a multi-barrier approach consisting of pre-treatment, combination of Constructed wetlands (Vertical-horizontal flow, horizontal-vertical flow and aerated), and disinfected using chlorine. Currently, the treated water is used for park irrigation, hand wash and toilets. The risk calculation suggested the reclaimed water can be used for any non-potable purpose ($r: < 6.4 \times 10^{-6}$ pppy). The approach was used to identify best designated use after each stage of treatment. The water after H-CW/V-CW can be reused for irrigating crops (consumed cooked) ($r: 7.4 \times 10^{-5}$ pppy), Aquaculture ($r: 3.2 \times 10^{-5}$), toilets flushing ($r: 6.7 \times 10^{-5}$); while, the water can be used for all non-potable purpose except hand washing and unrestricted spray irrigation after aerated CW. The study findings conclude a systematic risk-based approach can identify the fit-for-purpose water quality which is controlled by mode-of-application and degree of treatment achieved. Thus, the reclaimed water can be used effectively without undergoing an expensive up-gradation or retrofitting of the existing treatment facilities but by efficiently managing the health risk of each designated use.

Title: Microbial Contamination of Drinking Water from Vending Machines of the Eastern Coachella Valley

Thomas Hile, Loma Linda University

In 2014, a home hygiene assessment was conducted in the Eastern Coachella Valley. found that water coolers in private homes had more microbial contamination than the tap water. These water coolers were reported to have been filled with drinking water obtained from bulk-fill vending machines, the kind that are common in front of convenience markets, strip malls or grocery stores. The interim result was presented to a group of promotoras in April of 2015 who recommended further study to investigate the potential microbial contamination in these types of water dispensaries and potentially other sources of drinking water that are available for the public. This project addresses the microbiological quality of drinking water from vending machines in the Eastern Coachella Valley. In total, 1,020 L of water was sampled from nine vending machines and filtered through positively charged NanoCeram filters. Physico-chemical parameters, such as temperature, pH, turbidity, electrical conductivity, and chlorine level,

were examined and compared to the World Health Organization's standard. Heterotrophic plate counts, IDEXX technology, and flow cytometry were used to on the drinking water samples to determine the abundance of bacteria. Identification of potential pathogenic microorganisms in drinking water was accomplished by selecting a relatively short list of microorganisms to be used as indicators of water quality. The list included *Salmonella* spp., *Listeria monocytogenes*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, *Campylobacter jejuni*, and adenoviruses (40/41). Total coliforms and *Escherichia coli* were measured using the IDEXX Colilert Test, m-Endo, EMB, and MUG-EC broth methods. Real-time PCR was used to identify and quantify selected microorganisms in water samples. Selective broth and agar plates were also used to confirm and grow potential positive samples. We found that 73% of the water samples from vending machines (WVM) and 80% of swabs from drains had heterotrophic plate counts exceeding 500 CFU/mL. results from qPCR identified *Salmonella*, *Listeria*, *Serratia*, and *Pseudomonas aeruginosa* in all vending machines, and legionella in seven WVM. Two vending machines and almost all drain swabs had coliforms. No *E. coli* was found in either WVM or swabs. We conclude that microbial prevalence in drinking water from vending machines is related to lack of regular flushing and nozzle cleansing. Changing filters is insufficient to control the shedding of microorganisms in water for consumption. There is still much needed work on this project and much possibility to include the community in the research process.

Title: Modeling WASH-Related Enteropathogens and Interventions: A Tool for Applying Empirical Data to Policy Decisions

Elizabeth Sajewski, Emory University, Benjamin Lopman, Matthew Freeman

As shown in systematic reviews, studies demonstrate varying impacts of WASH interventions. The majority of those that show effects rely on observational data and cross-sectional studies while trial-based studies show inconsistent and often little effect. Mathematical models leveraging empirical data from these studies can serve as key tools for policy development, bridging the gap between scientific data and generalizable policy implications and applications. In the WASH context, models have primarily been used to in low-income settings to characterize epidemics and investigate outbreak response (i.e., cholera epidemics) or in high income settings to describe transmission dynamics for foodborne or recreational waterborne diseases (i.e., *Salmonella* or norovirus). In this presentation, we propose the use of mathematical models to examine the dynamics of WASH-related enteropathogens in a low-income, endemic setting and the ways in which person-to-person or environmental transmission could be mitigated by WASH interventions. In proposing this model, we first reflect on the lessons learned and use of mathematical models historically and in the WASH field as tools for public health decision making. We used specific examples to focus on the broad application of models to understand the current or future burden of disease, to characterize the transmission and natural history of pathogens, and to assess the potential effects of various intervention strategies. Building from these examples, we next discuss the specific challenges in modeling WASH-related enteropathogens, focusing on the impact of multiple pathways, multiple pathogens, and multiple types of interventions on population disease dynamics. Multiple pathways, in addition to informing the differing routes of transmission by setting, also inform differing levels of transmission within a population, varying from close-contact, household-level transmission to more dispersed, community-wide transmission pathways. When applying models to settings burdened by a diverse array of enteropathogens, it is key to consider the unique characteristics of viruses, bacteria, and parasites, and how these factors impact disease transmission as well as the determinants of disease. Consideration of pathways and pathogens leads to consideration of the types of behaviors and technologies that can be used to interrupt these pathways and reduce exposure to pathogens. While addressing these complexities, we propose mathematical modeling as a tool to address some of the fundamental WASH study design challenges, such as the lack of a true counterfactual and the difficulty in measuring intervention fidelity and uptake. Additionally, models can integrate information from various studies to provide a more informed and generalizable understanding of the potential impact of technology and behavior changes on improving health and reducing the negative impact of WASH-related pathogens. As a proof-of-concept, we use a combined quantitative microbial risk assessment (QMRA) and compartmental transmission (SIR) model, as has been proposed previously in the literature but not previously developed, to demonstrate the application of modeling to the unique challenges presented within the WASH field. Through exploration of model outcomes and sensitivity to input parameters, the model framework and demonstration suggests how mathematical modeling can support application of ecological and trial data to support broader policy decision making.

Title: Mothers' Perceptions and Behaviors to Safe Child Feces Disposal Practices in Odisha, India

Rebekah Williams, Emory University, Gloria D. Sclar, Parimita Routray, Linelle M. Blais, Tom Clasen, Bethany A. Caruso

Background: A critical but often neglected aspect of sanitation is the lack of consistent, proper disposal of child feces. When not safely disposed, child feces can become a source of exposure for enteric disease, potentially leading to impaired growth in children. Reasons for not properly handling child feces include the belief that child feces pose low risk, a lack of understanding of the pathogenic risks, a lack of access to diapers, potties and/or cleaning supplies, and a lack of knowledge about safe disposal practices. As most children under the age of five are dependent on mothers and/or caregivers for their defecation practices, they are key for sustained behavior change in this age cohort. However, there is a need to assess how mothers perceive external influences and personal motivations around child feces disposal management (CFM). A cluster-randomized controlled trial was conducted in Odisha, India to evaluate the effectiveness of a multi-level intervention that aimed to increase latrine use among latrine-owning households. An aspect of the multi-level intervention was a Mothers Group, targeting mothers of children under age five to increase knowledge safe child feces disposal behaviors and provide safe disposal tools (potties/scoops). This study aimed to qualitatively assess mothers and caregivers attitudes and perceptions of child feces disposal management after attending the Mothers Group. Methods: Qualitative data collection was carried out in six villages. Twenty-four in-depth interviews (IDIs) were conducted in three villages that received the Mother's Group intervention to assess their opinions of the intervention activities, including the messages and hardware delivered. Four focus group discussions (FGDs) were conducted in three villages that did not receive the intervention to understand feces disposal practices broadly and potential spillover of information from neighboring intervention villages. Inductive coding was used to guide the development of codes and thematic analysis was used to explore the dimensions of emerging patterns and variations. Results: Results found that women's narratives provide a deeper understanding of the sociocultural context of child feces management, especially in regards to perceptions of family networks and perspectives of

risk. Findings indicated that women's household responsibilities and restrictions in their movements outside the home were barriers that prevented them directly experiencing the sanitation intervention. Mothers-in-laws and grandmothers commonly attended the intervention instead of mothers with children under the age of five, the target demographic. Among women that did experience the Mother's Group there was variation in how they implemented the safe disposal tools related to child comfort using of the tool, perceptions of the training process, and access to a functional latrine. Conclusions: These findings demonstrate that future interventions should be purposive in building trust with elder female gatekeepers, in order to accommodate the movement restrictions of younger mothers. These findings also indicate that the design of the tool may need to shift to better meet the needs of both mother (ease of cleaning) and child (comfort during use). We intend that these findings encourage further research and discourse on CFM solutions that benefit the well-being of both mother and child.

Title: Moving Performance Improvement Plans from Myth to Reality: Emerging Evidence from Kenya

Japeth Mbuvi, DAI – KIWASH, Mike Ogoi, Kakamega Water and Sewerage Company; Heather Skilling, DAI

Africa's urban population will triple by 2050. Yet the Joint Monitoring Programme data of 2017 shows that the share of the urban population with water piped to their premises has declined, from 43 percent in 1990 to 33 percent in 2015. At the current rate of urbanization, utilities will continue to lose ground every day and more people, especially the poor, will resort to unsafe, expensive and inconvenient sources. However some cities are making progress, even in increasing coverage to the poor (Heymans 2016). Despite different operating contexts, the common themes among cities, or utilities, that are making progress is the degree of commitment and a willingness to close the gap between policy and practice through the use of transparent, robust, yet tailorable, instruments to chart and measure progress. A Performance Improvement Plan (PIP) is a comprehensive strategic work plan developed to address a variety of utility management issues, with the aim of improving utility performance against specific metrics and enabling the utility to achieve its short – and medium-term objectives (GWOPA). PIPs have been used in the Africa Water Sector for more than 20 years, with early promulgation through the Water Utility Partnership – Africa, but evidence of their effectiveness has been limited and the data is now relatively dated. In Kenya, USAID (through the KIWASH project) is working with county governments to tackle the serious operational inefficiencies of six Water Service Providers (WSPs) that were ranked in the bottom 25 percent of WSPs in the Water Services Regulatory Board's (WASREB) Impact Report. Kakamega County was an early adopter of the PIP approach and has been able to reach several performance milestones including:

- Increased revenues through adoption of customer focused technology and marketing approaches.
- Improved responsiveness to customer complaints and accountability leading to better customer satisfaction and application for water connections.
- Improved revenue collection by 25% leading to a shift in credit worthiness and successful application for a commercial loan.
- Performance contracts with clear targets backed by clear performance incentives signed by key utility personnel.

With a fourfold increase in investments needed to meet the SDGs is beyond what most governments can afford (Hutton and Varughese 2016), this kind of efficiency improvement and the related ability to better access commercial finance is an approach that needs to be replicated and scaled.

Title: Multidimensional Tradeoffs across Sanitation System Alternatives in an Informal Settlement in Kampala, Uganda

John Trimmer, University of Illinois at Urbana-Champaign, Hannah Lohman, Diana Byrne, Stephanie Houser, David Katende, Dan Semakula

The growth of urban areas in low- and middle-income countries has placed increasing pressures on sanitation and resource infrastructure, with many urban households relying on onsite sanitation facilities that may be unsafely managed. In particular, current approaches in informal settlements fail to meet the needs of already vulnerable populations. Efforts to specifically address fecal sludge management are gaining prominence but remain understudied, particularly with respect to multidimensional sustainability outcomes assessed through integrated frameworks that examine tradeoffs across factors such as economic viability, environmental impacts, and social appropriateness. This work represents a collaboration among Community Integrated Development Initiatives, Makerere University, and the University of Illinois at Urbana-Champaign to characterize and assess multidimensional aspects of existing and alternative sanitation systems in Bwaise, an informal settlement in Kampala, Uganda. Within a social-ecological systems framework, we combine local data collection, stakeholder engagement, and quantitative modeling to elucidate local drivers and evaluate each alternative system's potential to recover resources (nutrients, energy), life cycle economic implications, and broader environmental impacts (greenhouse gas emissions). Over 800 household surveys were conducted with questions covering water and sanitation infrastructure, hygiene practices, child health, energy, and agriculture. To further understand local conditions, challenges, and opportunities, meetings were also held with several key actors, including local government authorities, non-governmental organizations, and utility operators. Survey responses, stakeholder discussions, and relevant literature informed quantitative modeling. Models for each sanitation alternative were conceptualized as interconnected sequences of modular processes (from onsite facilities through conveyance, centralized treatment, and potential recovery and reuse), all embedded within a Monte Carlo framework to evaluate uncertainty and sensitivity. Preliminary findings begin to reveal tradeoffs across multiple dimensions of sustainability and demonstrate how individual processes can affect system outcomes. For example, in systems employing pit latrines, resource recovery potential is constrained due to losses occurring during pit storage (e.g., nutrient infiltration, organic matter degradation). In contrast, replacing pit latrines with container-based facilities (in which liquids and solids are stored separately and frequently collected) can reduce onsite storage losses, raising the potential for recovery during centralized treatment. Container-based systems may also emit lower quantities of greenhouse gases, as frequently collected storage containers will release fewer direct emissions from fecal decomposition. However, citywide sanitation development plans suggest motorized transport may still be necessary to reach centralized treatment facilities, potentially increasing conveyance costs even if containers are initially collected manually. Regarding centralized treatment, anaerobic digestion may perform better (both economically and environmentally) than existing sedimentation, lagoon, and solids drying processes, particularly if biogas can be captured and sold locally as cooking fuel. However, the logistics of bottling recovered biogas to create a marketable product may create new challenges for sanitation actors. Overall, this work illustrates the importance of evaluating sanitation options using integrated sustainability models that consider multidimensional outcomes informed by contextual drivers. Employing these approaches across various contexts and systems can inform decision-

making at multiple scales, while also providing generalizable insight into appropriate sanitation and resource recovery strategies that lead to sustainable development and harmonious interactions between engineered and natural systems.

Title: National Advocacy for Menstrual Hygiene Management in Uganda: Policy Achievements and the Role of Government

Mulumba Jane Nabunnya, Lydia Mirembe Ssenyonjo, IRC International Water and Sanitation Centre Uganda

Menstrual Hygiene Management (MHM) is a combination of roles a girl or a woman undertakes to ensure a healthy cycle of the monthly flow of blood. These may include personal hygiene, menstrual material disposal, pain management and psychosocial support. The 2012 MHM Study by IRC International Water and Sanitation Centre and SNV Netherlands Development Organisation sought to establish what particular challenges and issues girls faced in Uganda in order to inform evidence-based advocacy. Key findings from this study indicated that one in ten menstruating girls in Uganda skips school four to five days in a month or completely drops out and the subject of menstruation is still a taboo with many negative cultural attitudes associated with it, including that menstruating women and girls are contaminated, dirty and impure. However, over the past 10 years, Government of Uganda working with different partners has promoted MHM in the country. Following the first national MHM conference in August 2014 in Kampala, there has been a number of positive steps taken to promote MHM in the country. In the Second National Development Plan (NDP II), government committed to designing and implementing partnership frameworks to address social, cultural and other barriers to girls' and boys' attendance and retention in schools; develop and implement programs that ensure a safe and non-violent and inclusive learning environment in schools and improve infrastructure in our institutions. In 2015, the Ministry of Education and Sports (MoES) with other ministries and partner NGOs developed and signed a MHM Charter in which they committed to; policy development and advocacy, research, promotion of public/private partnerships, knowledge management and public information and education. The MoES has also been involved in a number of actions related to the strengthening of policy and operational guidance to schools and local Government and the development of approaches to ensure the inclusion of MHM in monitoring and reports. The MoES currently chairs a Task Force on MHM which includes other line ministries as well as development partners and civil society. In the same year (2015), government together with its partners signed the MHM Charter committing to promote the rights of girls and women during and after the menstrual cycle. The MoES also sent out a MHM Circular to all districts, schools and institutions on MHM in schools and has continued to conduct capacity building programs of senior women and men teachers in a number of districts. This presentation provides insights, lessons, challenges and achievements of Uganda's national advocacy campaign on MHM and how Government through the MoES has spearheaded the campaign and attracted support from different partners.

Title: Occurrence of Metals Derived from Drinking-Water Systems in Three West African Countries

Michael Fisher, The Water Institute at UNC, Amy Z. Guo; J Wren Tracy; Sridevi K. Prasad; Emily G. Browning; Kaida M. Liang

Toxic metals (TMs) such as antimony, cadmium, chromium, lead, manganese, mercury, nickel, and others, as well as semimetals such as arsenic and selenium, are environmental contaminants of public health concern. Exposure to these contaminants can lead to acute toxicity; chronic cardiovascular, kidney, and other disease outcomes; cancers; and/or lifelong neurodevelopmental impairment. Drinking water can be an important source of environmental exposure to TM contamination; metals may occur in drinking water either due to groundwater contamination, or due to corrosion of water system components themselves. Several studies in the US and other high-income-country (HIC) settings have reported the occurrence of metals in drinking water at concentrations of health concern in piped water systems and private wells. However, few robust, multi-country studies have reported on the potential occurrence of metal contamination in West African settings at a meaningful scale. Furthermore, co-occurrence of metals has not been analyzed. The present study reports concentrations of 9 metals and semimetals of potential health concern from 370 water samples obtained from 262 community water systems across large rural regions of Ghana, Niger, and Mali. First-flush samples were collected using trace-metal clean sampling protocols, and were analyzed at local laboratories by ICP-MS and ICP-OES according to standard methods. In addition, groundwater samples were collected from selected water systems, and selected water system components from these systems were sampled and digested for metals analysis. Multivariable regressions and geospatial analysis were used to characterize the occurrence of metals of health concern in water systems in the study area, and generate hypotheses about their potential sources. Arsenic, cadmium, chromium, lead, manganese, nickel, and selenium were all detected at concentrations exceeding WHO guideline values in one or more samples. Approximately 10% of samples had concentrations of one or more TMs exceeding applicable WHO guideline values in the study setting. Occurrence of these metals was not associated with water system age or implementer. However, occurrence of these metals was associated with water system type, country, and/or groundwater chemistry (e.g. pH and/or conductivity) for several TMs. Co-occurrence of metals in water samples was characterized, and results suggest that several TMs of health concern are derived primarily from corrosion of water system components in the study setting, while others are primarily derived from groundwater aquifers in these settings. Finally, associations between water system component composition and the occurrence of metals in water samples are reported, and implications for preventing, correcting, and monitoring TM contamination in drinking water systems in these settings are discussed.

Title: OCTOPUS (Operational Collaborative Tool for Ongoing Practices in Urgent Sanitation) – Reasons and Results

Marine Ricau, Solidarites International, Alberto Acquistapace, Emma Maisonnave, Aude Lazzarini, Julien Barbier

In the early stages of a rapid-onset emergency, selecting an appropriate treatment and/or disposal site for faecal sludge is critical. Although some guidance on safe faecal sludge management (FSM) exists, they are often not fully applied in practice. SI and Borda were funded by the Humanitarian Innovation Fund to find solutions to this issue. The key objectives of the project were first to provide answers to the following questions:

- What materials are being used by humanitarian practitioners to guide faecal sludge management in emergencies?
- If humanitarian practitioners are looking for information on FSM where would they search for this?

- What are the gaps with regard to available information on FSM in rapid-on set emergencies?

