VERBAL PRESENTATIONS
Over the last decades the contamination of groundwater by geogenic arsenic has been highlighted as an environmental disaster, known as the "largest poisoning of a population in history". Long-term exposure to arsenic through contaminated drinking water causes severe health effects leading to skin lesions, skin cancer, internal cancers (kidney, liver, and lung), cardiovascular disease and other adverse effects. There is also increasing evidence of negative effects of exposure to arsenic in drinking water on fetal growth, fetal loss, and infant mortality as well as neurodevelopment in school-age children. Although various national and international aid agencies and local governments are trying to decrease the extent of arsenic exposure by supplying safe drinking water to local communities, the success has been limited and the problem prevails. Hindustan Unilever Ltd. has developed a novel technology, the Pureit As+ water filter, to improve drinking water quality by removing arsenic as well as microbiological contamination. A randomised, controlled intervention trial to assess the uptake and effectiveness of the novel table-top water filtration system was conducted in two neighboring villages in the district of North 24 Parganas, one of the nine arsenic-affected districts in West Bengal. In these two villages, all public water sources were identified to be contaminated with arsenic over the legally enforceable Indian standard of 50 µg/L. A baseline survey (n=405) was conducted to collect socioeconomic and demographic data as well as to collect data on current drinking water and rice cooking practices. Samples of drinking water as well as a sample of urine from the female head of the household were collected. The sample of drinking water was analysed using a rapid portable field kit. Households that accepted to provide urine samples and whose water was identified to be contaminated with arsenic using the portable kit were eligible for participation in the study and were randomised to either the control (n=134) or the intervention (n=135) in a public lottery. Each participating intervention household was provided with one free Pureit As+ filter and a replacement battery. Households were encouraged to drink only filtered water, take filtered water to work and or school in a safe container (narrow-neck container) and to wash and cook their rice in filtered water. Households were followed for a four-month period post-baseline. Monthly visits were made where enumerators collected data on drinking and cooking practices, gathered both self-reported and objective indicators of HWT-use, and collected samples of drinking water and urine from the female head of the household. Water samples were analysed for thermo tolerant coliforms (TTC) using membrane filtration and for total arsenic using ICP-MS. Urine samples were analysed for total urinary arsenic using HG-AAS. Over the first two months of follow-up, 78.8% of intervention households reported drinking filtered water, 47.5% drinking directly from the filter while the remainder drank water from a narrow-neck container. Upon inspection, 85.1% of filters looked in use during both visits (using objective indicators) and 87.3% had water (either in the top or bottom container) in both visits. 74.4% of households reported to have a properly working filter at both occasions while 93.0% of intervention households with school-aged children reported that their children took filtered water to school. Nonetheless, only 49.6% of intervention households reported not drinking raw water (non-filtered) in the preceding 24 h at both follow-up visits. 13.2% reported drinking raw water at both instances. With regards to under 5 year olds, caretakers reported in 61.9% of cases that their children had not drank untreated water in the preceding 24h in both visits, while 4.8% did so at both instances. Using the Pureit As+ filtered water for washing rice was relatively uncommon, with only 13.2% of household reporting to do so at the first two follow-up visits. On the other hand, cooking with filtered water was relatively more common (37.2% of households reported doing so at both visits). These figures will be updated once all four follow-up visits are completed in July 2015. During the follow-up period the intervention proved to have a
significant yet sub-optimal impact on the microbiological quality of the drinking water. Overall, 57.6% of intervention households had drinking water in compliance to WHO standards, in comparison to only 35.4% of control households (p=0.01). Similarly, while 36.9% of intervention households had safe drinking water at the first two follow-up visits, only 17.0% of control households did so (p<0.001). We are still waiting for the results of the arsenic testing of both the water and urine samples. We hope to be able to report on these in August 2015.

Does Decentralized Community-Based Water Governance Lead to Improved Potable Water Access for Peri-Urban and Informal Settlements? Evidence from Malawi

Ellis Adjei Adams, Michigan State University

More than 8000 people, including 4500 children under age 5, die unnecessarily from lack of potable water access in Malawi every year. This is a growing concern especially in the informal settlements where several thousands of people rely on few public-water kiosks. Peri-urban demand for potable water continues to intensify from population growth and rapid urbanization. Currently, over 76 percent of Malawi’s current urban population lives in the peri-urban and informal settlements where high population densities, inadequate infrastructure, poverty, and insecure tenure exacerbate the challenge of providing water. Consistent with experiences across Sub-Saharan Africa, centralized water-policies have proven unsuccessful for Malawi, and many peri-urban residents are still without potable water. This has shifted attention to community-based water governance approaches as an alternative option that emphasizes the capacity of communities to diagnose and advance solutions to their own water problems. In 2006, the Malawi government transferred water-supply roles in peri-urban areas to Water User Associations (WUAs) as part of broad decentralization programs. Based on fieldwork in the peri-urban areas of Lilongwe, Malawi’s capital and largest city, this study investigated the emergence of community-based water supply for peri-urban areas. Specifically, we examined whether decentralized community-based institutions can improve access to potable water in peri-urban areas. Using Malawi’s case, our central hypothesis for this study was that "institutionalization of community-based WUAs improves access to potable water in informal settlements compared to the areas served predominantly by publicly-managed water kiosks". We attempted to address the hypothesis by employing mixed methods (645 household surveys, key-informant interviews, participant observations, and using government policy documents). While our initial analysis does indeed validate this hypothesis, we also discover that due to the nature of peri-urban/informal settlements, often characterized by limited social cohesion and heterogeneous mix of residents, community-based water management has not received adequate attention and acceptance by community-members. This study reveals the role community-based approaches play in water services delivery for peri-urban and informal settlements and whether or not they hold promise for the rapidly expanding cities as more populations migrate and create new settlements. The main contribution of this work stems from answering an important question: what happens when community-based approaches, traditional used in rural areas, gets transferred to peri-urban areas as a policy option? How does the commodified nature of water, sold in a demand-based setting with expectations of cost-recovery, and the complex nature of a peri-urban setting often neglected by governments for reasons such as: lack of legitimate tenure, overcrowding, and limited potential to recover costs affect such approaches? In answering this question, the study advances our understanding of alternative ways of delivering water to peri-urban and informal settlements. Our results, discussions, and their implications will appeal and be useful to both scientists and policy makers at the "Water and Health "conference.
A 21st Century Water Atlas for Haiti

James Adamson, Northwater International

Haiti is considered to be one of the water poorest nations in the world. Over 3.1 million people (30% of the population) lack access to safe drinking water, yet Haiti has abundant water resources available, only 9% of the country’s renewable water resources are consumed. The unavailability of water information, combined with the lack of capacity to retain earned data and knowledge contributes significantly to the water challenges faced by the nation. This issue has contributed to hundreds of millions of dollars in failed investments, depleted and contaminated aquifers, and ineffective response in recent emergency situations. Within this context, a consortium in partnership with the Haitian government has initiated the design and development of an interactive and publicly available 21st century water atlas for Haiti. The atlas design includes the architecture to evaluate the quantity and quality of available water resources and tools to track the population's access to water. The atlas integrates the functionality to compile, build and maintain a robust system of data, knowledge and information. Modules will support decision making with query, forecasting and predictive modeling capabilities. The atlas is a tool that can support economic growth, encourage investment, improve public health, guide climate change adaptation and support the development of aligned and actionable water policy in Haiti.

Factors Affecting Cleanliness of Shared Urban Slum Toilets in Dhaka, Bangladesh

Mahbub-Ul Alam, ICDDR,B

Stephen Luby; Ronald Saxton; Fosiul Nizame; Farzana Yeasmin; Abdullah-Al Masud; Guy Norman; Anita Layden; Habibur Rahman; Nasrin Akter; Abdus Shaheen; Probir Ghosh; Peter Winch; Leanne Unicom

Background: Shared toilets in urban slums are often unclean and poorly maintained. Dirty, poorly maintained sanitation facilities may be underutilized or abandoned encouraging open defecation. Previous studies have measured cleanliness based on user's perceptions. This study describes multiple objective indicators of cleanliness of shared toilets and identifies the factors associated with toilet cleanliness.

Methods: We selected 23 urban slums from three different areas of Dhaka, Bangladesh as part of a cluster randomized control trial and conducted a pre-intervention baseline survey among users of 1,226 shared toilets during December, 2014 to January 2015. The field team interviewed one adult from the second nearest user household to the toilets and inspected all toilets to assess structure and cleanliness indicators. These included provision of water, distance to water source, presence of visible feces, urine, other liquid, dirt, or solid waste inside and on the way to the toilet. We defined a toilet as clean if there was an 'absence of feces, liquids, dirt or paper within the squatting area and pan of the toilet'. To identify the factors associated with toilet cleanliness, we estimated the prevalence ratio (PR) using generalized estimating equations to account for clustering. Results: Of 1,226 respondents, 74% were female with a mean age of 30 years. Most (65%) of the toilets were built by the landlord; 18% were built by NGOs. More than half (57%) of the toilets were observed connected to a canal or ditch, which continuously released excreta into the environment. Only 27% of toilets had a functional water seal. Twelve percent of toilets had water available inside or beside the toilet and a further 45% had no water storage facility. The mean distance from the toilet to a water point was 18 feet. Only 5% had toilet cleansing materials inside or immediately beside the toilet. The field team found visible feces inside the pan hole among 47% of toilets, inside the pan among 28%, and on the path leading up to the toilet among 14%. Participants reported that they often used the toilet for solid waste disposal: 16% disposed menstrual cloths/rags, 12% disposed
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Paper, and 9% disposed plastic bags in the toilet; whereas only 0.5% had a waste bin observed inside the toilet cubicle. Only 34% of toilets were classified as clean. Seventy-eight percent of respondents said they rotated the cleaning responsibility among the user households and 10% reported that the landlord paid a caretaker to clean the toilet. The landlords were responsible for emptying the septic tank or pit toilet (83%) and 21% of landlords reported that they hired manual labor. Almost all (98%) fecal sludge was disposed into the slum environment. Landlord built toilets were more commonly connected to a canal or ditch than NGO built toilets (63% vs. 26%, PR: 2.7, 95% CI: 1.8-4). NGO built toilets were more commonly pit, septic tank or piped sewer system toilets with a functional water seal than landlord built toilets (39% vs. 3%, PR: 8.3, 95% CI: 4.2-16). Toilets were more commonly clean when water was available inside or beside the facility than where no water was available (18% vs. 9%, PR: 1.9, 95% CI: 1.5-2.4); as where toilets that had a water storage beside toilet (58% vs. 53%, PR: 1.1, 95% CI: 1-1.2). Our analysis found no associations between cleanliness and whether the toilet was built by an NGO or landlord, toilet types, reported waste disposal into the toilet, or presence of a caretaker for toilet cleaning. Conclusion: Improving future toilet construction to effectively separate fecal contaminants from the environment is an important step to reduce community exposure. Shared toilets were not clean; efforts to provide adjacent sources of water should be considered.

Environmental Enteropathy and Baby WASH: Testing Community Interventions to Reduce Infant Fecal Exposure in Rural Zambia

Kelly Alexander, CARE USA

Brianna Reid; Stephanie Ogden; Khrist Roy; Rebecca Stoltzfus; Jennifer Orgle

Background: Children in low-income contexts who suffer from malnutrition and diarrhea are likely also affected by a subclinical condition called environmental enteropathy (EE). Environmental enteropathy is damage to the intestines caused by chronic exposure to pathogens from animal or human feces. Growing evidence suggests that the ingestion of high quantities of fecal bacteria by young children through mouthing soiled fingers and household items leads to intestinal infections that contribute to stunting. While infants are most vulnerable to stunting and other irreversible effects of EE, current water, sanitation, and hygiene (WASH) interventions do not interrupt the fecal-oral pathway of crawling and toddling children. In other country contexts, corralling free-range livestock has not been culturally acceptable or economically feasible for sustenance-farming households. Therefore, strategies that target WASH from infants' and toddlers' perspectives are necessary to reduce their risk of suffering from EE. Methods: In order to identify strategies for rural households to reduce children’s exposure to human and animal feces, we observed 30 households from six villages with a child under the age of 24 months in rural Zambia. We recorded livestock presence and visible feces throughout the household, mouthing behaviors of infants, and water, sanitation, and hygiene-related practices of caregivers to identify possible fecal-oral pathways among infants. Surveys were also conducted with mothers regarding their child's behavior and their thoughts on what could be done differently. After baseline observations were conducted, education modules on baby-specific WASH interventions were introduced to communities through caregiver support groups and 24 families from the baseline were selected to pilot either commercial play yards or community-designed and locally made play yards for children. The pilot of play yards was conducted as a participatory research strategy--trials of improved practices (TIPs)--that consisted of survey and interviews with caregivers to identify culturally acceptable and feasible approaches to infant-focused WASH interventions. Results: We conducted 143 hours of observation of 30 caregiver-infant dyads in households in rural Zambia. Handwashing was rarely observed, and although 70% of households had a latrine, human
feces were seen in 67% of compounds. Most animals were un-corralled, wandering freely around the house and compound, with the highest observable counts of feces from chickens, pigs, and cattle. In addition to infants mouthing visibly dirty hands, play-things, sibling’s body parts, and food, 47% of infants actively ingested an average of 6.1 (SD± 2.5) handfuls of soil and stones. One child was observed ingesting animal feces 6.0 times in the span of 5 hours. 93% of mothers reported observing their child eating soil and 17% reported observing their child eating chicken feces. When prompted, mothers came up with various ideas for separating their children from the contaminated environment such as wear on back, keep in house, put on a mat, and put in playpen. The intervention-study is currently ongoing and the results from the six villages will be completed by August 2015; with results ready for sharing by the October conference. Conclusions: Infants in low-income communities ingest feces and soil on a regular basis. Mothers are generally aware of these practices, and are open to changing where babies spend their time. Interventions aimed at restricting children or animals to a specific area of the compound, along with other sanitation and hygiene measures, are potential solutions for reducing the risk of environmental enteropathy among vulnerable children in rural Zambia. This presentation will describe the results of baseline and endline studies examining probable pathways of infant fecal exposure, as well as the results of our trial of improved practices testing the uptake of protected play spaces and other interventions aimed at restricting infant exposure to environmental fecal contamination.

Using the Life Cycle Cost Approach to Inform School WASH Advocacy in Kenya

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Alex Mwaki; Malaika Cheney-Coker; Matthew Freeman

Background: Understanding the life-cycle costs of school WASH programs is a challenge. Allocation of funds from donors and governments typically include capital expenditures, but rarely provide sufficient resources for recurrent costs, or maintenance of facilities. Understanding the full costs of water, sanitation and hygiene facilities and services in schools is an essential component of building sustainable WASH programs. The life-cycle costs approach (LCCA) developed by the IRC to assess the costs for setting up, maintaining and sustaining water, sanitation and hygiene programs (WASHCost) in lower-income rural and peri-urban areas did not include an approach for assessing life-cycle costs (LCC) in schools. The SWASH+ Project undertook a study within Kenyan primary schools in order to strengthen and give specificity to advocacy recommendations to the Government of Kenya on their school WASH investments. Previous research from an earlier phase of SWASH+ saw a doubling of public funds for school WASH in part due to findings such as a preliminary costing study of school WASH investments. Methods: The study took place in three diverse counties of Kenya: Kisumu (west), Nyeri (central) and Kilifi (coast). For this study we augmented survey tools derived from WASHCost for four different purposes: 1) interviewing key government officials, 2) interviewing NGOs working in school WASH, 3) price inquiries in local shops and 4) interviewing primary school principals. We utilized the same six domains as used by the WASHCost project to assess life-cycle costs: capital hardware, capital software, operation and minor maintenance, capital maintenance, direct support and indirect support. Surveys with government officials and NGOs focused on costs of training (capital software), infrastructure (capital hardware), minor maintenance, and time spent on training or advocacy (indirect costs). Surveys in schools, conducted by staff trained in school WASH programming, were an extensive process of recording the school’s current WASH facilities and the school’s previous or current costs of infrastructure, maintenance and supplies. The final piece of the survey was a process of estimating costs that the school has not incurred due to lack of funds; for example soap, latrine repairs or other items needed to maintain a basic WASH program. The surveys in shops recorded the
prices of WASH-specific items, such as latrine construction materials, handwashing containers, soap and sanitary pads, in order to cross-check the cost-estimates made at the school level. Results: Data was collected from 89 schools, 6 NGOs, 3 local government offices and 7 hardware shops. The average costs for establishing and maintaining a school WASH program, including infrastructure, for a school of 400 students is 920KES (~9.82USD) per child per year for the first five years. For schools with existing infrastructure, the average costs for minor maintenance and recurrent costs of a basic WASH program is 228KES (~2.43USD) per child per year. Data revealed that 70% of costs currently used for WASH, (from the school's budget), is spent on water-related items; 29% is spent on sanitation and 1% is spend on hygiene. In terms of needed repairs, 34% of schools reported needed repairs to their water facilities, such as cementing around borehole, or replacing tubes, pipes or gutters. One hundred percent of schools needed repairs done to their latrine facilities, including resurfacing floors or walls, improving drainage, or replacing doors or vent pipes. Hygiene facilities, such as handwashing stations, were all either in need of an upgrade, (new container or taps), or schools had no facilities at all. Similarly only 9% of schools mentioned "soap for handwashing" as a current cost. Conclusions: The vast majority of school WASH costs are covered by NGOs. This limits the sustainability of school WASH programs in the longer term, particularly for those schools that have not received external support. For schools which have benefitted from externally-supported WASH infrastructure and training, they require an additional budget in order for them to sustain programme activities - such as handwashing with soap, clean, functioning latrines and safe water for drinking. Government investments are needed to provide consistent, long-term funding for school WASH, however given scarce resources, governments can benefit from research that reliably calculates minimum and ideal investments and provides recommendations on how to prioritize spending and make investments. For the first time in the Kenyan context, the LCC study has provided decision makers at school and government level with numbers on the cost effectiveness of ongoing investments in repairs, maintenance and recurrent inputs, thus reducing the need for repeated investment in costly infrastructure down the line.

Effective Guidelines for Water Treatment in Humanitarian Operations: Evidence from Refugee Camps in South Sudan, Jordan, and Rwanda

Syed Imran Ali, UC Berkeley

BACKGROUND Ensuring access to adequate quantities and quality of water is essential for the control of waterborne diseases in refugee/Internally displaced persons (IDP) camps. Centralized batch chlorination remains one of the most widely used approaches for emergency water treatment due to its low cost, relative ease of use, and residual protection. Humanitarian organizations have developed guidelines stipulating targets for free residual chlorine (FRC) at camp water distribution points on the assumption that some chlorine residual will remain to protect the water against recontamination until consumed. These guidelines however are based on conventions stated in the WHO Guidelines for Drinking-water Quality (GDWQ) and derive from experience with municipal piped-water systems--i.e., from fundamentally different conditions than those encountered in refugee/IDP camps. As the CDC observes, the GDWQ targets are only appropriate when users drink water directly from the flowing taps of a piped system. These FRC levels are unlikely to provide sufficient protection when water is collected at the tapstand into containers, transported through the camp environment to shelters, and then stored for 24 hours or more before being consumed, especially in camp settings where environmental hygiene may be poor. Reports of water recontamination and associated public health impacts in both emergency and non-emergency settings abound in the literature. Facing this critical knowledge gap during the Maban County refugee crisis in South Sudan in 2012-13, we launched research to develop guidelines for emergency water treatment that derive from field evidence and are effective for protecting water through the entire period...
of consumption in the refugee/IDP camp setting. METHODS We launched observational studies of how residual chlorine protection changes between distribution and consumption in multiple refugee camps in diverse environmental settings. We began in dry season floodplains in Maban County, South Sudan (Mar-Apr 2013); expanded to observe multiple seasons in the desert Azraq camp in Jordan (Jul-Aug 2014 and Mar-Apr 2015); and carried out a final field phase in a tropical forested setting in Rwanda (Jun-Jul 2015). Primary data collection entailed observing water quality at four points post-distribution: 1) directly from tapstands; 2) after collection into containers; 3) after transport to households; and 4) following 6 to 24 hours of household storage and use. Water quality parameters analyzed included free and total residual chlorine, turbidity; pH, oxidation-reduction potential, electrical conductivity, and water temperature, all measured using field analysis devices. Selected household water samples were also analyzed for E. coli levels using Aquagenx compartment bag test kits. We also documented respondents' water handling practices via spot check and respondent self-report, first at the tapstand and again later in the household, in order to identify factors affecting the safe water chain. We used water quality data to model chlorine decay rates and reaction rate orders in MATLAB, which we could then use to determine what free chlorine levels must be at the tapstand in order to ensure a desired level of chlorine protection at a designated time post-distribution. FINDINGS Across multiple sites, data revealed that the current FRC guideline (ie, 0.2-0.5 mg/l) offers insufficient residual protection post-distribution in the camp setting. Emergency FRC guidelines should be increased in order to better protect safe water supply in refugee/IDP camps, while not being so high as to drive taste/odor-driven rejection. We observed that the rate of chlorine decay varied substantially across sites, suggesting that context-specific guidelines may be required. In dry season floodplains camps in South Sudan, chlorine decay was rapid due to high temperatures and poor environmental hygiene. According to modeling, increasing FRC at tapstands to 1.0 mg/l would provide 0.2 mg/l of FRC protection up to 10 hours post-distribution. It did not appear possible to maintain residual beyond this point without excessive chlorination, in which case, additional safe water strategies may need to be considered such as household water treatment, improved storage and hygiene, and higher frequency supply. In the summer desert setting in Jordan, modeling indicated 0.8-0.9 mg/l FRC at tapstands would maintain at least 0.2 mg/l residual up to 24 hours post-distribution. In winter/spring conditions at the same site, the decay rate was lower indicating that FRC guidelines should be designed for summer conditions in order to be conservative. Findings for Rwanda are forthcoming in summer 2015. Across all sites, modeling indicated a high level of agreement with second-order decay, corroborating the literature. In general, a FRC target of 0.8-1.0 mg/l appears to optimize longevity of safe water while minimizing taste/odor rejection in the refugee/IDP camp setting.

**Associations Between Maternal Water Consumption and Birth Defects in the National Birth Defects Prevention Study (2000-2005)**

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Evan Coffman; Anna Maria Siega-Riz; Thomas Luben; The National Birth Defects Prevention Study,

Background: In the United States, water and water-based beverages constitute a major part of daily fluid intake for pregnant women. Fluid intake during pregnancy supports mechanisms required for healthy fetal development, yet few epidemiologic studies have investigated the role of water consumption during pregnancy in the development of congenital anomalies. Methods: We used data from the National Birth Defects Prevention Study (NBDPS; 2000-2005) to conduct a case-control study investigating associations between maternal water consumption during pregnancy and selected major structural congenital anomalies. We used self-reported interview data on daily average water consumption during the first
trimester of pregnancy among 14,454 mothers of infants with a birth defect (cases) and 5,063 mothers of infants with no congenital anomalies (controls). Average daily maternal water consumption from all sources (e.g., tap and bottled water), was estimated using exposure variables constructed from the NBDPS water module portion of a Computer Assisted Telephone Interview, assessing mother's water consumption for the period one month before conception through the first three months of pregnancy. Adjusted logistic regression models were used to assess effects of water consumption on odds of birth defects. Average daily water consumption was analyzed as a continuous variable and also by quartile, to account for possible non-linear relationships. Models were adjusted for maternal race, maternal age, maternal education, maternal BMI, plurality, prenatal vitamin use, and maternal diet. A validated dietary survey, administered as part of the NBDPS questionnaire, was used as an indicator of dietary quality, in order to account for the possibility that maternal water consumption could serve as a surrogate for maternal diet. Results: Mean (SD) daily maternal tap and bottled water consumption among mothers of infants with no birth defects was 4.6 (3.1) 8-ounce glasses, whereas case mothers drank an average of 4.3 (3.1) 8-ounce glasses per day. We observed decreases in estimated odds associated with increases in water consumption for several birth defects and defect groups, including neural tube defects (e.g., spina bifida), oral clefts (e.g., cleft lip with or without cleft palate), musculoskeletal defects (e.g., gastrochisis, limb deficiencies) and congenital heart defects (e.g., hypoplastic left heart syndrome, right-sided obstructions, pulmonary valve stenosis). For example, after adjusting for potential confounders, including an indicator for dietary quality, we found an odds ratio of 0.68 (95% confidence interval 0.50, 0.92) for spina bifida when the highest quartile of maternal water consumption was compared to the lowest. Conclusion: These preliminary analyses suggest that increased daily water consumption during early pregnancy may be associated with a decreased odds of some birth defects. Whether these associations are indicative of a favorable influence of water consumption itself or water consumption as a surrogate for a generally healthier lifestyle or reduced consumption of sugary beverages requires additional analyses. Disclaimer: The views expressed in this abstract are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency

Household and Compound Sanitation Conditions and Synanthropic Filth Fly Populations in a Peri-Urban Setting in Kenya

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Oliver Cumming; Bernard Okech; Jane Mumma; Amber Barnes; Richard Rheingans

Background Current global urbanization trends have resulted in high rates of urban poverty and rapid increases in peri-urban population density without improved water and sanitation services. Poor housing and sanitation infrastructure for impoverished residents of these communities leaves them and their children vulnerable to exposure to household and community contamination. Poor human and solid waste disposal leads to large concentration of fecal and decaying material ideal for breeding and sustaining large synanthropic fly populations of families Sarcophagidae, Muscidae, Calliphoridae. Little is know about the dynamics between human urbanization in informal settlements and fly populations and the effects this relationship has on the potential for childhood exposure to diarrheal disease. Methods In this cross-sectional study, data from household sanitation surveys (N=800) and estimates of compound fly density using fly catches as proxy indicator of density were combined to better understand the relationship between household and compound sanitation conditions and fly-transmitted child diarrheal disease. Households were selected using a two-stage cluster sampling design from peri-urban households located within Nyalenda A & B, Kanykwar (Obunga and Nyawita community units) sublocations around Kisumu,
Kenya during the dry season from late February-late March 2015. Filth flies were collected from compounds where surveyed households had a child member aged 6-36 months old (N=371) using baited Quickstrike traps equipped with a fast-acting poison that quickly kills flies for collection and identification. Flies were trapped at either the location where household garbage was deposited or at the latrine for a period of 30 minutes in each compound. The location was selected based on the highest density estimate from Scudder grill measurements at both garbage and latrine sites within the compound. Fly catch counts were analyzed using univariate and multivariate negative binomial regression models in STATA 12 with observations of compound and latrine conditions, socio-economic status (SES), location and classification as improved or unimproved facilities (WHO/UNICEF JMP classification) as predictor variables. SES was represented as terciles of households grouped from an index of asset scores. Nine nested models were tested and compared for mode fit using likelihood-ratios. Results The model with the best fit contained latrine characteristics (smell and visible feces on latrine floor), presence of animal or human feces on the compound premises, SES and community. Comparing incident rate ratios (IRRs) for compound fly density in Nyalenda A were 1.6 (p<0.0001) times higher than for households located in Obunga and Nyawita. Rates for latrines that smelled inside or outside the latrine were 1.4 (p=0.05) and 1.5 (p=0.004) times higher, respectively, than latrines with no smell. Interestingly, the presence of visible animal feces in the compound area reduced the compound fly density by a factor of 0.8. Conclusions These results suggest that proper maintenance and ventilation of latrines is important for reducing compound fly density, not just improved or unimproved classifications of sanitation facilities. Aspects of the filth fly microhabitat must also be considered as dispersed animal and human feces may draw flies away from garbage and latrines to other locations in the compound. Interventions and infrastructure upgrades in high density settlements such as Nyalenda A must go beyond simple pit latrines in addition to increasing access to improved and well-maintained sanitation.

Risk Perceptions of Wastewater Use for Urban Agriculture in Accra, Ghana

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Sandy Cairncross; Anne Peasey; Adam Biran; Jane Bruce; Jeroen Ensink

Poor food hygiene is a significant risk to public health globally, but especially in low and middle-income countries where access to sanitation, and general hygiene remain poor. Food hygiene becomes even more pertinent when untreated or poorly treated wastewater is used in agriculture. In such circumstances the WHO recommends the adoption of a multiple-barrier approach that prescribes health protective measures at different entry points along the food chain. This study sought to assess the knowledge and awareness of wastewater use for crop production, its related health risks, and adoption of health protective measures by farmers, market salespersons and consumers using questionnaires and focus group discussions. In the period from September to December 2012, 490 participants were randomly selected from eight neighbourhoods in Accra and interviewed during the dry cropping season. The study found that awareness of the source of irrigation water was low among consumers (30%) and street food vendors (21%), though comparatively higher among market vendors (66%). In contrast, health risk awareness was generally high among salespersons (76%) and consumers (73%), but low among farmers (37%). In terms of knowledge of diseases, just over 50% of all participants did not associate any health risks with exposure to wastewater, or failed to correctly mention a disease associated with exposure to wastewater. Knowledge of wastewater related diseases was highest among domestic consumers with 66% correctly identifying diseases such as diarrhoea/cholera and worm infections, but lowest among farmers (26%). The study found that consumers did not prioritize health indicators when buying produce from vendors, and that
only 2% of street food consumers relied on health indicators. Rather, consumers were motivated to buy produce, or prepared food based on taste, friendship, cost, convenience and freshness of produce. For domestic consumers, buying produce was not influenced by awareness of health risk, nor was it influenced by the source of produce. Buying of produce was, however, strongly associated with knowledge of the source of irrigation water used for vegetable cultivation with those who were aware of the source of water 8 times less likely to buy wastewater irrigated produce (p < 0.001). Similarly, street food consumers who were aware of wastewater related health risk were 2.2 times less likely to buy salads, or add salad to their food, if they knew the produce was wastewater irrigated (p = 0.03). The study also found that farmers’ awareness of health risk did not influence their adoption of safer farm practices. From the foregoing, this study seem to suggest that relying on health indicators to raise awareness or reduce health risk, and to promote the uptake of health protective measures or the multi-barrier approach may not be sufficient to influence positive behaviour change. The study recommends the promotion of interventions that would result in more direct benefits (especially economic benefits) to both producers and vendors, such as credit and loan support, together with hygiene education and enforcement of food safety byelaws in order to influence behaviour change, and increase the uptake of the multiple-barrier approach. Keywords: Ghana, wastewater irrigation, risk perceptions, behaviour change, produce

Social Microbes: a Systems-Level Approach for Identifying Environmental Transmission Pathways for Infectious Fecal Microbes

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Fundamental understandings about how water, sanitation, and hygiene (WASH)-transmitted pathogens propagate throughout an environment and impact human populations have traditionally been based on methods that are reductionist in approach. Single microbes are often used as proxies for a broad class of viral, bacterial, or parasitic organisms to identify transmission pathways or to estimate environmental exposure risks. The etiology of WASH-associated disease in low-income countries includes dozens of unique pathogens, which fluctuates variably over space and time. Well-defined disease ecologies for many of these microbes affirms that the dispersion of microbes in the environment also varies based on ecological or host reservoirs, adaptability to environmental stressors, and infectivity to a host. This creates dynamic human-environment microbial transmission patterns, which suggests that exposure risks are not static over space and time. In environments impacted by poor human or animal waste management, the spatial-temporal dispersion of fecal pathogens and the associated exposure risk for humans may be particularly complex in scope and magnitude. Reductionist modeling approaches may fail to elucidate broader generalizable patterns about microbial propagation and to account for interdependent effects between microbes. A systems-level approach has been suggested for modeling diarrheal disease risks to account for population-level effects that are not obtained by a simple linear aggregation of individual-level effects. However this same concept has not been well applied in modeling diarrhea exposure risks, especially in environments where the framework of exposure pathways is amplified by poor feces management. Microbial transmission across an environment and at the human-environment interface must also be considered a system of interrelated microbes with population-level effects. This project explores this hypothesis by using environmental microbiology tools that detect a broad range of potential indicators, robust signal processing techniques that detect microbial concentration patterns at local and regional scales, and related information frameworks for facilitating systems- and pathogen-level pattern recognition and knowledge discovery in the spatial-temporal propagation of organisms, as well as their
inherent interdependencies. We hypothesize specifically that microbial propagation across a landscape can be understood using social network architecture. In social network models, specific actors can be grouped based upon common activities or behaviors. Given sufficient information about microbial actors in a system, microbial social networks (MSN) can identify those that exhibit similar activities and therefore act as co-indicative clusters. The dyadic ties that link microbial actors could be shaped by host social behavior (ex. shared use of an open defecation site), by environmental forces (ex. waterborne dispersion of organisms), or by the biological properties of the microbe (ex. inactivation rate). We will present the results from several pilot studies ongoing at sites that differ in human or animal waste management practices. The study design involves 3 iterative phases of data collection and analysis, each phase informed by the former. Each round of data collection involves extensive landscape mapping plus environmental sample collection at locations around a waste-impacted site. A new microfluoridic, quantitative PCR tool is used to characterize each sample's unique "sanitation fingerprint", as defined by the presence and concentration of one or more of 20 fecally-transmitted microbes and their biological properties. A preliminary MSN infrastructure is derived based upon identifying the co-indicative relationships between microbes in a fingerprint, and across a landscape of distal and proximal locations with separate fingerprints. Each round of output from MSN analysis identifies physical locations where patterns of relatedness between proximal sanitation fingerprints have emerged, which then guides the sampling decisions for the subsequent round of data collection. The final MSN map that visually displays related pathogen clusters is superimposed onto the landscape map to locate environmental drivers that influence these propagation pathways. The MSN is further restructured to distinguish between human versus non-specific sources in the system, and estimate the effect of different sources on pathways. Our end product will generate a data-driven set of guidelines for conducting empirical research on enteric disease transmission, from exploration of disease ecology, to WASH impact evaluation, to quantitative microbial risk assessment. Next steps will build on these pilot projects by superimposing MSNs with human social networks to disentangle environmental from social forces of propagation.