Secondly, it was to find an innovative learning and dissemination solution to share guidance and practices. The first phase of the project used applied research to identify factors that encourage or discourage practitioners from referring to existing guidance on safe FSM, as well as associated levers or barriers, with the aim of identifying effective means through which to encourage their utilisation. The research employed a mixed-methods approach combining literature review with semi-structured key informant interviews (n=10) and online practitioner survey (n=98). Findings show that 65% of WASH practitioners consulted guidance when making decisions on FSM in first phase emergencies. Most common advantages for using guidelines:

- making quick and easy decisions (21%),
- choosing FSM solutions (20%),
- ensuring adherence to norms and standard practices (21%).

Most common disadvantages:

- lack of context specificity (38%),
- too time-consuming (18%),
- preventing thinking outside the box (13%).

Based on these results, SI created the OCTOPUS (Operational Collaborative Tool for Ongoing Practises in Urgent Sanitation), an online platform for FSM in emergencies. The objective of the platform is to support sanitation practitioners:

- to collaborate and share practices (through case studies and indicators) in specific emergency contexts,
- to share local WaSH Cluster and governmental guidelines and standards,
- to rapidly compare different practices of the same contexts,
- to take timely and rapid decisions,
- and to improve their practices.

The platform has been tested for the Cox's Bazar crisis where, together with the WaSH Cluster's Sanitation Technical Working Group, a case study template and associated indicators have been identified. Once finalised, the platform will document sanitation practices and guidelines in major ongoing humanitarian crises based on this common set of information. First findings show that practitioners need to have common and objective information to compare and make decisions. However, although the platform enables rapid comparison between practices within and between crises, the information and data collection and their formalisation are still considered too time-consuming for the practitioners who are not yet used to collect the required information in their daily operational monitoring. Further use and dissemination and the endorsement of the platform by the Global WaSH Cluster as a standard coordination tool should trigger an improvement in the operational monitoring of practitioners and make the platform easier to use.

Title: Open Defecation in Households with Toilets during the Swachh Bharat Mission in Rajasthan, India

Natalie Exum, Johns Hopkins University, Emma Gorin, Anoop Khanna, Kellogg J. Schwab

To end the practice of open defecation (OD) in India the government initiated the Swachh Bharat Mission (SBM) or "Clean India Mission" in 2014. Rajasthan embraced the mission and was declared Open Defecation Free (ODF) in March 2018. To reach ODF status nearly 8 million toilets were constructed in rural Rajasthan households. This achievement is notable given the target of reaching ODF by October 2, 2019 to mark the 150th birth anniversary of Mahatma Gandhi. Ongoing monitoring of toilet use is key to ensuring long-term sustainability of ODF in Rajasthan. Since 2016, Performance Monitoring and Accountability 2020 (PMA2020), in collaboration with the Indian Institute of Health Management Research University, has collected state-wide data on the practice of OD in Rajasthan on an independent basis. These data indicate that while there are promising decreases in OD practices, Rajasthan has remaining challenges to ensure households are utilizing the toilets constructed under SBM. The objectives of this study are to: i) investigate OD trends in Rajasthan during SBM from 2016-18; ii) characterize the main sanitation facilities used by households; and iii) analyze the underlying factors driving household members to continue OD practices in households with access to sanitation facilities. PMA2020 data shows a steady decrease in households that report OD as their main household sanitation option. However, the state is not ODF. In 2016 46.0% of households practiced OD as their main sanitation option, (63.3% rural vs 12.6% urban). This statistic dropped to 38.8% in April 2017 (53.6% rural vs 11.9% urban), 35.9% in October 2017 (49.2% rural vs 11.6% urban), and 33.3% in July 2018 (45.8% rural vs 9.4% urban). Regular practice of OD was reported more commonly, suggesting inconsistent use of sanitation facilities among household members with access to a facility. Although OD has declined, the most recent 2018 survey shows at least one household member openly defecating in a majority of households with sanitation access (51.7%: 67.5% rural and 21.5% urban). The types of sanitation facilities most widely used by households that do report access in 2018 include: pour-flush toilet to a septic tank (49.5%), pour-flush toilet to a pit latrine (16.4%), pour-flush toilet to a sewer network (13.5%), ventilated improved pit latrine (10.6%), pit latrine with a slab (5.4%), pit latrine without a slab (1.9%) and a pour-flush toilet to elsewhere (1.8%). Multivariate logistic regression models of households with access to a sanitation facility (n=3,078) found that toilet sharing was an important factor associated with regular practice of OD. For households sharing a toilet with ten or more households there was an adjusted odds ratio of 9.3 (95% confidence interval: 2.7, 32.5) that at least one household member would regularly openly defecate compared to households with an unshared, private toilet facility. This highlights the importance of investigating the use and acceptability of sanitation facilities while SBM is in its final phase. The construction of toilet facilities may have outpaced behavior change campaigns to encourage their use and ensure the long term sustainability of a clean India.

Title: Pilot-Scale Investigation of Water Quality in Intermittent Water Supply

Mariam Alkattan, University of Massachusetts Amherst, Dr. Emily Kumpel

One billion people globally receive piped water for less than 24 hours day in what is referred to as intermittent water supply (IWS). IWS poses a risk to public health because the nature of intermittency allows for contamination via bacterial regrowth and intrusion. There are still many gaps in our understanding of IWS, which has been a limitation in creating appropriate solutions to maintain water quality in IWS systems. However, we hypothesize that extensive literature on stagnation in continuous water supply (CWS) can be linked to phenomena in IWS. To validate this potential link, we plan to run a study to compare stagnation in IWS with stagnation in CWS. For this study of IWS, we designed and constructed two identical pilot-scale pipeloops, 22-foot closed loops of 2-inch diameter PVC, to simulate a full-scale distribution system. Both pipeloops circulate municipal tap water with a water residence time of 24 hours. During the planned 6-week study period, there will be a weekly 'on' period of 4 days and 'off' period of 3 days. During the 'off' period the flow in both pipeloops will be stopped. One pipeloop will be drained while the other is kept pressurized with water. This will simulate stagnation in CWS versus the depressurization that occurs in IWS, so that water quality between the two systems can be compared. A significant part of this study will also be analyzing the biofilms that grow on the interior of the pipe walls. Biofilms act as a reservoir for pathogens and are a potential source of bacterial and pathogenic contamination. Comparisons between biofilm growth in IWS and CWS will help us further characterize IWSs. The analytical results being presented as part of this research are disinfectant residual, turbidity, DO, pH, HPC, and ATP. In addition, each pipeloop has a set of biofilm sampling coupons installed. The sampling coupons consist of 20mm plugs that fit into holes drilled into the pipeloops. Biofilms will grow on the coupon surface that is in contact with the water in the systems. Biofilms from the pipeloops will undergo microscopy analysis which will include coverage, thickness, density, and tomography of the biofilms. We hypothesize that bacterial load (HPC and ATP values) will be elevated in the intermittent system and that biofilms in the intermittent system will be thicker. Preliminary results from an initial 6-week trial run of the experiment have also suggested that turbidity may also be elevated in the intermittent system. The results of this study will guide the direction of future research that aims to understand the mechanisms influencing IWS water quality and measures that can be taken to reduce the public health risks that are part of IWS.

Title: Political and Ethical Determinants of Water Quality Data Use in Rural Kenya

Saskia Nowicki, University of Oxford, Dr Katrina Charles

Explicit inclusion of water quality in the definition of 'safely managed' shifts emphasis from infrastructure towards ongoing water safety planning. In rural Sub-Saharan Africa, however, water quality is largely untested. Data from the WHO/UNICEF Joint Monitoring Programme indicate that in 2015 just over 70% of urban households in SSA received drinking-water free from faecal and priority chemical contamination. In contrast, only 43% of rural households had basic water services and data were insufficient to judge quality. This lack of information reflects urban-rural inequality and frustrates the 'leave no one behind' imperative. Rural service providers are beginning to address the information gap with water quality monitoring programmes, building capacity and adjusting to resource constraints in doing so. Yet the utility of such programmes depends on stakeholders' responses to them, including whether information is shared within and between organisations. Sharing is important because water provision in rural SSA is an undertaking of numerous stakeholders with regulatory, asset development, maintenance, operational, and household-level management roles, each impacting water safety. To understand which factors influence stakeholder responses, this study sought feedback on a water quality monitoring programme piloted in rural Kenya by a water supply maintenance provider. Monitoring began in November 2018 and generated weekly (3 sites) and monthly (88 sites) microbial and chemical water quality data. Results were reported in accordance with directions from the County government and suppliers. Feedback was sought from eighty-four representatives from the national water services regulator (2 representatives); the Ministries of Water and Health at national (4), county (5), and sub-county (4) levels; two water service providers (4); two donors (4); three NGOs (5); community-based management committees (33); school and health facility administrators (14, 3); and entrepreneurial suppliers (6). Interviews were conducted in three stages (prior to monitoring and after three and six months of monitoring) with all but twenty-seven of the representatives (who were available for fewer meetings). Additionally, single interviews were held with representatives from three water supply maintenance providers who run monitoring programmes elsewhere in SSA. Dilemma Analysis was used to create a structured synthesis of the ambiguities, judgements and problems expressed by the representatives in relation to acting on the monitoring data (including sharing it). The monitoring data challenged stakeholders' assumptions and increased visibility and understanding of water safety challenges. In all stakeholder groups, rationales for acting on the data, or not, had political and ethical foundations – hinging on meeting mandates, maintaining legitimacy, and adhering to moral concepts. Action resulted from perceived opportunities to demonstrate good work, increase or improve use of resources, and empower household-level water managers. Action aversion resulted from concerns about influencing political rivalries, distracting from political priorities, causing distress, and instigating maladaptive behaviours. Rationales were shaped by the perceived locus of responsibility for safe water. This perception varied within and between stakeholder groups and was strongly determined by distinctions between microbial and chemical safety. In summary, political and ethical rationale influenced collaborative use of the water quality data, thereby impacting the utility of the monitoring programme for improving rural water safety.

Title: Poultry Ownership is Associated with Campylobacter Infection and Infant Malnutrition: Formative Evidence from Ethiopia

Sophie Budge, Cranfield University, Dr Alison Parker, Dr Paul Hutchings, Camila Garbutt, Tizita Tulu, Mesfin Gizaw

Diarrhoeal disease from enteropathogen infection is the fifth largest contributor to infant mortality, causing 374,900 deaths worldwide in 2016. With a direct impact on nutritional status and on malnutrition-related disease, addressing infant diarrhoea remains a major focus of global public health efforts. Whilst the use of oral rehydration therapy can effectively manage diarrhoea, global stunting prevalence has not significantly decreased. Moreover, standalone nutrition interventions have shown the greatest effect addressing the immediate determinants of nutrition, with less evidence for stunting prevention. The Water, Sanitation and Hygiene (WASH) sector has become increasingly aware of the correlation between poor WASH and malnutrition. However, recent randomised controlled trials have shown negligible or no impact from either WASH, nutrition, or combined interventions on infant health. Whilst thorough in design, these interventions focused on improving sanitation, point-of-use water treatment and hygiene promotion, perhaps not sufficiently interrupting the complex pathways between environmental contamination and infection to improve infant

health. Furthermore, interventions overlooked managing the substantial burden of enteropathogen contamination from domestic animals. Whilst the amount zoonoses contribute to enteric infection is uncertain, the significance of faecal contamination in diarrhoeal incidence means exposure to domestic animals and their faeces is a clear risk factor for infant health. Faecal contamination of the domestic environment is a key source of enteropathogens to infants whereby through normal hand-to-mouth behaviours, contaminated hands and floors contribute to infection and stunting. In a small formative study, we used microbial analysis and survey and observational data to characterise bacterial transmission pathways to infants in the home, considering WASH facilities, infant behaviours and animal exposure. Infants frequently mouthed their own hands or their caregivers (mean 31 and 21 times per hour respectively) which were both frequently visibly dirty (90% and 86% respectively). Microbial swabbing showed common contamination of hands and domestic floor surfaces from thermotolerant coliform bacteria, suggesting infants were frequently exposed to faecal pathogens through linked transmission pathways. Domestic animal husbandry practices, such as keeping animals inside, contributed significantly to contamination across these pathways (all $p < 0.005$). There was no evidence that coverage of latrine facilities mitigated contamination across infant ($p = 0.76$) or maternal ($p = 0.86$) hands or floor surfaces ($p = 0.36$). Our results suggest that WASH interventions are unlikely to interrupt faecal-oral transmission to infants if animal husbandry is not considered. Furthermore, any intervention designed to improve infant health may have limited effect when animals are present. The 2030 targets for the Sustainable Development Goals to eliminate direct and indirect exposure to human faeces would still miss risks associated with animal faecal exposure. Similarly, new, more targeted programmes such as the 'Baby WASH' initiative may reduce infant zoonotic transmission and diarrhoea, but large-scale interventions must focus on controlling animal faecal pathogen transmission and limiting infant exposure. Reducing pathogen infection will require considering all key transmission pathways, which may mean reconsidering the basic methodologies of traditional WASH interventions. Malnutrition is a multifactorial problem with multifactorial solutions. Nutrition, WASH and animal husbandry should not be considered 'sectors', but managed strategically together in an aspiration toward genuine 'total environmental hygiene'.

Title: Poultry Raising in Bangladesh: High-Risk Hygiene and Waste Disposal Practices along Pathways for Transmission of Antimicrobial Resistant (AMR) Bacteria

Mahbub Ul Alam, International Centre for Diarrhoeal Disease Research, Bangladesh, Mahbubur Rahman, Abdullah-Al-Masud, Mohammad Aminul Islam, Muhammad Asaduzzaman, Supta Sarker

The unregulated use of antibiotics is linked with intensive poultry farming in developing economies, including Bangladesh. In low-and middle-income countries, the dissemination of antimicrobial resistance (AMR) has also been attributed to contamination, poor public health infrastructure and inadequate waste disposal practices. In Bangladesh, poultry meat alone contributes 37% of the total meat production and at least 6 million people are involved in the industry. We explored direct and indirect human exposure to poultry and waste, focusing on hygiene and waste disposal practices in small-scale poultry production and processing to identify probable pathways for transmission of AMR bacteria. We employed in-depth interviews and structured observations to assess exposures, hygiene behaviours and waste-disposal practices relating to poultry production in Bangladesh. Interviews ($n = 18$) were conducted with commercial poultry farmers, backyard poultry owners, and live poultry market workers. Structured observations were conducted for six-hours in five households, five commercial farms and five urban live bird markets to assess the frequency of transmission/ exposure events in these settings. All interview were analyzed manually after transcription and translation by following thematic analysis and all data from structured observations were analyzed using STATA (version 13). Interviews identified existing practices that can contribute to transmission of AMR bacteria from poultry to humans. In households and farms, untreated poultry waste and carcasses were disposed of on agricultural fields and in water bodies which may contaminate surface water and soil with poultry faeces. Biosecurity precautions were not used, and hands were rarely washed with soap after handling poultry. In urban markets, live poultry slaughter and processing was done on site with bare hands which were subsequently rinsed in water stored in containers without soap. Solid waste from poultry processing was disposed into municipal waste disposal stations and liquid waste was discarded into open drains. Structured observations revealed that workers in live poultry markets had the highest direct contact with poultry and poultry waste, almost tenfold higher than those working in poultry farms or with domestic poultry (59 vs 544 observed direct poultry exposure events) placing them at particularly high risk of exposure to faecal bacteria. All settings lacked biosecurity measures. In 88% (606/689) of observed exposure events, no handwashing took place. Eating and drinking after handling poultry and without washing hands were observed in all three settings. Intervention strategies that reduce environmental contamination should be prioritised to decrease risks of AMR bacterial transmission from poultry. Data on prevalence of risk behaviours and AMR transmission to humans along environmental pathways can inform policy and intervention strategies.

Title: Precipitation and Salmonellosis Incidence in Georgia, United States of America

Debbie Lee, Temple University, Howard H. Chang, Stefanie E. Sarnat, Karen Levy

Compared to other regions of the United States, the southeast consistently has high salmonellosis incidence rates, but the drivers of disease remain unknown. *Salmonella* is regularly detected in the natural environment in this region, leading to numerous exposure opportunities. Rainfall patterns may impact the survival and transport of *Salmonella* in the environment in ways that can affect disease transmission. This study investigated the impacts of short-term precipitation (extreme rainfall events above the 90th percentile of daily rainfall) and longer-term precipitation (rainfall conditions antecedent to these extreme events, categorized into tertiles of eight-week sums of daily precipitation) on county-level salmonellosis counts using negative binomial models. We found that in the counties of the Coastal Plain of Georgia, where *Salmonella* is frequently detected in the environment, extreme and antecedent rainfall conditions had significant impacts on salmonellosis counts. Specifically, in these counties, extreme rainfall was associated with a 5% increase in salmonellosis risk (95% CI: 1-10%) compared to weeks with no extreme rainfall. Antecedent dry periods were associated with a 9% decrease in risk (95% CI: 5-12%) while antecedent wet periods were associated with a 5% increase in risk (95% CI: 1-9%), compared to antecedent periods of moderate rainfall. In models considering the interaction between extreme and antecedent rainfall, extreme rainfall events were associated with an 11% increase in risk (95% CI: 5-18%) when they occurred following

moderate rainfall or wet periods. These estimated effects were substantially magnified when restricting analyses to salmonellosis cases attributed to serovars commonly isolated from wildlife and the environment (e.g. Javiana). Given the observed impact of short-term extreme rainfall events and longer-term rainfall conditions on salmonellosis incidence, efforts to inform the public of the risks of contact with the environment following heavy rainfall events, especially during the rainy season, may be an important aspect of prevention.

Title: Prioritizing Research and Development Pathways for Decentralized Treatment of Bodily Waste

Rebecca Andrus, University of Illinois at Urbana-Champaign, John T. Trimmer, Diana M. Byrne, Hannah A.C. Lohman, Brian T. Hawkins, Jeremy S. Guest

The target of the United Nations' Sustainable Development Goal 6.2 is to provide adequate access to sanitation to the 2.3 billion people who currently live without it. The enormous cost associated with the installation of centralized waste treatment facilities make conventional sanitation options infeasible for many developing communities. Even if cost could be minimized, the disparity between inconsistent land tenure and fixed collection system infrastructure (e.g., sewers) in many developing communities makes centralized systems particularly challenging to implement, suggesting decentralized sanitation facilities will play a critical role in achieving universal coverage (particularly in remote, resource-limited areas). This study evaluates research and development pathways for decentralized bodily waste treatment systems as an alternative to centralized treatment. The research centers on an emerging decentralized treatment technology developed at the Duke University Center for WaSH-AID. The technology separates influent excreta into solid and liquid streams to simplify downstream treatment. The liquid treatment system, composed of ultrafiltration, granular activated carbon, and electrochemical disinfection, reuses treated blackwater as flush water. In the solid treatment process, waste is dried and combusted to eliminate pathogens before ash is transported offsite. The system has been shown to effectively meet ISO 30500 treatment standards for non-sewered toilets, but projected costs must come down to increase the financial viability for developing communities. Using technoeconomic analysis (TEA) and life cycle assessment (LCA), the costs and environmental impacts were quantified under uncertainty. In addition to the existing system design, alternate disinfection processes, use intensities (number of users per day), and detailed design decisions (e.g., pumping rates) were evaluated under a range of potential implementation scenarios (e.g., locations to deploy). Through sensitivity analysis, primary cost and environmental impact drivers were elucidated to prioritize research and development pathways towards increased commercial feasibility. The findings of this work will be used to expedite the development and deployment of the system and inform investment in similar decentralized treatment technologies.