Development of a New Taqman Environmental Exposure Assessment Tool for Diarrheal Pathogens and Helminths

Kelly Baker, University of Iowa

Kayla Dreeszen

Waterborne diarrheal diseases are estimated to cause approximately 1.8 million human deaths every year. Common methods for estimating exposure risks from fecally-transmitted pathogens often use single microbe indicators as proxies for a broad class of viral, bacterial, or parasitic pathogenic organisms. In low-income countries, the etiology of WASH-associated disease fluctuates over space and time, suggesting that exposure risks are not static. The relationship between any given set of fecal indicators, especially natural gut flora and infectious agents may fluctuate significantly with spatial-temporal factors. Furthermore, environments that are highly impacted by poor human or animal feces management practices may also be characterized by a more complex system of exposure risks that involves the simultaneous transmission of multiple infectious pathogens at one time or within a short period of time. The overall goal of this study is to characterize the scope and magnitude of exposure to infectious enteric pathogens in different fecally-impacted sites and quantify the informational gains in exposure detection by using combinations of infectious enteric disease targets. The first objective is to optimize a new, rapid, microbial exposure assessment tool to generate high quality quantitative information about the presence and concentration of 20 commonly-transmitted human and zoonotic enteric pathogens in the environment. The second
Objective is to map the correlation matrix between individual indicators in samples collected from several sites with different potential fecal impact hazards, and identify exposure indicators that have a high probability of accurately detecting and quantifying a true exposure risk from any other fecally-transmitted organism or group of organisms. The third objective is to test whether the probability of exposure and disease for humans in these environments could be more accurately estimated using additive or multiplicative combinations of indicator organisms. We have developed new microfluidic, Taqman array card (TAC) that simultaneously screens for 20 unique viral, bacterial, protozoan and helminth targets in water and soil samples. The environmental TAC allows us to characterize the true etiological scope and magnitude of fecal exposure (the "sanitation fingerprint") in environmental samples collected from several sites characterized by low and high risk for impact by human and animal waste. We screened three extraction kits to assess the extraction efficiency and quality of nucleic acid recovered from piped and river water, and from soil samples spiked with known concentrations of viral, bacterial and protozoan microbes. Then, the quality of the DNA and RNA produced by each kit was tested using the Quantifast Pathogen DNA and RNA kits with Internal control. Extraction efficiencies for the Powersoil Total RNA plus DNA accessory kit, the Fast DNA/RNA Spin kits, and the PowerViral Environmental RNA/DNA kit were all similar. However, total recovery of bacteria, protozoans, and virus was higher for the Powersoil and FastDNA/RNA kit due to minimized need for pre-processing. Inhibition was not detected in extracted DNA or RNA from water samples. However, inhibition was observed in one soil sample after extraction by the PowerViral kit. The other phases of the project are ongoing. A first round of water and soil samples have been collected from a local Iowa watershed at upstream and downstream locations from a waste treatment plant, and a community employing individual septic systems. The watershed also runs through a pig farm, and three cattle farms. Fecal E. coli measured using the Idexx Colilert system were identified in all water (median 102, range 102 - >103, n=7) and soil (median 102, range 102 - 103) samples. TAC testing and repeat sampling is in process. Data collection and analysis will completed in Iowa and in Kisumu, Kenya this summer. An optimized microbial exposure assessment tool that can rapidly detect, type, and quantify multiple potential infectious pathogens could be employed in numerous situations, ranging from sporadic monitoring and validation of food and water monitoring data, to emergency responses after extreme events like floods or sewer leaks, fecal source tracking, and evaluation of water, sanitation, and hygiene interventions. In diarrheal-disease endemic areas, improved environmental exposure assessment could provide a more accurate picture of the transience or persistency of a variety of pathogens, and the primary pathways by which they traffic through a population. We would be able to expand beyond pathogen-level risk assessments and estimate disease-level risks from multiple organisms. This tool would also address fundamental methodological challenges in interpreting non-detects by reducing the uncertainty in presence or absence of many targets. This research will give us a better idea of how to detect risk with complicated disease etiologies.

**Buy, Give, Take and Share: WASH marketing in the South Pacific**

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Srinivas Sridharan; Regina Souter; Stephen Saunders; Semisi Meo; Katherine Shields; Jamie Bartram

Stimulating access to and use of improved sanitation through market-based mechanisms has been very popular amongst WASH practitioners in recent years. Its success has been demonstrated in many regions of the world, resulting in more governments and civil society organisations (CSOs) showing interest in applying the approach in their respective countries. In particular, countries in the South Pacific such as Fiji, Vanuatu, and Solomon Islands are interested in exploring market-based approaches to increase the uptake
of appropriate WASH technologies, services and habits. Nevertheless, there is very limited evidence and
guidance into the applicability of a market-based WASH approach to countries in the South Pacific region.
In particular, very little research has addressed the WASH situations within informal impoverished
settlements, a top urban policy concern for governments. To address this gap, our research aims to
determine: How current WASH exchange systems function in informal settlements in the South Pacific;
How these systems relate to individual and group WASH desires and behaviours; How communities and
the enabling environment (e.g. governments, community service organisations, utilities, private
businesses) can nurture these systems and assist communities to realise their WASH aspirations. Our
hypothesis is that working within existing patterns of economic activity, often emphasizing relationships
and accentuating the role of historical time and events, has greater potential to be sustainable for long
term WASH improvement than introducing unfamiliar and potentially uncomfortable forms of market-
based exchange. We employ a participatory action research (PAR) approach to engage informal
communities in Fiji, Vanuatu and Solomon Islands. Within PAR community members themselves act as
researchers through activities such as household- and community-scale systems mapping, transect walks,
focus groups and in-depth interviews. The research findings show that there are many existing and
emergent exchange systems that people use to acquire WASH in informal settlements of the South Pacific.
Such exchange systems may be market-based (a willing buyer and seller enter into an exchange through a
market pricing mechanism), but can also be: non-market based (the supplier receives no explicit form of
payment from the recipient when the good or service is provided); command-based (an authority provides
goods and services through a regulatory institution that pursues a provision motive rather than a profit
motive); culturally-determined (where a provider and recipient enter into an exchange relationship
primarily sanctioned by social traditions and norms). There are variations of exchange systems used, from
selling WASH goods as a small business, to providing them to neighbours in an act of community spirit, to
charging the neighbours a fee to access services. The acquisition of some WASH devices and services is
often being achieved through a hybrid mechanism containing more than one type of exchange system.
Even within the same settlement, preferences of users are heterogeneous, meaning that there is unlikely
to be a single type of WASH exchange system that will best enhance the situation of people throughout
the community. We are using the knowledge developed through these participatory activities to work in
partnership with the communities and local enabling actors to develop sustainable WASH exchange
systems in these settlements. This is consistent with the sentiment that ultimately, markets are "ongoing
processes of economic organising constituted by bundles of practices" (Lindeman 2012). We are also
working closely with the enabling actors to investigate how this participatory methodology and its results
could be adapted for use in other settlements, and how understanding exchange processes within
informal settlements may influence future policy-making. This is consistent with a related sentiment about
markets that they are the "practical outcomes of organising and shaping efforts by various market actors"
(Araujo, Finch, and Kjellberg 2010).

Taking Household Water Treatment and Energy to Scale: Program Development and Initial Adoption
Data from the Implementation of the Tubeho Neza Program in 100,000 Households in Rural Rwanda

Christina Barstow, University of Colorado/ DelAgua Health

Evan Thomas

Meaningful impacts on drinking water contamination and indoor air pollution will only be realized through
large scale program implementation. However, taking a program from a single village to a regional
program presents challenges that need to be integrated into the piloting and planning process. Specifically
programs with highly involved behavior change, must balance methods to provide quality education and training while still realizing the benefits and efficiencies of large scale programming. Following a two-year pilot of 2000 households, DelAgua Health, in partnership with the Rwanda Ministry of Health (MOH), has brought to scale the Tubeho Neza program, providing point-of-use water filters and high efficiency cookstoves to the poorest 30% of households in Rwanda's Western Province. 820 MOH Community Health Workers (CHWs) conducted over 100,000 individual household visits during a three month campaign in the fall of 2014. Inclusive within Tubeho Neza was an extensive behavior change program which included a multi-day training of CHWs so they could become proficient in use and maintenance of the products but additionally techniques for meaningful engagement and communication in target households. BCC strategies included social marketing through radio advertisements and pre-distribution sensitization meetings, as well as household educational materials developed based on a household's aspirations with interactive and personalized tools which were integrated into a household's daily activities. This presentation will discuss the Tubeho Neza program from pilot to implementation to the initial six months following households receiving the products. The implemented program design will be described within the context of integrating the piloting process with the constraints of program scaling. Specific emphasis will be placed on development of the behavior change and monitoring program with insight into challenges specific to large-scale program needs. Additionally, the program's initial adoption metrics will be presented from monitoring data collected approximately six months after households received water filters and cookstoves.

**Spatial and Behavioral Influences on Household Fecal Contamination in Two Low-Income Urban Settings**

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Increasing urbanization strains existing water, sanitation, and hygiene (WASH) infrastructure in low-income settings. High population density may increase the potential for transfer of microbes and disease, exacerbating the consequences of poor sanitation coverage. Because of the blurred line between public and private domains in these dense settings, residents may come into contact with fecal contamination in a variety of ways both inside and outside the house. Adult and child behaviors of a specific household, house location in the neighborhood, and the context of the households around it, may all influence the spread of fecal contamination to that household. The goal of this study was to quantify the contributions of the household- and neighborhood-level context to fecal contamination within urban households in two low-income neighborhoods. Environmental samples were collected in public toilets and households in the Cinna Allapuram (CAP) and Old Town (OT) neighborhoods of Vellore, India. In public toilets, swabs of surfaces within the toilet were collected, while in households, both swabs of surfaces and rinses of children’s hands were collected. Household surveys were conducted to assess housing and sanitation conditions, as well as self-reported adult and child behaviors related to potential exposure to fecal contamination. GPS points were collected for all samples and surveys and also at open defecation fields. Environmental samples were tested for E. coli as a measure of fecal contamination. E. coli concentrations and household conditions/behaviors were evaluated for local and focal clustering using Geti’s G and G* statistics, Kulldorff’s spatial scans, and Diggle’s method. Associations between survey responses and microbiological contamination were assessed at the household- and cluster-level. Focal clustering was evaluated around open defecation fields and public toilets. CAP and OT differed significantly for most household-level characteristics, including sanitation coverage, with households in OT reporting less than
half the coverage of toilets (33% vs. 78%) and over twice the prevalence of open defecation (80% vs. 40% in children under five, 79% vs. 21% in children five to twelve, and 68% vs. 19% in adults) compared with CAP. Toilets in OT primarily emptied to the open drains (82% of toilets), while those in CAP emptied to drains (35%) or were emptied by a trucking service (47%). Clustering of household sanitation characteristics and flooding was observed in both neighborhoods; however, local clustering of microbiological contamination in environmental samples was not apparent. In the household-level analysis, presence of a toilet was associated with a one-log10 increase in E. coli colony-forming units (CFU) per 100 cm² on swabs of household surfaces in OT, but this relationship was not consistent in CAP. Swabs of public toilets in OT were significantly more contaminated than those from households (2.2 vs. 1.3 log10CFU/100cm²). At the cluster-level, households within a significant cluster of low toilet coverage/high open defecation, or those within 120-130m of the open defecation fields in OT, had significantly lower concentrations of E. coli on swabs from household surfaces by approximately 1 log10 as well. Conversely, children in households within a significant cluster of high toilet coverage in CAP had lower E. coli in hand rinse samples by 0.7 - 1.0 log10 CFU per pair of hands. Within OT, there was clustering of higher concentrations of E. coli in child hand rinses close to the most contaminated public toilet, while there were low E. coli concentrations on household swabs clustered farther away. This study examines the association between toilet locations and magnitude of fecal contamination of household surfaces and hands in the context of local sanitation coverage. While we would expect toilets to be associated with reductions in fecal contamination in that particular household and on hands of children using it, high local sanitation coverage may be necessary to see these effects. In areas with low sanitation coverage, the presence of a household toilet may actually increase the levels of fecal contamination present in the household, possibly due to increased sharing of the few existing toilets in the area and poor maintenance. Future analysis of sanitation coverage should consider not only the presence of household toilets, but also the associated fecal sludge management, toilet maintenance, and the overall neighborhood sanitation coverage and spatial clustering.

Scaling Up Rural Sanitation in India: Positive Determinants of Success in Eight Indian States

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In October 2014 the World Bank Water and Sanitation Program (WSP) initiated a study to document its engagement in the rural sanitation sector in India between 2002 and 2013 in order to learn from achievements, challenges, and the lessons from the past as WSP and other stakeholders intensify efforts to address the huge challenge of universal rural sanitation in India. The study covered a cross section of eight States in which WSP has worked (Bihar, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh, Maharashtra, Meghalaya and Rajasthan), as well as an examination of activities at national level. The primary source of information was 138 structured interviews carried out by consultants in each of the States, and with key informants at national level. As a result of this study, a timeline of sector milestones, government actions and WSP interventions at national and State levels was developed. This timeline shows a combination two very different types of intervention on the part of WSP: low-profile but patient and persistent interventions to build awareness, commitment and capacity, and high profile, evidence-based advocacy for major policy change when opportunities emerged. The interventions are characterised by a firm commitment, from the outset, to demand-led sanitation; a commitment that arose well before this approach was widely recognised and accepted in the global sanitation sector. In addition, WSP went beyond the promotion of demand-led sanitation and looked for ways to support the approach at several
levels - specifically at the levels of policy, enabling environment and the market. A comparison across the eight Indian States shows varying levels of success, with markedly less traction in Bihar, Jharkhand and Madhya Pradesh. Further analysis reveals that certain external factors (positive determinants) had significant impact on whether it was possible to help the State make progress on sanitation. These factors were: Awareness of poor progress in sanitation resulting in a willingness on the part of government decision-makers to take action, and to try innovation; An opportunity to initiate action in an area where households have some resources - that is, areas that are not the poorest, where progress in sanitation based on household investments could be demonstrated before rolling out to a wider population; The presence of "local champions" who were willing to take action, be outspoken and provide leadership? The presence of few other development actors working in the sector - where WSP acted almost alone it had more success than in the States that had many development agencies present; Enabling cultural factors that made demand-led sanitation more likely to work, or less likely to fail - these include factors such as cohesive tribal societies, a tradition of social mobilisation and high literacy rates. The positive determinants were not specific to WSP; any other development agency would also have found their absence a constraint to success. Analysis of key interventions shows that some specific approaches could be used to overcome the absence of some of these positive determinants, and to influence outcomes. While not always fully successful in all States, these constitute what this study has revealed to be the key interventions undertaken during the period of the study. These interventions can broadly be categorised as being related to either 1) advocacy with decision makers (engagement with the political economy of rural sanitation), or 2) support to an enabling environment for progress, including provision of new models of implementation. The interventions are: Advocacy with decision-makers: Creating champions through study tours and the pro-active use of champions to create political commitment; Increasing awareness and willingness to act though targeted, high quality research and guidelines, such as the research on the economic cost of inadequate sanitation Support to the enabling environment: Building capacity through training; Documenting and promoting best practice through development of handbooks and manuals; Bringing new and innovative implementation models to the sector, such as the introduction of outcome monitoring Each of these interventions brought challenges. Many of these relate to the fact that the sector as a whole is still struggling with a clear theory of change that defines a pathway to success at a large scale, and that clearly identifies areas for intervention. WSP is examining ways that it can be more effective in the future, in particular in relation to two challenges: 1) how it can best add value and support government efforts to address obstacles and better use its convening power to build partnerships at different levels, and 2) how to scale up technical assistance to support entire States based on proof-of-concept at district level.

Crowdsourcing Water Quality Data Using Low-Cost Quantal E. coli Tests With Ambient-Temperature Incubation

Joe Brown, Georgia Tech

Background. The forthcoming Sustainable Development Goals (SDGs) are likely to include a recommendation to include direct measures of water safety in global monitoring, with the guideline value being ≤10 cfu/100ml E. coli. We have developed and piloted a low-cost ($0.50) presence/absence test for E. coli that (1) results in a color-change signal when E. coli is present, (2) has a lower detection limit of 11 cfu/100 ml to distinguish low and high-risk sources, (3) can be incubated at ambient temperatures above 22C, (4) can be reliably performed by volunteers in low-income settings, and (5) works in concert with a mobile phone reporting platform we have developed that calculates mean estimates and confidence intervals at multiple scales. In this presentation, we present laboratory and field-testing data from India.
and Bolivia on development of the system for at-scale monitoring of water safety in settings where laboratory access is limited. Our hypothesis is that many low-cost, quantal tests can be an accurate and field-deployable method of determining mean E. coli counts in drinking water sources when compared with estimates derived via membrane filtration in relatively high-cost quantitative assays. Methods. We processed water samples for E. coli via the new presence/absence test and membrane filtration followed by incubation on selective media (standard method) in both laboratory-prepared waters \((n = 420)\) as well as in samples of drinking water in Bolivia \((n = 120)\) and in India \((n = 520)\), deriving data on the performance of the test across a wide range of counts and using both standard incubation temperatures \((35 - 37^\circ C)\) and ambient temperatures \((22C - 35C)\) at 18, 24, 48, and 72 hours. We compare mean estimates and 95% confidence intervals for both membrane filtration and using quantal tests in most probable number calculations by water source. We also pilot-tested a reporting platform whereby volunteers in rural India were given the tests with brief instructions and a telephone number for reporting via SMS. We developed a smartphone application to receive and process SMS data sent from the field, with progressive computation of mean estimates from the quantal tests. Results. In laboratory testing, sensitivity and specificity of the test was 96% and 90% at standard temperature incubation and 96% and 87% at 22C after 72 hours, with reliable detection of the color-change signal at 11 cfu/100 ml. In both field sites, 84% of all ambient temperature-incubated quantal tests were accurate in distinguishing between sources \(\leq 10\) cfu/100ml and >10 cfu/100 ml E. coli as determined by the standard method. Mean estimates across sources were lower than arithmetic means when derived via MPN estimation, however. In terms of reporting, we found that 47% of participants in rural villages were willing to conduct and return the tests, with 45% of active participants sending their water testing results via SMS. Further feasibility tests conducted at a local school found that 85% of students we visited conducted the tests, with over 50% reporting their results via SMS. Conclusion. Low-cost quantal assays for E. coli can be useful for rapid, at-scale monitoring of drinking-water safety in low-income settings. Our results suggest proof of concept for using this type of assay to generate reliable risk information at relatively low cost.

The Costs and Benefits of Continuous Piped Water Access: The Case of Hubli-Dharwad

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Ayse Ercumen; Emily Kumpel; Kara Nelson; John Colford; Narayana Billava; Nayanatara Nayak; Isha Ray

Globally, piped water access had reached 56% of people by 2012 (WHO/UNICEF 2014). Yet the disparity across regions is high in terms of both coverage and quality of service. In many countries it is often available only intermittently (WHO 2000). Systems with intermittent water service (IWS) have decreased water quality and impose 'coping costs' on households who need to wait for deliveries, and then collect, treat and store their water supply (Kumpel and Nelson 2013, Zérah 2000, Pattanayak et al. 2005). Upgrading to continuous water service (CWS) has the potential to save time, improve health and enhance household economy, by improving both water quality and availability. Yet, CWS often has a higher cost of service, and therefore such an upgrade may require steep tariff increases. Therefore it is not always clear whether and when the benefits of CWS outweigh the costs (Zérah 2000, Pattanayak et al. 2005). The Karnataka Urban Water and Sanitation Improvement Project (KUWASIP) is a pilot program, initiated in 2007 under a public private partnership, which brought CWS to 10% of the residents of Hubli-Dharwad. The residents outside of the pilot zones continue to receive IWS, typically 2-3 hours every 3-4 days. Using a quasi-experimental approach called genetic matching (Sekhon 2009), 8 control wards were chosen such that they matched with the 8 pilot zone wards across across a long list of household characteristics for socio-economic status, hygiene and access to water and sanitation. Visual inspection was conducted on
every neighborhood by the research team in order to verify the match and split each ward into clusters, i.e. zones within the ward that display homogeneous economic and demographic make-up. 250 participants were enrolled from each ward, where the number of participants to enroll from each cluster was determined qualitatively based on the population density of the cluster to obtain a representative sample of the ward. 4 rounds of surveying were conducted over the course of 14 months. The survey instrument was extensively piloted in order to ensure that it reflected the specific ways in which people interacted with water in Hubli-Dharwad. A principal-components analysis was performed on asset ownership in order to categorize households into wealth quartiles. In this study, the average time spent on water related activities, average financial investment and average monthly expenditure are compared across CWS and IWS. Valuation of the time spent is done using several different methods as part of a sensitivity analysis (James et al. 2002, Zérah 2000, Whittington et al. 1989). The cost-benefit ratio of continuous supply is calculated and compared with estimates for other interventions. Equity impacts are explored across income quartiles as well, including the accumulation of arrears owed to the local utility.

REFERENCES


Community-Led Total Sanitation Open Defecation Free Communities and Ebola in Northern Liberia

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Haron Njiru

The Ebola Virus Disease (EVD) epidemic entered Liberia from Guinea through Foya in Lofa County in February 2014 and quickly spread to two nearby health districts where Global Communities (GC) and the Lofa County government had been implementing the IWASH project since 2010. The last EVD case in Lofa County was in November 2014. By early 2015, had been 928 reported Ebola cases, 422 confirmed and 648 deaths in Lofa County. After the epidemic began, international attention largely focused on clinical EVD treatment in health facilities. Very little was understood about household and community risk factors
related to EVD. Community-Led Total Sanitation (CLTS) was the IWASH project sanitation approach. Before the epidemic began, 115 communities had been "triggered" and 98 had been certified as "Open Defecation Free" (ODF). Reports and official health statistics identified differences between communities with EVD and similar communities in the same area with no EVD. IWASH reports also found no EVD in project communities that had achieved ODF status. This study sought to confirm reports that there was no EVD in IWASH ODF communities by using mixed quantitative and qualitative methods, examine the relationship between CLTS/ODF status and EVD, and identify key factors in behaviors. A survey of 541 households in 43 communities, with and without EVD, was followed by Focus Group Discussions (FGDs) in 14 communities. Results were analyzed and triangulated according to community CLTS/ODF status before the epidemic, and compared with those that did not start CLTS. Demographic and socioeconomic data was also collected to identify potential confounding factors. IWASH behaviors including hand washing, latrine use, water treatment data was also collected. No EVD was found in IWASH communities that achieved ODF prior to the 2014 outbreak. Holding all other factors constant, higher income households, those without hygiene training from a Natural Leader (i.e. no CLTS), those without a community radio and those with low levels of knowledge on signs and symptoms of Ebola were more vulnerable to Ebola. Households in communities without Natural Leader training (no CLTS) were almost five times more likely to have EVD in their community than CLTS communities OR = 4.87. FGDs confirmed communities' perceptions that practicing WASH behaviors before the epidemic prevented Ebola from entering their communities. Only one (of 17) communities that started CLTS, but did not reach ODF status, reported EVD supporting reports from other CLTS projects that triggering itself may result in some positive WASH behavior changes. Hand washing, latrine use, and point of use water treatment prior to the EVD outbreak were reported at significantly higher percentages in CLTS communities than in non-CLTS communities. The survey that hygiene training in CLTS communities began before the Ebola epidemic started in 2014. CLTS, where ODF certification independently confirmed specific behaviors, (hand washing with soap, latrine use, etc.) were already in place, was the most likely explanation for the differences in EVD between communities. As the epidemiology of the outbreak is better understood, however, more research will be needed to confirm these findings and identify additional potential confounding factors. Reaching ODF in CLTS communities required communities to practice several important protective behaviors and depended upon the work of Natural Leaders who are the established and trusted community mobilization facilitators that are identified during CLTS triggering. They have remained active throughout the epidemic, continue to trigger additional communities and remain actively involved in Ebola Response Hygiene Promotion. CLTS implementation intentionally starts in small communities; communities are not randomized. Large communities must be broken into sectors. This was starting when IWASH was overtaken by the EVD outbreak. Communities that participate in CLTS might be "positive deviant communities," meaning they could differ from other communities in their motivation and capacity to respond to opportunities and threats. This included communities that took the first step to participate in CLTS and submitted letters of interest to participate in triggering to IWASH. Presence of Natural Leaders in communities that are identified during triggering may also be an indicator of existing capacity between communities. These factors may all provide the enabling environment for change. Detailed national protocols for ODF certification provide objective verification that targets and standards have been met and may also have been a factor in motivation to complete the process to ODF. CLTS may also share common characteristics with other community-based programs implemented in communities where there was no EVD, but additional research will be needed to identify what they are.
**Water Options in a Drier Climate: Optimization of Water Supply and Reuse**

Jim Chamberlain, University of Oklahoma  
David Sabatini

Continued population growth, frequency of drought conditions, and contamination of both surface and groundwater sources have led to more creative ways of reusing wastewater. Planned indirect potable reuse requires a set of treatment schemes to meet the water quality criteria carried by the environmental buffer. Direct potable reuse bypasses an environmental buffer, but requires a higher level of treatment. Finally, long-distance conveyance of cleaner water from a remote freshwater source (often outside the watershed) requires less treatment but high energy costs needed for conveyance. Where politically feasible, cost and/or energy usage will likely be the ultimate driver for decision makers. We consider and juxtapose these valid water supply options as an optimization problem using available cost and energy usage data from community water systems (CWSs) in the United States. Monte Carlo analysis is used to model ranges and distributions of cost data, reflecting both robust specialization and economies of scale. The goal is to provide an estimate of a range of optimal CWS plant sizes (MGD) at which each of these three options is optimal, based on cost, energy usage, and fresh water extraction. A sensitivity analysis is done on each of the significant drivers of cost and energy, and a qualitative discussion of risk for each option is also provided. After presenting the theoretical model, the use of the model is demonstrated by optimizing options for the cities of Altus (pop. 19,800), Norman (pop. 110,900) and Oklahoma City (pop. 610,000), Oklahoma.

**Sanitation-Related Psychosocial Stress: Measuring the Social, Psychological, and Emotional Impact of Women’s Limited Sanitation Access in India**

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Background: The link between access to basic WASH resources and psychosocial outcomes is an area of emerging importance in global health research. Psychosocial stress, in particular, has been linked to water availability and water access in multiple low- and middle-income countries. Prolonged stress has been linked with a variety of physical and psychological health outcomes including: depression, anxiety, cardiovascular disease, and impaired immune function. In this study, we sought to quantify the psychosocial impacts of sanitation access and sanitation use among women of reproductive age in multiple infrastructure-restricted settings in India. Specifically we: 1) developed a theoretically informed scale of sanitation-related psychosocial stress (SRPS), 2) identified the determinants of SRPS in our study population, and 3) utilized path modeling to assess the relationship between SRPS, its determinants, and standardized measures of mental and general well-being validated in South Asian. Methods: We surveyed 360 female respondents randomly selected from three geographic areas (low-income urban, rural, tribal) with equal representation from four predefined life course groups: adolescent girls, newly married women, pregnant women, and established adult women. Surveys included a series of 45 binary response questions (yes/no) related to stressors encountered during sanitation access and sanitation use in the past 30 days. Questions reflected three domains of sanitation-related psychosocial stress: stressors related to the physical and built environment, stressors related to the social environment, and stressors related to
sexual- and gender-based violence. Through the iterative application of Mokken Scaling procedures, we identified a parsimonious set of questions that were combined into a single SRPS scale with three sub-scales reflective of each of the three theoretical domains of stressors. Regression modeling was used to assess the relationships between scale values and a variety of potential determinants, including access to a sanitation facility, access to water infrastructure, life-course group, geographic location, caste, and socioeconomic status. In the final stage of our analysis, we use path modeling to compare our SRPS scale and its predictors to the WHO5 Well-Being Index, a rapid assessment tool for measuring overall quality of life.

Results: Our final SRPS scale consisted of 30 questions divided into three subscales: environmental stressors = 9 questions; social stressors = 13 questions, and sexual violence stressors = 8 questions. Scores ranged from 0 - 28, with 21% of respondents having an SRPS Scale value of zero, suggesting a zero-inflated distribution. The median non-zero score was 13. Internal consistency of the final scale was excellent (Cronbach’s alpha = 0.94). All women with a zero SRPS score had access to a sanitation facility. Because of the lack of variability, respondents with a zero score were excluded from further analysis. Among respondents with a non-zero SRPS score (n = 278), women with a sanitation facility had an average marginal score of 6.6 on the SRPS scale, compared to a score of 14.8 among those without a facility (p < 0.001). SRPS scores among respondents belonging to a scheduled caste or tribe were on average 3 points higher (13.7 vs. 10.7, p = 0.001). Geographic location had a stronger association with SRPS than life stage, with urban samples scoring 3 - 6 points higher than similar life stage groups in rural or tribal areas. In our final path model, SRPS has a small but significant impact on WHO5 scores (coefficient = -0.11, p < 0.05).

Access to a sanitation facility, life course group, and scheduled caste or tribe had no direct association with WHO5, but retained their significant relationships with SRPS. Conclusions: We identified a robust, theoretically grounded scale for assessing sanitation-related psychosocial stress. The relationship between sanitation facilities and psychosocial outcomes was complex. Among women with no reported SRPS, all had sanitation facilities. However, the inverse was not true: many women with access to sanitation facilities still reported SRPS, however measured SRPS was much lower. The impact of sanitation facilities on overall quality of life, as measured by the WHO5, was indirect and mediated through sanitation-related psychosocial stress. Improving access to infrastructure will only partially address issues of fear, anger, and shame women face in relation to sanitation practices. More attention is needed to expand access to infrastructure to vulnerable groups as well as further examine the process of accessing and utilizing infrastructure in a way that promotes the health and safety of all.

When Pits Fill Up: Sanitation Technology Adoption and Adaptation in Urban Malawi

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As the cities of Sub-Saharan Africa rapidly urbanize and population density increases, pit latrines - the dominant sanitation technology in low-income and high population density areas - become unsustainable because safe pit-emptying services are generally unavailable and lack of space prohibits construction of new pit latrines. Ecological sanitation has been promoted as an alternative sanitation system to overcome these limitations, but uptake has been very slow. We conducted a mixed-methods study to examine how homeowners in urban Malawi respond to the challenge of meeting sanitation needs when pit latrines become unworkable: do they seek to adopt new technologies, or do they adapt existing technologies to meet changing circumstances? We carried out 60 in-depth interviews and examined sanitation technology choices of 1,300 property owners from 27 low-income and high population density settlements. Results suggest that property owners in this setting strongly prefer to adapt existing pit latrine technology,
including adjusting the way they build, operate and maintain pit latrines, to adoption of alternative sanitation technologies that require significant changes to behaviour, technologies, or the user experience. These findings underscore the importance of understanding what adopters want in the context of sanitation technology innovation and diffusion. We conclude that incremental, grassroots innovation by users themselves has resulted in promising strategies to overcome current challenges to urban sanitation in Malawi. We further describe ways that authorities and donors can provide support to scale up low-cost urban sanitation that works to contain excreta in this challenging context.

**Water Quality Interventions to Prevent Diarrheal Disease: Results from the Updated Cochrane Review**

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Diarrhoeal diseases are a leading cause of mortality and morbidity, especially among young children in developing countries. While many of the infectious agents associated with diarrhoeal disease are potentially waterborne, the evidence for reducing diarrhoea by improving the microbiological quality of drinking water has been equivocal. We present new results from Cochrane review on water quality interventions to prevent diarrheal disease. The review was first published in 2006 and cited more than 500 times. Since the original review, the number of eligible studies (RCTs and controlled before-and-after studies) and blinded trials has nearly doubled. At the same time, a series of other systematic reviews has led to conflicting conclusions about the role of water quality interventions–particularly those at the household level–resulting in confusion about the role of water quality in preventing disease. We searched the Cochrane Infectious Diseases Group Specialized Register, CENTRAL, MEDLINE, EMBASE, and LILACS, all through November 2015. Two authors independently determined study eligibility and extracted data. We used meta-analyses to estimate pooled measures of effect and investigated potential sources of heterogeneity using subgroup analyses. We used GRADE to assess the strength of the evidence. Fifty-six trials (including 67 independent comparisons) covering over 98,000 participants met the inclusion criteria. Differences in settings, interventions, study designs, outcomes and other methods limited the comparability of results and the probity of pooling by meta-analysis. Overall, the evidence suggests that interventions to improve the microbiological quality of drinking water are effective in preventing diarrhea both for populations of all ages and children under five years old. Community-level improvements in water supplies such as protected wells were borderline protective for all ages (RR 0.74, 95% CI 0.54 to 1.0, 8 comparisons), but not for children under 5 years (0.90, 95% CI 0.74 to 1.10; 5 comparisons). This estimate does not include household connections for which there were no eligible studies. Point-of-use interventions were protective for all age populations (RR 0.60, 95% CI 0.50 to 0.73, 59 comparisons), and for children under 5 (0.61, 95% CI 0.49 to 0.77; 45 comparisons), but the reported effect may be exaggerated due to bias. Household based chlorination may reduce diarrhea episodes by around one quarter (RR 0.76, 95% CI 0.65 to 0.89, 10 comparisons). Compliance with the intervention as measured by residual chlorine in water samples varied from 32% to 89%. Ceramic filters and sand filtration systems, used to filter drinking water in the home, probably reduce diarrhea episodes by around half (ceramic filters: RR 0.42, 95% CI 0.27 to 0.60, 8 trials; sand filtration: RR 0.47, 95% CI 0.39 to 0.57, 5 trials). Effectiveness was positively associated with compliance. Interventions were effective even in settings without improved water supplies or improved sanitation. While the overall evidence suggests that interventions to improve drinking water quality are effective in preventing diarrhea, the strength of the evidence is only low to moderate. Subgroup analyses suggest that household and other point-of-use interventions may be more protective than community and other interventions at the point of delivery. However, substantial heterogeneity among results suggests that the actual level of effectiveness may depend on other conditions that research to date cannot fully explain. Rigorous trials and other longer-term evaluations of programmatically-delivered interventions (including household connections) using
objective outcomes may help clarify the conditions that influence the effectiveness of water quality interventions.