Title: Quantitative Microbial Risk Assessment of Contaminated Private Wells Impacted by Hurricane Harvey Flooding

Anna Gitter, Texas Water Resources Institute

Microbial contaminants were measured in water samples collected from flood impacted wells, located throughout the Gulf Coastal region of Texas, following rainfall from Hurricane Harvey. A quantitative microbial risk assessment (QMRA) was utilized to estimate the human health risks associated with ingestion of contaminated well water. To calculate the risk for a gastrointestinal illness, fecal indicator bacteria (FIB) data, specifically *Escherichia coli* (*E. coli*), was used to develop a reference pathogen dose. A comprehensive human health risk assessment following exposure to contaminated well water, especially from flooding due to a hurricane, has not been conducted. Estimating the potential human health risks associated with drinking well water contaminated with microbial contaminants is instrumental for improving risk communication and developing management practices for well owners affected by hurricane and flood related natural disasters.

Title: Randomized Controlled Trial Evaluating the Effectiveness of the CHoBI7-Program on Handwashing with Soap in Hospitals

Fatema Zohura, Johns Hopkins University, Christine Marie George

Background: Diarrhea is the second leading cause of child mortality globally. For severe diarrhea cases, hospitalization is required. Health facilities in low resource settings are often a high-risk environment for the transmission of infectious diseases, particularly for family members accompanying diarrhea patients to these health facilities. Family members are often responsible for cleaning the feces and vomit of diarrhea patients in health facilities. The Cholera Hospital-Based Intervention for 7 days (CHoBI7) is a water treatment and handwashing with soap intervention that leverages the time patients and caregivers spend in the health facility for WASH intervention delivery. The CHoBI7 program, delivered at the diarrhea patient's bedside, includes a pictorial module on diarrhea transmission, a handwashing station (covered bucket with tap and plastic basin), soapy water bottle (water and detergent powder), covered drinking water vessel with tap, and chlorine tablets for water treatment. Methods: To evaluate the effectiveness of delivery of this intervention on handwashing with soap practices in a health facility setting, we conducted a RCT of the CHoBI7 program among 202 caregivers and their accompanying household members five years of age or older in two health facilities in Dhaka, Bangladesh. The "Standard Message" arm received the standard message in Bangladesh given to diarrhea patients on the use of oral rehydration solution (ORS) at discharge. The "Health Facility Visit + Soapy Water" arm received: (1) the standard message; (2) the CHoBI7 module delivered by a health promoter bedside to the diarrhea patient in the health facility; and (3) a soapy water bottle provided in the health facility. The "Health Facility Visit + Handwashing Station" arm received this same intervention plus a handwashing station which was filled with water by the caregiver during the CHoBI7 module. Within 24 hours after intervention delivery, trained research assistants conducted three-hour structured observations of handwashing with soap practices at the following key events: (1) after contact with feces and vomit, and (2) before food related events. Results: Participants in the Health Facility Visit + Handwashing Station arm had significantly higher handwashing with soap compared to the Standard Message arm at key events (47% vs. 26%) (OR 2.60: (95% CI: 1.18, 5.71)). There was no significant increase in handwashing with soap at key events associated with delivery of the Health Facility Visit + Soapy Water arm compared to the Standard Message arm (30% vs. 26%) (OR 1.21

(95% CI: 0.63, 2.62)). Conclusion: These findings demonstrate that the CHoBI7 module with a handwashing station presents a promising approach to increase handwashing with soap practices in a health facility setting in Bangladesh.

Title: Randomized Controlled Trial of the CHoBI7 Mobile Health Program to Reduce Pediatric Diarrhea

Christine Marie George, Johns Hopkins School of Public Health,

Background: Diarrhea is a leading cause of death in young children globally. Effective WASH interventions are urgently needed to reduce pediatric diarrheal diseases. Mobile health (mHealth) presents a scalable approach for which messages can be sent to households at minimal cost and can serve as valuable cues to action to facilitate behavior change. CHoBI7 Program: The Cholera-Hospital-Based-Intervention-for-7-Days (CHoBI7) is a handwashing with soap and water treatment intervention program delivered by a health promoter bedside in a health facility and through home visits to diarrhea patients and their household members during the 7 days after admission to a health facility. In a RCT of cholera patient households in Bangladesh, the CHoBI7 program significantly reduced cholera and led to sustained improvements in drinking water quality and handwashing with soap 12-months post intervention. In an effort to develop a low cost scalable approach to deliver this program in Bangladesh without the need for in-person visits, we have developed a mHealth module for the CHoBI7 program to reinforce the WASH behavioral recommendations given in the health facility. Methods: To evaluate the efficacy of this program in reducing pediatric diarrhea, we are conducting a RCT of 825 children under 5 years in Dhaka, Bangladesh. Diarrhea patients and their household members presenting at icddr, Dhaka Hospital or Mugda Hospital were recruited for this study. The "Standard Message" arm received the standard message in Bangladesh given to diarrhea patients on the use of oral rehydration solution. The "Health Facility Visit + mHealth" arm received: (1) the standard message; (2) one visit by a promoter to deliver the CHoBI7 pictorial module at the health facility during the time of illness; and (3) CHoBI7 mHealth voice and text messages at least once every two weeks for 12 months. The "Health Facility/Home Visits + mHealth" arm received these same activities plus two home visits by a promoter during the first week of intervention delivery. Monthly diarrhea surveillance was conducted. In this abstract we present the findings from the first 11 months of this ongoing 12 month trial. Results: The CHoBI7 mHealth program resulted in a significant reduction in pediatric diarrhea in both the Health Facility Visit + mHealth arm (Prevalence Ratio (PR): 0.80, 95% CI: 0.67, 0.95) and the Health Facility /Home Visits + mHealth arm (PR: 0.71, 95% CI: 0.60, 0.85). This result suggests WASH mHealth programs present a promising approach to reduce diarrhea among young children. Conclusion: These findings demonstrate that delivery of the CHoBI7 program through a single health facility visit reinforced with WASH mobile health messages can significantly reduce pediatric diarrhea. This result suggests WASH mobile health programs present a promising approach to reduce diarrhea among young children.

Title: READY: Global Readiness for Response to Major Disease Outbreaks: Case Study Presentation on WASH Links to Cholera and Ebola Outbreaks

Marielle Snel, Save the Children,

Infectious disease emergencies, also known as public health emergencies of international concern, have disastrous impacts on families, societies, systems, and economies. The impact of the 2014-2015 Ebola epidemic in West Africa stretched well beyond the estimated 11,210 lives lost or the 28,616 known to have contracted the disease. Many health workers were lost and health systems were unable to cope- severely restricting access to routine and life-saving health services. Millions of children lost months of schooling- many never returned, thousands of children lost parents, siblings, and family members, and disruption to markets and livelihoods had dire consequences for the poorest communities. Major outbreaks in recent years, including influenza Zika, the plague in Madagascar, Diphtheria in Bangladesh and Yemen, and Yellow Fever in DRC and Angola have demonstrated that governments, donors, and aid agencies are severely challenged in their response capacity and coordination, highlighting continued gaps in the global humanitarian community's ability to respond to far- research disease epidemics. In 2018, the United States Agency for International Development (USAID) Office of U.S. Foreign Disaster Assistance (OFDA) awarded Save the Children with a three-year, \$8 million award to lead a global consortium aimed at strengthening capacity for response to major infectious disease outbreaks or pandemics. By diversifying NGO capacity in coordination with other global outbreak initiatives, the consortium known as READY will strive to improve the humanitarian community's response to infectious disease outbreaks that become international humanitarian emergencies, and even prevent many from ever becoming global. Operational consortium members will be supported to build and retain standing capacity to more quickly and effectively respond to large-scale disease outbreaks. The program will also design and roll-out a multi-sectoral response approach that seeks to address the holistic needs of outbreak-affected communities- with community engagement and communications at the heart of the program design. This presentation will focus on how READY works in relation to WASH related outbreaks specifically Ebola and Cholera. READY brings together leadership from Save the Children (SC), JHU's Center for Humanitarian Health (JHU-CHH), JHU's Center for Communication Programs (JHU-CCP), UK-Med, MERCY Malaysia (MM), and EcoHealth Alliance (EHA) to fill critical gaps in outbreak response capacity and capability by leveraging the best parts of what works across our operational, academic, clinical, and communications organizations. The presentation will provide case study examples from the Middle East (Yemen), Africa (DRC) and Asia (Bangladesh) in terms of technical coordination through platforms to ensure effective and integrated multi-sectoral approaches to these major outbreak responses; strengthening the operational capacity of organizations to more efficiently launch an integrated humanitarian response to infectious disease outbreaks and pandemics; and developing an effective technical preparedness and readiness across relevant sectors for WASH responses.

Title: Recommendations for Bucket Chlorination Implementations in Emergency Contexts and Cholera Outbreaks

Gabrielle String, Tufts University, Mustafa Sikder, Yarmina Kamal, Annie Huang, Karin Gallandat, Daniele Lantagne

Bucket chlorination (BC) is a commonly implemented intervention for water treatment employed during emergency situations, such as cholera outbreaks. In a BC program, agents are stationed near a water source and dose beneficiaries' water containers with chlorine. Guidelines provide two

different recommendations for chlorine dosage: a fixed dosage (2 mg/L for <10 NTU or 4 mg/L for >10 NTU) or a variable dosage (determined via jar testing) that provides a free chlorine residual (FCR) of 0.5 mg/L 30 minutes after treatment. To understand the efficacy of these guidelines and implementation factors that impact their effectiveness, we are investigating bucket chlorination in a laboratory study and field evaluations. In the laboratory, we assessed the inactivation of *Vibrio cholerae* in the aqueous phase by treating with three different chlorine types at the recommended dosages in prepared waters of varying turbidity and total organic carbon (TOC) concentration. Samples were analyzed via spread plates and viability qPCR for the presence of culturable and viable but nonculturable *V. cholerae* 30 minutes and 24 hours post-treatment. FCR was monitored at 30 minutes, and 4, 8, 24 hours. Finalized results expected Spring 2019 include whether recommended dosages inactivate *V. cholerae* and can maintain a 0.2 mg/L FCR 24 hours after treatment. Preliminary results indicate that most chlorine types and dosages achieved >3-log reduction in *V. cholerae* 30 minutes post-treatment. At 24 hours, culturable *V. cholerae* was present in ≥ 5 NTU water when it was not detected at 30 min, indicating regrowth after incomplete inactivation. Furthermore, variable dosages provided higher FCR at 30 min than fixed dosages for high TOC water. For field evaluations, we developed a mixed methods protocol for assessing programs to understand: the implementation modalities of response organizations, the effectiveness of bucket chlorination in meeting program goals, and the perceptions of the intervention by program staff and beneficiaries. To accomplish this aim, we conducted key informant interviews, structured observations of chlorination points, chlorine concentration testing, focus group discussions, and household surveys. Additionally, drinking water samples were collected in the household and at the source for microbiological and FCR testing. To date, four evaluations have been completed in DRC (2), Cox's Bazar (1), and Haiti (1), including 40 chlorination points and 702 associated households. One additional evaluation is planned (April). Preliminary results indicate variability in average chlorine concentration (0.18-3%), when targeting a solution of 1%, and varied chlorine solution preparation, testing, storage, and dosing protocols. Despite high variability in program implementation, *E. coli* levels were generally reduced from the source to storage in a majority of households 30 minutes post-treatment; however, presence of total coliforms and non-detect FCR (80% and 11% of households respectively) indicates recontamination risk and the importance of safe household management practices. This presentation will include results from the laboratory study on the efficacy of chlorine types and dosages at inactivating *Vibrio cholerae* as well as six field evaluations on the effectiveness of BC interventions and program challenges. Conclusions will provide the basis for the development of recommendations to align existing guidelines.

Title: Relating Antimicrobial Resistance and Virulence in Surface Water *E. coli*

Connor LaMontagne, UNC Chapel Hill, Elizabeth C. Christenson, Anna T. Rogers, Megan E. Jacob, Jill R. Stewart

While the role of the environment in the spread of antimicrobial resistance (AMR) is being increasingly recognized, little is known about the carriage of virulence among resistant bacteria in environmental systems. Associations between virulence and AMR may assist in understanding some of the health risks these organisms pose. However, few studies have evaluated such relationships in the environment, and results from human and animal-associated isolates have been inconsistent. Using *E. coli* isolated from surface waters in Eastern North Carolina, we aimed to compare virulence gene prevalence between isolates resistant and susceptible to antibiotics. We also assessed if this comparison changes between isolates from watersheds with or without commercial hog operations (CHOs) – a potential contributor to environmental resistance. Of 912 isolates previously evaluated for susceptibility to 11 antibiotics, a subset of 127 pairs (254 total isolates) was created by matching resistant and susceptible isolates from the same sample date and site. These pairs were tested for the presence of seven virulence genes (*bfp*, *fimH*, *CNF1*, *STa*, *EAST1*, *eae*, and *hlyA*) via PCR. At least one virulence gene was detected in 24.7% of isolates. An exception to this was *fimH*, which was found in 93.1% of isolates, and which was excluded from further analyses to avoid masking the results of the less common genes. Overall, resistance to at least one antibiotic was negatively associated with presence of at least one virulence gene (OR: 0.44; CI: 0.21, 0.89). Deeper investigation revealed that tetracycline resistance was a negative predictor of the presence of at least one virulence gene (OR: 0.46; CI: 0.21, 0.95), and that resistance to at least one antibiotic negatively predicted presence of the gene for *E. coli*/heat-stable enterotoxin (*STa*; OR: 0.19; CI: 0.028, 0.77). Associating tetracycline resistance and *STa* presence also returned a negative association (OR: 0.24; CI: 0.036, 0.99). To our knowledge, this is the first evidence of a negative association between virulence and AMR in surface water isolates.

Title: Rethinking Community: Prediction of Household Toilet Ownership is Sensitive to Geographical Scale Selection and Neighbor's Characteristics

Jinyi Kuang, University of Pennsylvania

Background: Household's sanitation decisions are influenced by the characteristics of others in close geographical proximity. In the sanitation literature, the adoption of predefined administrative boundaries or other agency-defined zones (e.g., census blocks) is a common approach used to delineate geographical units. However, this approach may be problematic due to: 1) administrative units being drawn for general purposes that are not tailored to specific sanitation problems; 2) administrative units not always capturing relevant social ties that influence sanitation behaviors. In particular, these arbitrary delineations might fail to capture the organic connections that arise across units that may have more influence on sanitation behaviors. In addition, the cluster-level effect (i.e., the ratio of latrine ownership) is particularly sensitive to the choice of geographical scale. Therefore, to improve our understanding of toilet construction decisions, it is important to empirically demonstrate the spatial dependence of toilet construction and its sensitivity to the choice of unit scale. Method: Data were drawn from 24 clusters in Tamil Nadu, India. To map toilet distribution, we performed spatial autocorrelation analysis and interpolate the predicted probability of owning a toilet spatially. To examine the degree to which the neighbors' demographic characteristics are related to a household's propensity to construct a toilet, we first divided administrative units into squared sub-clusters, then developed fixed effects spatial regression allowing for spatial factors in both the dependent and the explanatory variables. To determine how the spatial dependence of toilet ownership diminishes as the sub-cluster scale increase, we performed a sensitivity analysis to quantify this effect. Results: We found considerable spatial heterogeneity in household latrine ownership both between and within administrative units. Clusters with high toilet ownership tend to be concentrated geographically, indicating contextual and social factors might influence a household's propensity to construct a toilet. This geographical dependency diminishes when a coarser subscale was applied.

Implementation: Our method allows for the creation of higher resolution maps to visualize the variation in household toilet distribution. It provides a more comprehensive profile of toilet ownership inequalities within an administrative unit. Our results map the statistical prediction to a realistic map for visualization, which will facilitate practitioners to comprehend the statistic result and identify intervention areas with an evidence-based approach. Our spatial model provides programs designer a feasible tool to guide the uptake of equity-sensitive policies.

Title: Risk Factors of Human Fecal Contamination in Urban Mozambican Households in the MapSan Trial

David Holcomb, University of North Carolina at Chapel Hill, Jackie Knee, Trent Sumner, Joe Brown, Jill Stewart

We assessed the sources and extent of fecal contamination in compounds—household clusters sharing an outdoor courtyard and sanitation facilities in poor condition—in unplanned, low-income neighborhoods of urban Maputo, Mozambique. Samples were collected at five nodes of potential transmission and exposure: source water, stored water, food preparation surfaces, latrine entrance soil, and household entrance soil. Sociodemographic, sanitary, and child health surveys were administered concurrently, and latrine sludge and fresh animal feces were collected opportunistically when encountered during sampling activities. We obtained daily meteorological records from the Maputo airport weather station through the NOAA NCEI database. Each sample was analyzed for five locally validated microbial targets: culturable general fecal indicator *E. coli* (cEC), molecular *E. coli* marker EC23S, human-associated molecular markers HF183 and Mnif, and avian-associated molecular marker GFD. Molecular target concentrations were estimated from standard curves fit using Bayesian multilevel models, in which the slope and intercept were permitted to vary by instrument run and processing batch to account for instrument variation and target loss during sample processing. To identify risk factors of fecal contamination, we estimated associations with sociodemographic, meteorological, and physical sample characteristics for each microbial target and sample type combination using Bayesian censored regression for target concentration responses and a Bayesian logistic regression for target detection status. We collected 366 samples from 94 households in 58 compounds. At least one microbial target was detected in 96% of samples (353/366), with both *E. coli* targets present in the majority of samples (78%). Human targets were frequently detected in soils (59%) and occasionally in stored water (17%) but seldom in source water or on food surfaces. The avian target GFD was rarely detected in any sample type but was most common in soils (4%). *E. coli* was also more abundant than human targets: mean EC23S and HF183 concentrations were respectively 6.5 and 3.8 log gc/dry g of latrine soil and 4.3 and 1.4 log gc/100 ml of stored water. Associations with risk factors were generally weak and often inconsistent in sign between different targets and sample types, though relationships were somewhat more apparent for physical sample characteristics. In particular, wet soils were associated with elevated concentrations of cEC and EC23S and odds of detecting HF183. Water storage containers with wide mouths, lacking lids, or extracted by dipping—characteristics that provide opportunities for hand contact—were all weakly associated with increased odds of human target detection. Our results describe a setting impacted by pervasive domestic fecal contamination, including from human sources, that is largely disconnected from local variation in socioeconomic and sanitary conditions. This pattern suggests that in such heavily burdened settings, transformational changes to the community environment may be required before meaningful impacts on fecal contamination can be realized.

Title: Ruminant Fecal Contamination Introduced to Drinking Water after Collection from Shared Water Sources in Rural Kenya

Latifah Hamzah, Stanford University, Amy J. Pickering, Marlene Wolfe, Jenna Davis, Alexandria Boehm, Angela Harris

In rural Kakamega county, Kenya, many families travel to collect water and store it in their homes for daily use, with contamination after collection a concern. Thus, this study aims to: i) compare the differences in the levels and origins of fecal contamination between source and stored drinking water, and ii) identify combinations of household characteristics that are associated with contamination. Stored and source water samples were collected from 45 households and analysed via culture methods for *E. coli* and enterococci indicator bacteria as well as molecular microbial source tracking (MST) assays for human (HF193 taqman), avian (Avian GFD), and ruminant (BacR) contamination. Assay validation was conducted using fecal samples collected on site and assessed for sensitivity and specificity using quantitative and binary methods. Stored water samples had similar *E. coli* concentrations as source water, but elevated enterococci concentrations ($p < 0.01$, Wilcoxon matched-pairs test). In addition, the ruminant target was detected more often in stored than source water samples (89% vs 27%, $p < 0.01$, McNemar's exact test). However, the avian and human targets were only detected in a small fraction of samples (4% in both cases), with the differences between source and stored samples not statistically significant. Given that the results suggest ruminant contamination is often introduced after collection from the source, fuzzy-set quantitative comparative analysis (fsQCA) was employed to highlight different combinations of household characteristics that are each associated with ruminant fecal contamination of stored water. fsQCA was conducted on the subset of households that had no source water contamination, with the characteristics included comprising ruminant presence in the compound, floor material, hand washing during critical times, water management practices during storage and retrieval, education, and assets. The combinations identified can help identify cost-effective strategies for protecting water quality during collection, transport and in-home storage.