**Household Drinking Water Treatment in Rural China: Microbiological Effectiveness and Socioeconomic Predictors**

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**BACKGROUND** Globally at least 1.8 billion people lack access to safe drinking water [1,2]. After decades of uneven success promoting household water treatment (HWT) using retail products such as chlorine and ceramic filters, boiling remains the most common HWT method globally [3]. Although boiling is microbiologically effective, indoor air pollution (IAP) from biomass and coal combustion causes cardiovascular and pulmonary disease, biomass harvesting is time-consuming, fuel is often costly for poor households, water boiled in pots is easily re-contaminated, and black carbon emissions exacerbate climate change [4-6]. In China, where there is a strong cultural preference for boiled water, 85% of the rural populations (~ 607 million people) heat/boil their drinking water [7]. This figure includes most of the households who purchase large (19L) bottles of drinking water. However, at least 280 million Chinese still lack safe drinking water [8], and most of the rural population is regularly exposed to IAP from boiling, cooking, and heating, with documented negative health outcomes resulting [9-11].

**RESEARCH OBJECTIVES**

Our research collaboration was formed through a shared desire to better understand the prevalence and effectiveness of the HWT methods used in rural China, with the goal of expanding sustainable access to safe drinking water, while ideally reducing IAP exposure. METHODS We used a geographically stratified cross-sectional design to survey 570 households in 2013-2014. Household drinking water samples were collected and assayed for Thermotolerant Coliforms (TTC), physicochemical analyses were conducted for village drinking water sources, and remote temperature sensors were used to corroborate self-report boiling data. RESULTS HWT prevalence was: 27.1% boiling with electric kettles, 20.3% boiling with open-pots, 34.4% purchasing bottled water, and 18.2% drinking untreated water. Households using electric kettles had the safest drinking water, associated with a 73% reduction in geometric mean TTC versus untreated water. Households boiling with open-pots were 1.5 times more likely to have TTC detected than households using electric kettles (risk ratio, RR=1.51, 1.02-2.22, p<0.05) and households drinking untreated water were twice as likely (RR=2.03, 1.42-2.90, p<0.001). Multilevel mixed-effects regression analyses revealed no evidence of confounding, and electric kettles were associated with the largest Log10TTC reductions (-0.60, p<0.001). A number of socioeconomic variables (e.g., head of the household's age, household size, access to healthcare) were significantly associated with different HWT methods.

**CONCLUSIONS** This is the first HWT-focused study in China, and the first to identify the comparative advantage of electric kettles. Our results suggest that electric kettles may provide a viable option for expanding safe drinking water access while reducing IAP exposure and its associated negative health outcomes.

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Taste Detection and Acceptance Concentration Thresholds for Sodium Hypochlorite and Sodium Dichloroisocyanurate (NaDCC) In Drinking Water in Dhaka, Bangladesh

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This study identified taste detection and acceptance chlorine concentration thresholds in drinking water among residents of a low-income community in Dhaka, Bangladesh. Chlorine—in tablet, liquid, and powder form—has long been promoted as an inexpensive and effective household water treatment option. However, studies have repeatedly found low rates of consistent use of these products, limiting the effectiveness of point-of-use chlorination as a treatment approach. Barriers often cited to chlorine use are aversion to its taste and smell. Currently available chlorine products are designed to dose sufficiently in settings with high chlorine demand (i.e., >2 ppm), thus increasing the likelihood of taste and smell complaints in settings with low or average chlorine demand. Lower, but still efficacious, chlorine doses may improve user acceptance; the World Health Organization, for example, recommends a minimum of 0.2 ppm free chlorine residual for safe water. In addition, acceptability may vary for different forms of chlorine disinfectant. Identifying the level at which consumers can detect chlorine in drinking water, as well as determining local consumer preference for one chlorine formulation over another, could inform the design of chlorine treatment interventions and strategies for marketing specific chlorine products. We enrolled 50 residents of a low-income community in Dhaka, Bangladesh, and used the forced-choice triangle test method to identify the concentrations at which they could detect chlorine in drinking water. This method entails giving participants a set of three samples, then asking them to choose one sample that is different from the other two. Half of respondents evaluated only samples prepared with liquid sodium hypochlorite (Safex bleach, Bangladesh); the remainder evaluated only samples prepared with tablet sodium dichloroisocyanurate (NaDCC, Aquatabs, Medentech Co.). For each of 5 chlorine concentrations (0.2, 0.5, 1.0, 1.5, and 2.0 ppm) in increasing order, field staff gave each respondent 3 sets of 3 samples of bottled water (Mum brand, Dhaka; total: 45 samples). In each set of samples, provided in 5-oz paper cups, one sample contained chlorine. Respondents were asked which sample among the three provided they believed to be chlorinated. The experiment concluded when the respondent correctly identified all chlorinated samples at a given concentration and also rated the taste of the water as “unacceptable.” Free chlorine in prepared solutions was measured using a digital colorimeter (LaMotte Company, Chestertown, Maryland) before and after experiments were conducted; the average was used as the exact concentration for analysis. Each participant’s detection threshold was defined as the geometric mean of
(1) the lowest concentration at which s/he correctly identified all chlorinated samples and (2) the next lower concentration. We also identified each respondent’s acceptance threshold by asking, at each concentration, whether s/he would choose an alternative water source if that water was supplied at his/her primary water point. We defined acceptance threshold as the geometric mean of (1) the lowest concentration at which the respondent stated s/he would choose an alternative water source in order to avoid the chlorine taste or smell and (2) the next lower concentration. Both detection and acceptance thresholds were non-normally distributed; the Mann-Whitney test was thus used to compare median thresholds between the bleach and NaDCC groups. Median detection threshold was 0.70 ppm (average=0.81 ppm, SD=0.58) for liquid sodium hypochlorite and 0.73 ppm (average=0.99 ppm, SD=0.85) for NaDCC. Median acceptance threshold was lower for sodium hypochlorite at 1.13 ppm (average=1.16 ppm, SD=0.71), compared to NaDCC at 1.78 ppm (average=1.63 ppm, SD=0.73) (p=0.017). Seven of the 50 (14%) respondents had a lower acceptance threshold than detection threshold, indicating that they rejected samples in which they could not detect chlorine. Another 16 (32%) respondents had equal detection and acceptance thresholds, and the remaining (54%) respondents classified drinking water in which they could detect chlorine as acceptable. Respondents in Dhaka detected sodium hypochlorite and NaDCC at similar concentrations. However, respondents had a slight acceptability preference for NaDCC, with respondents willing to accept drinking water chlorinated at higher concentrations with Aquatabs (NaDCC) versus liquid bleach (sodium hypochlorite). Median detection thresholds for both chlorine forms were lower (<2ppm) than typical dosing for household drinking water chlorine products and greater (>0.2ppm) than the minimum dose required for safe water. These findings suggest that adjusting dosing of chlorine products to lower, but still safe, levels may contribute to increased acceptance of chlorine for drinking water treatment in Dhaka.

The Water, Sanitation, and Hygiene Performance Index: a Comparison of Country Performance in Realizing Universal WaSH

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Water, sanitation and hygiene (WaSH) are critical to human health and development, and are recognized as human rights. Proposed global targets for the post-2015 Sustainable Development Goals (SDGs) call for universal access to WaSH, and reduction of inequalities in access to these critical services. The forthcoming SDGs provide potential for convergence of human development and human rights policy. New instruments are necessary to monitor and evaluate country performance on WaSH, to enhance accountability, and to ensure progressive realization of the human right to water and sanitation. The WaSH Performance Index meets these needs by comparing country performance to best-in-class performance at different levels of water and sanitation coverage. We consulted WaSH stakeholders and experts to design the WaSH Performance Index. The Index assesses country performance in the following components: water access, water equity, sanitation access, and sanitation equity. Country data compiled by the WHO/UNICEF Joint Monitoring Programme (JMP) were used to calculate rates of change for each component. Frontier analysis was used to identify best-in-class performance at different levels of water and sanitation coverage. The most recent rate of change from each country was compared to best-in-class performance at each level of water and sanitation coverage to generate a benchmarked value between -1 and 1 which enables fair country comparison. Country trends were calculated for each of the components. Countries were ranked based on the sum of the components. We examined associations between component values and country characteristics (e.g. GDP per capita, percent urban, world region as defined by the World
Bank) and governance indicators (e.g. government effectiveness, control of corruption, regulatory quality, and rule of law). The top five performing countries in the initial 2015 WaSH Performance Index rankings are El Salvador, Niger, Egypt, Maldives, and Pakistan. The bottom five performers are the Dominican Republic, Gambia, Ghana, Samoa, and Timor-Leste. Despite the assumption that an increase in GDP will lead to an increase in country performance on improving access to water and sanitation, our data do not support this statement. Progress toward equity in sanitation is significantly positively associated with governance indicators including: control of corruption, government effectiveness, regulatory quality, and rule of law. These results indirectly suggest the important of governance and their contribution to progress in sanitation equity. Despite persistently being the region with the lowest water coverage in the world, water access performance among countries in Sub-Saharan Africa is in fact mixed, with many top and bottom performers. Among the most populated countries in the world, Pakistan, China, and Nigeria were top performers (ranked 5, 11, and 18 respectively). Conversely, Russia, the Philippines and India were bottom performers (ranked 72, 83, and 92 respectively). Among most top performing countries, neither water nor sanitation dominated the overall Index value, suggesting improvements in water and sanitation do not necessarily come at the expense of the other. The WaSH Performance Index provides national policy makers with a new instrument to inform investment decisions and identify areas in need of targeted improvement among water and sanitation access and equity. For the human rights community, the Index provides an accountability tool to assess country progress on meeting full realization of human rights obligations. The Index informs finance ministers, donors, practitioners, and investors on the types of investments to make - either in infrastructure, governance or both. The first version of the Index shows its potential use for the WaSH sector by offering some valuable insights on tracking country performance and identifying relationships between country performance and governance. The Index provides insight on access and equity from already-available water and sanitation data. It is designed to accommodate new types of data relevant to the SDGs. We will continue to update and refine the Index based on feedback from stakeholders to improve utility.

Assessing Latrine Utilization: a Cross-Sectional Study Comparing Measurement Methods in Rural Bangladesh

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BACKGROUND: Latrine utilization is difficult to measure accurately, but understanding use is critical for assessing the success and health implications of sanitation programs. Latrine coverage is often equated to latrine utilization in sanitation program and policy decision-making, though empirical evidence indicates that use cannot be assumed from coverage. In rural Bangladesh, we compared various methods of measuring latrine utilization, some of which have shown promise in Orissa, India. The purpose of this study was to determine the advantages, disadvantages, and comparability of latrine utilization results generated from: 1) self-reports; 2) latrine spot check indicators; 3) ladder scales that score household use frequency and demographic use profiles; and 4) instrument-recorded defecation events captured via passive latrine use monitors (PLUMs). METHODS: During June-August 2014, we conducted a cross-sectional study of 1207 households randomly selected from 52 village WASH committees throughout Bangladesh. Enumerators collected self-reported data on every latrine user's daily defecation practices, and subsequently performed latrine spot checks on each household latrine to assess its structure, functionality, and cleanliness. For each household, we generated a daily self-reported latrine use total by summing all reported latrine
Treatment of Fecal Sludge in a Prototype Supercritical Water Oxidation Reactor

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Our team has designed and built a technical scale prototype supercritical water oxidation (SCWO) system to treat the fecal waste produced by roughly 1000-1200 persons daily. The unit is housed in a standard 20 ft shipping container and has been undergoing testing at Duke since early 2015. The process, while high-tech is relatively simple. After moderate preheating, the waste slurry is mixed with supercritical water (~600 C) and air (which serves as oxidant), which rapidly brings the waste undergoing treatment to
supercritical conditions (~400 °C, 240 bars). Under these conditions, all organics are rapidly (i.e., few seconds) oxidized to CO2, with the corresponding heat of combustion released in the reaction medium. In our prototype, the reactor has a 19 mm ID and is 4.2 m long. After the reaction, heat recovery follows in a 39 m long heat exchanger. The system is well instrumented and operation is controlled using a programmable logic controller. Experiments were first conducted with isopropanol, prior to treating primary and secondary sludge. Detailed system performance including conversion of organics, process kinetics, and energy balances will be presented and discussed at the conference. The project is funded by the Bill & Melinda Gates Foundation.

Developing Disease-Resistant Communities in Liberia: A Case Study on Locally-Adapted CLTS for Sustainable Health Benefits

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Alice Urban

In Liberia, a group of open-defecation free (ODF) communities leveraged disease transmission knowledge and practiced safe hygiene and sanitation behaviors that helped guard against Ebola. Learned and supported through community-led total sanitation (CLTS) engagement, such preventative health behaviors were in place before the virus posed a threat to these communities in three of Liberia's hardest-hit counties. As part of the USAID-funded Improved Water, Sanitation and Hygiene (IWASH) program, Global Communities (formerly CHF International) engaged with 351 communities in Bong, Lofa and Nimba counties between 2010 and 2015. Of these communities, 284 (81%) became ODF and reported no cases of Ebola. An external assessment has confirmed that no ODF communities in heavily Ebola-impacted Lofa county were infected, although immediately neighboring communities reported high infection and mortality rates. This case study will describe Global Communities' adapted CLTS approach used in IWASH and its potential to develop more disease-resistant communities. To do this, IWASH: (1) employed a cost-effective CLTS strategy that used Natural Leader Networks to trigger and monitor target communities; networks were then activated during the Ebola crisis to promote heightened disease awareness in communities; (2) engaged Ministry of Health Environmental Health Technicians and other preventative health government actors to connect communities to Liberia's decentralized health system and develop a more robust WASH enabling environment; (3) built strong relationships with traditional leaders to gain local legitimacy and establish community-level accountability mechanisms; (4) trained WASH entrepreneurs who provided essential, affordable and local WASH services to remote communities before and during the Ebola outbreak; and (5) established sustained health behavior change at the community level that helped households maintain resilience against Ebola. With these components in place, communities were prepared to respond rapidly to the threat of the virus. Global Communities is now expanding on this model to increase traditional leadership participation in community health - which proved essential during the Ebola outbreak - and to incorporate more specific disease risk reduction components to our CLTS approach, particularly in at-risk border areas, to help communities to remain vigilant against the threat of Ebola and other communicable diseases.

Prevalence and Association of Diarrheagenic E. Coli Detected in Stored Complementary Foods and Flies Caught in the Same Rural Households in Bangladesh
**Introduction:** Consumption of contaminated complementary food can cause childhood diarrhea. Flies are a known vehicle of enteric pathogens transmission although their contribution to food contamination remains unclear. **Purpose:** We investigated the potential of flies to contaminating complementary food in rural households of Bangladesh by collecting food and flies from the same household and analyzing them for E. coli counts and pathogenic E. coli genes. **Methods:** We selected 182 households with children < 24 months old that stored complementary foods for >3 hours at room temperature. From each household we collected complementary food samples and used fly tapes to catch flies near the kitchen. We homogenized food samples and flies (one/household) with distilled water before processing with the IDEXX Quanti-tray system (Colilert-18 media) for enumeration of E. coli (detection limits: 100 most probable number (MPN)/fly and 1 MPN/g food). Culture broth from E. coli-positive IDEXX wells were examined by PCR for pathogenic genes, including eae, ial, bfp, ipaH, st, lt, aat, aaiC, stx1, stx2.

**Results:** E. coli was detected in 111 of 182 food samples tested (61%, mean 0.3 log10MPN/g food). Fifteen samples (8%) were positive for E. coli pathogenic genes, of which seven (4%) had enteropathogenic E. coli-specific genes (eae and/or bfp) and 10 (5%) had enteroaggregative E. coli genes (aat and/or aaiC). Of fly samples collected from 68 (37%) households, 41 were positive for E. coli (60%, mean 2.9 log10MPN/fly) and 1 fly (1%) was positive for enteropathogenic E. coli genes. For households with paired fly-food samples, each log10MPN E. coli increase in flies was associated with a 0.3 log10MPN E. coli increase in complementary food (p=0.01). **Significance:** Flies captured in kitchens in rural Bangladesh carry high numbers of E. coli. Limiting fly access to complementary foods may reduce child exposure to enteropathogens.

**Nudging Handwashing: Behavior Change -- Without Behavior Change Communication -- Among Primary School Students in Bangladesh**

Robert Dreibelbis, University of Oklahoma

Kamal Hossain; Adbul Mondol; Narsin Jahan; Mohini Venkatesh; Pavani Ram

**Background:** Educational and motivational messaging for improving handwashing with soap has achieved only limited success in changing handwashing behaviors and can be labor and resource intensive. Further, behavior change from educational and motivational messaging, particularly in institutional settings, may be contingent upon repeated reminders or cues to action. In high-income countries, "nudging" has gained increased attention as a strategy to influence desired behavioral outcomes. Nudges have been successfully used to increase recycling behaviors through visible footprints leading to recycling bins, increase stair use with arrows or signs directing individuals to stairs instead of elevators, and reduce portion sizes and food wastage by providing smaller plates to buffet diners. These small, environmental changes increase the likelihood of the desired outcome without direct messaging, education, or traditional motivational strategies. Nudges typically engage automatic thinking processes - thought processes that are fast and unconscious rather than self-aware and controlled. Rather than changing the decision-making process, nudges alter the context in which a specific decision - or behavior - is completed. We sought to assess the potential for nudge-based interventions to improve handwashing behaviors in a pilot among primary school-aged children in rural Bangladesh. **Methods:** Over the course of a week in August 2014, a team of researchers and implementing partners progressively adapted and modified handwashing infrastructure at
two rural primary schools in Bangladesh with latrines and on-site water points. After assessing the site-specific infrastructure, movement patterns, and layout of each site, a common set of nudges were developed to facilitate handwashing with soap after using a school latrine. These included: 1) building a dedicated location for handwashing - a raised concrete platform with a water storage tank, 2) connecting latrines to the handwashing station via paved pathways painted bright colors, and 3) painting footprints and handprints on infrastructure guiding students to the handwashing stations. No other hygiene promotion activities were included as part of the intervention. Trained staff positioned at discreet locations on school grounds completed structured observations of handwashing practices, specifically if children washed hands after leaving latrines and if a cleansing agent was used. Observations were completed at baseline (prior to construction), after construction was completed, and 2 and 6 weeks after construction was finalized. Results: Four rounds of data collection yielded 698 observations of children leaving school latrines. At baseline, only 4% of children (4 out of 114) washed both hands with soap after leaving the school latrine. The day after the final phase of construction - painting footprints leading from latrines to handwashing stations - 68% of children leaving the latrine (108 out of 158) washed both hands with soap. Two weeks after construction, 74% (151 out of 204) washed both hands with soap after leaving a latrine; and after 6 weeks, 74% (164 out of 222) washed both hands with soap after leaving the school latrine. Discussion: This pilot provides evidence that simple, low-cost nudges can result in higher rates of handwashing among school-aged children. We purposefully selected schools with robust water infrastructure in order to concentrate on the immediate environment surrounding handwashing. Our sustained presence in schools during construction may have altered students to the nature of the intervention even in the absence of direct hygiene education; however, high rates of observed handwashing at 2 and 6 weeks after construction suggest nudges have a lasting effect on behaviors. The potential application of handwashing nudges both in institutional and domestic environments warrants further investigation. Future investigations will assess the long-term benefits of nudges alone, the combined impact of nudges and health education, and how broader contextual factors influence the sustainability of nudge-based interventions.

**Multiple Household Water Sources and Uses in Pacific Island Countries: a Field Study Using a Concise and Novel Survey Instrument**

Mark Elliott, University of Alabama

Morgan MacDonald; Wade Hadwen; Terence Chan; Annika Kearton

Global WaSH research typically neglects aspects of household water management that are essential in many developing country settings. Notable among these are a lack of understanding of: (1) the role of multiple water sources in daily household (HH) water management, (2) the practice of moving the use to the source and its impact on reducing daily HH water volume needs, and (3) the practice of adapting these and other HH water practices to differences in seasonal precipitation. These deficits are reflected in the almost exclusive focus on the primary HH drinking water source in global surveys (e.g., DHS) and data sources (e.g., JMP). Additionally, household water quantity guidelines (e.g., from WHO) are generally interpreted to assume that HH water use requires some means to transport water to the home. However, in many settings, households "take the use to the source" (e.g., bathing and washing clothes at a river or spring); these practices can greatly reduce the daily per person volume of water needed in the household. Although knowledge gaps have been recently acknowledged by WaSH researchers (e.g., Evans et al., 2013; Shaheed et al., 2014), there have been few efforts to address them. This presentation will report on the use of a novel and concise survey instrument to provide detailed data on these topics and application of
the instrument in Pacific Island Countries. HH survey data from eleven diverse communities (n will be ~320 HHs) of the Republic of the Marshall Islands (RMI) and Solomon Islands (SI) will be presented, describing: (1) number and type of HH water sources and their uses, (2) changes in sources and uses between wet and dry seasons, and (3) water use at the home and at the source. Integration of the survey instrument into the SurveyCTO Android app for rapid delivery and automated data processing will also be addressed. Data collection and preliminary analysis is complete for five communities (3 in RMI, 2 in SI). Illustrative findings from these communities are discussed below. Of 143 households (99 in RMI, 44 in SI) in the preliminary sample, 135 (94.4%) reported using at least two water sources for their daily HH needs. All 8 (5.6%) that reported using only one water source were in RMI and relied solely on private rainwater harvesting (RWH) tanks. The mean number of water sources used RMI was 2.23 (range one to four) and in SI was 3.68 (range two to five). Although use varied between HHs, typical/illustrative rainy season use in RMI and SI are provided here to aid readers. Typical HHs in RMI used a private RWH tank (800-3000 liters) for drinking/cooking and a private well for handwashing and washing clothes; both RWH and wells were commonly used for bathing. Typical HHs in SI used private or shared RWH for drinking/cooking (often alongside a well or spring); rivers were the most common source for non-consumptive use, including handwashing, bathing and washing clothes (mostly at the source). The majority of RMI HHs reported sharing water with neighbors, whereas only one SI HH reported sharing water. Seasonal differences in HH water sources and uses were also studied. Nearly all SI HHs reported that they changed water use and management practices between rainy and dry seasons; in contrast, about half of RMI HHs reported changing their practices by season. In SI, nearly all RWH use was discontinued in the dry season, with use shifting to wells, springs, and rivers. In RMI, nearly all HHs continued using RWH, but about half practiced some form of austerity, typically shifting non-consumptive use from RWH to private wells. It is important to note that the RMI communities studied thus far receive about 3x the annual precipitation of the SI communities and the RMI dry season is much shorter. Many differences in the way HH water management has evolved in these communities are likely to have emerged from these differences in precipitation patterns. Integration of this survey instrument into SurveyCTO (Android app) enabled substantial time savings and error reduction. The 35-minute mean time for the complete HH interview included data collection on water sources and uses across wet and dry seasons and three climate-related hazards, in addition to consent, demographics, sanitation, specialized modules on RWH and reverse osmosis, and other topics. The average time to conduct a previous shorter version of this survey on paper was over 90 minutes, with subsequent time needed for data entry. This presentation will provide evidence of the diversity of HH water management practices in our study communities, and the feasibility of gaining a deep understanding of these practices through a concise HH survey. Knowledge of these aspects of HH water management is essential if researchers and practitioners want to understand or model the impacts of water on health, hygiene, livelihoods, climate change resilience and adaptation, etc.

Water Quality Effects of Intermittent Drinking Water Supply in Arraiján, Panama

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Intermittent operation of piped drinking water systems is considered to be a risk to water quality, because contaminated water can intrude into pipes through leaks when pipes are depressurized. Water quality grab sampling and continuous water quality, pressure and flow monitoring were conducted over a period of one year in four study zones in the drinking water distribution system in Arraiján, Panama, a peri-urban area outside of Panama City. Three of the study zones were operated intermittently, with intermittency
controlled by intermittent pumping, the diurnal emptying and filling of a storage tank, or valve operations by the utility. The fourth study zone was operated continuously, with the exception of a few wide-spread water outages, and served as a control.

Grab samples collected during steady-state supply conditions were analyzed for fecal indicator bacteria (total coliform and E. coli), turbidity and free chlorine. Series of grab samples collected during the “first flush” when supply resumed after being turned off were analyzed for the same parameters in addition to heterotrophic plate count (HPC) and spore-forming bacteria. Continuous monitoring stations measured free chlorine residual and turbidity at the entrance and a downstream location in each study zone to determine if water quality changed as water passed through the study zone. Pressure was also measured at the continuous monitoring stations to know when supply was on and off and to detect low and negative pressures. Monitoring stations uploaded data to an internet site every five minutes, so water utility personnel could detect water quality degradation events and hydraulic changes such as pump shutdowns and pipe breaks.

Only 1% of routine samples across all study zones and 4% of first flush samples were positive for total coliform bacteria and only one routine sample (0.2%) and four first-flush samples (1%) were positive for E. coli. In many cases when fecal indicator bacteria were not present, however, water quality was still noticeably degraded during the first flush, as evidenced by higher turbidity, lower free chlorine residual, and higher concentrations of HPC and spore-forming bacteria. Three first-flush events after pipe breaks and repairs included periods of highly elevated turbidity (>100 NTU), but samples taken during these events tested negative for coliform bacteria and had a detectable free chlorine residual. Online monitoring detected short-term events when turbidity was higher than normal and detected negative pressures in one study zone even during steady-state operation.

Despite intermittent operation, no water quality degradation was detected that appeared to be an alarming threat to public health. While this does not mean that intermittent supply is "safe" or a good idea, even in Arraiján’s distribution system, it shows that the water quality impacts of intermittent supply are not as serious in Arraiján as in another intermittent system previously studied in Karnataka, India. Further research would be required to determine why water quality is comparatively better in Arraiján, but potential reasons include the maintenance of a consistently high (> 0.5 mg/L) free chlorine residual and a lack of fecal contamination near buried drinking water pipes. In addition to the water quality data collected, this research provides a detailed characterization of hydraulic and operating conditions under a variety of intermittent supply regimes found within one system. The water quality monitoring methods developed could be used to assess the water quality risks posed by intermittent supply in other systems, and the continuous water quality and hydraulic monitoring methods developed could help operators keep abreast of the dynamic conditions in intermittent systems.

Developing a New Latrine in Rural Bihar: From Assessing User Needs Assessment to Design Validation

Jennifer Foster, PATH

Adam Drolet; Priyam Varma; Jane Verrall; Robyn Wilmouth; Andy Beddoe

Background: Roughly two thirds of India's population does not have access to improved sanitation facilities (JMP 2012). To address this gap, Population Services International launched a Bill & Melinda Gates Foundation funded-project called Supporting Sustainable Sanitation Improvement (3SI) in Bihar, India, which focuses on developing commercially viable business models that support a strengthened sanitation
product and service supply chain. As part of this project, PATH led a user-centered design process that began with understanding user needs around sanitation and then translating those needs into latrine designs that were then evaluated to gauge acceptability, usability, and manufacturability. This work culminated in a new low-cost latrine--the Rapido Latrine--that used improved processes to manufacture precast latrine components that can be easily assembled. This presentation describes the user-centered design process including the final user validation study conducted in Samastipur, Bihar (March 2015).

Methods: PATH conducted four rounds of user research in Bihar: (1) A rapid user assessment aimed at identifying key user needs around sanitation was conducted. Qualitative feedback was collected through interviews and a focus group discussion with experienced latrine users (December 2012). (2) The second round collected more detailed feedback from end users and other market actors on potential latrine superstructure and substructure elements to inform new latrine designs (April 2013). (3) The third round was a user-validation study of three new latrine designs (December 2013). Interviews and focus groups discussions were held with experienced and inexperienced latrine users, manufacturers, community leaders, and women's self-help group members. (4) Finally, based on feedback from the previous round of user research, a second user validation study was conducted to evaluate the acceptability, usability, and manufacturability of an improved precast latrine design. Interviews were conducted with experienced and inexperienced end users, manufacturers, as well as community and supply-chain stakeholders.

Results: The first round of user research led to the identification of seven key user needs statements around sanitation including safety, privacy and self-respect, and affordability. These criteria were then used to inform the design process as well as evaluate new latrine designs and features. While the initial latrine designs were found to be acceptable, specific product improvements were also identified, including reducing the cost of the latrines, improving manufacturability, and making the latrine more aspirational. The final round evaluated an improved pre-cast latrine design that included aspirational features from the previous designs and also addressed the issues of affordability and manufacturability. The participants in the final validation study--including end users, manufacturers, and community leaders--found the new design to be acceptable, affordable, and easy to manufacture. This design also met the user needs, such as safety and privacy that were identified in the initial formative assessment. Conclusion: PATH's application of the user-centered design process has advanced the development of new latrine design that is more affordable, easier to build, and can help address the unmet need for improved sanitation in rural Bihar.


Max Friedrich, Eawag

Hans-Joachim Mosler; Timothy Julian

Diarrhoea is one of the leading causes of child mortality. The need to promote handwashing with soap has been recognized by various national and international actors in the water, sanitation and hygiene sector, which led to numerous handwashing campaigns worldwide. But which handwashing technique is most effective in reducing the faecal contamination of hands and should thus be promoted? Are there crucial steps beyond using soap that lead to cleaner hands? To our knowledge, there is as lack of evidence on how hands should be washed most effectively in low-resource and hygienically challenging settings. The aim of this study was to tackle this research gap and to quantify the effectiveness of different handwashing techniques in reducing the faecal contamination of primary caregivers' hands in Harare, Zimbabwe. In a cross-sectional survey, the handwashing technique of 174 primary caregivers was observed at their homes and hand rinse samples were collected immediately before and after handwashing. Hand rinse samples were analysed for E.coli and total coliform bacteria. Generalized linear
models were fitted to the data to predict hand contamination after washing from handwashing location, moistening technique, soap use, hand scrubbing steps and their interactions, hand drying technique, hand contamination before washing, total handwashing time and socio-demographics of the participants. We found that cleaning under the finger nails, rubbing the finger tips, rubbing hands with soap and drying hands with a clean towel led to less E.coli contamination of hands after washing. Moistening hands using running water and rubbing the finger tips led to lower contamination of hands with total coliform bacteria after washing. Scrubbing hands for at least 20 seconds and the total wash time showed no effects on both indicator organisms. On average handwashing reduced contamination with E.coli from 1.43 (SD=0.85) log 10 colony forming units (cfu) per hand to 1.18 (SD=0.78) log 10 cfu per hand. Total coliform contamination was reduced from 2.53 (SD=1.02) log 10 cfu per hand to 2.21 (SD=0.93) log 10 cfu per hand. These findings show reductions that are much lower than typically observed in experimental efficacy studies. The data indicate that various steps are important for effective handwashing. On the one hand, the used hardware such as soap or running water is crucial. There is also evidence that drying hands with a clean towel leads to cleaner hands. On the other hand, the thoroughness of hand scrubbing, particularly scrubbing finger tips and under the nails is important. Further handwashing campaigns should not only promote frequent handwashing with soap at critical times, but also focus on the use of adequate handwashing facilities, scrubbing procedures and drying techniques.

**Forecasts of Mortality & the Economic Losses from Poor Water & Sanitation in Sub-Saharan Africa**

David Fuente, UNC-CH

This paper presents country-level estimates of water, sanitation and hygiene (WASH)-related mortality and the economic losses associated with poor access to water and sanitation infrastructure in Sub-Saharan Africa (SSA) from 1990 to 2050. We examine the extent to which the changes that accompany economic growth will “solve” water and sanitation problems in SSA and, if so, how long it will take. Our simulations suggest that WASH-related mortality will continue to differ markedly across countries in Sub-Saharan Africa. In many countries, expected economic growth alone will not be sufficient to eliminate WASH-related mortality or eliminate the economic losses associated with poor access to water and sanitation infrastructure by 2050. In other countries, WASH-related mortality will sharply decline, although the economic losses associated with the time spent collecting water are forecast to persist. These findings suggest that in a subset of countries in SSA, WASH-related investments will remain a priority for decades and require a long-term, sustained effort from both the international community and national governments.

**I Get Height With a Little Help from my Friends: Herd Protection from Sanitation in Rural Ecuador**

James Fuller, University of Michigan

Eduardo Villamor; William Cevallos; Joseph N.S. Eisenberg

Introduction-Infectious disease interventions, such as vaccines and bednets, have the potential to provide herd protection to non-recipients. Similarly, improved sanitation in one household may provide community-wide benefits if it reduces contamination in the shared environment. Sanitation at the household-level is an important predictor of child growth, but less is known about the effect of sanitation coverage in the community. Methods-From 2008 to 2013, we took repeated anthropometric measurements on 1,314 children under 5 years of age in 24 rural Ecuadorian villages. Using mixed effects regression, we estimate the household and neighborhood effects of sanitation on child growth. Results-
Sanitation coverage at the neighborhood level was strongly associated with child height, as those with 100% coverage in their neighborhood had a 5-fold reduction in the odds of being stunted (OR 0.21, 95% CL 0.05-0.84) compared to those with 0% coverage. Children from households with improved sanitation had a slightly lower odds of being stunted (OR 0.70, 95% CL 0.43-1.15). This protective effect of neighborhood sanitation is manifested primarily among girls during the second year of life, the time at which growth faltering is most likely to occur. Discussion—Our study highlights that a household’s sanitation practices can provide herd protection to overall community. Studies which fail to account for the positive externalities that sanitation provides will underestimate the overall protective effect. Future studies could seek to identify a threshold of sanitation coverage, similar to a herd immunity threshold, above which increases in coverage have no marginal benefit.