Title: Rural Water Service Provision: 5 Years of Experience in 40 Communities of Mexico

Ane Galdos Balzategui, Cantaro Azul, Fermín Reygadas, Héctor Castelán, Wendy Nicolás, Antolín Diezmo

The lack of safe water creates a tremendous burden of diarrheal disease and other debilitating, life-threatening illnesses for people in the developing world. Household water treatment and safe storage (HWTS) provides a solution, when employed correctly and consistently for managing water safety at home. However, the sustainability of HWTS remains a major issue. Many have recently argued to achieve high levels of sustained safe water provision there is a need to move away from the 'de-facto' focus on provision of hardware for first-time access and shift to post-construction support, or as others refer to it as "service delivery" (i.e. provision of a lasting service). This paper presents the results of an implementing organization's experience shifting from HWTS hardware provision to service delivery and its impact on the continued use and functionality of HWTS in rural communities. Interviews and technical functionality assessment of HWTS were carried out with 645 households in 26 communities located in

southern Mexico respectively (approximately 3700 persons). Each household had received a HWST (Mesita Azul, a UV water disinfection system, or a ceramic filter) and support from the Cantaro Azul Foundation in the proceeding 5 years. On average a family consumed 48.5L of safe water from the HWTS per week (1.46L per person). We found during our technical assessments 32% of households (n = 208) currently had a technical issue and 60% of the households had safe storage disinfected water. While the majority of HWTS were functioning properly at the time of the survey (68%), of these households with properly functioning systems only 12% reported they had discontinued use of the systems. Our results indicate shifting to service provision has resulted in continued functionality and consistent use of a HWTS in a low-resource, rural setting. As an implementing organization, we found retaining a consistent presence in a community and providing a lasting service had a strong positive impact on a household's ability to obtain and consistently consume safe drinking water. Our findings will hopefully provide evidence to research organizations, other implementing organizations, governments, and donor organizations that shifting to 'service delivery' strategies may improve the functionality of HWTS schemes and support/donor structures need to shift as well in order to achieve lasting results in target communities.

Title: Savings Groups: Unlocking Financing for Rural Water Operations and Maintenance

Chris Prottas, The Water Trust, Angeliqne Dioguardi

45% of water points in rural Uganda are estimated to be non-functional, and just 18% meet basic standards of yield, quality, and reliability. The performance of volunteer-led management committees has been, at best, inconsistent. Most water points have \$5-10 in funds for maintenance or repairs, if they have any funds at all. This reality might seem inevitable in communities where two-thirds of households report no cash savings at home or in an institution. However, we found that by creating savings groups in catchment areas groups of 30 households can mobilize \$1,500 in shared savings and interest, and collect \$100 to \$150 in a year for their water point. After an initial pilot in 18 communities in 2017, we have now trained more than 140 savings groups that finance maintenance and repairs for their associated water point. The initial results noted above have since been replicated in year two for the initial pilot, and in the expansion efforts. In addition, we have found the savings groups' well-attended weekly meetings to be effective platforms for hygiene and sanitation promotion. This intervention is an adaptation of the well-established Village Savings and Loan Association methodology, which itself has a long history and well-established evidence base a replicable, scalable model for creating robust, self-sustaining community financial institutions. After implementing and refining this approach for more than two years, we will also share operational challenges and lessons learned on integrating this component into a water, sanitation, and hygiene organization. We will also discuss the limitations of savings groups as vehicles for financing water supply, and where we conceive of savings groups fitting in a broader system of sustainable water service.

Title: Social Capital and Community Health Clubs in Haiti

Jason Rosenfeld, UT Health San Antonio, Blondel Joseph, Sophie Ravanbakht, Jude Francois, Ruth Berggren

One of the challenges facing WASH programs is that water and sanitation infrastructure are generally collective goods, while WASH behaviors involve individual responsibilities nested within collective norms, values and culture. Social capital is theorized to facilitate collective action and enhance the diffusion of water-related behavioral interventions by enhancing social cohesion and collective action. However, our understanding of how social capital influences WASH programs and facilitates changes in WASH behaviors and collective action remains limited. We used a mixed methods study to assess the relationship between social capital and a Community Health Club (CHC) program. We conducted a secondary analysis of data from a quasi-experimental evaluation of a CHC program in Haiti and held six focus groups with program participants and implementers. We tested three hypothesis using multi-level linear regression models: 1) intervention respondents would have significantly greater increases in social capital, WASH knowledge, and WASH behaviors than comparison respondents after a one year intervention; 2) intervention respondents would have significant increases in WASH knowledge and behaviors, independent of baseline social capital; and 3) social capital would partially mediate the effect of the CHC intervention on respondent's WASH knowledge and behaviors. Our primary outcomes included social capital (trust, group participation, social solidarity and social support), WASH knowledge (four question composite score), and WASH behavior (score from 16 structured observations). We used inductive and deductive methods to analyze the qualitative data collected from the focus groups where participants identified and described the factors that influenced perceived changes in WASH behaviors and collective action. We measured significant increases in average WASH knowledge scores among CHC-members ($p < 0.0001$), but no effect was observed on WASH behaviors. We also measured a marginally significant decrease in trust and social solidarity scores ($p = 0.07$) among CHC members from baseline to final. Further, baseline social solidarity scores were associated with a significant increase in WASH behaviors ($p = 0.03$). Finally, we found a marginally significant interaction between the intervention and participation scores on average WASH knowledge scores ($p = 0.08$) and a significant interaction between the intervention and social solidarity scores on average hygiene index scores ($p = 0.04$). None of the social capital measures were statistically significant mediators of the CHC intervention on WASH knowledge or behaviors. Qualitatively, discussion participants noted how CHCs disseminated knowledge and promoted WASH behavior change and collective action in intervention communities, built strong social bonds based upon trust and a sense of social solidarity, and how CHCs used trust and social solidarity to influence behavior change and collective action. We present a framework describing the ways in which social capital, as generated through a CHC program, influences WASH behaviors and collective action. As the first attempt to measure and document the relationship between social capital and a CHC intervention in Haiti, we find these results encouraging. Our results and framework describing the relationship between social capital and a CHC program advance our understanding of the relationship between social constructs and WASH behavior change programs generally, and should be utilized by CHC practitioners and evaluators to enhance program implementation and evaluation.

Title: Source Tracking Microbial Communities from Rooftop Harvested Rainwater to Irrigated Soil and Produce

Suhana Chattopadhyay, University of Maryland, L. Malayil, S. Allard, E.F. Mongodin, R.E. Rosenberg Goldstein, A.R. Sapkota

Rooftop harvested rainwater (RHRW) is gaining interest as a potential irrigation water source. Previous studies have indicated the presence of both biotic and abiotic factors affecting RHRW quality. However, very few studies have investigated the potential transfer of microorganisms, particularly metabolically active bacteria, from rainwater to irrigated soil and produce. To bridge this knowledge gap, we tracked and characterized metabolically active bacteria from irrigation water (ambient rain, first flush tanks, secondary tanks and municipal water) to irrigated soil and produce (chard) using two different DNA labeling techniques (5-bromo-2'-deoxyuridine (BrdU) and propidium monoazide (PMA)) coupled with next generation sequencing techniques. A total of 186 samples (irrigation water=36, soil=90 and produce=60) were collected from a vegetable raingarden in Maryland, U.S.A from June to August 2018. Subsamples were treated with BrdU and PMA. DNA from all treated and non-treated samples was extracted and PCR-amplified for the V3-V4 hypervariable region of the 16S rRNA gene and sequenced using the Illumina HiSeq 2500. The sequencing data were analyzed using QIIME, multiple R packages and SourceTracker. Additionally, both water and soil characteristics were recorded for the sampling period. Irrespective of sample type, BrdU-treated samples were characterized by statistically significantly lower alpha diversity. The top ten bacterial phyla identified across all samples irrespective of treatment were Proteobacteria, Actinobacteria, Bacteroidetes Firmicutes, Chloroflexi, Acidobacteria, TM7, Gemmatimonadetes, Planctomycetes and Thermi. Bacterial profiles common to both BrdU-treated and PMA-treated samples, irrespective of sample type, were *Pseudomonas veronii*, *Pseudomonas lurida*, *Sphingomonas* spp., *Aeromonas* spp., *Pseudomonas* spp., *Arthrobacter* spp., *Sediminibacterium* spp., *Bacillus* spp., *Janthinobacterium lividum*, *Curvibacter lanceolatus* and *Geobacillus thermodentrificans*. Additionally, metabolically active *Escherichia*, *Enterobacter*, *Citrobacter* and *Enterococcus* were observed in all sample types in BrdU- treated samples. Using the SourceTracker tool we were able to track and quantify the relative contributions of the irrigation water to the bacterial community of the irrigated produce. The knowledge and ability to track metabolically active bacterial pathogens from irrigation sources is critical, as these pathogens can be transferred from water sources to food crops, resulting in foodborne outbreaks. Our preliminary findings 1) suggest that these contamination events can occur through the use of RHRW to irrigate food crops; and 2) can be applied to develop appropriate on farm RHRW treatment technologies prior to irrigation.

Title: Spatial Proximity to Wastewater used for Irrigation and Childhood Diarrhea in the Mezquital Valley, Mexico

Jesse Contreras, University of Michigan Rob Trangucci, Horacio Riojas-Rodríguez, Rafael Meza, Jon Zelner, Joseph N.S. Eisenberg

Wastewater reuse for agriculture is a common practice worldwide with important benefits to climate resilience and water conservation. Associations between local presence of wastewater reuse and negative health outcomes have been found in past research across the globe, but little information exists on the relevant routes of exposure between wastewater reuse and poor health. The Mexico City-Mezquital Valley system is one of the largest wastewater reuse systems in the world and has been the site of key epidemiological studies on wastewater and health. To understand the potential importance of environmental routes of exposure, we assessed the relationship between diarrheal disease in children and spatial proximity to wastewater canals using data from a longitudinal cohort study. We enrolled 581 households from communities in the Mezquital Valley that use wastewater for irrigation. A total of 1,664 surveys were completed during three rounds of interviews. Interviewers collected GPS coordinates of participating households, and local authorities provided digital maps of the wastewater canal system. The shortest distance between a study household and a wastewater canal was calculated in meters (m) using GIS software. The association between distance to a canal and diarrheal disease in children under five was estimated in a hierarchical Bayesian logistic regression model accounting for repeated observations and residual spatial correlations. To account for a non-linear association, household distance was transformed to its natural log. After adjusting for relevant covariates, living farther from a wastewater canal was associated with decreased diarrheal disease in children (100m vs. 10m OR = 0.55, 95% CI 0.33, 0.91; 1,000m vs. 10m OR = 0.30, 95% CI 0.11, 0.82). These results suggest occupational and foodborne exposures are not the only important routes of exposure between wastewater and health, and community exposures may be driving negative health effects. Instead of only targeting specific groups, interventions should focus on whole communities to improve health where wastewater is reused.

Title: Strengthening Evidence of Gender Outcomes in WASH: A Review of Methodologies for Gender Evaluation

Jess MacArthur Wellstein, Institute for Sustainable Futures - University of Technology Sydney, Naomi Carrard, Juliet Willetts

The centrality of women's interest in WASH and the role of WASH in influencing gender equality and empowerment are well established. At the programming level, strong evaluation is key to understanding gender outcomes arising from WASH interventions and to ensure activities contribute to – and don't inadvertently undermine – increased gender equality. There is an opportunity to learn from the breadth of disciplines and approaches used in gender research and evaluation in order to strengthen evidence about the impacts of WASH on women and gender equality. To distill knowledge about current gender research and evaluation approaches, we conducted a systematic review of development-related academic literature; seeking empirical examples of gender focused research and evaluation. The search interrogated the breadth of disciplines driving gender research and evaluation approaches, such as anthropology, development, economics, geography, gender studies, psychology, and sociology. It also identified the relative prevalence of different sectors where gender research and evaluation has been undertaken, including agriculture, education, governance, and public health. We then analyzed these studies according to their theoretical foundations, methodology(ies) and domains of inquiry. Our review found two main clusters of typical research and evaluation within the literature. The first cluster had a strong emphasis on analyzing the factors which could classify a woman as empowered. These studies typically relied on quantitative analysis of secondary data, and therefore are centered on readily measurable and available insights into women's lives. The second cluster reported how women were empowered through participation in a particular activity. These primarily qualitative studies reported a range of research approaches, though less explicitly articulated their methodological foundations. Additionally, we found that programs with an indirect application of gender commonly had a limited conceptual framing of gender equality. Narrowing in on unique and outlying cases beyond these two clusters, we identified and analyzed innovative concepts

and approaches most relevant to the WASH sector. These included innovative methodologies such as those addressing intra-household inequality and those with a focus on strengths through appreciative inquiry. We also identified new ideas for domains of inquiry, such as physical space, agency within and beyond the household, and the ability to critically analyze one's place in society. Insights from the systematic review – in terms of both evaluation approaches and domains of inquiry – can inform strengthened evidence of the ways in which WASH programs influence gender equality. These research findings will be useful to design rigorous, relevant and practical evaluation approaches for WASH sector programs, particularly those seeking to generate transformative gender equality outcomes.

Title: Supply and Demand: Assessing Costs and Willingness-to-Pay for Urban Sanitation in Bangladesh, Ghana, and Kenya

Rachel Peletz, Aquaya, Caroline Delaire, Alicea Cock-Esteb, Joan Kones, Guy Norman, Ranjiv Khush

Low-income households often cannot afford the costs of high-quality sanitation: constructing and managing safe on-site sanitation facilities, or connecting to sewerage networks when present. As a result, efforts to implement pro-poor sanitation solutions are likely to require a mix of both market finance (consumer contributions) and public finance (comprised of government funds, donor contributions, and, in some cases, “rich-to-poor” cross-subsidies). In most developing world cities, however, the extent to which low-income households can finance their own sanitation solutions, and the sizes of financing gaps, are largely unknown. This research compares the costs of selected sanitation solutions with household willingness-to-pay (WTP) in low-income urban areas in five cities across three countries: Rangpur, Bangladesh; Kumasi, Ghana; and Malindi, Kisumu, and Nakuru, Kenya. Our study methods include (i) detailed life-cycle costing models to accurately measure capital and operating costs, (ii) double-bound dichotomous choice WTP surveys, and (iii) real-money, randomized voucher trials of pit-emptying services and sanitation hardware. Our preliminary results indicate large gaps between consumer WTP and actual costs for sanitation services and hardware. In Kisumu, households were willing to pay on average 21 USD for vacuum truck pit emptying services and 32 USD for improved manual pit emptying services, which represents less than 50% of actual costs; actual prices were 40-60 USD for vacuum trucks and 60–130 USD for manual emptying. Financial gaps were even greater for sanitation facilities. Households were willing to pay an average of 191 USD for a high-quality pour-flush toilet to pit latrine and 203 USD for a pour-flush toilet to sewer, which represents less than 30% of actual capital costs (920 USD and 720 USD, respectively). Similarly, WTP for container-based sanitation services was 1.9 USD per month, approximately 32% of the actual cost. We will present similar results from all five cities, also including comparisons of revealed vs. stated WTP and installment vs. lump sum payment WTP. We will also provide calculations for the financing required for city-wide sanitation solutions. This study demonstrates rigorous WTP and costing methods, and quantifies the financial gap required to provide high-quality sanitation services to low-income urban communities.

Title: Supporting Adoption of Solar Pumping Solutions among Humanitarian Actors: 10 Country Learning on Common Misconceptions

Asenath Kiprono, Oxfam GB, Ibanez Llarío Alberto, United Nations Agency for Migration (IOM),

Recent technology advancements and cost reduction in solar and pumping technology has offered the possibility to use solar photo-voltaic (PV) pumping solutions for a vast range of contexts and locations. Use of clean energy solutions such as solar PV ones in water supply projects contributes towards achievement of both SDG 6 and 7. One of the components of the Global Solar & Water Initiative (GLOSWI) has been the support to WaSH actors in their efforts to adopt and/ or scale up the use of solar PV technology in their water supply projects. With this aim, a number of open-access activities have been carried out since 2016, including a number of technical training, onsite visits to over 70 refugee/ IDP camps and host villages in 10 countries (mostly in the East African Region), online resolution of over hundreds of queries and other different interactions with 93 different WASH organizations, all around the topic of solar pumping. While solar PV pumping adoption is becoming increasingly popular among WASH stakeholders, also in emergency situations and first phase camp contexts, little efforts have been done to capitalize on experience and document problems often encountered when using these solutions. This session will highlight findings on common misconceptions and mistakes that were almost systematically encountered as the GLOSWI team move from country to country. Based on a broad review of cost analysis comparisons of 80 water schemes with different layouts, power sizes and pumping technologies, onsite technical analysis of 70 solar water schemes, meetings with private sector contractors from 10 countries as well as over 100 interviews with WaSH Committee members, water operators and/ or field engineers, this session will summarize findings and briefly discuss 3 broadly found misconceptions in the adoption and use of solar pumping solutions by WASH humanitarian stakeholders. These are 1) wrong perceptions in cost saving and break even periods incurred for different power sizes and layouts of solar systems in various Sub-Saharan countries, 2) common current practice in tank sizing for solar water schemes and its limiting effects in the supply side and 3) water re-pricing related to solar pumping adoption and its effect for long term maintenance of water schemes. This session will also briefly provide details on learning and the improvements in support materials and methods that GLOSWI has developed and tested.