Efficacy of Highly-Bioavailable Zinc from Fortified Filtered Water: a Randomised Controlled Trial in Rural Beninese Children

Valeria Galetti, ETH Zurich

Prosper Kujinga; Comlan Evariste Mitchikpè; Christophe Zeder; Fabian Tay; Félicien Tossou; Joseph Hounhouigan; Michael Zimmermann; Diego Moretti

Background. Zinc deficiency and diarrhea are often found in combination in low-income settings in developing countries. Low zinc status impairs the immune system and increases risk for diarrhea, while diarrhea depletes the body of micronutrients, including zinc. A major risk factor for diarrhea is consumption of microbiologically contaminated water, whereas zinc deficiency is mainly caused by an inadequate intake of bioavailable zinc. Therefore reducing risk of diarrhea, such as improvement of water quality, or improving zinc status through increase of dietary zinc, could be beneficial for both conditions. We investigated the provision of bioavailable zinc through safe drinking water to synergistically lower the burden of both conditions. We used a point-of-use water ultrafiltration device (LifeStraw(R)Family, LSF) configured with glass plates for controlled zinc elution to produce water that is both purified and zinc-fortified. Our objective was to determine: 1) zinc bioavailability from zinc-fortified water; and 2) its efficacy in improving zinc status, decreasing zinc deficiency, and decreasing diarrhea. Methods. In a single-blind, cross-over stable isotopes trial conducted in 18 healthy Swiss adults, we measured fractional zinc absorption (FAZ) from zinc-fortified water consumed with (M+FW) and without (FW) maize porridge, and compared it to zinc-fortified maize porridge consumed with unfortified water (FM+W). In a double-blind, randomized, controlled trial, 277 Beninese children aged 5 to 10 years were randomly assigned to receive over four months a daily serving of zinc-fortified filtered water delivering 2.8 (±2.8) mg Zn (Zn+filter), non-fortified filtered water (Filter), or non-fortified non-filtered water (Pump) from the local improved supply. The main outcome was plasma zinc concentration (PZn) as an indicator of zinc status and was assessed at baseline, at a sparse midpoint between week 5 and 15, and at week 20. Secondary outcomes were the prevalence of zinc deficiency and diarrhea prevalence. Efficacy of the intervention was assessed using mixed effects models. We registered the studies at ClinicalTrials.gov (NCT01636583 and NCT01790321). Findings. We found that FAZ was significantly higher from FW (geometric mean (-SD, +SD) 65.9% (42.2, 102.4)) than from M+FW (9.8% (5.7, 16.7)) or from FM+W (9.1% (6.0, 13.7)) (p<0.001). In the RCT, we measured a significant time-by-treatment interaction effect on PZn (p=0.014). Over the study period, PZn in the Zn+filter group was significantly higher than in the Filter (p=0.006) or Pump (p=0.025) groups, but did not differ between the latter two groups (p=0.645). Prevalence of zinc deficiency in the Zn+filter group was significantly lower than in the Filter group (p=0.046) but not compared to the Pump group (p=0.770). There was no significant time by treatment effect on diarrhea prevalence. Interpretation. Consumption of
filtered water fortified with highly bioavailable zinc resulted in a significantly higher zinc status compared to the control groups, but there was no effect on diarrhea prevalence. Nevertheless, purified water as a fortification vehicle for zinc is a promising approach to improve zinc nutrition through 6-7 fold increased zinc absorption and should prompt more research into water-based intervention strategies. Larger community-based studies are needed to assess the effectiveness of zinc-fortified filtered water on diarrheal morbidity in communities relying on unimproved water sources and to establish whether the combined strategy of delivering zinc-fortified filtered water has synergistic benefits on plasma zinc and diarrhea, compared to water or fortification strategies alone.

**Handwashing Behavior Change: a Longitudinal Study on Interventions which Target Norms and Self-Efficacy in Enhancing Handwashing in Flood-Prone Areas of Dakar’s Suburbs, Senegal.**

Anna Gamma, EAWAG

Hans-Joachim Mosler

Hand washing with soap at key times has been shown to be an effective way to prevent diarrheal diseases and can lead to a significant reduction of morbidity and mortality in low-income countries. The two main suburbs of Dakar, Senegal’s capital are regularly flooded during and after the rainy season; partially the floods remain the whole year, what constitutes a high risk for the population and especially for children to suffer from infectious diarrheal diseases. The relevant behavioral determinants for hand washing have been investigated by a baseline study and the relevant factors have been used to elaborate different behavior change strategies, based on the RANAS model (risk, attitude, norm, ability, self-regulation; Mosler, 2012). The present study examines the effects of data-driven interventions which target norms and self-efficacy in enhancing hand washing and quantifies the impact of hand washing interventions on self-reported and observed hand washing frequencies. To measure the effects of the implemented hand washing promotion activities, 667 primary caregivers were interviewed by the mean of structured face-to-face interviews. Additionally, 200 of these households were observed. A longitudinal case control research design was applied, and two data collections were conducted. Between the data collections, the following promotion activities were implemented during 4 months and tested in 4 regional clusters: a theory-based and data-driven movie, pledging sessions in a public group, pledging sessions at home and household visits with focus on hardware (control group). Due to the fact that 41% of the households from the sample did not have a designated place for hand washing at the time of the baseline survey, this intervention focused on awareness-raising on the need to have a specific place for hand washing. The promotion activities were applied alone or in different combinations. The data analysis was done by different comparisons of means. The film group increased significantly positively in the self-reported food related hand washing, while for the stool related hand washing the combined interventions (commitment at home, film and household visits; public commitment, film and household visits; film and household visits) led to a significant positive change within these groups over time. For food and for stool elated hand washing, significant differences in means were found between the control group and three of the intervention groups. The observed behaviour showed the same tendencies as the self-reported behaviour. The highest effects in changing the food related hand washing behaviour was the film alone, what is very convenient for upscaling. In order to implement the most effective strategies to enhance the food and the stool related hand washing, movie sessions followed by public commitments are recommended.

**Survey of Utility Customers Following Low Pressure Events in a Drinking Water Distribution System: A Pilot Study**
Background: A study in Norway found that low pressure events (LPE) in distribution systems were associated with 58% increased risk of acute gastrointestinal illness (AGI). The links between illness and LPEs in disinfected U.S. water systems are unknown, and systematically collected data are needed to guide decision-making on appropriate responses. CDC plans to conduct a multisite epidemiologic study to assess whether individuals exposed to LPEs are at an increased risk for AGI or acute respiratory illnesses; in preparation, study procedures including a survey were piloted at one utility site. Methods: An LPE was defined as a service disruption event causing a presumed loss of pressure in the distribution system. Hydraulic principles, utility maps, and census data were used to identify LPE areas and to select non-LPE control areas matched on water source, infrastructure characteristics, and resident demographics. Selected households from both areas were mailed a survey about water use, recent service, activities, and illness symptoms, which they could mail in or complete online. Households received multiple mailings to encourage participation. The study goal was presented as understanding the links between water use and health, and participants were not told that LPEs and repairs were being studied. Results: The pilot included 3 main breaks and 3 planned repairs affecting 16 to 166 households for 45 minutes to 7 hours. No drinking water advisories were issued. Of 646 surveys mailed, 37% were completed (38% in LPE areas and 36% in non-LPE areas); 30% were completed online. The majority of residents (74%) reported drinking their home tap water in the last 30 days, and nearly all (99.6%) reported using home tap water for potable purposes (e.g. cold drinks, infant formula, ice, brushing teeth, washing produce). In LPE areas, 33% of respondents reported low pressure during the three weeks following the LPE, and 28% reported a complete loss of water service. In non-LPE areas, respondents reported low pressure about half as often (16%) as households in LPE areas, and <1% reported a complete loss of service. A minority of households in both LPE (21%) and non-LPE areas (14%) noticed a change in tap water taste, odor, or color during the three-week recall period. Neither the water utility nor the CDC call center received study-related calls from utility customers. Conclusions: This pilot study demonstrated the feasibility of collaboration between CDC and water utilities to investigate water service and health impacts related to LPEs. Modifications to improve response rates include increased community outreach, a shorter recall period, a telephone reminder, and an e-mailed link to the survey website. As most LPE-area households were unaware of low pressure, and customers did not express concern about the study, illness reporting in the multisite study is not expected to be biased by differential concerns about water quality in LPE and non-LPE areas.

Ascaris Lumbricoides Infection Following School Based Deworming in Western Kenya: Assessing the Role of Pupils' School and Home Water, Sanitation and Hygiene Exposures

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Introduction: Water, sanitation, and hygiene (WaSH) technologies and behaviors can prevent infection with soil transmitted helminths (STH) independently, but may also interact in complex ways, although these interactions are still poorly understood. The purpose of this study was to characterize how school and home WaSH exposures were associated with A. lumbricoides infection, and to identify relevant interactions between separate WaSH technologies and behaviors. Methods: We conducted a study on
4,404 children attending 51 primary schools in Kenya. We used structured observations and structured interviews to ascertain pupils’ access and use of WaSH, both at school and home. Our primary exposures of interest were pupils’ access to an improved water source, access to sanitation, and practice of handwashing, both at school and at home, although we also assessed other WaSH technologies and behaviors. Our outcome of interest was binary A. lumbricoides infection since the previous annual school-wide deworming. We used multivariable mixed effects logistic regression to characterize how these various WaSH exposures were associated with A. lumbricoides infection after school-based annual deworming, also considering important interactions and the hierarchical/correlated nature of the data.

Results: Of the many interactions we assessed, only the associations between handwashing and the type of water source were found to be important. Pupils who handwashed had a lower odds of A. lumbricoides infection compared to pupils who did not handwash, but only in schools that also had an improved water source (OR = 0.45, 95% CI: 0.23-0.89; p=0.02), and not in schools without an improved water source (OR = 1.99, 95% CI: 0.73-5.37; p=0.18). The pattern of handwashing depending upon access to an improved water source was observed to a lesser degree at home, where the OR for handwashing with an improved water source was 0.84, (95% CI: 0.52-1.35; p=0.47) and the OR for handwashing with an unimproved water source was 1.18 (95% CI: 0.76-1.84; p=0.47). The OR for handwashing at both school and at home, compared to neither place, among pupils who also had access to an improved water source was 0.38 (95% CI: 0.18-0.83; p=0.01). Counterintuitively, we observed that increased access to school latrines was associated with higher A. lumbricoides infection (OR = 1.58, 95% CI: 0.99-2.53; p=0.05); a finding possibly due to increased use at unhygienic sanitation facilities. However, when using a comprehensive definition of sanitation that simultaneously considered many different sanitation qualities both at school and home, we observed no association between sanitation and A. lumbricoides infection (OR = 0.93, 95% CI: 0.22-4.02; p=0.92). Conclusions: This study contributes to a further understanding of the impact of WaSH on A. lumbricoides infection and shows the importance of accounting for relevant interactions between different WaSH technologies and behaviors.

A Hospital Based Intervention Promoting Hand Washing with Soap and Water Treatment for Household Members of Cholera Cases (CHoBI7 Trial): A Cluster-Randomized Controlled Trial

Christine Marie George, Johns Hopkins Bloomberg School of Public Health

R Bradley Sack; Jamie Perin; Peter Winch; Elli Leontsini; Xiaotong Zhang; O. Colin Stine; Danielle Jung; David Sack

The World Health Organization (WHO) estimates that there are 3-5 million cholera cases worldwide per year. Currently there is no standard of care for the family members of hospitalized cholera cases who are at a 100 times higher risk of developing a cholera infection during the one week period after the cholera case is admitted to the hospital then the general population (21% cholera infection rate among case household members vs. 0.2% in the general population). This high cholera infection rate among household members of cholera cases is likely due to a shared contaminated environmental source such as water or food in the household or secondary transmission from infected household members due to poor hygiene practices. Therefore in an effort to initiate a standard of care for this highly susceptible population, we recently developed CHoBI7 (Cholera Hospital-Based Intervention for 7 days), a health facility based WASH intervention for cholera cases and their household members. The CHoBI7 intervention includes: (1) a cholera prevention package containing chlorine tablets for water treatment, soapy water bottles (a low cost alternative to bar soap), a hand washing station, and a sealed water vessel with cover to ensure safe water storage, and (2) a pictorial (“Chobi” in Bangla) module disseminated by a health worker promoting
hand washing with soap at critical times and water treatment. The health worker delivers this cholera prevention package and pictorial module to suspected cholera cases and their accompanying family members during a consultation session in the hospital, and these messages are then reinforced through home visits. The efficacy of the CHoBI7 intervention was evaluated by conducting a cluster randomized controlled trial (RCT) in Dhaka, Bangladesh from June 2013 to December 2014. A cluster was defined as the hospitalized cholera case and their corresponding household members. We randomized 221 cholera case household members to the control arm and 218 cholera cases household members to the intervention arm (439 household members total) based on the day they were admitted to icddr,b Dhaka hospital. Suspected cholera cases were defined as anyone reporting diarrhea (3 or more loose stools within a 24 hour period) and moderate to severe clinical dehydration (using the World Health Organization classification). The stool of suspected cholera cases presenting at icddr,b Hospital in Dhaka, Bangladesh was screened for Vibrio cholerae using the Crystal VC Dipstick Test, and confirmed by bacterial culture before case enrollment. Household members were defined as those sharing the same cooking pot as the index cholera case for the past three days. Case households were followed over a one week period at 5 time points for clinical and surveillance and a rectal swab sample was taken from enrolled household members at each visit to test for the presence of Vibrio cholerae in stool by bacterial culture. Bacterial culture results for Vibrio cholerae were available for 320 household members (73%). There were no significant differences between enrolled contacts with or without rectal swab culture results available when compared by gender (female: 60% vs. 56% p=0.38), age (mean (years): 18 vs. 21, p=0.15), study arm (intervention arm: 49% vs. 50%, p=0.88), or the prevalence of diarrhea (12% vs. 13%, p=0.59) or vomiting (4% vs. 3%, p=0.60). In this RCT of the CHoBI7 intervention, we observed a 47% reduction in the incidence of cholera infection (symptomatic and asymptomatic) (13% control vs. 6% intervention arm, p=0.08) among household members of cholera cases in the intervention compared to the control arm during the week after the cholera case was admitted to the hospital. Furthermore, the intervention eliminated all symptomatic cholera in intervention household members (5% control vs. 0% intervention arm, p=0.007). These findings demonstrate that the Hospital Based CHoBI7 intervention was highly effective in reducing cholera during the one week high risk period for household members of cholera cases. Therefore this form of intervention could represent a low cost approach for cholera control in Bangladesh. We would like to acknowledge the contributions of all the icddr,b investigators: Dr. Munirul Alam, Dr. Shirajum Monira, Mahamud-ur Rashid, Dr. K.M.Saif-Ur-Rahman, Toslim Mahmud, Zillur Rahman, Md. Sazzadul Islam Bhuyian, Dr. Farzana Begum, Fatema Zohura, Dr. Shwapon Biswas, Tahmina Parvin, Dr. Pradip Kumar Bardhan.

Geophagy is Associated with Environmental Enteropathy and Stunting in Children in Rural Bangladesh

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Recent estimates by the World Health Organization (WHO) report that a quarter of children under five years of age are stunted globally. There is a growing body of literature indicating an association between stunting and environmental enteropathy, a disorder defined by abnormal intestinal morphology, reduced intestinal barrier function, and increased inflammation. Although its etiology is not fully defined, environmental enteropathy is thought to be caused by unsanitary environmental conditions leading to repeated exposures to enteric pathogens. In the scientific literature most studies focus on the fecal oral
pathways for enteric infections described in the F Diagram (fluids, fingers, fields, flies, food). However, recent studies suggest that geophagy, defined as the consumption of soil, dirt, or mud, is frequent among young children and a potential risk factor for enteric infections. We hypothesize that geophagy also leads to impaired growth through increased childhood exposure to enteric pathogens from soil causing environmental enteropathy. However, there are very limited published studies assessing geophagy in pediatric populations, and none assessing the role of this behavior in environmental enteropathy or stunting. Therefore in an initial attempt to test our hypothesis, and determine the extent of geophagy in pediatric populations in rural Bangladesh, we have conducted the first prospective cohort study to assess the relationship between geophagy, environmental enteropathy, and stunting in children under five years of age. A prospective cohort study was conducted of 216 randomly selected children 6-30 months of age residing in Mirzapur, Bangladesh from February 2014 to November 2014. A geophagy event was defined as a child putting soil, mud, clay, or sand into their mouth. Geophagy was assessed at baseline using 5 hour structured observation and caregiver reports. Stool was analyzed at baseline for fecal markers of intestinal inflammation: alpha-1-antitrypsin, myeloperoxidase, and neopterin combined to form an environmental enteropathy disease activity (EE) score, and calprotectin. Height and weight measurements were used to calculate z-scores according to the WHO child growth standards at a 9 month follow-up visit. In addition, two soil samples were collected in the outdoor courtyard area where the enrolled child was observed playing in a subset of 128 randomly selected households to measure for the presence of diarrheagenic E. coli. Eighteen percent of children had observed geophagy events and 28% had caregiver reported events in the past week. Nearly all households had E. coli (97%) in soil, and 14% had diarrheagenic E. coli. Children with caregiver reported geophagy had significantly higher EE scores (0.72 point difference, 95% confidence interval (CI): 0.01, 1.42) and elevated calprotectin concentrations (237.38 µg/g, 95% CI: 12.77, 462.00). Furthermore, at the 9 month follow-up the odds of being stunted (height for age z-score <=-2) was double for children with caregiver reported geophagy (OR: 2.27, 95% CI: 1.14, 4.51). These findings suggest that geophagy may be an important unrecognized risk factor for environmental enteropathy and stunting.

Community-LED Ebola Management and Eradication (CLEME) Approach

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The continued spread of the Ebola Virus Disease (EVD) in Guinea and Sierra Leone demonstrates that the crisis will persist until a change in the population's behavior occurs breaking the virus's transmission cycle at community level. Even though case management capacities are now covering the needs in both countries, they will not be sufficient in halting the epidemic unless change in communities' behaviors is achieved. In Sierra Leone, since the start of the outbreak in May 2014, the sensitization of the communities to the epidemic has involved mass public campaigning that responded to the need of rapidly improving the knowledge of the population about EVD (prevention, transmission modalities, signs and symptoms, and the referral system). A "knowledge, attitude, practices" (KAP) survey conducted in August 2014 demonstrated that more than 90% of those interviewed were aware of Ebola, its signs and symptoms, and ways of transmission. However, the KAP also revealed poor change in practices by the population, which is essential to prevent the continued spread of the virus at community level. In order to respond to the context and the needs in Sierra Leone, Action Contre la Faim (ACF) - France has designed and piloted the "Community Led Ebola Management and Eradication" (CLEME) approach in Moyamba District. This approach aims at responding to the deeper need of social mobilization to trigger behavioral change in order to strengthen community resilience to EVD outbreak. The CLEME approach provides the communities with the tools to identify their unsafe practices that could lead to potential EVD infections and to identify solutions that fit the individual and community's needs, culture and available resources. In
the communities where ACF has piloted this innovative approach, the organization has overcome the reluctance of the communities to adopt specific behaviors to prevent the virus transmission and has successfully engaged community volunteers in surveillance activities ensuring that safety measures are implemented at community level and that risky behaviors are abandoned. Ensuring the respect of the social mobilization guidelines, as designed by the MoHS in collaboration with UNICEF and implementing partners and messages identified, ACF has developed the first CLEME manual in October 2014 adapting the Community Led Total Sanitation (CLTS) methodology to respond to the unique challenges of the Ebola outbreak. All along the initial stages of the crisis, when the virus spread was out of control and increasing, the CLEME approach was used as a means to support reduction of Ebola transmission within communities. Today, as the outbreak has evolved and the transmission continues at stagnant levels, reaching and sustaining the zero case level is the main goal of the CLEME. The methodology is based on interactive, often visual, tools that enable the participation of all members of the community, regardless of the literacy level. With this approach, participants feel empowered as they are actively involved in the exercise and they feel their contributions are valued. This both helps to maximize appropriateness of the intervention, and its sustainability through community ownership of decisions made. CLEME counts five main components: a) Pre-triggering, focusing primarily on building trust within community and raising awareness on Ebola; b) Triggering, including community mapping, identifying existing practices related to Ebola transmission: treating the sick, bury the dead, hand washing etc; c) Community action plan, which identifies necessary activities for disease prevention such as building a village isolation unit, establishing a Community Support Group, hand washing facilities at the household level etc; d) Training of key persons within the Community Support Group; e) Monitoring, coaching, and supervising on a weekly basis. In November 2014, ACF piloted the project in 12 communities of the Moyamba district, where ACF has worked since 2012, within clusters of EVD confirmed cases. Today, over 100 communities have been triggered in the district and 15 more in the district of Kambia, one of the last districts still affected by active transmission of the disease. The initial evaluation and feedback indicate that communities are responsive to the approach, Community Support Groups are active and villages are equipped with isolation unit built by the communities themselves. All this demonstrates that the CLTS approach can successfully be adapted to trigger communities to reduce the risk of Ebola using their own local resources. ACF is currently upscaling the CLEME approach up to 400 communities so as to support reaching and sustaining the zero case level in Sierra Leone. More detailed results and lessons learned are expected in coming months.

**Understanding the Mode of Functioning of CLTS on Psychological Determinants for Achieving Open Defecation-free Behavior in Cambodia, Lao PDR and Mozambique**

Miriam Harter, Eawag

Hans-Joachim Mosler; Sebastian Mosch

Rationale One billion people practice Open Defecation (OD), a fact that poses significant risks to public health. Community-led total sanitation is a widely used approach to reach open defecation free communities. However, the considerable grey literature on CLTS does not provide sufficient scientific evidence that CLTS is effective in changing behavior. Several implementing organizations apply a "light" version of CLTS, in which some elements of the original system are omitted; many of these organizations have reported success. The reasons for success or failure of CLTS, of both its entirety and individually for its key elements, are mostly unknown. According to the RANAS model (Mosler, 2012), successful behavior change needs the change of the mindset of the target population. This means that behavioral
determinants underlying the behavior have to be altered. The model describes factors classified into the following five factor blocks: risk, attitude, norm, ability and self-regulation. This project will demonstrate how different elements of CLTS work through psychological determinants by comparing people who still practice OD with people who do not and by looking at the differences between these groups with regard to their perception of CLTS elements and differences in behavioral determinants. Methods Between March and July 2015, a household survey is realized in three different countries, where CLTS has already been implemented (Cambodia, Lao PDR, and Mozambique). Face-to-face interviews with the primary caregivers are conducted in 600 households in each country (N=1800). A structured questionnaire is used to gain knowledge on OD behavior, Latrine Use and underlying psychological factors, as well as on aspects of community cohesion. Further spot-check observations of the households and the entire community is conducted. Results The data collection is still in process and will be finished in July, a detailed report on the results will be available for the time of the conference. Mediation analysis will disclose which behavioral factors--and, in turn, behaviors--are linked to the received set of CLTS elements. In detail, multiple linear regressions will reveal, which specific pattern of psychological factors are connected with Latrine Use and Open Defecation. Discussion The detection of the mode of operation of different CLTS elements and combinations of them will support the improvement of this campaign. The results will display how the different CLTS elements are perceived and how they are connected with open defecation and latrine use behavior. Following these findings practitioners will be able to gain insight into the specific needs of the target population to omit open defecation. The results will therefore contribute to a more apprehensive and targeted application of resources used for the achievement of an ODF community.

Impact of Unsafe Feces Disposal of <3 Years Child Among Households with Latrine Access in Rural Bangladesh

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Introduction: Worldwide 18% of the population practice open defecation. Even in settings where there is latrine coverage and adult open defecation has been minimized, young children frequently defecate directly in the living environment. Reported unsafe handling and disposal of child feces has been associated with greater diarrhea risk. However, reported hygiene behaviors can be unreliable, representing substantial underestimates of unhygienic practices. This analysis aimed to determine the sensitivity of reported feces disposal practices as an indicator for presence of feces in the domestic environment and to understand household characteristics that are associated with reported unsafe disposal of young children’s feces. Methods: We nested our analysis within baseline data collected from 5551 participants of a large-scale cluster-randomized control trial of water, sanitation, hygiene and nutrition interventions in rural Bangladesh, among which 96% had access to a latrine and 21% had at least one <3 years child, yielding a total of 1141 households for our analysis. Field workers recorded reported practices for the latest defecation among children <3 years and disposal of their feces and conducted spot checks for the presence of feces within the courtyard and compound areas. We defined safe disposal as feces disposed/rinsed into latrines or specific pits or buried. We defined unsafe disposal as feces disposed/rinsed into the drain or ditch/bush/jungle/garbage or left on the ground. We categorized household latrines as improved vs. unimproved using the WHO/UNICEF Joint Monitoring Programme definition. Additionally, we defined hygienic latrines as non-shared latrines with a piped sewer system or with a septic tank or a pit latrine with a water seal or a pit latrine with no water seal but with a lid and we
defined unhygienic latrines as pit latrines with no water seal and absence of lid or pit with no slab or a hanging latrine or latrines directly open to the environment. We determined the relative risk (RR) of unsafe feces disposal as a function of socioeconomic and household characteristics using generalized estimating equations (GEE) to account for clustering at the compound level. Results: Unsafe disposal of child feces was reported by 76% of the 1141 households with latrine access in our study. The majority of households (52%) disposed of feces in the bush/jungle, 9% left feces on the ground and the rest disposed of them in the garbage or drain. Among the households reporting unsafe child feces disposal, 5% had observed feces in the courtyard and 15% within the compound. Among households that had observable feces in the compound area, 90% reported unsafe feces disposal, indicating that the reported practice was highly sensitive as an indicator for actual presence of feces. Households where the <3 year old child’s mother or father had at least secondary education (versus no or only primary education) were less likely to report unsafe child feces disposal (RR for mother: 0.82, 95% CI: 0.76, 0.88, RR for father: 0.81, 95% CI: 0.74, 0.88). Unsafe feces disposal was less common among households where a potty was available for child defecation (RR: 0.69, 95% CI: 0.59, 0.79) and more common among households where the child < 3 years old was reported to defecate in a nappy or on the ground (versus in a potty; RR: 5.11, 95% CI: 3.34, 7.82). Unsafe disposal was also more common among households that had an unimproved latrine (versus improved latrine; RR: 1.11, 95% CI: 1.02, 1.20), unhygienic latrine (versus hygienic latrine; RR: 1.20, 95% CI: 1.10, 1.31) or shared latrine (RR: 1.18, 95% CI: 1.09, 1.28). Conclusion: Feces were observed in the courtyard or compound area in approximately one-fifth of households in this rural Bangladeshi population; these areas serve as a play grounds for young children and open feces may expose them to fecal pathogens. Despite having latrine access, we detected unsafe child defecation and child feces disposal practices. Further research might help to identify strategies for safer child feces disposal.

Making Water Quality Monitoring more Affordable: the AWQUA Initiative

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The water at this conference is almost certainly safe to consume, a feat that has required constant vigilance during its treatment and distribution. The US Environmental Protection Agency requires routine monitoring of real-time water quality parameters -- turbidity is often measured as frequently as four times per hour. This vigilance stands in stark contrast to many other areas of the world, where monitoring technology is often unaffordable, unmaintainable, or unsuited to intermittent (or absent) electricity and telecommunications. The pursuit of universal access to adequate supplies of safe drinking water is a daunting and multi-faceted challenge -- requiring the control of physical, chemical, and microbiological aspects of water quality, the sustainability of distribution networks and markets, and the support of good governance. The Affordable Water Quality Analysis (AWQUA) Initiative aims to resolve one aspect of this challenge: making real-time monitoring of key water quality parameters easy, affordable, tailorable, and suited for use in remote and rural conditions. Founded by the Open Source Water Lab at Johns Hopkins University (Department of Geography and Environmental Engineering), The AWQUA Initiative is taking a three-fold approach to the vast global disparities in water monitoring: (1) Build open-source electronics for affordable real-time measurement of key water quality parameters such as turbidity and chlorine residual: We have established a public repository of schematics for electronic water quality monitoring devices; providing layouts for circuit boards, detailing required electrical components and assembly requirements, and specifying firmware for operation and procedures for calibration. All published plans are made open-source (Creative Commons, Attribution / Share-Alike), and submitters are encouraged to suggest hardware and software modifications to improve performance, lower costs, or make devices more durable, dependable, and versatile. (2) Implement common communications protocols so that open-source water
quality monitoring devices may communicate their data to stakeholders wirelessly: While some key parameters such as pH can be affordably measured with commercially available electronic (or paper) devices, the need for human action in the collection and reporting of monitoring data is a major bottleneck -- data can only be collected during an operator's work schedule, may be incorrectly recorded owing to human error, and may be lost or forgotten before it can be shared. Members of the AWQUA Initiative are working to develop common communications protocols for broadcasting water monitoring data, and low-cost, open-source communications hardware to connect water quality monitoring tools directly to cellphone networks and the web. (3) Develop tiered device performance standards for individual water quality parameters: Performance standards should not be monolithic. Many commercial water quality monitoring tools (like turbidity meters) are developed to very exacting American and European standards -- increasing monitoring power while driving up device costs and, surely unintentionally, pricing poorer communities out of the monitoring market. The AWQUA Initiative acknowledges that monitoring standards influence monitoring cost. Besides working to reduce the hardware cost of devices, we are working to articulate tiered performance standards that water quality monitoring devices should meet. Ultimately, the AWQUA Initiative aims to make continuous water quality monitoring a reality in every village on this earth -- by publicly developing, reviewing, and refining the hardware, communications, and performance criteria needed. We would love to have your input.

Maintaining Quality at Scale: Leveraging Existing Reporting Mechanisms within MFIs in Bihar, India for Rural Sanitation

Genevieve Kelly, PSI

Shankar Narayan

The state of Bihar, India, has some of the poorest sanitation indicators in the country: 88% of rural households have no toilet facilities. The vast majority of the population of Bihar (89%) lives in rural areas, and of these rural families, 68% belong to the poorest two wealth quintiles, where access to improved toilet facilities is the lowest. Due in part to the high rates of open defecation and fecal contamination of the environment, Bihar has one of the highest rates of malnutrition among children in the world, with over half of the child population being underweight (56%) or stunted (56%), and a high prevalence of diarrhea among children under five (11%). Furthermore, the infant mortality rate (62 deaths/1000) is higher than the national average for India. The sanitation crisis is due to several challenges--(1) Broken supply chain for toilets which are often expensive and difficult to acquire; (2) Low consumer demand due to the inability of government-subsidized, low quality toilet campaigns to convert need into action; and (3) Limited financing options for sanitation-related enterprises to expand their business, as well as limited financial liquidity among consumers in the market to convert household needs to purchase. To address these challenges, PSI, with funding from the Bill and Melinda Gates Foundation (BMGF) has been working since 2012 in partnership with Monitor Group (now Deloitte), PATH and Water For People to implement the Supporting Sustainable Sanitation Improvements (3SI) Project to address the market shortcomings on both the demand and supply side to achieve sustainable and scalable solutions to meet sanitation needs among consumers in Bihar. To date, the 3SI project has made tremendous progress in the design and development of components for a standard toilet product; training and hands-on support to sanitation-related enterprises to enhance their skills to produce quality toilets; and marketing and sales efforts to assist households with the purchase decision and process of acquiring a quality toilet to meet their sanitation needs. Beyond the number of toilets constructed, PSI has identified quality as a key indicator, which is defined as a toilet that is hygienic, constructed in a timely manner, according to the household’s
preferences and one that it is not at risk of contaminating nearby water sources. By increasing the number of households that are satisfied with their toilet, PSI aims to increase usage as well as reduce the likelihood of fecal contamination of the environment. Since April 2015 3Si facilitated the sale of over 10,500 toilets in rural Bihar, and through the utilization of a 3Si phone helpline, over 7,100 households have been contacted to verify that their toilet is either under construction or complete. Of these, about 750 households have been visited in person by 3Si Technical Associates. With rigorous training and monitoring of enterprises on the production end of the supply chain, to quality checks at the other, PSI is able to ensure the project is meeting its goals. As 3Si continues its progress towards scale, however, the team is invariably faced with a challenge; thorough verification of quality construction, even just a small percentage, becomes a time-consuming, tedious process. PSI hypothesizes that that the built-in feedback loops within MFIs, such as consumer repayment rates and subsequent loan applications, can be leveraged to monitor quality upon delivery of the toilet, with PSI supporting enterprises to ensure quality at production. MFI loan officers spend large amounts of time within the 3Si project areas to sell loans and collect payments for 3Si-supported enterprise toilets as part of their regular work; they will often be the first to hear if a consumer is dissatisfied with the quality of the product. PSI will continue to ensure quality at the production end of the supply chain. Through regular engagement with its partner MFIs, PSI will be able to leverage existing reporting mechanisms for real-time data to ensure quality upon construction and increase the effectiveness of the project to reduce fecal contamination and the spread of disease in Bihar.

**Market Development, an Evolutionary Process for Rural Sanitation in Bihar, India**

Genevieve Kelly, PSI

Yasmin Madan

Supporting Sustainable Sanitation Improvements (3SI) - launched in August of 2012 in partnership with Monitor-Deloitte, PATH and Water For People - is a PSI project to build and sustain the market for sanitation in Bihar, India. Bihar has some of the lowest sanitation coverage in India, with approximately 78% of the rural population practicing open defecation. Through close collaboration with Monitor-Deloitte, PSI conducted extensive landscape research to map out the various actors and functions in the market for sanitation to identify gaps, constraints and failures. A key landscape finding was that households in Bihar that wished to purchase a toilet had to visit numerous input suppliers for the individual components of a toilet - such as the bricks, the pan, the cement, the door - and that this process was often complicated, time-consuming and expensive. By further unpacking this finding, PSI realized that there were no actors playing an aggregator role for a complete sanitation solution, and there was a lack of understanding of where and how to buy a toilet. Based on Monitor-Deloitte’s recommendations, PSI tested two business approaches to improve supply: a full-aggregator model where a household could purchase a complete toilet, including delivery and construction, from a single provider, as well as a partial-aggregator model, where existing manufacturers of cement rings (which line toilet pits) became an information center for households to easily navigate the toilet-purchasing and construction process. On the demand side for market development, PSI trained sales officers to visit households to inform them of the availability of quality, affordable toilets as well as to take orders to the enterprises. From the problem analysis and potential solutions, PSI hypothesized that the full-aggregator model would be the most successful; creation of a one-stop-shop for toilets provided convenience, quality-guarantee as well as cost and time-savings for the household. In a nascent market such as Bihar, however, this hypothesis proved invalid. What PSI found was that households favor a process in which they could acquire materials from their preferred outlets, or even supply materials they already had - such as leftover bricks from home.
construction. Despite PSI and PATH having worked to develop a toilet design that was cheaper than what initially existed on the market, households did not trust that the full-aggregator gave them a fair price. Instead, cement ring manufacturers, trained and supported by PSI, were seen as an opportunity for customization and perceived cost savings. Market development is an incremental process as the market evolves over time. While efficiencies in both supply and demand generated over time may lead a full-aggregator model to emerge, cement ring manufacturers are the most appropriate point of aggregation in the current nascent market. The lessons learned from the market evolution for rural sanitation in Bihar may have implications for other market development approaches globally.

Assessing Medium-Term Use, Microbiological Effectiveness and Health Impact of a Household Drinking Water Filter in Rural Rwanda -- a Matched Cohort Study

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Ghislaine Rosa; Corey Nagel; Thomas Clasen

Background Unsafe drinking water and household air pollution are two significant environmental health risks and contribute to diarrhoea and pneumonia, two major causes of death for children under 5. Rural areas are particularly vulnerable, due to lack of piped water and clean fuel sources. Household water filters and advanced cookstoves are two technologies that could reduce the risks associated with high exposures. In a pilot distribution programme in rural Rwanda in October 2012, the implementer, DelAgua Health, provided approximately 2200 cookstoves and water filters to households and promoted their use through quarterly-biannual community health worker visits. The filter was the Lifestraw 2.0, a new tabletop version of Vestergaard-Frandsen microbiological water purifier designed to last a family 3 years or more. We undertook a matched-cohort study to assess medium-term uptake of the filter 12-24 months after intervention receipt, and to determine, among other things, its impact on fecal contamination of drinking water in the home. Methods Of the 15 villages that received the intervention in October 2012, nine were selected for follow-up. Village-level matching to nine control villages was performed using a combination of restriction, propensity score matching and rapid assessment. In each village, we enrolled all consenting households with a child under 5 that belonged to the poorest socio-economic tertile according to an official village roster. Houses were enrolled and visited once between November 2013 and May 2014 (round 1) and a second time between May 2014 and November 2014 (round 2). At each visit, a household survey was administered to the primary cook of the household and consisted of questions regarding household demographics and household water practices. Usage and acceptability of the filter was assessed using a mixture of self-reports and observational indicators. At the end of each visit, a drinking water sample was collected and assessed for thermotolerant coliforms (TTC), a WHO-approved indicator of fecal contamination, using the membrane filtration technique. Results In round 1, 113 intervention and 156 control households were enrolled and surveyed; 91 of these intervention and 144 of these control households were followed up approximately six months later in round 2. In both rounds, >85% of intervention households still had the filter that was reported to be working properly, and 90% of intervention households reported currently using the filter, 95% of whom within the previous two days. Among intervention households that had drinking water in the house at time of visit, 74% in round 1 reported the water had been treated (99% using the filter), and 78% in round 2 (97% with the filter). In round 1 and round 2 respectively, 31% and 14% of respondents reported drinking unfiltered water sometimes or most of the time while at home, while 13% and 8% of respondents reported drinking unfiltered water on the previous day. Forty-three percent and 27% of intervention households reported their child under 5 sometimes or most of the time while at home drank unfiltered water in round 1 and 2
respectively. In round 1, 12% of children under 5 in the intervention arm reportedly drank unfiltered drinking water on the previous day, while in round 2, this increased slightly to 15%. Overall, 3% of intervention children drank unfiltered water in both rounds, while 23% drank unfiltered water in at least one of the rounds. Using combined data from both rounds, household drinking water quality in control households overall had a geometric mean of 6.3 TTC/100mL (95% CI, 4.6-8.5) compared with 1.3 TTC/100mL (95% CI, 0.8-1.9) in intervention arm. Thirty-nine percent of control households had drinking water quality <1 TTC/100mL (95% CI, 30-50%), compared with 70% of intervention households (95% CI, 63-78%). The odds of having contaminated drinking water (>=1 TTC/100mL) were 3.7 times higher in the control arm than the intervention arm (p<0.001). Discussion This study found high uptake and sustained use of a household water filter 1-2 years following intervention delivery. While the water filter improved household drinking water quality overall, a substantial proportion of households still have water that did not meet WHO drinking water standards of 0 TTC/100mL. Furthermore, exclusive use of the filter—which is necessary to prevent exposure to unsafe drinking water—remains a challenge in this setting.

Resilience of On-site Wastewater Treatment Systems Following an Extreme Storm Event

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By 2050, it has been estimated that 70% of the world's population will live in cities, increasing the concentration of waste in urban centers and decreasing the land available for waste treatment and disposal. As a result, use of decentralized and on-site wastewater treatment systems (OWTS) to achieve broad sanitation coverage is projected to grow. Yet knowledge of the impacts of decentralization and resulting privatization of operations on lifetime performance and consequent risks to public and environmental health is minimal. As the use of decentralized sanitation technologies increases, together with the movement toward multi-objective planning incorporating life cycle costs, long-term sustainability, design appropriateness and various environmental and health concerns, such knowledge is highly relevant. Reliability and resilience are two characteristics of functionality over a system life cycle; the former is associated with consistent performance within a range of normal conditions and the latter usually associated with extreme events. We propose that while science and technology are important factors, long-term performance including consistent treatment (reliability) and the ability to recover from perturbations (resilience) also depend on human and societal variables that govern operation and maintenance. Globally, natural hazards associated with climate change threaten both the physical and functional integrity of infrastructure including wastewater treatment facilities. Lack of wastewater treatment system resilience can relate directly to public and environmental exposure to wastewater contaminants during and after such an event. In a study of 209 publically owned treatment works (POTWs) in the US operating with National Pollutant Discharge Elimination System (NPDES) permits, the recovery time after a permit violation was modeled using compliance data and found to range from two to five months, with small plants more likely to experience the longest recovery time (lowest resilience). While we hypothesize that on-site treatment system resilience is also low, comparable information about post-failure recovery of owner-operated residential scale treatment systems (OWTS) is virtually nonexistent. In this study we examine the effects of decentralization on the resilience of wastewater treatment systems in the face of extreme events and statistically characterize the resilience of highly decentralized wastewater infrastructure, namely the time and costs required for an OWTS to restore operation after a failure. In October 2013, the Front Range area of Colorado experienced a 1000-year storm. Boulder County received approximately 50 cm of rain over a period of four days and experienced significant flooding and damage to
Infrastructure, including 20 POTWs and over 14,000 OWTS. Using records of flood repair permits and inspections as a result of the 2013 Boulder flood, a Generalized Linear Model (GLM) regression method predicts the time to OWTS repair as a function of system location, i.e., proximity to repair services, roads, and neighbors and household income based on structural value. At the same time, POTWs were also disrupted to varying degrees. Quantification of costs, social and environmental impacts and recovery time for the range of Boulder County wastewater systems provides a case study for comparison of the response of sanitation system functionality to an extreme event as a function of the degree of decentralization (on-site to highly centralized); ownership (public and private); and regulation (compliance-based versus design-based).

Making Toilets More Affordable for the Poor Through Microfinance: Lessons Learned from Introducing Microfinance Loans for Sanitation in Rural Cambodia

Phyrum Kov, World Bank

Susanna Smets

From 2000 to 2012, access to sanitation in Cambodia's rural areas increased by only 1% per year. By 2012, 66% of population practiced open defecation which is the highest in the region. Though open defecation rates are highest among the poorest rural Cambodians at 86%, they are still quite high even among the richest at 32%. Extensive previous experience with sanitation marketing approaches illustrates there is strong household demand for sanitation and the domestic sanitation market is capable of meeting it. At the same time, challenges remain in reaching low-income households that do not have the cash to meet upfront payment costs to purchase sanitation products. While there is strong demand for improved latrines in Cambodia amongst the rural poor, this demand goes unmet largely because these consumers cannot afford to pay upfront for a latrine that meets their preferences. Having access to microloans could help alleviate this challenge; however, microfinance institutions (MFIs) often perceive non-productive loans as high-risk, particularly when the borrower is not a trusted existing business client. A 13-month pilot (July 2012-2013) was conducted to introduce microfinance for sanitation on top of an ongoing sanitation marketing program to help cash-constraint households gain access to sanitation. Two MFIs participated in the pilot offering group loans and individual loans without requiring hard collateral. Loan financial database of the two MFIs was used for the analysis to understand the average loan size for a latrine, characteristics of customers (existing vs. new customers), socio-economic of customers (poor vs. non-poor customers), loan sufficiency ratio, loan acquisition cost, and revenue. The results after the pilot have generated a number of insights that are useful for WASH practitioners and MFIs. Firstly, it is learnt that there is demand for latrines even among poor households and a sanitation loan program offered by socially-oriented MFIs helps to increase uptake of sanitation among the poor. The key success factor to this is attributable to a small loan size and a poor-inclusive application process offered by MFIs. Secondly, MFIs can increase the number of loans offered, reduce loan processing time, and increase a household's likelihood of committing to a sanitation loan by dedicating loan officers to the sanitation portfolio. Thirdly, allowing borrowers to repay loans close to where they live increases the likelihood of interest in this loan product. Borrowers will hesitate if they have to travel long distances, especially for small loans. Fourthly, a close partnership between an MFI and a latrine business that has the motivation and capability to produce and deliver on time is needed to maximize commitments from customers and avoid losing latrine orders. Fifthly, a poor-inclusive sanitation loan program is financially viable and sustainable given the right support, and if loans are managed carefully.
Sustainable WASH for Conflict-Affected Communities

Adrienne Lane, Water for Good

Erin Boettcheer

Introduction The 2015 Millenium Development Goal for water access has been met. However, the remaining 768 million people without access are more difficult populations to reach, especially those facing emergency situations. In particular, people living in conflict zones face unique obstacles to obtaining access to WASH services, including displacement, damage to infrastructure, and security threats. WASH responses in conflict settings usually involve temporary relief efforts that save lives and can be adapted as populations shift and resettle. However, there is also a need for long-term WASH solutions in conflict settings, especially where low levels of water access existed before the crisis. Water for Good and Arc Solutions would like to share lessons we have learned working in WASH in the Central African Republic (CAR) and Somalia. Water for Good has worked in CAR for 10 years and has continued operations over the past two years as CAR descended into civil war. Roughly 20% of the country has been displaced and an estimated 2.5 million people are in need of humanitarian assistance, accounting for over half of the country's estimated population. Arc Solutions is committed to providing WASH services exclusively in conflict zones, working in Somalia for the past two years. In Somalia, 70% of the population does not have improved access to water, as the government has been unable to provide WASH services to its population for over two decades. Our experience in CAR and Somalia has shown that emergency relief efforts can be adapted to support communities living through protracted conflicts, namely through approaches that sustain water and sanitation infrastructure and promote the resilience of local institutions. Approaches to WASH development in conflict-affected regions

1. Prevent the deterioration of existing infrastructure In war-torn countries, public and private water providers often fail to maintain WASH infrastructure. Water for Good and Arc Solutions are working to provide regular handpump maintenance for a network of nearly 1,000 pumps in CAR. Many of these pumps are located in areas where displaced people have fled. In order to keep the water flowing reliably, local, professional maintenance teams travel to reach pumps on a regular basis to provide performance checks and minor repairs. Over the last five months, 93% of pumps were functional upon the departure of local well maintenance teams. In the midst of conflict it is difficult to predict the local financial, administrative, and technical resources that will remain available to maintain WASH infrastructure. In response, we have connected local staff/partners to international supply chains and we provide ongoing logistical and financial support.

2. Support resiliency of local institutions The strategic expansion of sustainable WASH services can shore up and support local institutions that assist displaced populations and their host communities. In CAR, churches, mosques, schools, clinics and other local institutions are hosting tens of thousands of displaced people. Recently, many of these local facilities have requested that Water for Good drill water wells to help support the people living in their compounds, relying on their services. In Somalia, Arc Solutions' partnership with schools has been a crucial strategy in the successful distribution of clean water and hygiene training to almost 10,000 children in Mogadishu. These types of projects serve the immediate needs of conflict-affected people and local institutions' ability to support the population after conflict subsides. Our organizations have discovered the importance of operating through local staff and partner organizations. This is desirable in most contexts, but becomes essential in the midst of emergencies, where foreign staff will likely be evacuated or hyper-restricted in their travel. Greater emphasis on local project management and implementation leads to greater prospects for project success. Working through local staff and organizations builds capacity within the country, creating a positive impact long after the completion of our projects.

Conclusion If we are to achieve universal access, the WASH sector cannot ignore those living in conflict zones. We must adapt our expectations and approaches in order to reach remote, conflict-affected people. In countries with low
state capacity and active conflict, sustainable WASH can play a critical role in bolstering civil society and maintaining infrastructure. Rapid, emergency relief efforts certainly hold great value, but there is also a crucial need for strategic investment in meeting the long-term needs of vulnerable communities in emergency conflict zones like CAR and Somalia. -A version of this abstract was published on WASHFunders.org.

Mobile Phones, Rent-to-own Mobile Installment Payments & Water Filters: Evidence from Kenya

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Five million children under age five die each year in the developing world from preventable causes with known solutions. Many of these solutions suffer from an "adoption puzzle" - they are available, effective, and relatively inexpensive, simple to use, and offer expected long-term benefits - and yet they are adopted at surprisingly low rates. We need to understand how to increase the adoption of important health-promoting products. Durable, gravity-driven ceramic water filters are an effective, relatively low-cost solution to the problem of scaling safe drinking water, yet are not widely adopted. Contaminated drinking water contributes to the deaths of 750,000 children under age five every year due to diarrheal diseases. A number of randomized controlled trials have shown that low-cost ceramic water filters are microbiologically effective and, when used, can improve health. In several studies, consumers preferred water filters to chlorine-based point-of-use treatment, which may lead to higher usage over time. All told, filters may be the most promising point-of-use water treatment option for achieving scale. Yet like many durable health products, filters suffer from low adoption. Three primary barriers preventing filters' widespread adoption are 1) poor information - many consumers are not well informed about how filters work and how effective they are; 2) liquidity constraints - the large upfront cost of durable products such as filters can be a barrier for many consumers who face liquidity constraints; and 3) present bias - that is, the tendency to overweight today's costs of adoption over the future benefits. We experimented with a sales offer for durable ceramic filters that combined a free trial to overcome product uncertainty and any present bias, and rent-to-own installment payments to overcome liquidity constraints. In a randomized trial of 300 households in rural western Kenya, purchase rates doubled under this sales offer, to 31%, compared to a traditional lump-sum sales contract, and were zero at baseline. To lower transaction costs, we collected installment payments using Kenya's vast mobile banking network, MPESA. Mobile repayment rates were low; roughly half of customers paid more towards their filter during in-person visits to request payment after multiple SMS messages went ignored. In-person payment requests add social pressure and potentially force an end to procrastination, but are much more costly at scale. Furthermore, sales offers were made to wives, who often make water treatment decisions, yet husbands often hold possession of the phone and are in charge of financial decisions. While the rent-to-own mobile offer is attractive to increase uptake of durable filters, more work is needed to reduce transaction costs in rural and peri-urban Kenya to find scalable means for expansion.

Protecting Sewer and Wastewater Workers from Ebola Risks and Other Emerging Pathogens

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Kelsey Pieper
The 2014 Ebola epidemic highlighted a critical need to evaluate the potential for exposure of sewer and wastewater workers to Ebola contained in hospital liquid wastes discharged to sewer systems. Previous research has documented that sewer and wastewater personnel are at increased risk of infectious illnesses, but no information exists about risks of infection with emerging pathogens such as Ebola. In order to aid in the development of emergency preparedness protocols for managing the risks of pathogen transmission via fecal matter and wastewater in outbreak settings, this presentation will summarizes potential exposure routes via raw sewage for sewer and wastewater personnel and will present results of a quantitative model assessing risks to sewer and wastewater workers in contact with liquid waste from hospitals treating Ebola patients. In addition, the presentation will describe a draft protocol for managing liquid wastes of Ebola patients in U.S. hospitals developed by a multi-stakeholder group including public health specialists and representatives of the wastewater treatment industry. The findings of this project are relevant not only to protecting sewer and wastewater workers from risks of Ebola but also from future risks arising from emerging pathogens.

Child Faeces Disposal Practices in Urban Slums of Orissa: a Cross Sectional Study

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Belen Torondel; Parimita Routray; Thomas Clasen

Background: An estimated 2.5 billion people worldwide lack access to improved sanitation facilities. This includes 1 billion people practicing open defecation, of which 60% reside in India. Even among households that have access to improved sanitation, children's faeces- a potentially important source of disease transmission-are not always disposed of safely. The unsafe disposal of child faeces may present a particular health risk due to the fact that children have the highest incidence of enteric infections and their faeces are more likely to contain pathogenic agents. Young children tend to defecate in areas where susceptible children could be exposed, especially as children spend time on the ground and practice exploratory behaviours such as putting fingers and fomites in their mouths. The current definition of safe child faeces disposal used by the JMP (defecation of the child in the latrine, faeces rinsed/ put in the latrine or faeces buried) deals only with the disposal site of children's faeces and does not include data on the other stages involved in the management of child faeces, for instance where the child defecates, how the faeces are collected, and whether the caregiver engages in hygiene behaviours afterwards.

Methods: We undertook a cross-sectional study to gather information on the current child faeces management practices and factors related to child defecation and disposal practices in urban settings in Orissa, India. We collected data from 694 households in 42 urban slums in Cuttack and Bhubaneswar. Households were eligible to participate if they had a child under five years old and reported having access to sanitation. The data collection tools included a structured questionnaire of the primary caregiver, spot-checks of the sanitation and hand washing facilities, and demonstrations of how the primary caregiver would manage the stools if the youngest child was to defecate at the time of visit. Findings: Of the 694 households, 39.9% of households reported using private sanitation, 24.5% shared sanitation, and 29.1% communal latrines; 6.5% reported not using latrines despite having access. There was a total of 850 children under 5 in the 694 households. The main defecation sites of the children for the last time the child defecated were on the ground inside the household compound (28.1%) followed by in the latrine (20.4%). Only 25.5% of the faeces were disposed of safely (direct defecation in the latrine (20.4%) and disposal in the latrine (5.2%)). The main disposal sites were throwing the faeces in the garbage (20.6%) and throwing the faeces in the canal or drain (22.1%). Safe disposal increased with child age and mobility category and was associated
with the place of defecation of the child and consistency of the faeces. Of the faeces that were safely disposed of some had been defecated on the ground directly, others on paper put on the ground or on cloth put on the bed where the child sleeps. The faeces were disposed of using paper, polythene, cloth, water or a broom. After disposing of child faeces 99.3% of the primary caregivers reported washing their hands but 39.3% of them used only water. The average age reported by the caregivers to start training their child to use a latrine was 3.8 years (range: 1-14) and caregivers expected their child to be able to use a latrine by himself at the average age of 5.3 years (range: 1-14). Further results will be presented to show the pathways from defecation to the disposal of the faeces. Multivariate analyses investigating factors associated with safe child faeces disposal will also be presented. Conclusions Even though the households included in this study had access to a sanitation facility, the faeces of children were only disposed of safely 25.5% of the time. The complex behaviours involved in child faeces management requires further research to define microbiologically and epidemiologically what should be considered safe. Meanwhile, safe disposal should encompass other aspects of child faeces management.

An Evaluation of the Morne a Cabri Wastewater Treatment Facility: Fecal Sludge Management in Port au Prince, Haiti

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INTRODUCTION: Prior to the 2010 Haiti earthquake, the majority of fecal sludge collected from latrines and septic tanks in Port au Prince was buried or dumped into canals, bodies of water or solid waste dumps. The ensuing cholera epidemic that began in October of 2010 sparked international investment, enabling the National Directorate for Potable Water and Sanitation (DINEPA) to begin construction on five wastewater stabilization pond (WSP) systems across the country. As of April 2015, the Morne a Cabri facility, located northeast of Port au Prince, is the only functioning facility in Haiti. At present, the facility receives 160 m3 of fecal sludge per day from metro Port au Prince and surrounding departments. 70% comes from pumper trucks that empty septic tanks or cesspools while the remaining 30% comes from barrels carrying fecal sludge from latrines that has been manually excavated. This latter waste is of much higher strength, containing a higher load of organic material and solids. Although WSPs such as Morne a Cabri are ideal for tropical climates like Haiti, more research is needed on the impact of high strength fecal sludge from latrines. At DINEPA's request, the Centers for Disease Control and Prevention (CDC) conducted a performance evaluation at Morne a Cabri to determine if the facility was operating in accordance with the original design and to better characterize the influent fecal sludge. As DINEPA is in the process of rehabilitating and finishing construction at four other facilities around the country, this evaluation will help guide designs for future facilities, as well as improve the performance at the existing facility. METHODS: Initial sampling for the evaluation was conducted in March 2014, with additional sampling taking place in November 2014. Grab samples were taken from incoming trucks, between all ponds in the system, and from the system effluent. The performance evaluation assessed the reduction of certain parameters, including five-day biochemical oxygen demand (BOD5), chemical oxygen demand (COD), suspended solids (TSS), E. coli, enterococci, total nitrogen (TN), and total phosphorus (TP). BOD5 was the principle parameter analyzed, as this was the main criteria used in the design of the WSP. Analyses were carried out either at the National Public Health Laboratory (LNSP) in Port au Prince or CDC in Atlanta. RESULTS: The weighted average for influent BOD5 from all sources was over three times higher than the design value. The incoming volume to Morne a Cabri, however, was a third of the predicted value; thus, the actual volumetric loading rate of BOD5 was approximately the same as the design (205
and 198 g/m3 day, respectively). Overall reductions of BOD5 and other parameters including COD, TN, TP, and TSS were 96% or higher, and E. coli and enterococci log reductions were 4.25 and 2.80, respectively. The BOD5 reductions for individual ponds were 88% and 57% for the parallel anaerobic ponds 1 and 2, 56% for the facultative pond, and 72% for the maturation pond. DISCUSSION: While the volume of fecal sludge coming to Morne a Cabri is less than a third of the design value, the estimated volumetric loading rate of BOD5 is at capacity due to the high strength waste coming from latrines. Preliminary estimates indicate that this facility may be receiving only 25-40% of the fecal sludge produced in Port au Prince, so much more capacity is needed in order to support the entire metro area. The facility is performing largely in line with the original design in terms of overall reduction of BOD5; however, performance of individual ponds is variable. In particular, less BOD5 removal is taking place in the second anaerobic pond. More analysis is necessary to confirm results, but accumulation of sludge in the anaerobic ponds from the high solids content may be a contributing factor to decreased performance. High ammonia content of the latrine fecal sludge may also affect performance in the facultative pond. Although the facility is not currently discharging into the environment, the high value of TSS found in the effluent of this system is approximately nine fold higher than World Health Organization (WHO) standards for reuse. If this facility or others in Haiti would begin discharging into the environment, special care would need to be taken to reduce risk to the environment or population of Haiti. RECOMMENDATIONS: As Morne a Cabri is the only operating facility in Haiti, expanding overall capacity in the country is imperative to protect public health and the environment. Also, a plan to routinely monitor the performance of Morne a Cabri and future facilities is important to guarantee that the systems are working according to design. Finally, DINEPA may consider some design modifications in this facility and future construction that would better accommodate the high-strength waste being received.

Microbiological Effectiveness of Household Water Treatment Technologies Under Field Use Conditions in Rural Tanzania

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Household water treatment and safe storage (HWTS) has been proposed as an interim solution for improving water quality in settings with unreliable or unsafe water supplies. We assessed microbiological effectiveness of treatment options in situ in Tanzania, to pilot technologies before consideration for national scale-up of HWTS. Participating households received supplies and instructions for practicing six HWTS methods on a rotating five-week basis. We collected and analysed 1202 paired samples (source and treated) of drinking water from 390 households, across all technologies. We analysed samples for thermotolerant (TTC) coliforms, an indicator of faecal contamination. All HWTS methods improved microbial water quality, with reductions in TTC ranging from 99.3% for boiling, 99.4% for Waterguard® brand sodium hypochlorite solution, 99.5 % for a pot-style ceramic filter, 99.5% for Aquatab® sodium dichloroisocyanurate (NaDCC) tablets, 99.6 % for PUR® flocculent/disinfectant sachets, to 99.7 % for a ceramic siphon filter. Differences between technologies were not statistically significant. Nevertheless, all HWTS methods yielded water that was consistently free of detectable faecal indicator bacteria. Given that microbiological performance across technologies was comparable, decisions regarding scale-up should be based on other factors, including uptake in the target population and correct, consistent, and sustained use over time.
From Measurement to Management: Lessons on Linking Evaluation and Practice from iDE's Scale Up of Sanitation Marketing in Cambodia

Christopher Nicoletti, iDE

Stu Taylor

Since late 2011, iDE's sanitation marketing efforts in Cambodia have resulted in over 150,000 sales of improved pour-flush latrines across seven provinces in rural Cambodia. In that time, we have seen improved latrine coverage across those seven provinces increase from 29% to 45%. The results achieved to-date are not the result of a static implementation strategy, but rather have required a process of continual reflection and revision of approach. In the context of an evolving program strategy, our approach to measurement has had to remain nimble and relevant. We summarize some examples of evaluation questions, methods, insights and influence on operations and identify some of the factors that have allowed iDE to successfully link rigorous evaluation and program management decisions in this case. With private sector actors as the central players, a key question for the team has been to identify the business strategies and market factors driving or constraining profitable sales of rural toilets at scale. This presents some significant challenges, as the business partners are mainly small, local operators with minimal management systems. iDE collected quarterly business data from these partners and combined these data with bi-weekly sales, and other known parameters, to estimate metrics such as operating ratio, breakeven and salesforce performance. These data provided important insights, including high drop-out rates for latrine businesses (including several that appeared successful); the importance of latrine sales for short-term cash flow and the importance of effective "sanitation teachers" - the sales agents that iDE was helping latrine businesses to cultivate. Based on these findings, the sanitation marketing team has moved to a more "hands-on" approach to managing the salesforce - emphasizing the role of latrine producers as suppliers rather than drivers of front-line sale - and developing customized sales strategies for "sanitation teachers" at the commune level using a series of longitudinal maps showing coverage rates, infrastructure, population density and latrine business locations. The sanitation marketing team also needed to understand customer behaviour post-purchase in order to gauge the impact of marketing activities on actual use of latrines. Sample-based customer follow-up surveys provided data on installation, use, customer profile and satisfaction. While installed latrines appear to be used at a high rate (more than 95% of adults report consistent use), there is a bottleneck with installation. 12 months post-purchase, only 62% of customers had actually installed their latrine (consistent with other field observations that customers tend to delay installation until they have the other components for a robust and aspirational shelter). The program team is using this information to design offerings that encourage faster installation - including affordable shelter options that are bundled with toilet purchase and a pay-for-results "smart" subsidy scheme that rewards installation with a small rebate to low-income customers. Over the past three years, the team has worked closely with local financial institutions to develop and test sanitation finance products. In order to test the effectiveness of an emerging sanitation finance product, iDE, in partnership with a research team from IDinsight estimated willingness-to-pay as measured with a randomized bidding game. This trial found a four-fold increase in uptake when customers were offered financing for their toilet purchase. This allowed the team to estimate cost-effectiveness of different finance delivery options and has pinpointed constraints to the scaling up of sanitation finance (primarily operational constraints for providers, despite a profitable and effective product). The findings also highlighted the fact that, despite the impressive increase in uptake, 50% of non-latrine-owners would still not purchase a latrine at current market prices. iDE, working with research partners Amplify Markets and Causal Design, has now entered a second phase of operational research, testing new delivery mechanisms for finance, along with embedded subsidies to boost penetration in low-income markets. The examples highlighted here demonstrate the
benefits of linking rigorous evaluation with program management and strategic direction. Reflecting on these experiences, we highlight a few key components that have led to success in making these links. These include: support from funders who recognize the importance of investments in good measurement and build in flexibility to modify program strategies mid-stream; research partners who understand managerial priorities and emphasize decision-relevance of evaluation questions; in-house expertise that bridge the potential gap between technical evaluation considerations and operational perspectives; and management systems that reward results, incentivizing managers to use evidence to optimize program outcomes.

Hygiene in Restaurants and Among Street Food Vendors in Bangladesh

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Introduction: In Bangladesh, with rapid population growth, urbanization and industrialization, food consumption patterns of people are changing and restaurants and street food vendors have an important role in meeting food demands. Food is a likely vehicle of pathogens in low income countries where hand hygiene and food handling put consumers of restaurant and street food at risk of foodborne disease. Sufficient water and readily available soap can impact hygiene practices. This study aimed to collect a range of hygiene indicators from nationally representative restaurants and street food vendors to provide baseline data for use in advocacy, planning, intervention design and monitoring. Methodology: We conducted a national hygiene study among restaurant staff and street food vendors in Bangladesh from July to October 2013. We used two-stage stratified cluster sampling using a probability proportion to size sampling method and selected 50 urban and 50 rural clusters. The quantitative study included structured observations, surveys including spot checks, handwashing demonstrations; respondents were asked to show how they usually wash hands before food preparation and serving food in 3 restaurants and among 6 street food vendors from each cluster. The quantitative component explored restaurant service staff, cook and food vendor hygiene practices, including hygiene while handling food with hands and cleaning utensil, and inspected hygiene facilities. Additionally, in a qualitative assessment, anthropologists purposively selected 8 urban and 8 rural clusters from the 100 surveyed. The qualitative study included in-depth interviews in 2 restaurants and with 2 street food vendors from each of the 16 clusters, and explored restaurant service staff members', cooks' and food vendors' perceptions of hygiene related to food handling. Findings: During spot checks of 300 restaurants, 99% (298) had water and 91% (273) had soap and water present at handwashing location for customers. However, only 42% (124) had water and 33% (100) had both soap and water at locations convenient for restaurant staff. Of 600 street food vending stalls, 32% (190) had water and 11% (68) had soap and water at the time of spot checks. During handwashing demonstrations, 90% (270/300) of restaurant service staff, 86% (259/300) of restaurant cooks and 16% (98/600) of food vendors washed both hands with soap. During structured observations, cooks used soap to wash hands on food handling occasions infrequently; these included 4% (6/151) before food preparation, 7% (2/28) after cutting fish/meat/vegetables, 1% (25/2335) before serving food, and 1% (2/142) before mashing food/salad preparation, whereas no street food vendors washed hands with soap during these food handling events. During structured observations, the field team detected that 40% (122/300) of restaurants and 44% (258/600) of food vendors dipped utensils into the stored reused water for cleaning. At the time of spot checks, depending on food type, the field team observed that between 3 and 25% of foods in restaurants; and between 5 and 45% of foods served by street vendors was kept
covered. In the qualitative study, the majority (70%, 45/64) of the respondents perceived that customers select a vendor based on tastiness of the food, whereas no one mentioned the need to maintain hygiene during food handling. Most respondents (80%; 51/64) reported that during food preparation and serving they did not touch anything dirty that would contaminate their hands. A small portion (14%, 9/64) of the respondents considered "hand to water contact" while washing vegetables and utensils as reasonable handwashing. Conclusion: Low rates of handwashing with soap were detected as was limited soap and water availability especially at street food vending stalls. Poor hygiene and food handling practices were common; almost half of the food handlers dipped utensils into the stored reused water for cleaning, likely causing water and utensil contamination. Further examining customers perceptions regarding food hygiene and food venue selection can inform development of an effective hygiene intervention for restaurants and street food vendors. As a strategy for increasing demand for better commercial food hygiene, a customer focused food hygiene intervention may motivate handwashing and safe food handling. Improving handwashing among street vendors will need to begin by improving availability of water and soap.

SSH4A: Pathways to Sustainable Sanitation in Rigid Socio-Political Conditions

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Introduction: Community Led Total Sanitation (CLTS) approach aiming to eliminate open defecation (OD) has only been pioneered about fifteen years ago while subsidy driven approaches failed to produce intended results. However, fluidity and adaptability of the approach itself made it so popular that it quickly got tremendous spread across the regions within few years of its formal inception. Many national and sub-national governments, international and national organisations consider it as a vital tool to eliminate OD. However, long-term sustainability of these programmes largely remained untested. Two recent studies (WSP (2011) and Plan International (2013)) found that villages only maintained ODF status at the basic level. Most toilets do not meet the JMP standard of improved sanitation, thus overall achievement of CLTS is questioned. This paper on the contrary argues that even in rigid socio-political conditions in a country like Laos, where organized social actions are systematically discouraged, and centralized government structure control actions, if properly designed and implemented, CLTS may still be a vital approach to bring lasting change in sanitation behaviour. About the programme: Since 2010, SNV Netherlands Development Organisation in Laos implements Sustainable Sanitation and Hygiene for All (SSH4A+). SNV's sanitation framework incorporates five synergistic components to attain sustainable sanitation and health for all. These include, i. sanitation demand creation focusing on triggering the demand of individuals, households and communities for better sanitation; ii. strengthening market-based supply chains by engaging with micro, small and medium size enterprises that supply sanitation materials, and analysing the supply chain to identify barriers and areas for improvement; iii. Developing, testing and scaling-up localised behavioural change communication strategies addressing and challenging misconceptions about sanitation and hygiene practices; and iv. Improving WASH governance by working through multi-stakeholder approaches the programme aims to improve the capacity and competence of relevant actors and stakeholders, to better support the delivery of sanitation and hygiene services. The programme is implemented in collaboration with the Provincial and District Rural Development and Poverty Reduction Office. In practice, nominated people from each of these government departments form the district CLTS team who are provided with intensive training on CLTS by SNV. These teams directly work with the village level formal committees and conduct village level triggering, post-triggering, and follow-up and progress monitoring. Method of evaluation: Data for this evaluation was collected in October, 2014 from 1200 households from the programme areas. Considering 95% confidence level, 5% margin error and at best (50%) probability of
picking a choice of sample as well as Probability Proportional to Size Cluster Sampling Technique, a total sample of 1200 were selected and interviewed. Research Randomizer (http://www.randomizer.org/) was used to select villages and households. A pre-tested structured questionnaire was used to interview household and to collect information. Results: The evaluation suggests that 83% toilets in the programme areas were built since the programme started in 2010. Although our programme is based on zero subsidy approach, 5% households reported to receive some financial assistance which is less than 20% of the total cost of a toilet. All the toilets meet the criteria of improved toilet as per JMP definition and almost all toilets were seen well-maintained. However, 7.5% households share the toilet with others and only 3.9% toilet outlets were connected to open drains. Thus, if shared toilets and un-confined pits are excluded, still 89% of the toilets meet the JMP improved sanitation criteria. Compared to other countries in the region, once motivated, Laotians' build expensive toilets; the average cost was USD 200/ toilets which is more than the average monthly income of a household in rural Laos. 13% households experienced their pits became full and most of the households took measures to keep their toilets running. Only 2% households reported to return to open defecation because they could not afford the cost to empty their pits. Conclusions: While interests are re-growing in the WASH Sector for subsidy based approaches, this evaluation confirmed that CLTS is still the best suited approach in the context of Laos and similar conditions and that it brings lasting improvement in sanitation behaviour change. The approach itself is flexible to be employed even in rigid socio-political conditions and has the strength to motivate people to spend on improved sanitation and sustained their behaviour. Thus, it is0important to keep experimenting and improving this approach to bring a lasting change in sanitation situation.