Title: Sustaining Urban WASH Services through Finance and Governance Reforms in India: Ex-Post Evaluation Lessons

Leslie Hodel, Social Impact, Elizabeth Jordan, Holly Dentz

Background: India's rapid urbanization demands a sustainable approach to ensure the Government can plan and finance urban water and sanitation to meet expanding demand. We conducted an ex-post evaluation of the USAID-funded Financial Institutions Reform and Expansion-Debt and Infrastructure (FIRE-D) activity to explore whether governance and financial reforms as well as private and market-based financing were sustainable seven years after the end of the project. FIRE-D was implemented in 16 states across India from 1994 to 2011. It used pilots and large-scale activities to test approaches to improve decentralized WASH governance, local capacity to plan and manage water and sanitation services, financial management, revenue stability, and alternative financing options, including the introduction of municipal credit ratings and bonds. The most successful solutions were then expanded and incorporated into a large Government of India (GoI) urban development scheme. Methods: The team purposively selected six states and six cities where FIRE-D conducted activities representing a wide variety of contexts, intervention types, and

perceived levels of present-day success. In March 2018, the evaluation team reviewed secondary data on municipal water and sanitation access and completed 49 key informant interviews with stakeholder groups representing national, state, and municipal government; utilities; informal settlement advocacy organizations; former implementers; and donors. Results: In most of the cities evaluated, the proportion of households with piped water service and household toilet access increased or remained the same since FIRE-D ended despite population growth. Several reforms and practices introduced by FIRE-D remained in effect seven years after the project ended. FIRE-D municipal accounting reforms are still in effect in supported sites, and the GoI has expanded FIRE-D's accounting system across the country by tying this reform to its WASH scheme grants. Most municipalities noted improvements to revenue stability since FIRE-D ended. Some attributed this to in part to initiatives promoted through FIRE-D such as municipal asset mapping, property tax reform, and e-governance platforms. However, inefficient tax and tariff payment recovery continues to cripple several cities evaluated, impairing their ability to access private or market-based finance for WASH development. Through its large WASH schemes, the GoI has continued to promote and expand municipal credit ratings, as initially piloted by FIRE-D. However, interest in and uptake of market-based financing was generally low across evaluation sites given the abundance of government or donor grant funding or other lower cost, less administratively burdensome financing options. The evaluation also observed very low interest in public-private partnerships for urban water and sanitation development due to a perception that inefficient user fee collection and political incentives to keep tariffs low impair their commercial viability or profitability. Conclusions: This evaluation illustrates the interlinked governance and financial forces that influence urban water and sanitation sustainability. It particularly highlights the great importance of partnering with a committed government, as USAID did, to achieve sustainable WASH governance and financial reforms. It also illustrates the interplay of public financing with alternative options and the fundamental importance of establishing municipal revenue stability as a precursor to accessing private or market-based financing options.

Title: Swachh Survekshan - Tool for scaling up Decentralized Wastewater Treatment (Faecal Sludge Management) service delivery in India
Kalimuthu Arumugam Pillai, WASH Institute, Abhinav Akhilesh

On the other hand, FSM is not recognized as the city government's responsibility, largely because of three reasons—one, cleaning of septic tanks is considered the responsibility of a household; second, FSM is not in the essential list of responsibilities of city governments in most states; and third, network systems are considered as the ideal solution. Currently, FSM services in cities is largely limited to desludging, and that too mostly by unregulated private players who more often than not, dispose it in the open environment. Thus, the major challenge for the Government of India today remains to identify ways of encourage city governments to provide FSM related services and to take measures for treatment for fecal sludge. To address this challenge, WASH Institute and KPMG India as National Program Management Unit (funded by USAID and BMGF), helped Indian Government to introduce an innovative approach—introducing competition through an annual ranking survey (Swachh Survekshan) to encourage cities towards sanitation including FSM service delivery. This annual survey ranks cities on cleanliness, sanitation, and related service delivery. It was first introduced in 2016 in 73 cities, and has now been scaled up to all 4203 statutory cities in the country. The survey measures progress by triangulating data on service level progress, direct observation and citizen feedback. The survey, one of its kind, and the largest of its sort in the world, uses field level survey, third party verification, and use of ICT in engaging city governments and citizens as the methodology to rank cities on cleanliness and sanitation. The large scale impact of this exercise pushes city governments for action on achieving results on all indicators on sanitation including FSM. The findings of 2018 and 2019 survey indicate that it has been very instrumental in affirming the need to manage fecal sludge which was otherwise ignored by city governments earlier. The survey has encouraged cities to undertake measures to provide for, regulate, and deliver FSM services. The presentation will share city level findings from the survey, and different approaches adopted by cities to deal with the challenge of fecal sludge management. In this process, the presentation will provide insights on how cities can be motivated to provide FSM services in a country with an urban population of around 400 million and in a short span of time which otherwise would have taken more than a decade.

Title: Tackling the 'Political Will' Problem: How Local Leadership Development Has Accelerated Sanitation Uptake in Cambodia
Allison Salinger, WaterSHED, Janita Bartell, Pavle Vizintin, Sophy Ny, Nareth Chhoun, Marion Jenkins

Background: WaterSHED's Civic Champions program engages elected commune councilors in rural Cambodia to iteratively discover new, non-WASH-specific leadership behaviors, develop them through practice and coaching, and deliver tangible achievements using their leadership skills. The cycle repeats every three months over a twelve-month period. Participants must apply to join and pay a participation fee. Peer-to-peer learning and in-person, field-based coaching by district government supervisors are core methods embedded in the program. Provincial and district level government officers (with mandates for rural development and sanitation targets) are engaged to take on facilitator roles; the eventual goal is that the program is managed and resourced by government ministries. Methodology: Village chiefs administered the baseline coverage survey prior to the start of the program and tracked newly installed latrines for each program cycle. Commune councilors aggregated data and WaterSHED conducted quality assurance spot checks. Coverage data from program areas was compared to that from non-participating districts, which was already being collected monthly using similar government-led data collection mechanisms to monitor effectiveness of WaterSHED's Hands-Off sanitation marketing program. Changes in leadership skills and perceptions were assessed in in-depth interviews with participants and by using worksheets and written reflections, which were completed by participating commune councilors as part of program activities. Results: 205 (19% of all eligible) commune councilors from 105 communes, across 16 districts, participated in the program. During twelve months (2015-16) of implementation, 15,320 new latrines were installed in participating communes. This is equivalent to a 6.9 percentage point increase in sanitation coverage. For reference, the average annual increase in sanitation coverage across all provinces in Cambodia was 3.2 percentage points (2011-15). The program significantly accelerated growth in the sanitation market. During the one year of implementation, there was a 20 percentage point growth in annual latrine sales in participating districts and the quarterly sales rates in participating districts were 13 times those of non-participating districts. Participants reported increased work commitment, greater perseverance in overcoming challenges, and improved public speaking. The evaluation also found increased teamwork and information sharing within commune councils. Discussion: Comparisons to secular trends help attribute impact on sanitation uptake to the program itself. While further research should be conducted to fully characterize the causal linkages between changes in leadership skills and

accelerated sanitation uptake, the evaluation points to a few specific components of the program that were particularly effective. The cascade facilitation model was instrumental in taking the project's concept to scale. The model allowed district and provincial government staff to co-design and facilitate training activities, build their leadership skills, and leverage their expertise in working with commune councilors. Additionally, monetary incentives for those who had met sanitation uptake targets and exhibited strong leadership skills were important motivators for participants.

Title: Techno-Economic Analysis (TEA) of Model Fecal-Sludge Management and Sewer-Based Systems in India

Andrew Helming, RTI International / Sanitation Technology Platform (STeP), Jeannette Laramee, Chengyan Zhang, Andrea Stowell

In recent years, programmatic investment in fecal sludge management (FSM) infrastructure in India has increased significantly as a result of national policy to mainstream FSM services in urban areas by 2019. However, minimal information is available on the financial costs to build and operate such infrastructure. Moreover, the costs of FS-based sanitation compared to traditional sewer-based (SB) sanitation are not well understood. To help fill this knowledge gap, we define eight sanitation archetypes, develop a cost framework based on engineering design for each archetype, determine cost curves according to population served for each archetype, and collect field-based evidence on capital and operational costs of FS and SB systems in India. Sanitation archetypes were defined to encompass a range of system types from extensive/passive treatment to intensive/mechanized treatment options. To calibrate and validate the eight archetype models, detailed operational and financial data were collected from seven FSM systems, two SB systems, and one co-treatment (CT) system across India. Data across the entire sanitation value chain was collected through site visits to treatment systems; interviews with vacuum tanker operators, treatment system operators, and engineers-in-charge; and review of project documents including detailed project reports, bills of quantities, and construction drawings. Our study provides a practical cost model and field-based data on the lifecycle capital and operational costs of FS and SB sanitation systems in India. It also provides a comparison of costs across various sanitation systems and identifies key cost drivers within systems, thus highlighting the suitability of treatment options in varying contexts. As part of the study, a dynamic TEA Cost Framework Tool was developed that helps the user understand the following: range of costs for FS and SB sanitation service provision, key cost drivers for FS and SB sanitation, project stage (capital versus operational) where costs are incurred, and location along the sanitation service chain that drives costs for FS and SB sanitation.

Title: Testing of an Integrated Waste Treatment System for a Women's Toilet in India

Claire Welling, Sanitation Technology Platform (STeP), Sarani Sasidaran, Prateek Kachoria, Antony Raj, Brendon Lynch, Brian Hawkins

The Duke Empower system is a technology designed to treat blackwater for onsite reuse. Liquid enters the system as waste and flush water that has passed through a solid-liquid separator. The liquid passes through settling tanks and granular activated carbon (GAC) and is treated by an electrochemical reactor that oxidizes chloride salts from urine to generate chlorine which is used as a disinfectant. The treated liquid can then be sent to the cistern of the toilet to be reused as flush water (Rogers et al., *Water Res* 144: 553-560, 2018). The system was tested 11 months at a privately-owned textile mill in Coimbatore, India, where it was installed in a toilet block that serves a women's dormitory and consists of three stalls available to users (20 women), one of which is connected to the system. The block was custom-built and features private toilet stalls with 6-L cistern flush and tap for personal wash, separate shower stalls, a hand washing station, and cloth washing (laundry). The block also includes an adjacent engineering area where the system processes the waste and where the field team conducts lab testing of water quality parameters. The toilet stall connected to the Empower prototype has a sewage diversion option, allowing the stall to be open to users at all times, even while the prototype was undergoing maintenance. Flowmeters attached to the tap water line into the stall were used to measure use of wash water and total liquid flow into the system. The onsite team included a woman engineer who was able to access the user facilities and ensure that the system was usable by the population for whom it was designed. Subsystems were stress-tested by continuous operation and the operational time of each subsystem was measured to establish maintenance requirements and component lifetimes. Water quality parameters including those required by ISO 30500 were measured and analyzed daily throughout the system by on-site personnel and periodically by offsite third party labs to monitor system performance. Utilization of the cistern flush represented a low fraction of the overall water usage, likely attributable to the cultural preference for pour flushing. However, supplying the flush cistern with reused water did not affect cistern use. The Empower system produced a clear, colorless effluent with turbidity in range of 0.5-10 NTU, average chemical oxygen demand (COD) < 150 mg/L and NH₃ < 15 mg/L, and generated 10-50 mg/L of free chlorine, and helminths, *E. coli*, and coliforms were all below their detection limits in the effluent. The system processed a total of 7860 L of liquid over the testing period. The electrochemical cell operated for 646 hours and was cleaned every 75 hours of operation to remove scaling on the electrodes, with no observable degradation of electrode performance. GAC columns were operated for up to 3977 hours, required minimal backwashing maintenance, and functioned well throughout the testing period without replacement. The high effluent quality and minimal maintenance required suggest that this system is viable for onsite blackwater treatment and reuse.

Title: The Clean Clinic Approach: An implementation Case Study of 11 Healthcare Facilities in the western highlands of Guatemala

Jason Lopez, Maternal and Child Survival Program (MCSP), Dr. Sergio Tumax; Ana Rodas

Background: WASH services are cornerstones to providing safe healthcare services, improving patient satisfaction and care seeking, and responding to health emergencies. On World Water Day 2018, the UN Secretary-General raised a call to action for universal WASH coverage in healthcare facilities (HCFs) citing increased infections, longer hospital stays, and loss of life. Improving WASH in HCFs contributes to achieving Sustainable Development Goals 6.1 and 6.2 as part of universal WASH coverage. Globally, one in four HCFs lack basic water services (26%), one in five lack basic sanitation (21%) and one in six have no hygiene services (16%). Little data exists on access to basic WASH services at various points of care within HCFs. For Guatemala, there is no publicly available national data on WASH in HCFs. However, in 2016 the JMP estimates that 5% of HCFs in Latin America had no water services. From February 2018 to March 2019, the Ministry of Public Health and Social Assistance of Guatemala (MoH), supported by USAID through the Maternal and Child Survival Program (MCSP), implemented the CCA in 11 HCFs (4 tertiary and 7

secondary) offering labor and delivery services. Through a 10-step process, the CCA supports HCFs to make incremental and effective cleanliness and infection prevention improvements, without relying on external investments, with the goal of contributing to improvements in quality of care and reductions in puerperal and neonatal infections. Methods: The team developed evaluation criteria and a monitoring tool based on national standards for WASH and IPC and the JMP indicators for WASH in HCF. MCSP then worked directly with HCFs to improve their quality of care relating to WASH and IPC based on initial assessments, and provided limited material support in the way of “start-up” kits. Each facility received three evaluations conducted by representatives of the MoH and the HCFs in conjunction with MCSP. Results: Each facility was evaluated across three wards (emergency/general, labor and delivery, and postnatal), in eight technical areas (water, sanitation, hygiene, sterilization, waste management, cleaning, administration and wastewater). Over a period of 6 months, all 11 HCFs improved their average emergency ward Clean Clinic scores, from 41 points at baseline to 87 points at endline, on a 100-point scale. For maternity wards, the scores went from 50 to 91 points, and for postnatal 46 to 90. Conclusions: The CCA tool facilitated a systematic way for the HCFs to target, prioritize and measure their improvement activities as well as to compare their progress to other facilities. Still, further work is needed to involve local government and community members and to adapt the process and tools based on qualitative feedback from users. Moving forward there is opportunity to revise the tool to encompass primary care facilities, serve as the basis for defining Guatemala’s advanced service level of the JMP service ladder, and expand its use to a national level.

Title: The Difference a Day Can Make to Safe Water Access in Bangwe Slum in Malawi

Heather Price, University of Stirling, Ellis Adams, Peter Nkwanda, Theresa Mkandawire, Richard Quilliam

Access to clean drinking water in urban slums is woefully inadequate, despite the United Nations’ declaration that access to safe water is a human right. People in slums often have access to multiple sources of water and make decisions about which source to use based on factors including affordability, safety, availability and reliability. These factors are not temporally static; instead, they will change over time, for example from season-to-season and over shorter time periods, from day-to-day. Global water monitoring initiatives, such as the WHO & UNICEF Joint Monitoring Programme (JMP) – responsible for monitoring progress towards Sustainable Development Goal (SDG) 6 – miss this temporality in safe water access experienced by slum dwellers. However, despite this theoretical underpinning of changing risk, there is a lack of empirical evidence of changes to people’s abilities to access sufficient safe drinking water in urban slums. The aim of this research was to address this research gap in Bangwe slum in Blantyre, Malawi. We tested water quality (pH, EC, *E. coli*) in 30 households in Bangwe over seven consecutive days in both the dry season (July 2017) and the rainy season (January 2018). In total, 395 household drinking water samples were tested (48 % tap, 31 % borehole, 17 % protected well and 4 % other). In addition, we carried out daily water surveys with household members to determine key factors in understanding contamination risk (e.g. water source, transport and storage). We also undertook in-depth questionnaires with these households to better understand general water, sanitation and hygiene (WASH) practices. Responses to the in-depth questionnaire were also gathered for 451 further Bangwe households. *E. coli* data were categorised into four risk levels (no risk, low risk, medium risk and high risk). Of the 23 households that were directly matched (in terms of household and household members) between both sampling campaigns, 35 % changed drinking water source type for at least a day during the sampling campaign and 48% had some days when drinking water was characterised as safe and some days when drinking water was characterised as high risk. These short-term changes in safe water access undermine the usefulness of global initiatives like the Sustainable Development Goals in monitoring progress in accessing sufficient safe water. We recommend that future water access and quality monitoring takes account of the short-term temporal dynamics of safe water access.

Title: The Effects of Water and Sanitation Conditions on Household Illness in Peri-Urban Lusaka, Zambia

Sydney Hubbard, Centers for Disease Control and Prevention (CDC), Martin I. Meltzer, Warren Malambo, Jennifer Murphy, Eric Mintz, Joan Brunkard

Limited access to adequate water and sanitation is one of the key developmental challenges facing Zambia, where approximately 40% of the population lives in urban areas. The problem is most critical in the capital city Lusaka, where the existing infrastructure—built in the 1960s and 1970s for a population of 300,000—is insufficient to meet the needs of the current population of approximately two million people. The situation is especially acute for 70% of Lusaka’s population living in peri-urban areas (PUAs). In October 2016, the U.S. Centers for Disease Control and Prevention launched a 12 month cross-sectional household survey to assess the burden of diarrheal and respiratory disease; economic indicators; water availability, access, cost, and time spent collecting water; water-and-sanitation (WASH) knowledge and behaviors; and flood-related impacts. A two stage sampling strategy was used. In the first stage, clusters (smallest census unit) were selected using probability proportionate to size. In the second stage, all households within selected clusters were geocoded and then selected using simple random sampling. Heads of household were interviewed using standardized questionnaires in Nyanja, Bemba or English; data were electronically captured on tablets by trained enumerator teams. A total of 12,511 households representing 60,575 individuals (8,079 <5 years old) in 15 PUAs in Lusaka were interviewed over a 12 month period. The prevalence of general illness (defined as having diarrhea or respiratory illness in the past 7 days) in the household was 26%, with 13% and 16% of households reporting one or more members with diarrhea and respiratory illness, respectively. Multivariable analyses indicate that having an additional household member, having children <5 years old in the household, and living in a rental home were all statistically associated with general illness, diarrhea, and respiratory illness. Households in which the respondent reported not using soap for handwashing were at higher odds of general illness (OR: 1.18, 95% CI: 1.08-1.30) and diarrhea (OR:1.17, 95% CI: 1.04-1.32). Sharing a toilet with >18 people was also associated with general illness (OR: 1.16, 95% CI: 1.05-1.30) and diarrhea (OR: 1.32, 95% CI: 1.15-1.50). Higher levels of education among head of household (secondary vs. primary or less than primary) were inversely associated with general illness (OR: 0.88, 95%CI: 0.80-0.97), and showed similar trends for diarrhea and respiratory illness (all OR<1.00) although these associations did not reach statistical significance. Households observed to have some or no covered water storage containers had higher odds of diarrhea than households in which all water storage containers were covered (OR: 1.25, 95% CI 1.07-1.46). Households consuming less water (<20L/day per person on average) had lower odds of diarrhea (OR: 0.86, 95% CI: 0.77-0.97). These preliminary baseline results highlight a number of demographic and WASH-related risk factors associated with

diarrhea and respiratory illness among persons living in PUAs, and demonstrate the need for WASH interventions to help prevent disease transmission within densely populated and underserved peri-urban areas.

Title: The Global Water Pathogens Project: Forming a Global Network to Address Sanitation and Water-Borne Disease

Colleen Naughton, University of California Merced, James R. Mihelcic, Matthew E. Verbyla, Joan B. Rose

The books “Appropriate Technology for Water Supply and Sanitation” and “Sanitation and Disease Health Aspects of Excreta and Wastewater Management” by Feachem et al. were published in 1981 and 1983 respectively to facilitate the achievement of better public health through investment in sanitation systems. These texts have been used extensively by engineers and scientists, microbiologists, public health officials and other water professionals. However, as a comprehensive data resource it was 30 years out of date. The goal of the Global Water Pathogen Project (GWPP) is an online open-access data base and knowledge platform to disseminate information relating to efficacy of treatment technologies and quantitative data to support risk assessment. In September 2019, the GWPP Book (that accompanies the online platform) will be officially launched at the International Water Association (IWA) 20th International Symposium in Vienna, Austria. What began as a small group meeting in North Carolina, has become a 21st Century online platform (<http://www.waterpathogens.org/>) with 115 chapters, 391 data tables, 7,336 scientific resources from a network of over 250 people from 52 countries with over 32,000 users and 68,000 views supported by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). A demonstration of the knowledge hub will be provided to conference attendees including how they may use the information and become part of the network. Feces produced per day around the globe varies an average of 32 grams per capita per day (a range of 4 to 102g). From the GWPP literature review, sewage contains the following in concentrations per liter: 10-100 cryptosporidium, 1.35×10^4 giardia, 46-204 ascaris, 9.1×10^9 adenoviruses, 4.87×10^7 rotavirus. The Risk Management section of GWPP includes a comprehensive review of Sanitation Technologies and Disinfection agents and their effectiveness at removing and inactivating pathogens (bacteria, viruses, protozoa, and helminths) in sanitation infrastructures. Both onsite sanitation and sewer systems that contain the following unit processes are included: primary treatment and settling, anaerobic reactors, activated sludge systems, membrane bioreactor and biofilters, trickling media filters, waste stabilization ponds, constructed wetlands, advanced tertiary processes, land application, water reuse technologies, and sludge management. The assembly of authors, along with the development of the online book platform, contributes to the compilation of data on fecal indicators, pathogen occurrence in the environment, survival and overall development of sanitation management strategies. Each chapter is peer reviewed and released to the public through the website and distributed to the global population via United Nations regional hub network in three languages. The next step for GWPP is the Knowledge to Practice Project (K2P) that will support water and sanitation safety planners in using an evidence-based approach for managing health outcomes. We will establish a coalition of national and local stakeholders in Uganda as our first partners and develop analytical Information and Communication Technology (ICT) tools for estimating loads of waterborne pathogens, selecting sanitation technologies to support decision-making for safe sanitation. Overall, the GWPP is a valuable resource to engineers and scientists to protect human health and an example how similar knowledge should be accumulated and disseminated moving forward.