Sustainable Fluoride-Removal Solutions in Ethiopia and Kenya

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In the East African Rift Valley millions of people rely on groundwater with fluoride concentrations higher than the World Health Organization guideline value (1.5 mg/L) for drinking and cooking. As a result, dental and skeletal fluorosis is common. To date, despite many attempts, there is no sustainable and scalable solution for fluoride removal from drinking water for poor rural communities, largely because of costs and weak institutional support. Over the last couple of years, Eawag collaborated with two organizations in East Africa (in Kenya and Ethiopia) and together, we explored cost-effective fluoride mitigation technologies. While the technologies promoted by the local partners were found to be appropriate in the local context, concerns were raised if current implementation models are sustainable and scalable. For this reason, our focus was expanded to also explore economically viable business models. In-depth case studies were developed for both organizations, which describe the local production and sales of fluoride removal materials, the construction and operation of fluoride removal community filters and different other ways to generate revenues (e.g. sales of by-products and household water filters). Both case studies indicate various successes. Filter material (particularly bone char) is now locally produced at consistent quality in Kenya and Ethiopia and was accepted by targeted end-users. With respect to technology, community-based fluoride-removal solutions are the most cost effective to operate, and filtration is the favored option due to the minimal operation and maintenance requirements. Operating community-based fluoride-removal solutions economically requires minimizing the life-cycle costs. These depend critically on the fluoride uptake capacity per cost unit of the filter material over its full lifetime (including material production and regeneration cycles) but also on efficient monitoring and filter material replacement procedures. Nevertheless, various challenges were also identified. There is a limited ability and willingness
to pay for fluoride-safe water by end-users. It was found challenging to sustain high water consumption at installed community filters and there are no long-term subsidies available from the government. Financing largely depends on donations from non-profit organizations. Costs per m3 treated water still exceed the current revenue (excluding donations) due to high service delivery costs, high production and regeneration costs, and the limited fluoride uptake capacity of the filter material. The Ethiopian partner currently operates 12 community filters with 4,700 people benefiting from 14 m3 of fluoride-mitigated water per day. The Kenyan partner installed nearly 150 community filters in Kenya with 12,000 users and around 36 m3 of fluoride-mitigated water per day. For the private company in Kenya, our results suggest that the average annual costs over the past three years outweighed the revenue. The Ethiopian not-for-profit organization’s results indicate that the annual average revenue over the past three years were sufficient to cover all expenditures but only due to substantial donor funding. In general, there is a consensus on the need to reach larger scale and financially sustainable fluoride mitigation approaches, but anecdotal evidence indicates mixed outcomes at best. We conclude that there is need for clearly defined business models for the delivery of fluoride-free water. Both partner organizations need better monitoring of key data and regular reporting for improved decision-making. In addition, the two organizations should further reduce the life-cycle cost of bone char and consider the introduction of more cost-effective filter materials such as hydroxyapatite (HAP). Lower life-cycle costs decrease the costs per m3 of treated water, which makes it more likely that the current prices for fluoride-safe water (for end-users) of around $0.65 - 1.00 in Ethiopia and $1.10 - 1.70 in Kenya per m3 could cover the costs. Policy makers should rethink the need for subsidies for the mid-term and the poor, results-based finance could provide the right incentives.

An Assessment of Fecal Sludge Management Policies, Programs and Practices in Tamil Nadu

Nidhi Pasi, WaterAid in India

Census 2011 results have indicated that nearly 17 mn urban households (> 20% of the urban households in India) suffer from inadequate sanitation. Amongst the existing improved sanitation facilities, vast majority rely on onsite sanitation systems, such as septic tanks and latrines. India, has recently started focusing on what to do with septage/ fecal sludge (FS) that accumulates inside these systems with usage. Although septic tanks and latrines are major contributor to groundwater and surface water pollution in many cities nationwide, fecal sludge management (FSM) is one of the most ignored solution to addressing urban wastewater problem. According to CBCB (2009), the estimated sewage generation from cities and towns is 38254.82 million liters per day (MLD) out of which only 11787.38 MLD (30%) is being treated. The remaining is disposed into the water bodies untreated due to which 3/4th of surface water resources are polluted. The problem is further exacerbated by the fact that most of the states in India lack guidelines or regulations or monitoring frameworks for FSM. The FS disposal is neither connected to a sewerage network nor managed by a treatment plant. Consequently, this FS gets being dumped into water bodies, open spaces and agricultural fields without treatment. Thus, FSM is and will be the most challenging and complex problem for the urbanizing India to deal with, specifically in context of for small towns and municipalities where there is clear lack of sewerage system. A primary survey study was conducted in the state of Tamil Nadu across 10 Town Panchayats and 10 Municipalities to document and assess the existing FSM practices and to understand their impacts on health. In Tamil Nadu. 45.7% of the state’s population resorts to open defecation due to the absence of proper sanitation facilities. NFHS 3 states that 57 per cent of the households in Tamil Nadu have no toilet facility. The proportion of notified and non-notified slums with no latrine facility is significantly higher for Tamil Nadu; 27 per cent and 40 per cent respectively. These towns are neither connected by a sewage system nor have any Septage treatment plants. The State has formulated two strategies in the urban sanitation sector, coverage of all towns by
Under Ground Sewerage System and total elimination of Open Defecation by 2015. It has been planned to implement UGSS in a phased manner in the Corporations and Municipalities with necessary financial assistance under various central schemes. However, the primary current focus of state government is on addressing the issue of open defecation & their focus, research and investments on FSM is very limited. Within 10 years of time, FSM will be one of the biggest challenges for rural & urban areas and this study will suggest, possible way forward in FSM for small towns in Tamil Nadu. The field study has revealed that there is limited/partial or no underground sewerage system in Town Panchayats and Municipalities; septic tank is the most used system of FS collection; lack of adequate equipment for desludging and transportation of the sludge collected; irregular frequency and cycle of FS collection; lack of transparency on the data on collection quantities, operative guidelines prescribed in standards for septage management for collection and role of operators (government or private). There also exists a lack formal training in desludging. Several problems with the use of septic tanks were also reported that included lack of proper construction, overflow and opening during rainy season, water pollution, and cost of cleaning and gas formation during cleaning. It was also reported that proper and demarcated sites for sludge disposal are virtually non-existent with most of the fecal sludge collected being disposed in agriculture land, outskirts, and municipal dump yard leading to related environmental issues. The private operators are playing a key role in sludge collection and although most of them use modern equipment with safety measure, many lack formal training and are not treating sludge before disposal, especially in Municipalities. The key challenges faced by these private operators are the absence of proper place for disposal, opposition from public, harassment of government officials and police while carrying out the task during daytime. The communities reported about health issues and social disharmony as impacts of poor FSM during the study.

Water Source and Quality Variation in the Ethiopian Rift Valley

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Marc Jeuland; Tewodros Rango

Water access and quality is a major concern for residents of the Ethiopian Rift Valley. The most dependable drinking water sources, from groundwater, are often contaminated with high levels of naturally-occurring fluoride. Consumption of this groundwater causes dental and skeletal fluorosis, a disease with a significant lifelong health burden. Surface water sources tend to be lower in fluoride, but carry greater pathogenic risks. Rift Valley households therefore face a hypothetical health tradeoff between water sources, which is complicated by the dynamics of failing wells and seasonally varying surface water availability and quality. Households therefore typically use a variety of sources to fulfill their water needs. We hypothesize that these dynamic sourcing patterns lead to variation in exposures to different water contaminants, as well as their negative health effects. [METHODS] We conducted 3 waves of surveys with 400 randomly selected households in 20 villages of the Ziway-Shala Basin of the Main Ethiopian Rift Valley during 2012-2014. The household survey included detailed questions about water sources and health, as well as climate change, livelihoods, and other socioeconomic characteristics. We also evaluated fluoride levels in drinking water samples taken by representatives from each village throughout the study period. Trained health professionals conducted health and dental evaluations -using the Thylstrup and Fejerskov (TFI) index - with an average of three members in each survey household, at two points in time. We analyze water sourcing choices, and dental fluorosis and diarrheal disease outcomes, using longitudinal multivariate regression methods. [DATA AND RESULTS] Water access and quality is a major concern of our study population, and most households rely on multiple sources of water. Average household expenditures on water are around 12% of annual income, including transport and
water fees. Within the 20 study communities, 12 have deep borehole wells, and 4 of those had major service disruptions during the 3-year-study period. Households report frequent water shortages; for example 60% of survey households experienced a water shortage prior to the 2013 survey. Analysis of our water samples for fluoride shows a large variation year-to-year by village, and month-to-month within households. The average fluoride level in drinking water across our three sites is 5.08 mg/L (standard deviation 0.89 mg/L), far above the WHO guideline of 1.5 mg/L. In our analysis of monthly water samples in each community, we again find large variation across the year, with a month-to-month average standard deviation of 1.55 mg/L. Dental fluorosis is a significant health threat; average TFI scores across examined individuals are 2.8, indicating substantial fluorosis disease. At the same time, diarrheal disease prevalence across households is also high (10%). Ongoing analysis is considering the potential tradeoffs between water sources, and the impact that water quality variation has on fluorosis and diarrheal outcomes. [DISCUSSION] Researchers and policy makers should take into account the fact that households in settings with unreliable water supplies are likely to use multiple water sources. Our results suggest that there is significant variation in water sources and thus potential exposure to contaminants, as well as health outcomes. In addition to the health considerations, obtaining water from multiple sources is costly, particularly if households are attempting to obtain water of higher quality.

How Much Should an Improved Latrine Cost? Results from Randomized Willingness-to-Pay Experiments in Rural Tanzania

Rachel Peletz, Aquaya
Alicea Cock-Esteb; Emily Kumpel; Ranjiv Khush; Pascaline Dupas

Background: Open defecation and unhygienic sanitation facilities promote exposure to fecal pathogens, which are a major cause of poor health in developing countries. In rural Tanzania, most households have access to a basic pit latrine, but few of these latrines meet the WHO/UNICEF Joint Monitoring Programme’s definition of 'improved' because they lack a cleanable surface. Tanzania’s Ministry of Health has recently launched a National Sanitation Campaign, which includes the promotion of latrine slabs: by providing a smooth, easily cleaned, and safe opening for pit latrines, slabs are a simple option for improving sanitation facilities. Currently, however, latrine slabs are not readily available in rural Tanzania. To evaluate the potential for selling improved latrine products through rural retail outlets, we are quantifying household willingness-to-pay (WTP) for these products in two rural regions and measuring the influences of the following factors on WTP: the National Sanitation Campaign, hygiene information, prior exposure to the products, and the availability of product choices. Methods: We enrolled approximately 1,500 randomly selected households among 40 rural villages that were evenly divided between the Njombe and Morogoro regions of Tanzania. In each region, we randomly selected between villages that had participated in the National Sanitation Campaign and those that had not. Each household received a randomly selected purchase voucher that either specified a discounted price (the discounts ranged from 15% to 90%) for one of three latrine products or offered a choice of discounted prices for any of the three products. Working with village-level retailers who collected the vouchers and made the sales, we supplied the following latrine products: 1. locally made concrete slabs 2. commercially manufactured plastic slabs developed through the joint Water & Sanitation Program (WSP, World Bank) - International Finance Corporation (IFC) "Selling Sanitation" program 3. Pour-flush ceramic latrines imported from India and China To measure the effects of hygiene information on WTP, we tested a subset of household latrines for Escherichia coli (E. coli) contamination and shared the results with household members. To determine how prior exposure to the latrine products affects WTP, we installed concrete or plastic slabs in a few
Assessing the Influence of Social Capital on Water Point Sustainability in Rural Ethiopia, Guatemala and Honduras

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Introduction: Sustainability of rural, community-managed water supply is a critical challenge in low-income settings. While strong governance structures have been associated with more sustainable provision of water, understanding and quantifying the specific determinants of good governance and water point sustainability has proven difficult. Social capital of communities - the networks, norms, and trust that facilitate social behaviors - may play a critical role in the enabling environment at the community-level to manage these water supply systems. While explored in other development contexts, the role of social capital and its association with long-term functionality and sustained community water supply has not been explored. Methods: We piloted a social capital survey tool developed and validated by the World Bank to measure social capital and determine its influence on water point governance and sustainability in 32 communities in Ethiopia, 15 in Guatemala, and 30 in Honduras. We administered the social capital household survey in each community. Social capital was divided into six domains - groups and networks, trust and solidarity, information and communication, social cohesion and inclusion, and empowerment and political action - and each domain comprised a section of the household survey. Using the data, we created a social capital index. In each community we also conducted a survey with water committee members regarding water point functionality and water point governance. We created indices for functionality and governance, which we aggregated to the community level. We employed bivariate and multivariate analyses to test the association between our social capital domains and governance and functionality. Results: We found significant associations (p<0.05) between a number of social capital domains and governance in each study setting. In Ethiopia, groups and networks, trust and solidarity, and information and communication were significantly associated with governance. In Guatemala, trust and solidarity, social cohesion and inclusion, and empowerment and political action were significantly associated with governance. In both settings, governance was strongly associated with functionality, though a relationship between social capital and current functionality was not established. Data recently collected in Honduras is currently being analyzed but will be presented together with the data from Ethiopia and Guatemala. Conclusions: Identifying the domains of social capital associated with good water point management and sustained water supply will support implementers in development and evaluation of capacity building approaches for water supply provision. Social capital is culturally dependent, so research (and appropriate measurement tools) in varying contexts is critical. Additional research using these tools and approach, conducted prospectively, could help refine our understanding of how social capital predicts sustainability of water points, as well as understand if implementation of water supply itself could change social capital over time.
Fecal Contamination Along Multiple Environmental Pathways is Associated with Subsequent Diarrhea Among Children in Rural Bangladesh

Amy Pickering, Stanford

Ayse Ercumen; Benjamin Arnold; Laura Kwong; Sarker Masud Parvez; Craig Kullmann; Rokeya Ahmed; Leanne Unicomb; John Colford; Stephen Luby

Diarrheal pathogens are transmitted from feces to new hosts through a variety of environmental pathways, including drinking water, ambient waters, hands, soil, food, and flies. Understanding the relative health risks of exposure to fecal contamination along each of these pathways could be valuable in deciding which interventions to focus limited implementation resources on to maximize health benefits.

We conducted a prospective study among 1843 households in rural Bangladesh to quantify levels of fecal contamination along multiple environmental pathways and assess their association with subsequent risk of under-five child diarrhea. Data were collected through two subsequent visits to each study household. During the first visit, environmental samples from the household environment were collected; sampling at each household included child hand rinse, stored drinking water, source drinking water (tubewells), pond water, soil from the child's play area, food served to young children and flies captured from the food preparation area. All samples were analyzed for fecal indicator bacteria (E. coli and fecal coliforms) with the IDEXX most probable number (MPN) method using Colilert-18 media. During the second visit, conducted 4-10 days after the initial visit to represent typical incubation periods for gastrointestinal pathogens, data were collected on caregiver-reported child gastrointestinal symptoms. Multivariate generalized linear models with robust standard errors were developed to assess the relationship between environmental contamination and gastrointestinal illness by including all pathways that were significantly associated with gastrointestinal symptoms in a bivariate analysis at the p=0.20 level and controlling for household income and mothers' literacy as potential confounders. We found frequent fecal contamination along all environmental pathways we investigated, with ponds and soil having the highest levels of fecal indicator bacteria. A typical pond water sample contained over 5,000 E. coli and over 14,000 fecal coliform (MPN per 100 mL). A typical soil sample had approximately 120,000 E. coli and 240,000 fecal coliform per dry gram processed. Household stored water was more likely to have E. coli detected than tubewell water (58% vs. 24%). More than one-third (40%) of children had some E. coli contamination on their hands. Approximately two-thirds (59%) of stored food samples (predominantly rice) were contaminated with E. coli (geometric mean 2 MPN/dry g) and 82% were contaminated with fecal coliform. Over half (54%) of flies captured at the food preparation area had E. coli contamination; a typical fly had ~700 MPN E. coli. Fecal indicator bacteria present in stored water, on child's hands, in soil, and in stored food were significantly associated with subsequent gastrointestinal illness in children under the age of five. Diarrhea prevalence since the field team's previous visit to the household increased by 28% with E. coli presence on child hands (PR=1.28, 1.03-1.59) and 15% for each log10 increase in fecal coliform counts in soil (PR=1.15, 1.02-1.30). Blood in stool was significantly and positively associated with log10 fecal coliform count in stored water (PR=1.35, 1.08-1.69) and on child hands (PR=1.37, 1.10-1.70), as well as presence of E. coli in food served to the child (PR=2.35, 1.24-4.46). Our results suggest that high levels of fecal contamination on child hands, in stored drinking water, in soil, and in food are important risk factors for diarrheal illness and bloody dysentery among children under five in rural Bangladesh.

Usage of Carbon-Financed ("Lifestraw") Water Filters by Rural Kenyan Households

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In early 2011, 877,505 Lifestraw family water filters were distributed freely to >4.5 million people residing in Kenya's Western Province by Vestergaard Fransen. The company registered the "Carbon for Water" project under the Gold Standard voluntary market; carbon credits are awarded based on semi-annual audits. This program overlapped a large RCT ("WASH Benefits") evaluating the impacts of water, sanitation, hygiene, and nutrition interventions among households with newborns in rural villages in Kakamega and Bungoma counties. To characterize baseline water management practices and drinking water quality in the study population, we conducted independent household surveys of Lifestraw ownership and usage at 6 (n=499), 12 (n=344) and 18-24 (n=8,224) months post filter distribution; we also sampled stored drinking water to assess levels of E. coli contamination. We found 90.8% of the surveyed households had received a filter and 93.6% reported that a local Lifestraw behavior promoter had visited in the past 6 months. Reported filter use on currently stored drinking water declined progressively (31.8% at 6-mo, 12.0% at 12-mo, and 8.8% at 18-24mo). Although the percent of households that reported any filter use was higher, it also declined over time (62.7% at 6-mo, 44.0% at 12-mo, and 23.8% at 18-24mo). Few respondents obtained water directly from the filter when asked to fetch a glass of water for a young child (1.1% at 6-mo, 0.7% at 12-mo, 0.4% at 18-24 mo). Microbial quality was improved in Lifestraw filtered vs. unfiltered stored water, but typically still reflected E. coli contamination (geometric mean 21 vs. 28 E. coli per 100mL, p=0.021). Half (49.5%) of households reported filters were not functioning after 18-24 mo. Our data suggest carbon-financed water filters have not contributed to improved water quality among households in Kenya’s Western Province. While carbon credit financing has been promoted as an innovative means to finance water treatment for low-income populations, our data suggest the program is consistent with other studies showing poor adoption of household water treatment interventions provided programmatically.

Characterizing Lead Exposure in Private Water Systems in the United States

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Background: Approximately 15% of households in the U.S. are reliant on a private water system (e.g. wells, springs), which are not regulated by the Environmental Protection Agency (EPA) under the Safe Drinking Water Act. Through a Virginia Cooperative Extension program, metal concentrations were quantified in point-of-use water samples collected from private systems. This survey documented that 19% of households had lead concentrations in the first draw sample (i.e. sample collected after 6+ hours of stagnation) above the EPA action level of 15 µg/L, with concentrations as high as 24,740 µg/L. For perspective, a concentration of 400 µg/L meets FDA criteria for an acute health risk and 5,000 µg/L is a threshold qualifying a landfill leachate as a hazardous waste. After flushing five minutes, 1% of households had lead concentrations above 15 µg/L and some were as high as 159 µg/L. A local health department in North Carolina reported a sampling campaign in which 14% of private wells sampled exceeded the EPA action level, with lead concentrations as high as 191 µg/L. In addition, this health department linked several cases of childhood lead poisoning to water consumption from the lead contaminated wells. Therefore, this study aims to quantify the potential magnitude and patterns of waterborne lead release in private water systems and evaluate plumbing source materials responsible for lead release. Methods: We developed a profiling method, tailored to private water systems, to detect lead in water coming from
within the home plumbing system (e.g. from leaded brass and leaded solder), as well as, lead potentially derived from the well (e.g. galvanized iron, lead packer). Using this profiling method, lead in water was quantified in 19 households in Virginia and North Carolina. Preliminary Results: Three patterns of waterborne lead health risks at individual households and associated risks to homeowners were identified: no elevated lead or lead elevated in the first draw of water only (Type I), erratic spikes of particulate lead mobilized from plumbing during periods of water use (Type II), and sustained detectable lead concentrations (>1 µg/L) even with extensive flushing (Type III). For cases in which Type I and III lead release is confirmed, following EPA recommendations and flushing protocols as short as 15-30 seconds are adequate to minimize concentrations below 15 µg/L to limit human exposure to elevated lead. However, Type III exposure poses a more significant health threat, as significant chronic lead exposure risks cannot be readily cleared from the line with reasonable flushing. As for Type II exposure, the random detachment of particulate lead may render flushing ineffective in protecting the health of residents. Therefore, while flushing protocols and acid neutralizers may be an effective remediation for some homeowners on private well systems, the installation and maintenance of a certified point-of-use lead filter would provide improved protection at lower cost for all systems.

A Randomized Controlled Trial of the Effect of Pricing Variations and Household Visits on Adoption of Household Chlorination in Rural Haiti

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Daniele Lantagne

Background In households without safe drinking water, one method to reduce the burden of diarrheal disease is the use of household water treatment and safe storage (HWTS) options. The Safe Water System (SWS) is one HWTS option, and consists of water treatment with chlorine, safe storage of treated water, and education. The Jolivert Safe Water for Families program has sold sodium hypochlorite solution (chlorine) and conducted household visits in rural Haiti since 2002 and has been managed by the organization Deep Springs International (DSI) since 2008. Previous research on the program has documented diarrheal disease reduction (OR=0.41, 95% CI = 0.21-0.79) and sustained use (55.7% of households tested had positive chlorine residual eight years after the program start). In 2013, DSI received donor support to cover certain program costs, which allowed us to increase the total number of household visits conducted and offer price discounts. Our objectives were to quantify the impact of price variations and household visits on chlorine use and to understand the tradeoffs of various managerial decisions on the program’s dual goals of high chlorine use and sustainability. Methods A total of 3,652 households were randomized to determine whether or not they received household visits and which price they received for a bottle of chlorine. Half of the households received monthly visits from sales agents, and half did not receive any visits. Independently, all households were randomly assigned to one of five pricing groups by raffle. Prices offered ranged from 5 gourdes to the established retail price of 25 gourdes ($0.11 to $0.56, respectively). One bottle contains 37 doses (treats 700 L) of water and lasts the average household 1-2 months. Each household was given a coupon indicating the price at which they could purchase chlorine for the duration of the study period. The study took place between October 2013 and May 2014. Households were phased in, and those for whom less than three months of data exists were excluded. Sales agents turned in monthly paper reports, which included dates and amounts of chlorine purchased by each household, including those who did not receive household visits. Additional information was collected for households that received visits (date of visit, result of chlorine test, and product used). Results Data on bottles purchased by households in each visit and price group has been tallied and used to construct
demand curves for households who were and were not visited. In the coming months, household-level data on purchase size, date, and chlorine residual results will be entered and analyzed. The analysis to date has documented that 3,354 bottles were purchased over 11,820 household-months (average bottles purchased per household per 12-month period = 3.40). Households who were offered lower prices purchased more than those who paid retail price. The demand can be approximated linearly ($R^2 = 0.99$), where each 1 gourde decrease in price corresponds to an increase of 0.15 bottles purchased per household per year. The price at which cost recovery is maximized is 1.6% less than the current retail price. At each of the five price points, households who received visits purchased more than those who did not ($p = 0.009$). The difference in usage rates between visit and non-visit groups was 39.0% (0.63 bottles per year) at the current retail price (25 gourdes), and 17.5% (0.55 bottles per year) for all five prices. However, the cost of paying agents to do visits was greater than the marginal increase in revenue among households who received visits. Discussion These data allow program managers to model expected outcomes of decisions regarding price and household visits. Decreasing the price relative to the current retail price would decrease sustainability of the program, but increase chlorine use and health impact. Similarly, a program seeking to maximize sustainability would not conduct household visits, even though doing so would provide additional health benefits. Lowering the price would be a more cost-effective subsidy to stimulate higher levels of use than doing household visits. However, subsidies to compensate the program for lowering the price and conducting household visits are both highly cost-effective given existing program infrastructure. These findings inform ongoing attempts to set government HWTS policy in Haiti with respect to taxation and expectations of cost recovery. They are also relevant to discussions of the role of subsidies and user fees in health interventions in developing countries.

Prevalence of Water, Sanitation and Hygiene Knowledge, Norms, Practices and Illnesses in Bateyes in La Romana, Dominican Republic

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Background: Bateyes are settlements where migrant Haitian laborers live in poverty while working in agriculture, including privately owned sugar plantations in the Dominican Republic. Approximately 500,000 people, or 5% of the total Dominican population, live in a batey. While national surveys estimate that 86% of Dominicans access improved water sources and 83% access improved sanitation, little is known about water, sanitation and hygiene (WASH) indicators in bateyes. A cross-sectional study was conducted to establish WASH knowledge, norms and practices, so as to contribute to the dearth of literature on the health of batey residents and design a community-based health education program.

Methods: In June 2014, the Center for Medical Humanities & Ethics at the University of Texas Health Science Center San Antonio conducted a cross-sectional study of bateyes in La Romana. Using stratified random sampling, 10 bateyes were selected proportionally to the following variables' distribution within a sampling frame of 53 bateyes; the presence of a bio-sand filter program and health promoter, distance from a town, and batey ownership. 183 self-identified male or female heads of household over the age of 18 years were consented and interviewed using a validated household survey. The primary outcomes were: preventive health knowledge; water treatment, defecation, and hand washing norms and practices; self-report cases of Chikungunya, and self-report diarrhea and acute respiratory illnesses in children under 5. This study was approved by the UT Health Science Center Institutional Review Board. Findings: The majority of households (88%) obtained drinking water from an improved water source and 73% reported treating their drinking water, irrespective of water source. Households in non-filter program communities ($p=0.001$) and in privately owned communities ($p=0.02$) were more likely to report using an unimproved source and respondents with no formal education ($p=0.006$) were more likely to report not treating their
drinking water. Half (55%) of the sample used an improved sanitation facility and 13% of households openly defecated. Households in non-filter communities were more likely to report using an unimproved facility (p=0.002). Of households with an observable latrine, 38% of were observed to be dirty and 76% were observed to be poorly covered. Households that reported using soap for hand washing (68%) self-reported that they wash their hands at more key moments during the day than households without soap (p<0.0001). At least one person was reported to have symptoms of Chikungunya in the preceding two weeks in 29.5% of households. The self-reported prevalence of diarrhea in the preceding 24 hours in children under 5 was 27% and self-reported prevalence of acute respiratory illnesses in children under 5 in the preceding 48 hours was 18%. The proportion of girls reported to have diarrhea (32%) and acute respiratory illnesses (28%) was greater than that of boys (21% and 8%, respectively). Finally, while the prevalence of diarrhea in children under 5 was observed to be higher in communities without the bio-sand filter program, in households that used an improved water source, in households that openly defecated, in households that did not have soap, and in households where the respondent had no education, additional analyses will determine the relative risk of each factor. 

Interpretation: This is the first study assessing WASH knowledge, norms and behaviors that we are aware of in Dominican bateyes. The proportion of households in our sample using an improved water source and treating their drinking water is higher than the national estimate for rural areas in the Dominican Republic. This is likely due to the ongoing filter program, but might also indicate awareness about the poor quality of water available from improved public sources in the Dominican Republic. In addition, our estimate for improved sanitation coverage is below national estimates for rural areas in the Dominican Republic (74%) and the proportion of open defecators exceeds the national estimate (8%). With little income and no land title rights, batey residents have limited mechanisms for sustainably addressing the widespread prevalence of disease risk factors and a high prevalence of preventable illness we measured. As a highly vulnerable population with little autonomy, we hope this study will encourage further research and advocacy. and that our findings will be used to design more robust interventions for this population. Finally, this study will assist in designing the focus of and key messages for a participatory education program aimed at preventing diarrheal, respiratory and vector borne illnesses.

**Does the Installation of Improved Water Sources Impact the Burden of Water Fetching? Results from Nampula, Mozambique.**

Kory Russel, Stanford University

This study evaluates the use of human caloric energy expenditure to account for changes in the activity of water fetching as a result of new water systems in Nampula, Mozambique. Roughly 1.7 million people must carry and store water from shared sources each day. Reliance on shared water sources is particularly high in rural sub-Saharan Africa (SSA), where only 5% of households have piped water on their premises. Water fetching is by most accounts a gender-biased activity. Worldwide, women perform more than three-quarters of all water fetching and on average must walk six km per day with containers weighing upwards of 20 kg (44 lbs) on their heads. More than 96% of rural households in least developed countries obtain water supplies from sources located at some distance from their homes. While prior research has investigated time savings and reduced diarrheal disease incidence associated with shifting to improved water supply into the house or yard, there has been very little research examining the impact on caloric expenditure. This new research shows that women in Nampula are spending as much as 30% of their measured daily caloric expenditure fetching water, which is likely to have negative long term health impacts. Accounting for the energy women spend while fetching water could be a significant cost for women depending on the new water sources and systems chosen. We attempt to answer two questions:
(1) What is the MET energy expenditure of water fetching for a sample of rural women observed in Nampula, Mozambique? (2) What is the change in energy expenditure cost (calories and monetary equivalent) as a result of newly installed borewells with handpumps? This study quantifies the caloric energy expended by women observed in Nampula, Mozambique while fetching water from different types of water sources (shallow wells, rivers and deep wells fitted with handpumps). This is believed to be the first caloric study of women undertaken in the context of a large-scale water supply intervention. Study site, sample frame, and data collection: The study consists of three data sources: (1) Surveys: completed in over 2400 household split between two sampling periods in 2011 and 2013. Surveys were administered in 62 communities by trained Mozambican enumerators. Data including age, terrain classification, and water container volumes were collected from all respondents. Global positioning system (GPS) data for households and water sources were also collected for a more accurate accounting of distance and terrain factors. These survey data are used to calculate the overall energy expenditure of women in the rural Nampula communities who received new water sources. (2) Community Case Study: In a sub-selection of three communities, the daily activities and water fetching of thirty women were recorded, while they were wearing a heart rate monitor and being observed by a Mozambican enumerator. The woman’s height (cm), weight (kg), water load (kg), and walking speed (m/s) were also measured. These data quantify the exertion and strain of water fetching in a real world setting. (3) Laboratory Control Trials: Thirty women performed water-fetching activities in a controlled laboratory setting at a local medical research facility in Nampula. The participants’ heart rate and oxygen consumption were measured and energy expenditure was calculated using indirect calorimetry. This data was used to create and verify the larger model of energy expenditure in the Nampula study sample. Data Analysis and Results: The research found that women in Nampula are spending approximately 30% of their daily-recorded energy expenditure on water fetching. Additionally, the study found that while the amount of energy expended on water fetching fell in communities that did receive new bodewell with a handpump, there was still a substantial percentage of daily energy expenditure used on water fetching. Using these insights, the observed metabolic energy expenditure data is being integrated into a new cost-benefit analysis for rural water investment. The goal of this analysis is to determine a more comprehensive understanding of the true costs and benefits of installing varying types of water systems and sources.

Scaling Up Indonesia's Rural Sanitation Mobile Monitoring System Nationally

Deviariandy Setiawan, World Bank

Amin Robiarto

More than 101 million people in Indonesia - 41.2 percent of the population - lack access to improved sanitation. More than half of those individuals live in rural areas. The Government of Indonesia has addressed this lack of access through a program called Sanitasi Total Berbasis Masyarakat (STBM). STBM is a community-based total sanitation program that includes demand creation, supply strengthening, and enabling environment support. In 2009, with support of the World Bank's Water and Sanitation Program, the Ministry of Health conducted a pilot to monitor the results of STBM in two districts in East Java using a mobile phone Short Message Service (SMS) text-monitoring (mobile monitoring) system. The initiative showed that community progress toward becoming open defecation free (ODF) and changes in household access to improved sanitation could be collected through SMS sent from mobile phones and stored in a central database. In 2012, the mobile monitoring system was expanded to all 119 districts and cities in five of the country's provinces, covering approximately 36 million households and 123 million individuals. Based on this success, the government is now rolling out a monitoring plan to reach all 500 districts in 34
provinces in the country by December 2015. As of August 2014, 3,787 of the 10,559 health center sanitarians in the country have sent village sanitation data via SMS and data for 42.9 million households from 40,470 villages have been uploaded into the mobile monitoring system. To identify improvements for the mobile monitoring system and document lessons learned during the scaling up, qualitative research was conducted in Pemalang, Semarang, and Brebes in Central Java, covering interviews and focus group discussions with a total of 170 persons from a wide array of stakeholders. The results of this research and practical lessons learned during the scaling up of a nationwide sanitation monitoring program will be presented. Key findings are that a structured approach, which allows for adjustments and improvements to be made, is needed in order for real-time village data mobile monitoring to scale up nationally. Moreover, a national harmonized approach to rural sanitation, with sector-wide objectives and monitoring framework is a necessary pre-condition for scaling up data collection. Challenges with data accuracy can be effectively addressed by utilizing multiple data verification systems. Although the national roll-out has been impressive, to increase the use of the monitoring system as a management tool for programming, feedback loops, a larger set of customized data information tools, and channels to reach specific target users could be explored.