Title: The Role of Cleaners in Promoting Health Care Facility Cleanliness: A Qualitative Study from Malawi

Hayley Schram, The Water Institute at UNC, Ryan Cronk, Raymond Tu

Health care facility support staff, including cleaners and grounds laborers, play an important role in promoting a safe and clean health care environment and preventing health care acquired infections (HCAIs). However, there is little evidence describing the role of cleaners in health care facilities (HCFs) in low- and middle-income countries (LMICs) and the enablers and barriers for cleaners to perform their duties effectively. To address this, we used a dataset of qualitative interviews with cleaners from 45 purposely-selected HCFs in rural Malawi to assess effective approaches to implementing safe environmental health (EH) conditions in HCFs in LMICs and to determine enablers and barriers faced by cleaners in promoting and sustaining clean HCFs. Interviews were conducted at both regional and district level HCFs. Within each of the three regions (northern, central, and southern) one central hospital was selected. In each district, one district hospital, one health center, and one health post or dispensary were selected. We found that when an HCF has an infection prevention committee, the committee is generally responsible for training other staff on infection prevention. Cleaners and grounds laborers often do not receive any formal infection prevention training beyond a basic orientation on how to use personal protective equipment (PPE) which was usually delivered from staff. The training content provided by the orientation was limited, with the majority of cleaners receiving training for only one day. The most common training covered infection prevention and cleaning practices including hand hygiene and waste management procedures. Facilities often do not have sufficient supplies (such as mops and disinfectant) to maintain HCF cleanliness. PPE such as gumboots and goggles were rarely available, though there usually were masks, latex gloves, and plastic aprons available for medical staff and cleaners. Heavy-duty gloves were occasionally available, but usually not at the health center or health post level. Staff often bring their own materials such as mops or soap for cleaning or, in one case, charcoal that was used to boil and sterilize medical equipment. Cleaning records or logs indicating tasks, frequency, or duration of cleaning were rarely found within facilities. Materials to ensure proper infectious waste disposal, including shovels and buckets, were absent from most facilities requiring cleaners to use their hands to collect and transport waste. Bins for segregating infectious and non-infectious waste were available, however some facilities either lacked or frequently ran low on bin liners. Some cleaners felt either fearful or at-risk of waste-related injuries regarding infectious waste, specifically placenta disposal, as they were thrown into waste pits and, in some cases, were only partially burned or incinerated. Many cleaners feel disrespected in their community as a result of their status within the HCF and the roles and responsibilities they undertake. The provision of basic PPE and cleaning supplies coupled with cleaner training on infection control and prevention and proper cleaning practices may lead to higher job satisfaction and motivation among cleaning staff and contribute to a cleaner and safer health care environment.

Title: Three Drinking Water Chlorination Intervention Evaluations in Cox's Bazar Refugee Camps

Mustafa Sikder, Tufts University, Gabrielle String, Daniele Lantagne

Background: Drinking water supply using tanker trucks is common in humanitarian emergencies with compromised water supply system. Emergency water trucking (EWT) is often implemented in humanitarian responses, with programs continuing, for months or years, because reliable alternative drinking water sources cannot be established. Despite EWT's widespread implementation, little research has been completed on EWT programs. The aim of this research is to evaluate the effectiveness and lessons learned of three EWT programs. Methods: We applied a mixed-method data collection protocol, including water collection and distribution point structured observations; key informant interviews (KII) with staff and truckers; household surveys; focus group discussions (FG); and, water quality sampling. We used key indicators from widely accepted humanitarian standards to evaluate the interventions (e.g. Sphere Standards, UNHCR). Results: We have completed two evaluations: in Goma, DRC and Cox's Bazar, Bangladesh. We have a third evaluation planned for April 2019 in Cox's Bazar. In Goma, enumerators surveyed 161 households, observed seven water collection and six distribution activities, interviewed five staff and nine truckers, and conducted one FG. The program supported residents without access to drinking water in cholera prone areas. Users call truckers directly when water is needed, and paid \$0.1 for 20L water (average). Lake Kivu water was chlorinated by an NGO, transported and sold by private truckers, and monitored by provincial government. We observed inadequate infrastructure at the water collection site. We found water at delivery points had free chlorine residual (FCR) between 0.6-1.4 mg/L and *E. coli* <1-27 CFU/100mL (median <1), while household water samples had FCR between 0-1.4 mg/L and *E. coli* <1-25,000 CFU/100mL (median 22). The NGO monitors the program monthly. Overall, this program provided high-quality water. Key lessons-learned included the need to improve and relocate the water collection site, to improve roads for delivery, and to develop an exit strategy engaging government, private sector, and users. In Cox's Bazar, enumerators surveyed 174 households, observed four water collection and distribution activities, interviewed three staff and three truckers, and conducted two FGs. The program supplied water to two refugee camps. Groundwater was extracted and chlorinated by one NGO, and transported and distributed by another NGO. The delivered water had FCR between 0.1-0.8 mg/L and *E. coli* <1-4 CFU/100mL (median <1), while the household water had FCR 0-1.2 mg/L and *E. coli* 5-180 CFU/100mL (median <1). We observed direct water delivery from trucks and no water quality monitoring. Users did not pay for water. Overall, the program provided high quality water at no cost. Key lessons-learned were to reschedule delivery times to avoid road traffic and ensure water delivery each day. Long-term recommendations included establishing alternative water sources or relocating the collection point closer to camps. Conclusions: A theme observed across both evaluations was the multiagency involved complex implementation modality that make programmatic decision-making difficult. Despite this, both programs provided high quality water. To our knowledge, this is the first research initiative that specifically aimed to evaluate EWT effectiveness in multiple emergencies. Evaluation results will guide donors and responders to improve interventions.

Title: Three Quarters of People in Port-au-Prince, Haiti, Get Their Drinking Water from Private Providers

Ian Ross, London School of Hygiene & Tropical Medicine (LSHTM), Pierre-Yves Rochat, Adrien Mazeau, Colette Vilgrain, Beatrice Mosello, Zael Sanz

Background: In Port-au-Prince, the capital of Haiti, three quarters of people get their drinking water from non-networked private sector sources. Demand for private services soared when the public utility, already in decline, struggled to recover from the 2010 earthquake. Methods: We characterised the market for water services in Port-au-Prince, focusing on services used by the 'bottom 40%' (B40). Methods include analysis of city-representative data from two national surveys, focus group discussions with B40 water users, and key informant interviews with numerous service providers at different stages of service chains. Results: This poster presents key results in the form of a novel 'water flow diagram', presenting flows of both water and money in a Sankey-style diagram. In doing so, it builds on both the 'shit flow diagram' and Whittington and colleagues' visualisations of water markets in the early 1990s. The public utility withdraws and distributes three times more water than the private sector, but only undertakes a third of sales by value. The water tanker truck market is atomised, with 700 independent trucks delivering water both to final consumers and to 10,000 resellers. By contrast, large firms dominate the kiosk and sachet market, with three companies supplying more than 75% of the water in those chains. Focus group discussions brought insight into the user preferences that contribute to these outcomes. Private kiosks are ranked above sachets in terms of quality and taste. Sachets are thought to be easier to access, but also perceived as cheaper (which is true on a unit basis but not on a per litre basis). Water from the public network is considered cheap but low quality, but it scores higher on quality and price than reservoirs reselling trucked borehole water. This implies that people would rather have network water than reservoir water if it was available in their area, and available when needed. Conclusions: The study findings bring insights for the regulation of the private sector in cities such as Port-au-Prince where it has become dominant. The visualisation helps illustrate which parts of the market are largest (in terms of volumes or revenues) and may need closer attention. Most officials in the national water and sanitation directorate (DINEPA) consider that the regulatory authority of their institution is limited to water service providers managing piped systems only. DINEPA is still de facto an operator of WASH infrastructure through its service provision arms, which are effectively utilities. Therefore, many DINEPA officials appear to see water entrepreneurs as competitors. Although the Ministry of Health is formally responsible for monitoring water quality, the most comprehensive water quality control campaign was undertaken by the Ministry of Commerce and Industry.

Title: Time, Economic, and Health Benefits of the Transition to Rural Piped Water Systems in Southern Zambia

James Winter, Stanford University, Jennifer Davis

NGO-led efforts to install piped water systems in rural villages is accelerating in Zambia. This project measures the benefits of piped water systems on two villages in southern Zambia and two matched control villages in the same district. The piped water systems consist of taps located in shared or private yards of households. We conducted surveys of 150 total households and measured the concentration of fecal indicator bacteria in source and stored water and the hands of respondents. We observed the size and composition of respondents' gardens as a measure of economic

utilization of water and, for a subset of respondents, we used GPS tracking devices to measure their location and walking speed every 5 seconds for 16-20 hours. We have collected two rounds of data in May and September of 2018. I will collect endline data in May and June of 2019. To date, we have measured significant decreases in time spent fetching water for men, women and girls in the household and significant increases in total water use per capita. We hypothesize that extended exposure to the piped water will significantly improve garden utilization and crop diversity. We anticipate presenting information on results from GPS tracking data to estimate path-based walk time to water sources, walking velocity, and time spent in and outside the home.

Title: Understanding Functionality of Hand Pumped Borehole Water Supply in Sub-Saharan Africa

Donald John MacAllister, British Geological Survey, Alan M. MacDonald, Helen Fallas

Perceived poor performance of hand pumped boreholes (HPBs) has been a persistent problem in Sub-Saharan Africa. The UPGro Hidden Crisis project has brought together an interdisciplinary team to examine factors and identify causal pathways that explain functionality of boreholes equipped with hand pumps (HPs) in sub-Saharan Africa. The project developed a tiered approach to define and measure functionality of HPBs. Applying the definitions to a survey of 600 hand pumped boreholes across Ethiopia, Uganda and Malawi the results, in agreement with national surveys, show that c.80% of HPBs produce water. However, <50% are able to deliver HP design yield reliably for more than 11 months of the year. Fewer still provide water that meet WHO guidelines on chemical parameters and total thermo-tolerant coliforms (TTC). To understand factors which contribute to functionality outcomes, detailed hydrogeological and engineering investigations were conducted on a subset of 150 HPBs. Within this second forensic survey stage a full range of HPB functionality outcomes were included. Data on aquifer properties, borehole construction and the condition of HP components were generated. Initial analysis shows that in each country there are specific contextual factors that influence functionality outcomes. For example, in Ethiopia deep water levels (>60 m) strongly influence HPB functionality classification. In some cases HPs are operating beyond lift limits (typically 45 – 80 m). Similarly, aquifer yield is an important control on functionality in Ethiopia, aquifer yield is an order of magnitude larger for fully functional HPBs than partially functional HPBs. In Uganda many HPBs operate close to the minimum aquifer yield required to sustain a HP (c.1 m²/d). Furthermore, in Uganda the use of India Mark II HPs and galvanized steel components, along with corrosive groundwater, results in high rates of corrosion. In all three countries water level, aquifer yield, borehole construction and pump cylinder placement interact to create conditions that are sub-optimal for HPs to meet design capacity (pumping head and yield). Current analysis focuses on identifying how these hydrogeological and engineering factors combine with social, institutional and economic factors to determine HPB functionality. The interdisciplinary analysis uses different analytical approaches, including predictive and causal statistics, systems thinking and qualitative comparative analysis. The presentation will provide an overview of; the projects definition of functionality, the methods used in the forensic surveys, results from the forensic survey analysis, and how these techniques can be used in functionality monitoring and asset mapping and assessment.

Title: Understanding Hand Hygiene Adherence: Results from a Mixed-Methods Study in Healthcare Facilities in Sub-Saharan Africa

Maggie Person, Centers for Disease Control and Prevention (CDC), Victoria Trinies, Marissa Vigar, Robert Quick

Background: Although healthcare provider hand hygiene is critical to providing safe, quality care to patients, healthcare provider hand hygiene adherence remains low across many settings. Little data exist on rates of healthcare provider hand hygiene in resource-poor settings. Additionally, the reasons for low adherence can be multi-faceted and context-specific, and investigation into specific barriers and enablers of hand hygiene in different contexts is needed. Methods: We evaluated handwashing practices as part of baseline WASH assessments conducted in 115 primary healthcare facilities (HCFs) in Ethiopia, Ghana, Mali, and Uganda to help partner organizations plan and implement an initiative to improve WASH in rural HCFs. In each HCF, an average of three healthcare providers participated in surveys about hand hygiene knowledge and practices. Enumerators also shadowed 140 healthcare providers (13–58 per country) to observe glove, hand hygiene (defined as washing hands with soap and water or using alcohol-based hand sanitizer [ABHS]) practices before and after patient contact. Finally, 15 healthcare providers (2–6 per country) participated in qualitative in-depth interviews that investigated motivators, enablers, and barriers to hand hygiene. Results: Survey results showed high scores on questions relating to knowledge of hand hygiene; for example, 97% of respondents (range across 4 countries 93%–100%) correctly stated that hand hygiene should be performed after direct contact with a patient. However, observations revealed that healthcare providers performed hand hygiene before direct patient contact only 11% of the time (18% in Ghana, 23% in Mali, 3% in Ethiopia, and 0% in Uganda) and after patient contact 24% of the time (23% in Ghana, 45% in Mali, 12% in Ethiopia, and 16% in Uganda). Qualitative interviews revealed barriers preventing healthcare providers from adhering to hand hygiene guidelines, including limited or intermittent water supply, lack of supplies of ABHS and soap, and the absence of a culture of hand hygiene at the HCF, among others. Healthcare providers reported that self-protection was a key motivator of hand hygiene. They reported prioritizing hand hygiene practice based on perceived personal risk, particularly in HCFs with limited water access, as determined by the severity of the patients' symptoms, the type of procedure performed, and presence of visible blood. Enablers of hand hygiene included the presence of functioning piped water taps in patient care areas, a consistent supply of ABHS, and internal programs to monitor adherence. Conclusions: Data from surveys, hand hygiene observations, and in-depth interviews reveal systemic challenges in creating an enabling environment for adequate hand hygiene in primary healthcare facilities in resource-poor settings. While many of the barriers, motivators, and enablers we found related to infrastructure and availability of supplies, several related to healthcare provider attitudes and cultural norms. These context-specific data can be used by governments and implementing partners to inform targeted hygiene promotion programs.

Title: Understanding the Changing Patterns of Droughts during Cropping Seasons of Pakistan from 1901 to 2010

Kamal Ahmed, Lasbela University of Agriculture, Water & Marine Sciences, Nadeem Nawaz, Shamsuddin Shahid, Irfan Malik, Najeebullah Khan

The droughts are found to be more frequent and varying in cropping seasons of Pakistan. The frequent droughts had severely affected the livelihoods of people primarily engaged in Agro-based economy. Characterization of drought in a systematic way is necessary in order to take

appropriate actions toward drought mitigation and sustainable development. A study is carried out to assess the droughts in cropping seasons of Pakistan during 1901 to 2010 using the standardized precipitation evapotranspiration index (SPEI). The temporal variations in droughts are assessed using a 50-year moving window with a 10-year time step. The annual maximum series approach was applied to estimate the return periods of droughts. Sen's slope and Modified Mann Kendal trend test are used to assess the changes and significance of trends. Results showed that droughts are mainly dominated in the southern part of the country where precipitation and temperature are found significantly decreasing and increasing respectively. The return period of Rabi and Kharif drought were found in the range of 6 to 7, 12 to 14, and 20 to 30 years while for Kharif return periods are found in the range of 7 to 9, 13 to 19, and 30 to 45 years moderate, severe and extreme drought for 50 years moving window. Results also revealed that reduced precipitation and increased temperature are the major causes of drought in the area, however, the temperature is found to have major impact on recent droughts of the study area.

Title: Unveiling Pathogen Hazards Associated with Sanitation Technologies in Tamil Nadu

Musa Manga, The Water Institute at UNC, Jill Stewart, Pete Kolsky, Beverly Medina, Andy Peal, Jamie Bartram

Sanitation is one of the most important interventions for reducing the spread and burden of excreta-related diseases transmitted by pathogens found in human faeces and urine. Since sanitation technologies (such as latrines, septic tanks, sewerage systems, etc.) are designed to interrupt the transmission of sanitation-related pathogens into the environment, then the number of pathogens that such technologies can inactivate before emptying or discharge to the environment, would seem a logical and useful indicator for assessing the performance of these technologies. However, to-date, the relative public health hazards posed by the different sanitation technologies and their performance in reducing pathogen hazards before discharge to the environment is still not well understood. This study, therefore, investigated the performance of sanitation technologies (i.e. fully-lined tanks, lined tanks with impermeable walls and open bottom, sewerage system, and direct discharge from black-water pipes) encountered in our study communities (i.e. Trichy and Coimbatore, in Tamil Nadu, India) in reducing pathogen hazards. Using a faecal sludge deep sampler, faecal sludge samples were collected from the bottom and top or effluent of the containment systems. Samples were also collected from points of the sewerage system that are associated with frequent blockages and overflows. Flexible plastic bags were used for collecting direct discharge from the black-water pipes. All collected samples were analysed for *Escherichia coli* (*E. coli*), and Total solids. Considering the pathogen hazards observed in the direct discharge (i.e. black-water pipes) as the reference, pathogen hazards reduction attained by each sanitation technology was computed. Using sanitation technology users' survey and observational checklist, more data was collected about the sampled containment systems (such as emptying frequency, storage duration of human waste in the containment system, number of users, etc.). The results revealed that there is a statistically significant difference in the performance of sanitation technologies in terms of pathogen hazards reduction, with $p = 0.0001$. Surprisingly, Household (HH) fully-lined tanks exhibited an excellent performance with 3.1 Log₁₀ cfu/g reduction, followed by HH lined tanks, Community toilets (CT) fully-lined tanks, and sewerage systems with 2.3, 1.8, and 0.4 Log₁₀ cfu/g reduction, respectively. However, there was no statistically significant difference between the performance of HH fully-lined tanks and lined tanks (with $p = 0.250$). Sewerage systems and black-water pipes exhibited the highest pathogen hazards in their discharges to the environment, with 7.3 and 7.6 Log₁₀ cfu/ml, respectively, while HH fully-lined tanks recorded the lowest pathogen hazards, followed by CT fully-lined tanks with 4.5 and 5.7 Log₁₀ cfu/ml, respectively. This suggests that human excreta safely contained for an extended storage period, pose less threat to public health than fresh waste discharged from black-water pipes or sewerage systems without treatment. The study revealed that approximately 49% of the pathogen hazards is associated with the solids fraction retained in the containment system until emptying, while the remaining 51% of the hazard is associated with the liquid fraction leaking to the environment. This is a significant finding to the sanitation planners/ engineers as it aids the prioritizing of sanitation interventions that will maximize public health benefits. Storage duration of human excreta in the containment system and emptying frequency were found to be the most important factors responsible for pathogen hazards reduction in the sanitation technologies, with $r = 0.773$, $p = 0.0001$ and $r = -0.504$, $p = 0.006$, respectively. This study results suggest that safe containment of human excreta for an extended time has greater potential to reduce the release of pathogen hazards into the environment as well as the spread of excreta-related diseases since extensive pathogen inactivation usually occurs during containment.