Involving Children for Better Sanitation in Schools: Case from Nepal

Neera Sharma, Save The Children

WASH in Schools is a first step towards ensuring a healthy physical learning environment. In Nepal, the National Framework of Child Friendly School 2010 (NFCFS) has set the minimum and expected indicators for the infrastructures and physical condition of the schools. The availability of a tap with potable water within school premises is one of the important indicators for the same. But the data shows that although 79% of schools have access to drinking water, the presence of actual safe drinking water out of that available water is unknown. Save the Children started interventions to improve water and hygiene in schools in their working district. Raising awareness on the health and sanitation in the schools and communities through young children was an approach that was used as a way of influencing large groups of people. Involving children in activities that emphasize learning about health and sanitation is a methodology that Save the Children is being using in coordination with its partners where it is implementing a School Health and Nutrition program. While celebrating school health and nutrition week, Save the Children facilitated mass awareness campaigns to reach the wider audience of the district. Mass awareness campaigns were conducted through local FM stations and TV stations to disseminate health and sanitation messages. As a continuity to mass awareness child club members, initiated street dramas and rallies in the local periphery along with demonstrating dance and songs related to health and sanitation for raising awareness on the need for sanitation in schools and community. The event was witnessed by nearly more than 350 people including local journalists and the event was broadcasted in local TV channels of the district. School Level Program Activities such as inter school Speech Competition on "Role of Students in keeping the healthy school environment" and "Importance of Safe drinking water in schools" and art events like the inter schools drawing competition was conducted on the topic "Clean and Hygienic My School Environment". Children from the schools took the initiative to advocate for and initiate testing of water quality in 80% of schools in district. Testing quality of water sources in 295 public schools of the district was conducted for the first time by District Education Office in partnership with Save the Children and District Water Supply and Sanitation Division. The test result showed that different water sources in 99 schools (almost 33.55%) were contaminated with E.Coli bacteria and therefore were unsafe for drinking purpose which needed immediate action for purification. The test result highlighted the urgency to further explore the grave situation of drinking water conditions in community schools which
was directly associated with the wellbeing of children in schools and the community at large. Government and non-governmental agencies expressed the need to support this initiative of DEO for ensuring every school has access to safe drinking water. As a result of the interventions, the need to focus on having safe drinking water in schools was highlighted and commitment to form a drinking water safety committee in every school was made. The committee was required to have a school water safety plan to ensure availability of safe drinking water in schools. An action plan for addressing the problem was developed for each school in the district. School Led Total Sanitation (SLTS) could be one important approach for changing community through the schools and involvement and participation of children in advocating for water testing could be the starting point for such approach. This could be achieved through effective involvement and active participation of children in water and hygiene related activities.

A Multi-Site, Mixed-Methods Crossover Trial of Adherence to Point-of-use Water Treatment in Post-Emergency Settings

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BACKGROUND: While point-of-use (POU) water treatment may be efficacious in laboratory or idealized intervention settings, its use as a strategy for delivering safer drinking-water is constrained by two major limitations: (1) low adherence (correct, consistent, and sustained use) and (2) relatively poor field performance compared with laboratory performance. Because POU treatment has been suggested to be most useful as an interim strategy, we sought to understand short-term POU adherence and effectiveness in settings affected by recent emergencies, in collaboration with Oxfam. We conducted a multi-site, mixed-methods longitudinal crossover trial in Zambia and Pakistan. The aim was to evaluate field performance, objective measures of adherence (chlorine residuals and used packet counts), and determinants of use over time.

METHODS: The trial was conducted in an urban slum of Lusaka, Zambia (n=200 households) prone to cholera outbreaks, and a semi-rural community in Sindh, Pakistan (n=233 households) subject to flooding. The two products assessed were combined flocculant-disinfectant sachets, both being considered by Oxfam for use in emergency response. Half of all households were randomly allocated to one of the two products for four weeks, and were then switched to the alternate product for another four weeks. Households were followed up via weekly unannounced visits. We tested free and total chlorine in reportedly treated water samples, collected used product sachets, and administered surveys. We also conducted semi-structured interviews and focus group discussions within a subsample to further explore product feedback, user experiences, and determinants of adherence.

RESULTS: Adherence: Objective measures of use indicated a clear decline in adherence in the second crossover phase in both countries and for both products (p<0.001). Household consumption of untreated water rose from 25% to 40% over the trial in Pakistan and from 48% to 62% in Zambia. Qualitative findings suggested that this was due to user fatigue, and the perceived costs of the products outweighing their benefits. Stated adherence was more than twice as high than objectively measured adherence in both countries (p<0.001). Greater overall usage was observed in Pakistan (2 treated litres/person/day) than in Zambia (1.25 l/person/day), partly due to perceptions of lower quality and more frequently at-risk source water. Perceived health risk, prior water treatment habits, and greater support within the household and
social circles were independent predictors of increased adherence in both countries.

Field performance: Higher chlorine residuals were observed in one of the products in both countries (p<0.001), though average residual levels for each were higher in Pakistan than in Zambia. Over 80% of water samples in Pakistan and less than 50% in Zambia met WHO minimum chlorine guideline levels. These differences were due to source water characteristics and adherence levels. Qualitative findings indicated that product performance could also be affected by source water contamination and poor packaging.

CONCLUSIONS: This study allowed us to compare and contrast findings from emergency-prone settings for POU usage in two countries. Adherence decreased markedly over the short 8-week trial period in both settings, and effectiveness differed between the two products and country sites. Adherence was linked to the perceived cost/benefits of the products, risk perception of untreated water, and prior water treatment habits. Our findings suggest that for POU to be consistently used - and thus deliver health impact - water-related behaviours, acceptability, and added-value to the user should inform intervention strategies alongside effectiveness, even under short-term use conditions.

**Participatory WaSH: a Process-Based Model of Policy for Context-Specific Action**

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The enabling environment is becoming increasingly emphasized as critical for effective and sustainable improvements in water, sanitation and hygiene (WaSH). Global monitoring of the enabling environment through the Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) indicates that over 80% of 93 countries reported having approved national policies. However, several countries have instituted either urban or rural policies, rather than those that cover an entire country. These geographically inspired policies have the potential to increase inequities, particularly when segments of the population, such as informal settlements or peri-urban areas do not fall neatly into the urban or rural category. In Fiji, informal settlements are excluded from the rural water, sanitation and hygiene (WaSH) policy, and not covered by urban utilities. As a result, these areas are not considered for infrastructural or financial WaSH support. For other countries, the focus on bringing interventions to scale has lead drinking-water and/or sanitation policies to focus on a "silver bullet" solution such as Community-Led Total Sanitation (CLTS). Adoption of these types of policies ignores the heterogeneity both between and within countries and leaves little room for context specific approaches. For example, the Solomon Islands recently adopted CLTS as the only sanitation approach for the islands in their rural WaSH policy. However, construction of rudimentary pit latrines which concentrate fecal matter may lead to groundwater contamination of the water lens on coral atolls. In drought prone areas, this groundwater contamination is likely to reduce access to safe water. We suggest that the adoption of policy which outlines processes for engaging communities around WaSH issues, rather than policies that impose particular solutions allow for locally specific and innovative WaSH actions. These actions may include adoption of new WaSH technologies, behaviors, or processes. The flexibility in process-based policy also allows for a single national WaSH, without the need for geographic division. Within this process-based policy context, countries may choose to adopt different standards for various contexts; however since all areas of the country falls under the policy, increasing inequities are unlikely. Finally, a participatory process-based
policy can allow countries to move beyond simply improving WaSH access for their populations, to a focus on improving community well-being. Data comes from an ongoing Participatory Action Research (PAR) project in informal communities in the South Pacific countries of Fiji, the Solomon Islands and Vanuatu. In the first phase of the project individual interviews with enabling actors (government and NGO stakeholders) were conducted in 2014. In phase two, we convened a series of participatory workshops in each country. The first workshop brought all enabling actors together for participatory stakeholder mapping and discussion on WaSH governance. A subsequent two-day workshop with the enabling actors and representatives of two informal communities sought to develop action plans for innovative WaSH marketing solutions for the participating informal communities. Interview and workshop transcripts are being analyzed thematically with an emphasis on actor relationships and processes of governance.

**Experiences in Developing an Independent Evaluation Protocol for Long Term Sustainability of Rural and Urban WASH Programs**

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Franz Rojas; Kirk Anderson

Billions of dollars in aid have been spent trying to ensure the world’s poorest have access to water and toilets, yet, as everyone in the WASH sector knows, an unacceptable percentage of water and sanitation projects fail within a few years of implementation, particularly in rural areas and most organizations do not know the functionality rates of their own projects. The Water for Life (WFL) rating is a certification of long-term sustainability for WASH sector, allowing donors to target their funding toward the most successful WASH programs. To date, three WFL Ratings have been conducted. Two of the ratings were conducted with NGOs operating in rural areas of Central America. The third was conducted with an NGO operating in urban and peri-urban slums of Dhaka, Bangladesh. The rating is based on a five-day field evaluation conducted by two independent evaluators. The objective of the field evaluation is to learn about the program being assessed, then compare the actual program outcomes to 22 established WFL criteria. Each of the criteria has a basic expectation and a high expectation. The organization being rated shares a complete list of projects implemented with the independent evaluators. From that list, four to six projects that have been complete for five years or more are selected for field visits to record observational and interview data that is compared to the WFL criteria. In Honduras, the NGO evaluated met basic expectations for 21 of the 22 criteria and met high expectations for 11. Since the 2011 rating, the NGO has taken several steps to improve outcomes in areas identified in the assessment, including establishing a loan fund to provide rural communities access to low-interest rate loans for water system construction, expansion, and repair. The second assessment of a Latin American NGO identified some challenges with sustainability related to level of water service provided. Communities were not satisfied nor paying for water at lower service levels. In Bangladesh, the NGO evaluated met basic expectations for sustainability in six out of 22 categories and met high expectations in thirteen. Challenges were identified regarding water quality monitoring, water metering and construction quality. Significant differences in sanitation outcomes were identified based on the restrictions placed by the donor. The WFL protocol is an effective tool for rapid assessment of long-term sustainability of water and sanitation programs implemented by local organizations. The protocol may also be useful for donors in assessing whether or not their restrictions are positively or negatively impacting the long-term success of the projects they are funding. The evaluation also allows for a field-level exchange of knowledge and ideas between practitioners because the ratings are open to participation by independent organizations. By applying the same criteria, donors can identify high-performing WASH organizations to fund and compare organizations operating in
Increased Latrine Cleanliness After an Intervention Tailored on Psychological Determinants: a Longitudinal Study in Burundi

Ina Sonego, Eawag: Swiss Federal Institute of Aquatic Science and Technology

Hans Mosler

Background: Access to improved and clean sanitation is fundamental for the prevention of diarrhea. Methods: A baseline survey in rural Burundi had revealed the relevant psychological determinants underlying cleaning behavior, namely satisfaction with cleanliness, self-efficacy and commitment. Through a follow-up survey, we evaluated promotional household visits targeting these determinants in order to improve latrine cleanliness. Households receiving a promotional visit about water related behaviors served as controls. Finding: Wilcoxon's sign rank test revealed that, after the intervention, latrine cleanliness, measured by short observations, had increased in the intervention group (N = 171; Z = -3.06; p = .002; r = .23), whilst there had been no change in the control group (N = 104; Z = -1.38; p = .167; r = .14). Results of a logistic regression showed that intrindividual differences in the psychological factors satisfaction with cleanliness, self-efficacy, perceived effort and perceived difficulty could explain the increase in the household's latrine cleanliness. Differences in "commitment" were not relevant. Discussion. The results confirmed that interventions tailored to relevant psychological determinants were able to effectively increase latrine cleanliness.

Evaluating the Impact of the Millennium Water Alliance Ethiopia Program on Household WASH Access in Rural Ethiopia

Sarah Sparker, Millennium Water Alliance

Anna Chard; Matthew Freeman; Melkamu Jaleta

Background: Community-based interventions to improve water, sanitation and hygiene (WASH) have the potential to improve health and wellness outcomes, but only if they are context specific, high quality, and sustainable. However, many implementers fail to evaluate their programs beyond measuring immediate program inputs and outputs. Program evaluations are necessary not only to document successes and failures of WASH programs in achieving their stated goals and objectives, but also to inform the broader evidence base for best practices in WASH programming. Here we present a program evaluation of the Millennium Water Alliance- Ethiopia Program, with emphasis on uptake, sustainability, and equitable distribution of water, sanitation, and hygiene technology and behaviors. Methods: We assessed the impact of the Millennium Water Alliance- Ethiopia Program (MWA-EP), an integrated WASH program aimed at providing equitable and sustainable access to safe water, hygiene, and sanitation in rural Ethiopia from 2011-2014. We employed a pre-post implementation design: at baseline, twenty kebeles within each of the five implementing partners' program areas were randomly selected for a total of 95 kebeles. The same kebeles were sampled at endline. Sampling was stratified by difficult and challenging (D&C) status, as improving coverage in D&C areas was one of the objectives of the MWA-EP program. Stratification was proportional to the number of D&C versus non-D&C kebeles in the partners' implementation areas. At baseline and at endline, twenty households in each kebele were randomly selected from a census list of all
households in the kebele, which was obtained from the kebele office. Trained enumerators administered a structured survey with spot-check observations of household WASH facilities. Data were collected in 4,006 households, 1,934 at baseline and 2,072 at endline. Univariable analysis of program impact was conducted using t-tests, accounting for stratified sampling by D&C status and the cluster-based sampling design, and employing sampling weights to account for household probability of selection. Multivariable analysis was employed to highlight factors associated with program successes and identify opportunities for program improvement. Analyses were stratified by households classified as "vulnerable," and by households located in D&C kebeles. Results: Univariable analysis revealed significant improvements in access to household WASH facilities in the MWA-EP program areas from baseline to endline. At endline, the use of improved water sources was reported in 65% of households (from 39%). Households collected an average of 15.1 liters of water per person per day, a significant overall increase from baseline (12.3 liters person/day), and meeting the government standard of 15 liters person/day. Latrine coverage increased to 80% (from 66%), although there was no increase in the households where a JMP-defined improved latrine was observed (2% at baseline and 0% at endline). The largest overall improvement came in the presence of a handwashing facility near the latrine - at baseline, handwashing facilities were observed near the latrine in only 2% of households, while at endline they were observed in 69% of households. At endline, vulnerable households (defined as being headed by a female alone; having a disabled, chronically ill, or orphaned household member; or being in the poorest fifth of the population) reported better WASH behaviors than non-vulnerable households for some indicators (water treatment, keeping animals out of the house), but they still lagged behind non-vulnerable households on other key indicators (open defecation, handwashing facilities). Households in difficult and challenging areas reported increases in the quantity of water collected, use of drinking water from an improved source, and lower water fetching times. Despite significant improvements in household access to WASH facilities, WASH behaviors still warrant improvement. Reported open defecation decreased, but was nonetheless practiced among 38% of households at endline. Reported treatment of drinking water was practiced among only 5% of households, although 11% of households reported treating water at baseline. Multivariate analysis of factors associated with equitable and sustained WASH access and behaviors is currently underway. Conclusions: These data reveal progress in increasing access to WASH infrastructure and hardware, as well as increased equity in access to these facilities among poor and vulnerable populations in the MWA-EP 2011-2014 program area. Data demonstrate a need for addressing WASH behavior change to sustain program impacts. Examples of how MWA partners have adapted programming in the current program phase based on these findings will be presented.

Establishing a Monitoring and Evaluation Plan for World Water Relief in the Dominican Republic & Haiti

Katherine Stanfill, Emory University

World Water Relief, an NGO dedicated to installing water systems in the Dominican Republic and Haiti, commits to providing each project site education, maintenance, and support for a full ten years post installment. Uniquely, a collective approach is taken towards the wash issues of the region, addressing water quality, sanitation, and hygiene education all with the infrastructure of a small group of full time staff living amongst the project sites. The organization, established in 2009, needed a monitoring and evaluation plan in order to document and quantify the progress being made towards the project goals. A program monitoring plan was developed under the logical framework of tracking the programs progress through identifying a series of indicators that lead to outcomes that are the result of the goals established for the project. Surveys were designed to measure the identified indicators by use of CommCare, a mobile technology application, and surveys were piloted in conjunction with training staff and school directors.
World Water Relief project sites were visited throughout a three month time span in 2015. Routine data collection has been established at each site through mobile technology that is aggregated and analyzed on a continual basis by the organization. Indicators monitored are under the categories of water quality, sanitation, and hygiene education. Abridged baseline results show that all tested purified water from World Water Relief systems measured negative for hydrogen sulfide-producing bacteria, hand washing stations were functional at 88% of the schools, and students in enrolled in the hygiene education programs self-reported missing an average of 2.0 ± 1.6 days. The established monitoring plan for World Water Relief will provide a continual tracking of the program's progress as well as helping to identify areas of weakness in order to strengthen the organizations ability to achieve their mission of "transforming the lives of children by providing safe water and hygiene education."

Soil-Transmitted Helminth Contamination of Soil in Rural Kenyan Households

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Kara Nelson; Jimmy Kihara; Sammy Njenga; Jenna Davis; Alexandria Boehm; Clair Null; Amy Pickering

The objective of this study was to characterize the prevalence of soil-transmitted helminth levels in soil collected from house entrances and latrine entrances among communities in rural Kenya with limited sanitation infrastructure. Globally, about 1.5 billion people are infected with at least one species of soil-transmitted helminth (STH). STH are parasitic worms that live in the intestines of humans and other animals. STH eggs are excreted in feces and get transferred to hands, food, and surfaces and are eventually ingested, leading to infection. Helminth infections can have severe health implications, such as malnutrition, anemia, vitamin deficiencies, stunted growth, and intestinal blockages. We conducted a pilot study to determine the prevalence of STH (Ascaris, Trichuris, and hookworm) in soil among rural households in Kenya. We adapted the US EPA method for detecting and enumerating Ascaris in biosolids via microscopy to identify STH eggs in soil. The recovery efficiency of our method was 37% for the detection of Ascaris, as determined by seeding and processing soil with a known concentration of eggs.

Data collection occurred from June to September 2014 in rural communities in Kakamega, Kenya. Field staff collected soil samples from the house entrance and the latrine entrance (if a latrine was present) from 67 households. We found that 27% of households (N=67) had at least one type of STH egg in the soil. Ascaris was the most common STH detected at the household-level (19%), followed by Trichuris (9%), and hookworm (1%). Prevalence of any STH egg in soil was slightly higher at the house entrance (19%, N=67) compared to the latrine entrance (11%, N=62), but the difference was not statistically significant (Fisher's exact test, p=0.32). Among positive samples, the mean STH concentration was 0.6 eggs/g dry soil. The mean STH concentration was 0.7 eggs per gram of dry soil at the house entrance and 0.3 eggs per gram of dry soil at the latrine entrance (Wilcoxon sign-rank, two-tailed, p=0.20). The presence of full sun exposure was significantly associated with decreased presence of STH in soil at the sampling location (logistic regression, β=−2.1, p=0.05). Detection of STH eggs in soil at almost one-third of households suggests that child exposure to soil (e.g. hand contact during play, accidental or intentional ingestion) may be a substantial health risk. Contamination of the soil at both the house and latrine entrances indicates there are multiple sites of helminth exposure within the home. The results from this study will inform soil sampling location and methods in a large randomized controlled trial to assess the impact of improved sanitation on levels of STH in household soil.

Effectiveness of Hollow Membrane Fiber Microfilters used for Household Water Treatment in Honduras

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Background Household water treatment and safe storage (HWTS) options are promoted in developing countries to improve microbiological quality of household drinking water and reduce diarrheal disease burden. The Sawyer PointOne Filter (PointOne) is a hollow fiber membrane microfilter recently promoted for HWTS. In the laboratory, the PointOne is efficacious at removing bacteria (>6-log reduction) and protozoan cysts (>5-log reduction). However, field effectiveness data published in gray literature has found bacterial contamination in 18-54% of filtrate from PointOnes used for 3-36 months. A non-governmental organization distributed 200 PointOne filters with WaSH education in six Honduran communities in 2010-2013. To provide more rigorous field evidence, we tested microbiological effectiveness of 50 of the distributed PointOne filters in 2014. Methods Prior to field testing, control microbiological efficacy testing of one new PointOne were performed with urban stream water in Maine and river water in Honduras. For five tests in each location, we: collected a source water sample, backwashed the filter three times, gravity-filtered water for one minute, and then collected a filtrate sample. Samples were collected in sterile bottles, placed on ice, and analyzed within eight hours using Standard Methods' most probable number (MPN) method for simultaneous detection of total coliforms (TC) and Escherichia coli (E. coli) using IDEXX Quanti-Tray 2000 and Colilert media. Field testing occurred in two communities with the most filters distributed (44 and 55 in each). In the first, all 23 households (52%) previously identified as having working filters were visited. In the second, 27 (49%) households were visited (nonworking filters excluded). At each household, we: 1) administered a survey on PointOne use; 2) collected duplicate source and filtrate water samples and processed them for E. coli and TC as above; and 3) tested source and filtrate water turbidities in duplicate with a portable meter. Geometric means, geometric mean reduction, and paired t-tests on log-transformed values were performed for E. coli, TC, and turbidity in source and filtrate waters. Samples were categorized by World Health Organization (WHO) guidelines for E. coli results as: in conformity (<1 MPN/100 mL), low risk (1-10 MPN/100 mL), intermediate risk (11-100 MPN/10mL), high risk (101-1000 MPN/100mL), and very high risk (>1000 MPN/100mL). Fisher's exact test was used to determine if category distributions differed at 0.05 significance between source and filtrate waters. Results The new control filter demonstrated ≥99.4% E. coli reduction and >99.96% TC reduction in all Maine tests (with all filtrate E. coli and TC <1 MPN/100 mL). In Honduras tests, the filter removed ≥98.5% E. coli (source: 66-249 MPN/100 mL, filtrate: <1 MPN/100 mL). TC in source water was >2419 MPN/100 mL, and filtrate ranged from 1300 to >2419 MPN/100 mL. In Honduras, 91% of respondents (n=44) had a positive impression of the filter, and 80% (n=49) reported using it within the last day. Nine filters (18%) had observed cracks or leaks, and 70% of users (n=50) demonstrated the correct backwashing procedure. Geometric mean E. coli was 48.9 MPN/100 mL in source and 5.5 MPN/100 mL in filtrate (88.9% reduction). Geometric mean TC was 1,677 in source and 539 MPN/100 mL in filtrate (67.9% reduction). Geometric mean turbidity was 5.4 NTU in source and 0.6 NTU in filtrate (88.6% reduction). All three water quality parameters were significantly lower in filtrate than in source water (p<0.001). Seven filters (18%, none with visible damage) had higher E. coli concentrations in filtrate than in source water. No source water was in conformity with the WHO guideline; 12% of source samples were low risk, 62% intermediate risk, 24% high risk, and 2% very high risk. The distribution was significantly different for filtrate samples (p<0.001), with: 20% of filtrate in conformity, 42% low risk, 32% intermediate risk, and 6% high risk. Discussion Currently, we are unaware of any peer-reviewed field effectiveness data for the Sawyer PointOne, a filter actively promoted for HWTS. We found that PointOnes in households improved drinking water quality; however, only 20% of filtered samples complied with WHO microbiological recommendations, 18% of samples had more E. coli in the filtered water than in unfiltered water, and TC removal was partial. These results are in contrast to a newly-purchased PointOne which removed all E. coli in natural waters. Average E. coli removal in households (89%) is consistent with published data for locally-
produced filters but is lower than that of ultrafiltration membranes. Our results may be affected by selection bias, as abandoned filters were excluded. More research is recommended to understand the discrepancy in new to used filter performance, PointOne failure mechanisms, and potential end-of-life indicators.

**A Multi-Scalar Geographic Analysis of Primary Drinking Water Sources in Ghana**

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Christopher Cowen

Rapid population growth in developing cities often outpaces improvements to drinking water supplies, and sub-Saharan Africa as a region has the highest percentage of urban population without piped water access. Many West African cities implement a rationing system to the distribution of limited piped water resources, and sales of privately-vended sachet water--a sealed, single-use plastic sleeve of drinking water--have filled an important gap in urban drinking water security. While this phenomenon has been largely ignored by the development community due to lack of reliable drinking water data, Ghana's 2010 Population and Housing Census (PHC) is notable for surveying households' primary drinking water sources separately from the primary water sources for general household use. In this first nationwide analysis of sachet water consumption, spatial regression analysis at multiple geographic scales reveals strong urban-rural, socioeconomic, and geographic gradients in household reliance on sachet water as the primary water source, which exceeds 50% of households in some urban districts. District-level sachet water consumption rates are also highly correlated with what we call the "trust gap" in piped water use, i.e. the difference between the local rate of piped water availability and the rate of using piped water as the primary drinking source. Causality in the relationship between sachet and piped water use is theorized to run both ways. Thus lessons learned from the regional explosion in sachet water consumption may present implications for popular acceptance of new potable water projects as sub-Saharan Africa scales up water provision efforts in accordance with the Sustainable Development Goals.

**A Literature Review of Water Safety Plans: Lessons Learned from Case Studies and Evaluations**

Gabrielle String, Tufts University

Daniele Lantagne

Background: Water Safety Plans (WSP), although only conceptualized as such a decade ago, have their roots in risk management practices paramount to issues of public health. The WSP process is divided into five phases: Preparation, System Assessment, Operational Monitoring, Management and Communication, and Feedback and Improvement. The goal of a WSP is to balance the effort of stakeholders involved in water supply between testing of point-of-use water quality and risk assessment and management of the supply. Although the key goal of a WSP is to prevent incidents that are a risk to public health, additional benefits to the water utility include improved compliance to regulations, improved consumer trust and confidence of stakeholders, and cost effectiveness and investment planning. This literature review was conducted as the first deliverable of a cooperative agreement between UNICEF and Tufts University entitled Operational Research on Water Safety Plans in Afghanistan, India, DRC and Ghana, in order to inform the evaluation of case studies in chosen partner countries.
Methods: Documents were gathered via database searching, personal solicitations, and citation tracing. The databases PubMed, Engineering Village, and Google Scholar were searched using key phrases, including: "water safety plans", "water utility risk management", "rural water supply risk management", "evaluation of risk management water supply", and "evaluation water safety plan." Additionally, the IWA Water Safety Portal was reviewed, and publications were solicited directly from personal connections and the Household Water Treatment Google Group. Documents were included if they met the criteria of: 1) being a manual 2) describing lessons learned; 3) being a study in a rural community in a developing country; or, 4) being a study that evaluated a WSP based on specified performance indicators. Information was summarized and synthesized in a report to UNICEF.

Results/Discussion We identified 37 documents that met inclusion criteria, including 8 manuals, 16 peer-reviewed journal articles, and 13 grey literature documents. Of these, 8 were manuals describing how to conduct a WSP, 27 included lessons learned, 14 were conducted in rural communities in developing countries, and 13 provided evaluations of specific performance indicators. MANUALS. Manuals originally targeted water suppliers broadly, but specific guidelines have been adapted for contexts from small-scale community managed supplies to techniques for monitoring the entire WSP process. LESSONS LEARNED. The lessons learned for each phase of WSP implementation were synthesized from 27 documents and summarized as: Phase 1: Assemble a well-supported, multi-agency team that is committed to the long-term strategy. Phase 2: Ensure that the team has a solid understanding of risk analysis when evaluating the system from catchment to consumer. Phase 3: Ensure strict adherence to a monitoring plan in which clear control indicators have been outlined for continual evaluation. Phase 4: Train staff and develop clear goals to create a more collaborative management team that does not grow complacent in following through on the iterative nature of the WSP process. Phase 5: Clearly define metrics for measuring indicators to evaluate the system, make improvements, and ultimately determine the impact of the WSP. RURAL COMMUNITIES. Development of a WSP is more complicated in a rural water system as there may not be regional authorities, regulations, or testing equipment. The Water Safety Planning for Small Community Water Supplies manual by WHO provides guidance adapted to these environments. INDICATORS AND EVALUATION. Evaluation is paramount to create an evidence base on the impact of WSPs as a tool for water supply management and risk mitigation. The CDC's Conceptual Framework to Evaluate the Impacts of Water Safety Plans, in combination with their 25 key performance indicators, provide a basis upon which future WSP implementations can be evaluated. The indicators are divided into institutional, operational, financial, and policy outcomes that encompass the WSP process goals. Conclusions In our review we found: 1) multiple high-quality manuals to assist teams with developing WSPs, but most are goal oriented and lack task-based guidelines; 2) numerous lessons learned documents, particularly focused on operational strategy and WSP establishment; 3) studies that indicate rural communities may benefit from simpler forms of a WSP; and, 4) few published works on evaluations of WSPs based on key performance indicators. The WSP process has great potential to transform water management to improve public health and manage risk. Despite significant progress, more research is needed at all levels of WSP implementation to understand how to adapt the WSP process to different types of water supplies and to create an evidence base on the outcomes from WSPs.

Evaluation of Water Point Installations in Rural Communities in Malawi

Gabrielle String, Tufts University
Background: Officially, 95% of urban and 83% of rural Malawians have access to an improved water supply, although the Ministry of Irrigation & Water Development (MoIWD) estimates that the functionality of improved water points is approximately 75%. In 2003, the MoIWD transitioned to community based maintenance (CBM), with the aim to empower communities to identify their own needs, and construct, operate, and maintain their own services. A donor partners with organizations installing water points in Malawi within a CBM framework: Organization 1 (Org1), Organization 2 (Org2) and Organization 3 (Org3). Org1 has installed low-cost, user-maintained rope pumps throughout the country, while Org2 has installed Afridev pumps. Org3 has installed dispensers - source-based chlorination - at existing community water points. The goal of this study was to conduct an assessment to evaluate the functionality, quality, and sustainability of water points installed by Org1, Org2, and Org3 in Malawi to inform future funding decisions. Please note we have anonymized this data because the donor requested to share research results while maintaining anonymity for themselves and their partners.

Methods: In November-December 2014, Org1, Org2, and Org3 water points were visited. At each water point, a modified WHO and a Taylor sanitary survey were conducted to visually assess the risk of contamination for comparison against microbiological water quality. If water was available at the time of the unannounced visit, on-site testing was conducted for temperature, pH, TDS, EC and turbidity using standard methods and a 125-mL sample was collected for subsequent E.coli and Total Coliforms testing using membrane filtration. This testing was conducted on both untreated water and water treated with a chlorination or flocculation/chlorination option. The relationship between E. coli contamination and sanitary score was assessed using a t-test.

Additionally, research was conducted to compare site visit results to previous local and national evaluations, and key informant interviews were conducted with organizations' staff to gain an understanding of their maintenance models.

Results: A total of 68 water points were visited; including 28 rope pumps installed by Org1, 20 Afridev pumps installed by Org2, and 20 Org3 sites. Overall, 65%, 95%, and 100% of the Org1, Org2, and Org3 water points were functioning at the time of the unannounced visit. These results were generally consistent with previous studies where 78% of rope pumps and 81% of boreholes were functional.

The Malawian E. coli standard for rural wells is <50 E. coli/100 mL; 50% of Org1, 85% of Org2, and 95% of Org3 water points met this criteria. Concurrently, 0%, 65%, and 80% of Org1, Org2, and Org3 water points, respectively, met the WHO guideline of <1 E. coli/100 mL in water point water. After treatment, 100% of water points met Malawian standards, and 87-95% of water points met WHO guidelines.

Microbiological results for the rope pumps were similar to other studies conducted in Malawi where 68% of rope pumps were found to meet Malawian standards. Borehole results slightly outperformed other evaluations, which found only 60% of water points met Malawian standards, which could be due to the relative newness of the installations we visited.

Sanitary scores were lowest (best) in the Org2 sites (Taylor score: 0.6/5; WHO score: 2.5/10) and highest (worst) in the Org1 sites (Taylor score: 2.8/5; WHO score 4.6/10) where cracks and an apparent lack of maintenance were observed at the majority of installations. No correlation was found between E. coli
count and either sanitary score metric when evaluating all water points (p>0.05).

All water point installation partners identified Area Service Mechanics, spare parts, and Village Level Operation and Maintenance in relation to tariff collection and community engagement as the largest challenges to the long-term sustainability of their programs.

Conclusions / Recommendations: Our results highlight: 1) the tension of competing factors included in water point design such as: delivering high water quality and maintaining pump functionality while ensuring systems are user-maintainable and have low capital and maintenance costs, 2) the potential lack of relationship between simple to conduct sanitary surveys and actual microbiological results, and 3) the need to focus resources on the development of sustainable operations and maintenance models. The concordance between the results from this rapid, targeted evaluation and previous studies validates this methodology. Based on our results, it is recommended that operation and maintenance models become a programming focus of donors and implementers as a way to build towards sustainability and self-reliance of communities under the CBM model.