Title: Use of an Evidence Based Tool to Inform Action and Sanitation Investments in Kumasi, Ghana

Habib Yakubu, Emory University Center for Global Safe WASH, Benjamin Doe, Joshua Tetteh Nortey, Benedict Tuffuor, Casey Siesel, Christine Moe

Periodically, resource-challenged municipal governments in urban areas of low-income countries face decisions on how to set priorities for sanitation investments and focus resources for impact. This is primarily due to their lack of knowledge of existing innovative evidence-based sanitation tools. SaniPath exposure assessment tool evaluates the public health risks from poor sanitation and unsafe fecal sludge management in low-income urban areas. It has been deployed in 43 neighborhoods in 9 cities; Accra, Ghana; Vellore, India; Maputo, Mozambique; Siem Reap, Cambodia; Dhaka, Bangladesh; Atlanta, United States; Lusaka, Zambia; Kampala, Uganda and Kumasi; Ghana. The most recent shit flows diagram indicates that only an estimated 45% of the fecal sludge is treated. Four neighborhoods of varying geographic and socio economic characteristics were selected for the deployment of the SaniPath tool based on extensive engagement with Kumasi Metropolitan Assembly (KMA). Trained environmental health assistants collected environmental samples and behavior data from multiple pathways in Moshie Zongo, Dakodwom, Fante Newtown and Ahodwo. The nine pathways investigated were; river water, street food, raw produce, drinking water, bathing water, open drain water, soil, public latrines and floodwater. The unit of analysis of the tool is exposure to fecal contamination. Exposure is a measurement of the average amount of *E.coli*/ingested per month (dose) and the percent of the population exposed to fecal contamination per pathway. The most common dominant exposure pathway for children across all the four neighborhoods was open drains. A large percent of the child population was exposed, ranging from 85% to 95% and a high average dose between 10⁶ to 10⁸ colony forming units (CFU). For adults, the most dominant pathway varied across all the four

neighborhoods. Raw produce was the most common dominant pathway in Moshie Zongo, with 78% of the adult population exposed, and a high dose of $>10^7$. Bathing water was the most dominant pathway in Fante Newtown; with 81% of the population exposed and a high dose of $>10^7$. Open drains was the most dominant pathway in Ahodwo and Dakodwom with population exposed $>61\%$ and high dose values $>10^6$. KMA has used this information to take immediate action in two neighborhoods. Firstly, they investigated the source of contamination of a surface water and sanctioned the property owner who had illegally connected directly a shared latrine's fecal waste into a community river. Secondly, KMA rolled out a school hygiene program to educate primary school students on good hygiene practices within their school compound, in public spaces around open drains and in school toilets. There are other ongoing plans to use the results to inform their sanitation planning, practice and investments. These actions, show that with commitment and access to evidence based sanitation tools, municipal governments in urban areas are capable of using evidence based sanitation tools to prioritize and focus their sanitation investments.

Title: Using Evidence of Consumer Preferences on Basic Sanitation to Expand Business Development Strategies in Ethiopia

Monte Achenbach, Population Services International (PSI),

Introduction and Problem: USAID Transform WASH is a five-year project that launched in January 2017 to develop and test market-based models to increase demand for and supply of quality, affordable WASH products and services. The aim is to facilitate market access to basic sanitation for up to 400,000 households. In the first year of implementation, the project partnered with existing businesses, primarily hardware retailers, masons, and manufacturers of cement toilet slabs, to increase supply of basic sanitation options for households. As users almost universally discard iron and cement lids produced and delivered with the slabs, open pit holes are the norm wherever cement slabs are installed. **Initial Intervention:** To address this critical issue and to introduce other attractive features for consumers, USAID Transform WASH facilitated insertion of SATO plastic toilet pans, designed and produced by LIXIL Corporation, into the slab design. Relatively slow consumer uptake of this product, however, revealed that this solution could not address the large installed base of rudimentary latrines with wood and mud surfaces, which were ripe for upgrades but needed fit-for-purpose, less expensive options. **Monitoring and Evaluation:** We will present data on how a shift in strategy, installation practices, and business models led to improved sales results with a more flexible approach toward consumer demand and business offerings. This shift was based on the monitoring and evaluation techniques and the 'build, measure, learn, iterate' mindset of the project. The Transform WASH team also introduced survey and tracking tools to understand and monitor business partner capacity and sales targets to facilitate data for decision making. Finally, the team undertook action research to gain a quick understanding of the challenges to scale up of the proposed business models. **Results and Iterations:** As a result of initial M&E and action research activities, the Transform WASH business development team, led by business partner innovators, added an array of product and installation service options that addressed the newly identified consumer needs and high potential demand: pre-cast SATO mini-slabs, installation of SATO with cement skirting, and cement latrine retrofits, most of which consumers could buy and have installed for less than \$15. Finally, to get these options to market, the project also shifted its approach toward selection of business partners by inducting more entry-level masons who could move quickly door-to-door, sell their services, and take installation to scale. We will present data on the results of this program design iteration and provide recommendations for the next iteration based on the latest evidence.

Title: Using Fecal Sludge for Surveillance and Health Impact Assessment in Maputo, Mozambique

Drew Capone, Georgia Institute of Technology, Joe Brown

Wastewater monitoring is an emerging approach to community health surveillance, most prominently used for poliovirus detection in global eradication efforts. Using fecal waste streams – including fecal sludges where sewerage is absent – in surveillance for a range of enteric pathogens is possible and may be a compelling alternative to current methods in WASH health impact studies; fecal sludge collection is non-invasive, logistically easier than stool and scalable across settings. To assess the potential for fecal sludge to be used in surveillance and health impact assessment, we collected stool samples from 70 children from October 2017 to April 2018. Within 10 days of stool collection we collected fecal sludge samples from 70 on-site systems located inside the same compounds (1:1 match between stool samples and fecal sludge from the latrines children were using) in urban Maputo, Mozambique, part of Maputo Sanitation (MapSan) Trial. We analyzed stool using a multiplex end-point RT-PCR method and fecal sludge using a multiplex RT-qPCR method; both methods tested for the presence of the same seven bacteria, three protozoa and three viruses. Among the seven bacterial targets, the two most and three least prevalent in stool were detected in the same order of prevalence from fecal sludge: *Shigella* (stool 47%, fecal sludge 77%), heat-labile or heat-stable enterotoxigenic *E. coli* (stool 29%, fecal sludge 60%), *Salmonella* spp. (stool 10%, fecal sludge 10%), Shiga-like toxin 1 or 2-producing *E. coli* (stool 7%, fecal sludge 19%), *Clostridium difficile* toxin A or B (stool 3%, fecal sludge 7%), *Yersinia enterocolitica* (stool 0%, fecal sludge 3%), *Vibrio cholerae* (stool 0%, fecal sludge 1%). We detected the three protozoan targets in the same order of prevalence from stool and fecal sludge: *Giardia* (stool 50%, fecal sludge 86%), *Cryptosporidium* (stool 1%, fecal sludge 27%), *Entamoeba histolytica* (stool 1%, fecal sludge 9%). Additionally, we detected the three viral targets in the same order of prevalence from stool and fecal sludge: *Norovirus GI/GII* (stool 6%, fecal sludge 67%), *Adenovirus 40/41* (stool 3%, fecal sludge 47%) and *Rotavirus A* (stool 0%, fecal sludge 7%). Further analysis is ongoing and will be complete in May 2019; statistical analysis will assess if pathogens detected in fecal sludge are reliable predictors of children's enteric infections and if the sanitation intervention reduced the detection of enteric pathogens in fecal sludge. Findings will characterize fecal sludge as a potential end point for health surveillance in this setting and whether an urban on-site sanitation intervention reduced enteric pathogens present in fecal sludge.

Title: Using Public Subsidy to Unlock Household Finance: Evidence from the Field

Lesley Pories, Water.org, Luis Alberto Andres, World Bank; Edkarl Galing, World Bank-Philippines

Increasing access to safe water and sanitation is intricately connected with direct access to finance. The enormous projected costs of SDG6 have shocked the sector into exploring non-traditional approaches to finance, and one method that is gaining momentum is the provision of microloans for

household water and sanitation. In some cases, however, stakeholders have perceived efforts to incorporate financial solutions as a replacement and rebuke to the more traditional approach of government-provided subsidies to households in need. This presentation, a collaboration between the World Bank and Water.org, seeks to disprove the either/or dichotomy for WASH subsidies and commercial finance to achieve universal access to water and sanitation. Two datasets will be harnessed: the recently-completed World Bank Endline Survey for the Impact Evaluation of Overcoming Barriers to Adoption of Sanitation for the Poor Households in the Philippines and Water.org's database of loan data from WASH lending in the same country over the same period. The World Bank study was a randomized control treatment of low-income, predominantly female-headed households in the Philippines and the uptake in sanitation coverage based upon the provision of government subsidies at various levels as well as when access to credit was included in addition to the subsidy. Water.org has been assisting several microfinance institutions (MFIs) in the Philippines to offer WASH microloans for the past four years and has a rich database that contains data about borrower gender, income level, household size and repayment progress. The World Bank impact assessment revealed that sanitary toilet uptake increased by 38% when households were provided a 50% subsidy and a microfinance loan. The population group in this study featured 90% female respondents, 21% of whom are head of their household. Participant households that took loans (551) had a 98% repayment rate, suggesting that when offered a loan terms that are designed to meet the needs of low-income clients, repayment is manageable. Water.org loan data in the Philippines corroborates this theory, with 97% of borrowers for 532,000 water and sanitation microloans being female and an overall portfolio of a 99% repayment rate. Further dis-aggregation of loan data reveals 75% of those loans have been disbursed for sanitation. The study further identifies that households that installed toilets saw increases in ownership of luxury items such as television, refrigerators and motorbikes, suggesting that toilet investments had positive impacts upon household income. Deeper analysis of the impact evaluation data is forthcoming to derive additional understanding about decisions that were made at different income levels (within the poor) and comfort levels with borrowing. Together, these sources will demonstrate the encouraging, amplified impact of government subsidies and microfinance to accelerate water and sanitation access when they are strategically combined, ideally reducing the and/or assumption about public versus private WASH solutions and encouraging greater uptake of integrated solutions.

Title: WASH Coordination in Humanitarian Response: Evidence Summary

Travis Yates, Tufts University, Franck Bouvet, Dominique Porteaud, Daniele Lantagne

Background: National Humanitarian WASH Coordination Platforms (NHWCP) are designed to organize and align the WASH organizations responding humanitarian emergencies towards agreed implementation strategies and standards. Coordination and information management roles are critical to the success of NHWCP, requiring adaptive leadership and technical knowledge. We hypothesized that first-hand experiences and opinions from persons in coordination or information management (IM) roles can lead to overarching lessons to improve NHWCP coordination. Methods: Initially, a theory of change was developed to map the stakeholders and activities related to NHWCP coordination. Then, a qualitative approach was used to determine lessons from a broad context of humanitarian emergencies, including: 1) end-of-mission reports from short-term Global WASH Cluster teams available; 2) key informant interviews with experienced Cluster staff; and, 3) a desk review of Cluster related evaluations from current literature. NVivo software was used to summarize overall themes and lessons learned from these different qualitative data sources. Results: A total of 74 end-of-mission reports were assessed for expert feedback from individual assignments covering 32 countries. We identified 41 unique recommendations among the themes of information management, staffing, and coordination. The most common recommendation was to support information management, described by encouraging common templates and indicators, supporting knowledge sharing platforms, and reducing data and reporting duplication. Requests to increase dedicated staffing, and in particular, capacity building for IM were, regularly reported. Lastly, improving coordination between other clusters was a widely reported recommendation. Fifteen persons with significant country-level cluster experience were identified for a structured interview, 13 interviews were completed. Each person had coordination experience in multiple countries, with interviewees spanning more than 5-10 years of cluster experience and contexts. The interviewees expressed clear improvement of coordination over time, while also consistently stating that dedicated staffing was needed in coordination and IM roles. Additionally, respondents stated that context is critical to how the cluster functions, with the phrase 'it depends' a common initial response to several questions. Deeper anthropological understanding of local contexts and culture was also repeatedly recommended. Working with national governments was often described as difficult, as politics influenced the response strategy. The desk review included more than 30 documents from external evaluations and United Nations reports. Overall, findings and recommendations were consistent with end-of-mission reports and key informant recommendations. Discussion: These recommendations are in-line with activities that would be addressed through the Minimum Requirements for National Humanitarian WASH Coordination Platforms established by the Global WASH Cluster. The consistency between the three different information sources was maintained across years and humanitarian response contexts, which indicates the difficulties in addressing the challenges of coordination. This consolidated review of multiple resources could serve as guidance for change, as with increasing emergencies and a consistent strain on personnel resources, focused efforts to address these recommendations will better address critical humanitarian WASH coordination needs.

Title: WaSH in Pacific Island Countries: Baseline and Census Data from Fiji, Kiribati and the Solomon Islands. Key Results and Lessons Learnt

Carmen Anthonj, The Water Institute at UNC, Suliasi Batikawai, Waqapoirā Tikoisuva, UNICEF Pacific

The ability of Small Island Developing States (SIDS) to effectively manage water, sanitation, hygiene (WaSH) and waste management is constrained by their small size, geographical isolation and expansion, environmental fragility, small and predominantly rural, but rapidly urbanizing populations and limited human and financial resource bases. WaSH research, monitoring and global action are still lagging behind the necessary efforts to achieve health-promoting sustainable development. Fiji, Kiribati and the Solomon Islands, like other SIDS in the Pacific, are often not able to provide adequate WaSH services to their populations. Besides, these countries are facing significant challenges from a changing climate, and from increasing extreme weather events. Within the WaSH Sector Monitoring in Pacific Island Countries project, jointly conducted by UNICEF Pacific, the

governments of Fiji, Kiribati and the Solomon Islands and The Water Institute at UNC, baseline and census data were collected from rural and urban households, schools and health care facilities between 2016 and 2019. Key findings on comparative urban-rural analyses of domestic WaSH, and WaSH in schools in the Solomon Islands, and on WaSH in health care facilities in Fiji and Kiribati will be presented, along with lessons learnt from our partnership. The outcomes of the project support WaSH monitoring, planning for the implementation of national WaSH strategies and policies, and create representative baselines for SDG 6 reporting.

Title: WASH interventions effect on acute malnutrition in children under 5 : a systematic review

Heather Stobaugh, Action Contre La Faim (ACF), Andrea Angioletti, Danka Pantchova, Jean Lapegue, Stephanie Stern, and Dieynaba S N'Diaye

52 million children worldwide suffer from acute malnutrition (AM), or wasting. Although the immediate causes of AM are inadequate dietary intake and disease, the underlying causes can be multifactorial and complex. Recently the nutrition community has also turned to nutrition-sensitive programming including poor water, sanitation and hygiene (WASH). ACTION CONTRE LA FAIM (ACF) being as both an operational and research actor in WASH and nutrition is highly interested in this topic and seek to improve its evidence-based programming. Therefore, we developed the Research 4 Action project that aims to 1- Produce a synthesis of the state of scientific evidence on specific interventions on undernutrition; 2- Translate, with a panel of key academic and operational actors, these evidences into field actions, programs and policies. The 2019 Research 4 Action edition aims to pool and evaluate the strength of published evidence documenting links between WASH intervention and AM in children under the age of five in order to provide operational recommendations. We performed a systematic review using a computerized search of PubMed to identify English language articles published between Jan 1, 2000 and Oct 15, 2018. Selected studies had to 1) report the impact of WASH interventions on AM treatment or prevention, 2) report associations between WASH indicators and AM, 3) involve children under the age of 5 years old, and 4) report AM as an outcome defined as recommended by WHO. We selected only peer-reviewed studies designed as randomized controlled trials, quasi-experimental, case-control, cohort, meta-analyses, and systematic reviews. The strength of the overall body of evidence was assessed based on the size, quality and consistency of evidence and four categories were generated: No/very little, Limited, Moderate or Strong evidence. Of 527 articles identified through data base search, only 24 matched eligibility criteria and were included. Our results showed that the literature on WASH interventions impact on AM is scarce. Two studies were classify as moderate strength, while for eight of them evidence was limited and for seven studies there was no or very little evidence. Limited evidence have demonstrated that improving the water quality at the household level has an effect on improving AM treatment outcomes. Very few high-quality intervention trials have been conducted that demonstrate significant impact on AM prevention. The results are inconsistent, and the quality of studies are varied. AM association was documented with a moderate strength for two indicators, while for eight of them evidence was limited and for seven indicators there was no or very little evidence. No WASH indicators had strong evidence regarding its association with AM. Although hypothesized causal pathways are supported by strong logic, they have yet to be consistently proven through rigorous studies. There is a great need for high-quality, rigorous intervention studies. This evidence must be developed in order to guide decision-making regarding if and how WASH services are to be implemented.

Title: Water Affordability and Social Equity Implications in California's Human Right to Water

Jess Goddard, Energy & Resources Group at UC Berkeley, Carolina L. Balazs, Isha Ray

California's human right to water—established in 2012—provides an opportunity for state agencies to track and monitor water access with a focus on equity. Disparities in access to safe drinking water persist in California because of inequities in infrastructure, enforcement and regulatory design, uneven monitoring, high tap water and bottled water costs paired with low ability-to-pay, and unequal technical, managerial and financial capacity across systems. The impact of unaffordable water on these co-occurring and multilevel burdens is substantial for economically vulnerable households, who may compromise health and food-related expenses to pay for water and utilities. Water affordability is thus central to water access but remains a challenge to measure. How should water affordability be measured across the state, and for whom is water unaffordable? This project contributes to this question in three ways, representing the first statewide assessment of water affordability in California's community water systems. First, we identify five key dimensions of robust water affordability measures: scale, the minimum volume of water needed to meet 'basic' needs, available income, economic vulnerability of households, and criteria for affordability. Second, using these dimensions, we develop three affordability ratios measured at the water system scale for households with median, poverty level, and deep poverty (i.e., half the poverty level) incomes. We also estimate the percentage of households in each system below poverty and deep poverty levels. Third, we conduct a social equity assessment of our results by investigating the affordability of water in relation to several social-demographic characteristics, such as community disadvantaged economic status. We select social-demographic variables that capture previously identified inequities in water access (e.g. among communities of color and small water systems) in an effort to capture historically marginalized groups per human right to water equity aims. Our results demonstrate that water is, on average, affordable for households earning at the median income level but that basic needs water is often unaffordable for households earning at the county poverty and deep poverty levels across systems of all sizes. We identified several disparities across systems, such as very small systems with high water bills and low-income households within large, non-disadvantaged community water systems. Finally, previous work in California indicates that unaffordable water compounds and perpetuates water quality problems, leading to a "joint burden" on households and water systems (Balazs & Ray, 2014). As such, ongoing efforts in this project include an analysis of potential exposure to water contaminants and regulatory compliance violations as potential co-occurring burdens for households with affordability challenges. This work will inform a scenario matrix for community water systems to demonstrate the range of affordability and water quality contexts. We conclude with a discussion on social equity implications for the progressive realization of the human right to water in California.

Title: Water Borrowing is widely Practiced, and Associated with Market, Infrastructure, and Public Health Failures Globally

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Periodic water insecurity affects more than half of the world's population. Household-to-household water transfers within communities provide one theorized grass-roots means to alleviate immediate water stress. Here we use data from the Household water InSecurity Experiences Consortium (HWISE) which collected systematic, cross-sectional comparative evidence on water borrowing in 24 ecologically and politically diverse, very low-resource, highly water-insecure communities globally, spanning sub-Saharan Africa, the Middle East, Central/South America, and Asia in 2017-2018 (n=6,134 households). Household water borrowing practices were highly evident at all sites as 41.6% of all sampled households reported borrowing water at least once in the previous 4 weeks, ranging from 11.4% in Kathmandu, Nepal to 85.4% in Punjab, Pakistan. We used mixed effect nested logistic regression models with robust standard errors clustered within sites and random intercepts for each site to test how water borrowing behaviors were associated with household exposure inequalities and structural failures across multiple domains, including public health provision of safe water, market provision of water to purchase, and infrastructural provision of predictable water supply. Borrowing of water was consistently highly associated with absolute water need. Households in the middle need tercile (i.e., relative lack of sufficient water for drinking, washing, bathing, and cooking) had more than three times higher odds of borrowing (Odds ratio [OR] = 3.44, 95% confidence interval [CI]: 2.49-4.75, P<0.001) compared to the low tercile, while households in the high water need tercile had more than seven times the odds of water borrowing (OR=7.27, 95% CI: 5.23-10.1, P<0.001). Greater exposures to drinking unsafe water (proxy for public health failures) predicted more borrowing of water (3 or more times: OR=1.47; 95% CI: 1.08-1.99, P 0.014). Households that experienced interruptions to their day (proxy for technological/infrastructural failures) due to water problems 1-2 times (OR=1.79; 95% CI: 1.39-2.31, P<0.001) and 3 or more times (OR=2.37; 95% CI: 1.61-3.48, P<0.001) had higher odds of borrowing water compared to households who did not experience interruptions. Households that reported being unable to purchase water (proxy for market failures) 1-2 times (OR=1.55, 95% CI: 1.13-2.13, P=0.007) or 3 or more times (OR=1.48, 95% CI: 1.07-2.05, P=0.018) in the previous month were significantly more likely to borrow water than households that did not report an inability to buy water. Our analysis suggests that the patterning of water borrowing activity across (and within) sites is better explained as a response to broader technological, institutional, and governance failures that constrain household access to safe, reliable, and affordable water. Water borrowing is most frequently practiced by the most vulnerable households of these already water-insecure communities, suggesting that water sharing is a coping response borne of material deprivation rather than social preference. Further attention to water sharing networks in water-insecure settings may be critical for uncovering when, how, and why this virtually invisible grass-root collective coping strategy works, as well as clarifying the many socio-medical tradeoffs of water sharing, including increased exposure to potentially contaminated water.

Title: Water Quality Testing Laboratories in Rural Nepal: Installation and Operation

Rubika Shrestha, HELVETAS Swiss Intercooperation Nepal and Swiss Federal Institute of Aquatic Science and Technology (EAWAG) Switzerland, Sara J.Marks, Guillaume Clair-Callot, Ram Bahadur Shrestha, Ariane Schertenleib, Madan R. Bhatta

Water quality testing laboratories are required for the regular monitoring and assessment of microbial and chemical parameters in drinking water. However, access to such laboratories in rural areas of low- and middle-income countries, especially in remote hilly or alpine regions, remains very limited. As a result, service providers are often unable to systematically verify even the most basic water quality parameters, which contributes to a high incidence of waterborne disease. In remote rural settings, there are several barriers to establishing and operating water quality laboratories. Chief among these are difficulties related to infrastructure requirements, including low access to electricity, equipment, and materials for sample collection and processing. The second set of challenges relates to shifting the mindset of water users and service providers, since a focus on water quantity often outweighs concerns about water quality. Drawing on experiences from a field study in the Mid-Western Region of Nepal, we present a strategy for implementing community-led water quality monitoring for 21 gravity-fed piped water systems, including centralized data management using Akvo Flow, five solar-powered field laboratories, a network of volunteer sample collectors, and trained local technicians. To test the type of local institution that can best host field laboratories over the long-term, we established pilot laboratories at a high school, a health post, and water supply and sanitation user's office. A water safety planning (WSP) group was established at each scheme. One person from each WSP group was trained to conduct sampling across the scheme and deliver samples to the laboratory for analysis. The laboratory technicians trained were teachers, a health assistant, and a village maintenance worker. Based on a pre-prepared schedule, data were recorded manually in a laboratory notebook, as well as on tablets using Akvo Flow. Simultaneously, to raise local support for the sustainable operation of the laboratories, a safe water promotion campaign was launched about the importance of water supply treatment and testing methods. We found that the collaboration between an employee of the host institution and a member of the study team provided enough incentive for achieving regular water quality testing and laboratory management over the medium-term. The average upfront capital cost for equipment to establish the laboratory with microbial, turbidity, free residual chlorine (FRC) and pH testing capacity was about US\$920. The average material cost for conducting one microbial test was about US\$2, and the cost for one FRC and one pH test was about US\$0.5. Human resource costs were minimal for this community-led approach; however, a professionalized approach to laboratory operation and management is suggested to better ensure sustainability.

Title: Water, Sanitation and Child's Health: Leaps and Bounds from Mozambique

Christian Borja-Vega, World Bank, Pavel Luengas, Barbara Evans

Adequate and safe access to water and sanitation services can prevent diseases that lead to gut dysfunction and child malnutrition. We contribute to an important knowledge gap on the differential impact by access to different types of services on child stunting. We account for other relevant factors explaining stunting such as household and child food security, access to health services, mother's characteristics, and wealth and consumption measures and find that access to improved sanitation associates with a stunting decrease of 4.1 percentage points in urban areas while access to improved water sources with a decrease of 3.9 in rural areas. The aggregate impact in urban areas masks that using toilets connected to sewage or

septic tank associates with a three times as large stunting reduction compared to using protected latrines (10.0 vs 3.3). In rural areas, it masks that using piped water associates with a twice as large reduction compared to using standpipes and boreholes (10 vs 5). The literature considers water from protected wells to be an improved water source but across different estimations we find no association between protected well use and child stunting. We also find a strong relation of stunting and vaccination. In rural areas, stunting on not vaccinated children is 20 percentage points higher compared to stunting observed in children with all vaccinations adequate for age. Consistent with the literature, we find strong associations of mother's height and child birthweight with stunting. These findings have important implications to invest in increasing access based on WASH sources that mitigate risks of malnutrition, based on adequacy and resiliency of WASH sources against social and environmental vulnerabilities.

Title: Water, Sanitation, and Hygiene Access for People with Disabilities: an Analysis from 14 Countries

Wren Tracy, The Water Institute at UNC, Ryan Cronk

Universal access to equitable water, sanitation, and hygiene (WaSH) has been recognized in international policy through Sustainable Development Goal (SDG) 6 as important to human health and development. Despite increased international attention on the provision of access to WaSH for all, there is little evidence examining whether WaSH services meet the needs of people with disabilities. With more than a billion people worldwide, roughly one in seven people, estimated to be living with a disability, it is necessary to identify any potential barriers to WaSH access for this population. To better understand what WaSH access barriers exist for people with disabilities, we analyzed data from 36,860 household surveys collected in 14 countries: Ethiopia, Ghana, Honduras, India, Kenya, Malawi, Mali, Mozambique, Niger, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. There were 2,246 households, approximately 6% of all households surveyed, where at least one member was living with a disability. Of households where a member of the household had a disability, 74% (n = 1,663) of respondents reported that the household member with a disability had difficulty accessing WaSH services; 70% (n = 1,573) reported difficulties accessing water compared to 19% (n = 431) and 10% (n = 233) for sanitation and hygiene respectively. Substantial differences in WaSH access for people with disabilities existed between countries; the proportion of households that had a member living with a disability who also had difficulty accessing WaSH services was highest in Ghana (95%) and lowest in Uganda (55%). Of households where the disabled member had difficulty accessing water (n = 1,573), transportation of water posed a major obstacle with many respondents identifying the weight of containers (45%) and distance to the water point (39%) as barriers to access. Of households where the disabled member had difficulty accessing sanitation services (n = 431), respondents identified the lack of handrails or support in the facility as the main barrier to access (33%). Of households where the disabled member had difficulty accessing hygiene services (n = 233), difficulty manipulating the hand-washing facility was the most commonly reported barrier to access (51%). Intra-household inequalities expressed in terms of disability access are masked in national and international WaSH statistics. The results of our study indicate that people with disabilities have frequent difficulty in accessing WaSH services, highlighting the need for more inclusive WaSH programming and training. Specifically, with water transportation being the most commonly reported difficulty, practitioners should scale up provision of on plot water service along with other adaptive technologies.

Title: What Drives Financial Viability of Rural Water Service Providers in Nepal?

Tom Wildman, Oxfam GB, Anjil Adhikari

In Nepal, only 25% of water supply schemes are functioning well. 36% need minor repairs and 39% need major repairs, rehabilitation or complete reconstruction. In earthquake-affected districts, between 65% and 90% of schemes have been damaged, with many waiting for attention. While there are several approaches to setting up schemes, there is only one model of ongoing service management – community-based management through local water user committees. This is applied everywhere, from small rural systems to larger, more complex systems in urban areas. Research has shown that these water user committees are often have been unable to operate water supply schemes sustainably. This is because they typically struggle to collect sufficient enough money through tariffs, lack don't have the technical capacity to carry out maintenance, and lack don't have enough accountability or transparency. Oxfam surveyed the condition of water supply schemes in two regions, collecting quantitative and qualitative data on technical, financial, governance and social factors affecting sustainability across 26 schemes. We then built a financial model (profit/loss statement) of a 'typical' scheme in the Hills and the Terai, based on (limited) available data, to assess the impact of these factors on profitability, and therefore sustainability. From this we performed a sensitivity analysis, building a model to quantify the impact of various interventions on the average Profit/Loss statement of water service providers. Our findings demonstrate that the most significant improvements in net profitability would come from partnerships with private sector actors for centralized account management, efficiencies in bill payment, government-managed service agreements, and targeted household connection subsidies. They also demonstrate that some common activities meant to improve sustainability – e.g community contributions in the form of labour – have actually proven to be a significant cost driver and has increased annual operational expenditure costs.

Title: Where does CLTS Work Best? Evidence from Four National Data Sets

Kara Stuart, The Aquaya Institute, Caroline Delaire, Jeff Albert, Ranjiv Khush, Rachel Peletz

Globally, Community-Led Total Sanitation (CLTS) has been embraced as an intervention to end open defecation (OD). To date, over 30 countries have incorporated the approach as part of their national strategy for rural sanitation. The literature shows that the success of CLTS at increasing sanitation coverage and reducing OD is a function of both program implementation and contextual characteristics. However, there has been no large-scale, quantitative and systematic examination of the drivers of CLTS performance and of their relative influence. USAID's WASH Partnerships and Learning for Sustainability (WASHPaLS) project collected, cleaned, and analyzed datasets from CLTS implementers in Cambodia (2,273 communities), Ghana (3,772 communities), Liberia (2,030 communities), and Zambia (20,398 communities). We used these datasets as well as publicly available, spatially-explicit data to derive a set of covariates (village size, remoteness, water supply, education level, poverty rate, flooding frequency, proximity to water bodies, and burden of waterborne diseases) at the finest possible spatial resolution. We examined relationships

between these covariates and three measures of CLTS performance: achievement of open-defecation free (ODF) status (all countries), increase in latrine coverage over time (Cambodia, Ghana, Liberia), and post-ODF slippage (i.e. reverting back to OD) (Zambia). Drawing on the literature, we developed a directed acyclic diagram for CLTS performance to guide the selection of multivariate models for the analysis. Preliminary results indicate that smaller village size was significantly associated with ODF status achievement in all four countries (all $p < 0.01$). Wealthier communities were more likely to achieve ODF status (data only available for Cambodia, $p < 0.01$). Results were mixed for other covariates depending on the country. Remote villages (measured as proximity to cities or roadways) were more likely to achieve ODF status in Zambia, though less likely to achieve ODF status in Liberia and Cambodia. In Zambia and Ghana, communities with better access to water sources were more likely to achieve ODF status, though this relationship was not significant in Liberia. We did not find any associations between waterborne disease and any of the CLTS performance outcomes. In addition to presenting final results, we will discuss data limitations and the implications of the findings for decision-making in rural sanitation programming. We will discuss the indicators that implementers should monitor to anticipate CLTS performance and how they can use this type of analysis to tailor their sanitation programming.

Title: Will the United States Meet Sustainable Development Goal 6, Water and Sanitation for All?

Colleen Naughton, University of California Merced, Arianna Tariqi

As a follow up to the Millennium Development Goals, the United Nations and member countries have set out to achieve seventeen Sustainable Development Goals (SDGs) by 2030 including SDG 6 to ensure water and sanitation for all. The United States government agencies, corporations, and non-profits often invest in Water, Sanitation, and Hygiene projects in developing countries and support their governments to achieve SDG 6. However, millions of Americans lack access to clean drinking water and 1.6 million lack access to complete plumbing facilities. Disproportionally, Native American populations, other communities of color, and Americans of lower socio-economic status lack access to clean, consistent and affordable drinking water. Many in the U.S. and throughout the World know of the Flint drinking water crisis but there are similar issues with lead in drinking water systems throughout the U.S. along with other harmful contaminants. In California, over one million Californians do not have access to clean drinking water with approximately half in the Central Valley of California which is one of the poorest areas of California. One fourth of the United States' food production comes from the agriculture in the Central Valley. This concentration of agriculture contaminates surface and groundwater used for drinking with fertilizers and pesticides. Historical industrial pollution and natural geology also contribute to harmful chemicals in the drinking water. The top five contaminants are arsenic, nitrate, uranium, total trihalomethanes, and haloacetic acids. Also, 1,2,3- Trichloropropane (1,2,3- TCP) from a now banned soil fumigant is of particular concern for a number of municipalities in the Central Valley. While previous literature has focused on the clear economic and ethnic disparities in clean drinking water access for disadvantaged communities in California, there is a gap in overlaying this with health data. The Central Valley has higher incidences of thyroid cancer, premature death rates, birth defects, and score lowest on county health ratings. From geographic and statistical analysis of agriculture, water, contaminants, health, and socio-economic data, there is clear overlap between disadvantaged communities and health disparities. These maps and analysis will help inform the public and policy leaders of the types of health-related concerns in relation to water pollution in the Central Valley and where to target interventions in order to achieve SDG 6 by 2030. This methodology will also provide a framework for other areas of the United States and the world.

Title: Women as WASH Change Agents

Molly Goodwin-Kucinsky, iDE, Rachel Rose, Greg Lestikow

Market-based approaches have gained prominence recently as a strategy for improving sanitation coverage. While much of the focus has been placed on women as "end users" of products like latrines, less evidence exists for understanding the roles that women play in the sanitation value chain and how their participation might affect key hygiene behaviors like latrine adoption. While many implementers focus on women as a vulnerable population in need of WASH services, iDE takes a broader view and strives to engage women as agents of change within WASH market systems. This presentation provides examples from iDE's global research of how to effectively engage women in the WASH value chain in different country contexts and how women's participation might affect behavior change. In Ghana, iDE explored how we might involve women in the sanitation value chain for long-term sustainability and provide income-generating opportunities for their households and communities. Research explored women and men's time use, barriers to engagement in sanitation enterprises, and motivations to engaging in WASH entrepreneurship. Programmatic recommendations include gender sensitivity training for program staff to better mainstream gender within programming, creating apprenticeships for aspiring female toilet business owners in conjunction with local universities, and tailoring promotional activities to engage women while they're at market days. iDE Cambodia has seen promising initial results from a pilot that aims to build business skills among female partners in family-run rural sanitation businesses, including more women reporting taking a salary from the business. The training pilot is still underway, with analysis expected to be completed by mid-2019. In Nepal, iDE conducted mixed methods research on how sales agent gender influences end-user hygiene and sanitation behaviors (purchase, installation, and use). We found that clients who purchased from female sales agents have higher rates of consistent latrine use and good hand hygiene behaviors, particularly among marginalized households, compared to those who purchased from male sales agents. Focus-group research suggests this may be because women sales agents are more persistent in client follow-up, and that they use frequent follow-up visits to talk about important sanitation behaviors. This presentation will share more complete findings from this critical research on the potential for women actors in the sanitation supply chain to effect lasting and positive behavior change.

Title: Womens' Empowerment through WASH Enterprises in Viet Nam, Indonesia and Cambodia

Melita Grant, University of Technology Sydney, IV Bbunthoeun, Simone Soeters, Nurul Indarti, Rokhima Rostiani, Juliet Willetts

Informing programming related to WASH markets from a gender perspective is critical, and yet commonly absent. Assumptions about related economic empowerment of women are prevalent, without deeper questioning as to the most suitable ways to support women's involvement, towards

both effective WASH market systems and mutually beneficial outcomes for the relevant women. This paper presents three examples of gender equality outcomes and empowerment experienced by individuals and institutions involved in WASH markets in three countries: Vietnam, Indonesia, and Cambodia, and the implications of these for improving WASH programming. In Vietnam, the study involved a qualitative exploration of empowerment experiences in a sanitation marketing program. The focus of this study was the implementing partner, the Vietnam Women's Union (VWU), at institutional and individual levels (Leahy et al, 2017). This study demonstrated the importance of recognising the potential for bringing about gender equality outcomes for partners engaged in program delivery, as well as the program beneficiaries themselves. In Indonesia, research examined the experiences of 18 women involved in WASH economic activities against the institutional backdrop of country where women may experience socio-cultural, legal and religious barriers to establishing and growing businesses. Findings demonstrated both where women showed significant self-belief and recognition of women's unique competencies to contribute to WASH markets, and equally revealed common challenges in role division in the home, which left women with limited time to focus on their businesses (Indarti et al, forthcoming, 2018). Research was conducted in Cambodia on the extent to which women were empowered (and specifically economically empowered), through their management of small-scale rural water enterprises (Grant et al, 2018). The study found that key barriers and enablers to establishing successful water enterprises were influenced by gender norms and expectations such as limited women's mobility, but that a number of the most prominent challenges (financial, operational and government and regulation issues) as identified by female entrepreneurs, were not directly linked to gender related barriers. The three studies show that while gender norms are limiting women in WASH markets in terms of mobility, household and family duties, and traditional views about women and men's domains, empowerment outcomes have been achieved through leadership of and involvement in WASH enterprises and sanitation marketing initiatives. These studies are helpful to NGOs, donors and governments incentivising WASH markets, to ensure that these interventions are not gender blind, and instead draw on evidence of the barriers and enablers for female WASH entrepreneurs and how these barriers and enablers are influenced by gender norms.