Understanding Rental Market to Assess Value of Improved Water Quality in Low-Income Urban Dhaka

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Background: Lack of access to safe drinking water in low-income countries contributes to diarrheal illness and death, particularly in young children. Point-of-use water treatment technologies that require households to individually treat their drinking water, additional cost, time and maintenance have produced consistently low uptake especially among households whose children are at highest risk of death. We have been exploring an alternative water treatment technology that does not requires individual level behaviour change and automatically adds an appropriate dose of chlorine to treat the water at the last stage of collection. In this study, we explored the potential to deploy and scale such technologies at the water point, rather than the household, in urban Dhaka, Bangladesh. Specifically, we explored the extent to which landlords of low-income properties might view an automatic water chlorination device for shared water points as conferring a competitive advantage in attracting and retaining tenants. More broadly, the study was designed to improve understanding of the rental housing market in Dhaka slums, including turnover rates, levels and strategies of competition among landlords, how and why landlords make investments in their rental properties, and the house and compound features that drive rental housing choice among tenants. Such information can inform how interventions that improve the safety of water might make appealing investments to landlords. Methods: We conducted the study from July to December 2013 in the Kallyanpur and Korail urban slums of Dhaka. To select study respondents fieldworkers collected a list of shared water point users from a NGO working on water, sanitation interventions and advocacy, Dustho Sasthyo Kendra (DSK). Fieldworkers developed a listing of compounds with landlords and compound managers who had a history of living in the slums and renting houses for at least 5 years, and at least one tenant who had lived in other low-income slums of Dhaka in the previous 5 years. Fieldworkers purposively selected 62 respondents based on their availability during data collection and willingness to participate in the study. Fieldworkers conducted three focus group discussions with eight respondents each: one with community tenants, one with landlords and one with compound managers. Fieldworkers also conducted 20 in depth interviews with the landlords; 10 from
each slum. Findings: The average monthly rental fee of a house, consisting of a single room shared with average six people, was US$21, which included electricity and water supply. Word of mouth in the community was the main strategy to attract new tenants. Written rental agreements were not signed because slum areas are not privately owned lands. However, landlords maintained oral rental agreements of payment details, rules and responsibilities of sharing water and sanitation facilities. Slum eviction occurs frequently when public land is reclaimed by the government, and tenants were forced to change slums and houses. All respondents reported that fear of being evicted made the landlords reluctant to invest in rental housing. Tenants reported that the most important factors when choosing a house to rent included the rental fee, vacant and available low-cost rooms, and no requirement for advance rent payments. Female tenants ranked their highest priorities as safe and accessible water supply and sanitation services to be shared with other family members and absence of male bachelors when choosing to rent a house. They reported being willing to pay higher rental fees for such amenities. Landlords reported that demand was lowest for housing units that were located near water bodies or garbage piles, have clay (non concrete) floors and lack water and sanitation services. Half of the landlords reported spending up to 13 to 16 US$ per year per house to renovate, upgrade and install new infrastructure including hand pumps, sanitary services, electrical services, and cooking areas in order to attract tenants. Notably, females, on both the tenant and landlord side were said to have the most influence over choices regarding which property to rent (or which applicant to select), because they spend a greater share of their time at home. Conclusion: Our findings suggest that low-cost housing facilities that do not require advance rental payments attract low-income people to stay in slums. Water supply and sanitation services were considered an important factor in attracting tenants, especially female tenants because they spend most of their time at home. Landlords invest in water and sanitation services, though the threat of eviction is a disincentive. Based on these findings, we hypothesized that a device which clearly improves water quality may provide competitive advantage in the rental market among female tenants. Future work could assess willingness to pay for a water treatment device among landlords.

Why Are Water Distribution Systems Run Intermittently? a Cross-Sectional Examination of the IBNET Database

David Taylor, MIT

Worldwide, more than 286 million people are served by intermittent water distribution systems. Intermittently-operated water distribution systems are more likely to recontaminate distributed water and distribute water less equitably than continuously-operated water systems. Researchers and practitioners disagree on both the primary reasons these systems are run intermittently and the biggest barriers to upgrading them. Three theories dominate the discussion: rapid (unplanned) urbanization, inadequate volume of water, and unsustainably-high consumer withdrawals. High leakage rates are occasionally cited as a fourth theory. This work evaluated the cross-sectional correlation between each of these four hypothesized drivers of intermittency and the level of intermittency of water utilities around the world. The International Benchmarking Network for Water and Sanitation Utilities (IBNET) is the world's largest database for performance indicators of water utilities, containing 22 thousand entries for 4466 distinct water utilities, from 137 different countries, serving 200 million customers and a population of 983 million people. This study evaluated IBNET entries from utilities in countries classified by the World Bank as Upper Middle Income, Lower Middle Income, and Low Income countries to assess the merit of the four hypotheses for why water systems are run intermittently. The hypotheses of population growth and supply shortfall both act to reduce a utility's water production per capita. This metric, measured in liters per person per day, was therefore used to simultaneously evaluate both of these hypotheses. Consumer
demand was evaluated by the metric of total water consumption per person per day. Leakage rates in the IBNET database are reported as non-revenue water. This metric, however, obscures the fact that if a system is pressurized for twice as long, its leakage rate will double. In order to normalize the values for comparison, the reported non-revenue water (NRW) levels were adjusted to their equivalent levels if the system were run continuously. A cross-sectional correlation was found to exist between each of these metrics and the utility's number of hours of water supply per day. The strongest correlation was observed between leakage rates and intermittency levels. Although these correlations are an important indicator, the more pragmatic question is how difficult it be to overcome each of these hypothesized drivers of intermittency, and therefore to achieve continuous water supply. For systems which operate less than six hours per day, converting to continuous supply was found to require an increase in the total water supply by a median of 345% (269% of this requirement due to the upgraded system's higher leakage rates and 76% due to an increase in consumer consumption). Systems operating between 6-12 hours per day would require 127% more water (61% leakage and 66% consumption increases); systems operating 12-18 hours per day would require 113% more water (25% leakage; 88% consumption); and systems operating 18-23.5 hours per day would require 116% more water (6% leakage; 110% consumption). These cross-sectional relations are limited in their predictive ability, as utilities that operate with longer supply hours may be correlated with more affluent locations where consumer demand is higher. The next step for this work is to complete a similar evaluation of these hypotheses using the longitudinal data within IBNET instead of the cross-sectional data. This work leveraged data on water utilities that serve one seventh of the global population to sort through the rhetoric of intermittent water supplies and to evaluate explicitly each of the four dominant hypotheses. Having identified leakage rates as the dominant barrier to improving water systems which operate for less than six hours per day, researchers and practitioners can now focus their efforts and improve intermittent water supplies more efficiently and effectively.


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An estimated 2.5 billion people lack access to improved sanitation. India represents a particular challenge, accounting for a third of worldwide population without improved sanitation and two thirds of those practicing open defecation. Governments have responded need by creating or supporting large-scale campaigns to improve sanitation coverage. Recent studies have shown that India's rural-focused Total Sanitation Campaign (TSC) left large proportions of villages without functioning latrines. There are also concerns about the extent to the program provided sufficient promotional support to encourage latrine use and to provide householders with necessary information about faecal sludge management. Methods: We conducted a cross-sectional study from September through December 2014 among 50 villages in Orissa, India that received latrines in accordance with the TSC between March 2011-February 2012. TSC subsidized latrines only for households that were below poverty line, which was around 70% in these villages. The 50 villages comprised the intervention group of a RCT to assess their health impact over the ensuing 21 months. In accordance with the TSC program, the pour flush latrines were designed for dual pits, though the program only constructed the first pit. We conducted surveys and spot checks to assess latrine coverage, use and attitudes or practices on faecal sludge management. All households in the villages were eligible for participation in the study, whether or not they were eligible to receive a latrine under the TSC. Results: Latrine Construction, Coverage and Use. Data was collected from 4398 households. Of these, 53% had some type of latrine. Among these, only 32% were complete, with the
balance 68% either under construction or otherwise incomplete. The mean age of the completed latrines was 4.8 years and for under-construction latrines 3.6 years. More than 99% of the latrines had only a single pit. Most latrine pits were constructed with 3 rings and had an estimated depth of 3-4 feet. We obtained use data from 97.8% of households that had some type of latrine (2285/2336). A total of 33% reported their latrines were not in use at all. Of the 1521 households that reported latrines being used, reported use was highest among women (97%) followed by men (78%) and children 6-14 years (40%); only 11% of households with young children (<6) reported that those children used the latrines or that their faeces were deposited in latrines. When households with latrines reportedly in use were asked about the frequency of latrine use, 78% (1185/1518) responded "always", while the balance responded "usually" (4.4%), "sometimes" (8.8%) or "never" (8.5%). Married women were most likely to report using the latrine always, while men were most likely to use it never or sometimes. Faecal Sludge Management. Data was collected from households which latrines presented signs of use assessed by spot checks. Only 2.3% (35/1494) reported that the pit had filled up after this 2-3 year period following construction. Among these, 23 reported emptying it and only 2 reported diverting waste to a second pit as intended by the latrine design; 5 households simply stopped using the latrine and reverted to open defecation. 27 households emptied their latrine once and 8 emptied twice or more. 18 households reported they emptied their latrines, 13 hired private scavengers and 4 used municipality services. A minority of persons emptying pits used gloves or boots. Householders generally reported that the pit contents were left in open places (38%) or used on crops (24%); only 24% reported burying the sludge in a hole. As so few latrines had actually been emptied thus far, we also asked a selected number of householders about their expectations regarding pit filling and emptying. 36% (160/446) of the respondents reported that when the pit was filled they would empty it, 26% reported that they would build a new second pit and divert the waste into it, 12% said they would build a new latrine and 3% said they would stop using the latrine altogether. Most expected that they would hire manual scavengers to empty it (52%); others that they would call the municipality (24%) and others that they would empty it themselves (13%). About a third (34%) reported that they would dispose the pit contents in cultivation fields; others would bury it in a hole (30%) or leave it in the open (23%). Conclusion: Two years after completion of the intervention in these villages, only half of households had a latrine at home. Only 1 third of these latrines were completed and 44% were functional. A third of the households with latrine reported never using them. Evidence suggest that faecal sludge management will be a major challenge, with most households expecting to empty fresh pit contents (or stop using the latrine) using uncertain or unsafe methods rather than building a second pit. Disposal of the sludge in open space or used on crops was the most frequent practice reported.

An Analysis of Critical Factors Responsible for Reduction of Diarrhoeal Burden Among Children - Findings from Six Select States in India

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Prasann Thatte; Manbendra Nath Ray; Preeti Dhillon

Diarrhoea is known to seriously obstruct the growth of children by leaving them malnourished and continues to be an important cause of morbidity and mortality in developing countries in spite of advances in public health management and increased use of oral rehydration therapy in the past decades. India, with approximately 123,668 annual under-five diarrhoeal deaths is highest contributor to the global diarrhoeal deaths. In this context, Save the Children India with support from Reckitt Benckiser conducted a study in select urban and rural locations of six Indian states to understand the risk factors and intervention which can contribute to reduce the diarrhoeal incidence amongst under-five children. A sample size of
6,188 caregivers of under five children from study locations of six states was subjected to both bivariate and multivariate analyses. The sample size was drawn assuming 5% change in anticipated variable at 5% level of significance, 10% margin of errors, 1.38 design effects and 10% adjustment for non-response rate and is representative of project and control locations in select states. Here socio-economic and preventive factors responsible for reduction of diarrheal incidence 14 days preceding the survey were analyzed. The 95% confidence interval (CI) is used to estimate the precision of the odds ratio (OR) while using logistic regression. Results reveal that young children in the age group of 6-23 months are 1.3 times (1.09-1.57) more likely to have diarrhea than children above the age of 2 years. Children of young mothers below age 25 years were at higher risk of diarrhoea as compared to the mothers above 25 years of age. Among the social indicators, caste group is found as a key determinant for diarrheal incidence, as children from Scheduled Caste (SCs)/Scheduled Tribes (STs) communities were (OR-1.3, CI:1.0-1.76) more likely to suffer from diarrhea than children from General caste. Children who were exclusively breastfed up to 6 months were (OR-0.78, CI: 0.65-0.93) less likely to have diarrhea than the children who were not breastfed exclusively. Further, children who received measles dose were 0.72 times (CI: 0.56-0.93) less likely to suffer from diarrhea. Hand washing practices emerged as a vital preventive measure of diarrhea. Children of caregivers who wash their hands with soap at any critical time were 0.68times less likely to suffer from diarrhea in comparison to children of those caregivers who did not wash their hands; children who wash their hands with soap at all critical times were 0.58 times less likely. Odds of having diarrhea among children who belong to the households that did not have access to improved toilet facility (OR-1.2, CI: 1.0-1.46) and who did not store drinking water safely (OR-1.4, CI: 1.14-1.78) were higher in comparison to children with access to sanitation and safe water. The analysis revels that children from state of Bihar were more likely to have diarrhea than the children from other states. The findings thus clearly reveal that for effective prevention and control of diarrhea, an integrated approach of treatment, protection and prevention is more likely to be effective amongst under-five children. The treatment must be addressed to avoid malabsorption of the nutrients of the diet, associated with replacement of the hydro-electrolytic losses and to prevent its prolongation. Similarly immunization, breastfeeding, improvement of sanitary conditions, access to safe water and hygiene are measures to be promoted with the objective of decreasing the morbidity/mortality of the diarrheal disease in children less than 5 years of age.

**Well Cleaning in Emergency Situations: Standard Procedure and Water Quality**

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During major flood events in developing countries, cleaning and disinfecting hand-dug wells is often one of the most urgent operations adopted by humanitarian organizations in order to restore the access to drinking water for the affected population. Among the different existing protocols, the "Technical note on drinking-water, sanitation and hygiene in emergencies Number 1" of the World Health Organization is undoubtedly the most used in different natural disasters such as flooding, earthquakes, but also civil unrest and other natural and man-made disasters that often cause damage to hand-dug wells. This technical note sets out the actions needed to repair and rehabilitate a well so that it can be returned to its former condition. In July 2010, during extraordinary floods in Pakistan, the Swiss Agency for Development and Cooperation initiated the implementation of a relief action based on a large-scale campaign of well cleaning in the most affected areas of the country. The floods resulted from heavy monsoon rains, which affected the Indus River basin over approximately 800'000 square kilometers (300'000 sq mi), one-fifth of Pakistan’s total land area. The floods directly affected about 20 million people. Within this emergency
operations, the SDC well cleaning campaign restored over 2,000 hand-dug wells in the areas of Nowshera and Charsadda in the in the Khyber Pakhtunkhwa Province. In parallel to the rehabilitation work, scientific data were collected for each single well in order to study the efficiency of the WHO cleaning protocol in restoring drinking water. The analytical parameters tested before and after cleaning were: i) Bacteriological, E. coli and fecal coliforms; ii) Physicochemical, major ions and agricultural pesticides, turbidity, pH, electrical conductivity, temperature iii) Sanitary inspection according to WHO standards. This field study proves the suitability of the WHO protocol for restoring drinking water access: the water quality data showed a decrease of fecal contamination in water samples from 80% before well cleaning to 20% after completion of the cleaning protocol. The study suggests further some improvements of the procedures regarding: i) the acceptability of the protocol by the local communities and ii) an improved dewatering procedure avoiding the risk of hydraulic ground seepage. This evidence-based study has been conducted in the field during real emergency operations and features an unprecedented amount of data on water quality parameters, over 2,000 sampling locations analyzed twice.

E.Coli and Bacteriophage Removal by High Flow Rate Ceramic Pot Filters

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Ceramic pot filters are locally produced in over 35 factories around the world with locally available resources, such as clay and rice husk (Rayner, et al., 2013), and are capable of removal bacteria and protozoa from source waters (van Halem et al., 2007; Brown et al., 2010; van der Laan et al., 2013). Hunter (2009) showed with a meta-regression analysis that compared to other interventions, such as SODIS and Biosand filter, the ceramic pot filter is the most effective household water treatment and storage intervention. Although ceramic pot filters are considered safe, robust and appropriate technologies, there is also general consensus that water revenues are very limited due to clogging of the ceramic element. When tested at the factory, initial flow rates consist of 1-3 L.h-1, however, particulate matter blocks pores during filtration of contaminated waters. Cleaning of the filter consists of a scrubbing procedure, where the top layer of the ceramic element is brushed and washed. Previous research has shown that this procedure results in an instant, yet very temporary, flow rate peak. The objective of this study is to investigate the potential of high flow rate ceramic pot filters to produce more water, without sacrificing their microbial removal efficacy. High flow rate pots, produced under highly controlled conditions, are compared to regular ceramic pots from the RDI factory in Cambodia. The high flow rate pots were produced with the same raw materials, but with lower clay:burnt material ratios, i.e., more rice husk was added to increase the porosity of the ceramic element. The performance of high flow rate pot filters (n=22) and reference filters (n=12) was assessed during two experiments: (1) a long-term loading experiment to determine removal of E.coli and MS2 bacteriophages, and (2) a intensive clogging experiment to identify (ir)reversible clogging mechanisms. The reference filters were manufactured according to the standard production process, as described by Brown and Sobsey (2010) at the RDIC factory in Cambodia. Standard RDIC filters are made of 30 kg clay, 9.7 kg rice husks, 1 kg of laterite and 14.5 L of water per batch of six filters. The rice husks are finely ground and sieved at a particle size of <1 mm. The high flow rate filters were produced in a pilot factory at the production site of RDIC in Cambodia. Filters were produced in batches of six, using a gas fired temperature-controlled kiln. Materials were the same as the normal production line, only the rice husk content was increased: 9.7 (references), 11, 12, 13 or 14 kg per batch of six filters. All ceramic elements were placed in a plastic receptacle (22L). To reduce the dead volume in the receptacle and to minimize the residence time of the water after filtration a
custom made ¼" thread connection (FESTO) was fitted in the bottom of the buckets with a tube and ball-valve. The first two liters of produced water were always discarded; subsequently the water samples were collected of the filtered water. Log reduction values for E.coli and MS2 bacteriophages were obtained by spiking high concentrations of these indicator organisms to the challenge surface water. This research study has confirmed the hypothesis that high flow rate filters, by increasing the rice husk content, provide more water yield during their lifetime, without sacrificing the log10 reduction removal for E.coli and MS2 bacteriophages. This research has also shown that scrubbing of the ceramic element does not prevent irreversible clogging. The irreversible clogging of the filters resulted in loss in flow rates, both in the reference and high flow rate filters, however, the high flow rate pots maintained their flow rate advantage with less frequent scrubbing events. An additional observation was that the reduction in flow rate during the lifetime of a pot filter has a positive effect on the log10 reduction values for E.coli, independent of the rice husk content of the filters. Brown, J., Sobsey, M.D. (2010) Microbiological effectiveness of locally produced ceramic filters for drinking water treatment in Cambodia. J. Water Health 8 (1), 1-10 Hunter, P.R., 2009. Household water treatment in developing countries: comparing different intervention types using meta- regression. Environ. Sci. Technol. 43 (23), 8991-8997 Rayner, J. et al. (2013) Current practices in manufacturing locally-made ceramic pot filters for water treatment in developing countries. J. Water, Sanit.Hygiene Dev 3 (2), 252-261 Van der Laan et al. (2014) Bacteria and virus removal effectiveness of ceramic pot filters with different silver applications in a long term experiment. Water Res 51, 47-54 Van Halem, D. et al. (2007) Ceramic silver-impregnated pot filters for household drinking water treatment in developing countries: material characterization and performance study. Water Sci. Technol. Water Supply 7 (5-6), 9-17

**Identifying Areas with High Likelihood of Private Well Contamination: a National Assessment of the United States Using Predictive Modeling**

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Kristen Malecki; Bill Johnson; Marissa Taddie; Logan Frederick

Approximately 15% of the US population relies on private water wells that are not regulated under the Safe Drinking Water Act or state regulations. However, few of these wells are tested except at the time of completion or at the change of ownership, and this testing is typically limited to bacteriological quality. This lack of data makes it difficult to prioritize resources to assess and address private well quality issues. To meet this need the Centers for Disease Control and Prevention and the University of Utah compiled extensive groundwater quality data from national, state and local sources and developed predictive models and tools to identify areas where private wells may have elevated levels of nitrate, arsenic and/or uranium. This nationwide assessment included data from over 270,000 wells. Four methods were used to identify areas where high levels of these contaminants were likely to occur: land use regression, classification and regression trees, inverse distance weighting and kriging. Nationwide data on over 30 potential predictors were compiled and spatially linked to the groundwater data. These included climate, geology, land use, topography human settlement, irrigation, and geochemistry data. The result of this effort is a nationwide assessment, including maps for each county depicting actual water quality levels, and predicted levels where no observations exist, on a 4 km x 4 km grid. The predictive models were assessed using a split-sample validation. Overall, there were few differences in the predictive ability across the four methods and the three contaminants. Area under the ROC curve values ranged from 0.73 to 0.90 with an overall mean of 0.83 (good). Model performance varied for any given method between sites and between contaminants. Average sensitivity when the specificity was above 0.70 was 80.6%. Average
sensitivity for models predicting arsenic (86.3%) was somewhat better than for uranium (78.4%) or nitrate (77.1%). These methods may be useful in other settings where groundwater quality are scarce to identify areas most apt to have high concentrations of contaminants. Land use and climate data, available for wide areas, may be used with available groundwater data to create similar predictive models. The purpose of this session is to present an overview of the methods and the results of the nationwide assessment, and provide access to the results and maps for use by the environmental health and groundwater professionals. The session will conclude with a discussion of how these methods could be applied to assess groundwater quality in other areas of the world where data are scarce.

Analysis of Monitoring and Evaluation Data from a Household Water Chlorination Program in Haiti

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Background In households without safe drinking water, one method to reduce the burden of diarrheal disease is the use of household water treatment and safe storage (HWTS) options. The Safe Water System (SWS) is one HWTS option, and consists of water treatment with chlorine, safe storage of treated water, and education. The organization Deep Springs International (DSI), managed a SWS program in Haiti before the 2010 earthquake. After the earthquake, DSI greatly expanded their Leogane program; first by distributing chlorine tablets free of charge for ten months and then returning to the pre-emergency strategy of selling locally-generated chlorine. Approximately 16,500 families are served in this program. The DSI program was externally evaluated two months after the earthquake, and found to be the most successful of 14 HWTS programs evaluated - with 91% of households surveyed having positive free chlorine residual (FCR). Since those external evaluations in 2010, DSI has continuously conducted monitoring and evaluation (M&E) activities. A total of 157 local community health workers (CHWs) visit program households monthly to provide the chlorine products, educate the household, and conduct an FCR test. Three DSI program supervisors spot-check CHW about once every three months, and also conduct an FCR test. Through an analysis of the supervisor and CHW data collected from 2010-2014, we aimed to: 1) assess data validity by comparing the external evaluation data, the supervisor data, and the CHW data; and, 2) assess whether programmatic success in the emergency response phase continued into the development phase. Methods Data was provided by DSI to Tufts as an Excel spreadsheet for the supervisor data and monthly paper forms for the CHW data. CHW data was entered using Google Forms; all data was cleaned and exported and analyzed in Stata 13.1. The main outcome of interest was the presence of FCR in stored household drinking water. Supervisor data were stratified and analyzed by individual supervisor, individual CHW, season (rainy/dry), program year, program month, and geographical location (plains/mountains) of the household. The overall positive FCR percent was generated for each of the CHWs. The data were analyzed using chi-square tests, t-tests, and Pearson’s correlation coefficients. The CHW data was analyzed to also generate an overall positive FCR percent for each CHW. Correlation between the overall positive FCR percent generated independently from the supervisor and CHW data was analyzed by Wilcoxon Signed-Rank Test. Results Overall, 65.3%, and 80.7% of households surveyed in the supervisor and CHW data, respectively, had positive FCR. Comparison of the overall positive FCR percent by CHW found that average results in the CHW data were 18.2% higher than in the supervisor data (p<0.001). Additionally, in the supervisor data, households were more likely to have positive FCR if they were: 1) visited by certain supervisors (p<0.001) or CHWs (p<0.001); 2) if the visit occurred during an earlier program year (73% in 2010, 52% in 2014; p<0.001) or program month (p<0.001); and, 3) if they were located in a plains area (p<0.001). Percent positive FCR did not differ significantly by rainy versus dry
season. Discussion In our analysis, we found sustained use of the SWS program implemented in the emergency context, as measured by ongoing supervisor and CHW data. Although there was an 18% discrepancy in the data sets, all sets of data exhibit evidence of high continued use over time. These data inform ongoing discussions in HWTS on: 1) collecting robust M&E data, comparing various M&E data sets, preventing bias in self-collected data, and validating M&E data; 2) the importance of individual CHWs and supervisors to program success metrics; and, 3) the decline in program metrics and outcomes over time, as the highest positive FCR percentages (72%) were during the acute emergency with free distribution, and usage dropped to 52% as the program transitioned to sales in 2014. More research is needed to investigate this decline, which could have been due to less household visits, less resources for promotion, cost of product, the changing nature of the post-emergency situation, and/or user fatigue. However, according to all three sources of M&E data, this program has still been found to be an extremely successful HWTS program.

The Impact of Water, Sanitation, and Hygiene Interventions on the Health and Well-Being of People Living with HIV: a Systematic Review

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Daniele Lantagne; Eric Mintz; Robert Quick

Introduction Persons living with HIV/AIDS (PLHIV) are at increased risk of enteric infections from waterborne pathogens that cause diarrhea, and experience more severe diarrhea, hospitalizations, and diarrheal-related deaths than immunocompetent populations. These risks persist even for patients on antiretroviral therapy (ART). Access to improved water supply and sanitation facilities is particularly poor in low- and middle-income countries (LMIC). Water, sanitation, and hygiene (WASH) interventions aim to break the fecal-oral transmission route and provide a foundation for health, nutrition, a safe living environment, and improved quality of life for PLHIV in LMIC. The objective of this review was to examine existing literature on the impact of WASH interventions on PLHIV. In this review, we assessed the quality of published studies and describe the impact of WASH interventions on the following thematic outcomes for a President's Emergency Plan for AIDS Relief (PEPFAR) review: 1) mortality, 2) morbidity, 3) retention in HIV care, 4) quality of life, and 5) prevention of ongoing HIV transmission. Cost-effectiveness was also assessed. Methods A literature review was conducted by searching published abstracts from 1995-2014 in six databases. Manuscripts were reviewed to include: 1) PLHIV (adult and adolescent populations); 2) LMIC; 3) one or more themes of interest; and 4) WASH program objectives and interventions. Abstracts that passed the initial screening were independently reviewed and collaboratively discussed to determine inclusion for full manuscript review. Manuscripts were then sorted by the five thematic outcomes listed above and scored (Good/Fair/Poor) to assess internal and external validity, impact, and cost-effectiveness. Based on existing published WASH programming, the overall quality of evidence and expected impact that addressed each outcome was rated (Strong/Medium/Weak). Results In this literature review, we: screened 3,355 citations, closely read 132 abstracts, evaluated 33 manuscripts, and included 16 manuscripts in the review. The focus of these manuscripts was mainly on morbidity (16), with a lesser emphasis on mortality (2). No manuscripts addressed the relationship between WASH and retention in HIV care, quality of life outcomes, or HIV transmission. Cost-effectiveness was evaluated in three included manuscripts. Results are presented, by outcome, below. MORTALITY The quality of evidence of studies examining mortality was 'poor', with 'uncertain' impact because of the limited number of studies and inconclusive results. MORBIDITY The overall quality of evidence of studies examining the impact of WASH programming on morbidity was 'good', with 'high' expected impact. Results are valid for all major aspects
of WASH programming: household water treatment (HWT); water supply; sanitation; and hand-washing. HWT - a meta-analysis evaluating the health impact of HWTS on PLHIV was conducted in 2013. In this meta-analysis, seven studies evaluating four different HWTS interventions (chlorination, hollow fiber membrane filters, ceramic filters, and filters plus UV radiation), diarrhea was reduced in PLHIV or their family members by 43% (pooled risk ratio = 0.57; 95% CI 0.38 - 0.86). Water Supply - access to improved water sources was associated with a lower prevalence of intestinal parasites (IP) and diarrhea among PLHIV and their household members (3 studies; AOR ranged 2.4-6.1, p<0.05). Sanitation - a lack of access to a latrine was an independent risk factor for IP and diarrhea (3 studies; AOR ranged 7.6-10.4, p<0.05). Contact with animals or dung was associated with an increased risk of diarrhea and IP (4 studies; OR/RR ranged 3.2-11.2, p<0.05); and, Hand-washing - the presence of soap in the home corresponded with a reduction in days ill with diarrhea among PLHIV (IRR = 0.58, p<0.05). WASH interventions targeting PLHIV were cost effective. Costs were favorable by slowing the rate of decrease of CD4 counts and below the general threshold of 3 times GDP/capita/DALY averted in two out of three studies. Discussion Waterborne diseases are a primary burden to PLHIV, and WASH interventions are effective in reducing this burden. Morbidity was the only thematic outcome of interest with sufficient research to generate firm conclusions. Access to an improved water supply, household water treatment, and latrines consistently reduced the prevalence of waterborne pathogens and the risk of diarrheal diseases in PLHIV. WASH interventions were also cost-effective for PLHIV morbidity. There remain significant research gaps on the effects of improved sanitation, hygiene education, holistic WASH interventions, and incremental benefits when combined with ART. Despite the need for further research, the evidence is clear that WASH interventions are beneficial to PLHIV.

Developing Online Spaces for Water, Sanitation, and Hygiene Capacity Building: Lessons Learned

Candice A Young-Rojanschi, CAWST
Clarke Foster, Olivier Mills

Introduction: Access to the internet in the developing world has grown 475% since 2005. In addition to the increase in connections, higher bandwidth speeds provide for easier access to bandwidth heavy resources such as videos, live streaming and large documents. In Africa, mobile broadband increased 40% in 2014 alone. There is an opportunity to engage water, sanitation, and hygiene practitioners through online tools and support them day-to-day in building their knowledge and skills, overcoming technical challenges, and expanding their initiatives.

In addition, as it grows, the Centre for Affordable Water and Sanitation Technology (CAWST) has faced a challenge in ensuring consistent communication of technical information from staff to clients.

Methodology: The Centre for Affordable Water and Sanitation Technology (CAWST) began expanding its services to online spaces in 2012 with a water, sanitation, and hygiene (WASH) Resources website housing training materials for download, and in 2013 with a Biosand Filter (BSF) Knowledge Base.

Results: The WASH Resources website serves over 5,800 registered users from 3,000 organizations in 183 countries. The BSF knowledgebase now serves over 1,000 registered users from 68 countries. In a 2014 user survey for the Knowledgebase, it was found that approximately 2/3 of these users were WASH practitioners or managers, while 1/3 were students, researchers, or interested members of the public. In the survey 42% reported using the Knowledge base to help initiate a BSF project, 35% to improve the
quality of their project, and 30% to train others (technicians and households).

Access to a central technical repository of information has also increased the organization's efficiency in providing technical support. Staff have been able to quickly and efficiently access documents and technical information, and have been able to use the frequently asked questions section of the knowledgebase to ensure consistent responses to clients regarding technical questions. It is estimated that over 150 staff hours are saved each month due to these online spaces.

The key challenge faced has been the time required to support these services. The web spaces considerably increased CAWST's clientele, and it has been necessary to develop clear structures to ensure that needs of these clients were being met. Maintaining and updating the content of the Knowledgebase has also been challenging. In addition, providing online services does not only require the work of a web developer at one point in time, but requires consistent support to address updates, troubleshooting, and bugs. Additional staff was hired to meet those needs.

Conclusion: The global increase in access to the internet makes it possible to reach an increased number of clients with online resources. However, the maintenance of online spaces and resources requires extensive time beyond the simple creation of these spaces. CAWST has successfully increased its client base using online spaces, but has needed to increase its staff to meet this need. We are currently working to expand our online services to include a Household Water Treatment Knowledge Base and an e-Library.
POSTER PRESENTATIONS
Drinking Water Quality Management for Improved Health in Ghana

Suzzy Abaidoo, Ministry of Water Resources, Works and Housing

Kweku Quansah

Topic: Drinking water quality management for improved health in Ghana

Abstract

The Government of Ghana (GoG) recognizes access to safe drinking water as a basic human right and essential to protect public health. The lack of access to clean water and sanitation is a central public health concern, contributing to 70% of diseases in Ghana (OECD, 2007). Consequently, the GoG through the Ministry of Water Resources, Works and Housing initiated a programme to develop a framework for managing drinking water quality in Ghana to ensure that drinking water quality is managed in a way that will ensure an improvement in the protection of public health in Ghana. The objectives of the programme were to: 1. Have a snap short of the status of drinking water quality in Ghana 2. Find out how drinking water quality is managed in Ghana in order to 3. Develop a comprehensive drinking water quality framework 4. Assess capacity needed to implement the Framework

The approach used for the assignment was participatory with the active involvement of relevant stakeholders in the monitoring of drinking water quality at district, regional and national levels. A snap short of the status of drinking water quality in Ghana revealed the following:

- There is wide spread bacteriological contamination which was low at the source (43.5%) than the household level (62%) and higher in the rural areas than the urban areas.
- In some instances there were found chemical contaminants like iron, fluoride, arsenic and manganese. Again, the levels of salinity of drinking water along some of the coastal areas do not also conform to standards.
- Household water treatment and safe storage is practiced on a low scale.
- The Ghana Multiple Indicator cluster survey (GMICS, 2011) reports that only 9% of the population in Ghana treat their water before using.

WASH related diseases like diarrhoea and typhoid are prevalent in Ghana. The findings in terms of the management of drinking water quality in Ghana include the following:

- The Standards in Ghana do not make it a requirement for water service providers to use the risk-based approach to manage the quality of the water they produce.
- The District Assemblies are responsible for ensuring water safety in their areas with support and in coordination with other regional and national level stakeholders but often lack clear and consistent guideline for managing drinking water quality and are mostly under resourced with inadequate staff capacity and logistics and are characterised by weak collaboration and coordination with other sector stakeholders.
- The roles and responsibilities to manage drinking water quality are not well coordinated among sector organisations. In effect, the management of drinking water quality in Ghana is currently based on only the reactive traditional approach where action is taken based on the results of water quality tests. The major disadvantage with this approach is that before results of water quality tests are obtained, exposure would have already taken place and that poses a major health risk to the public.

Based on the gaps and challenges identified, the study made the following recommendations:

- Enhance collaboration between stakeholder institutions
- Review of national drinking-water standards to incorporate a risk based approach (implementation of water safety plans) as a requirement
- Development of a comprehensive national drinking water quality framework
- A capacity needs assessment that will support the effective implementation of the National Drinking Water Quality Framework

The Ministry has initiated the following activities to support the implementation of the framework:

- The Ministry is currently facilitating collaboration meeting between key stakeholders to clarify roles and enhance collaboration between them - thus meetings between key institutions which have key roles to play in the drinking water quality management.
- The Ministry has also proposed to the Ghana Standards Authority to review the national water standards to make the risk-based approach to the management of drinking water quality a requirement.

A capacity needs assessment for the implementation of the framework is also on-going and is expected to be completed by May 2015. Immediate next steps
include the following: Establishment of a coordinating committee to improve upon coordination in the management of drinking water quality; Capacity building of some key water quality laboratories based on international standards; Development of high level indicators for monitoring water safety based on global indicators.

**Virus, Bacteria and Turbidity Removal by Chitosan Coagulation in Natural Waters to Optimize Ceramic Water Filtration for Household Drinking Water Treatment**

Lydia Abebe, The University of North Carolina at Chapel Hill

Mark Sobsey

Introduction: Viruses are major contributors to the global burden of diarrheal disease morbidity and mortality. Rotavirus is the leading cause of moderate-to-severe diarrhea in infants and children under age 5 and noroviruses are most common among adult populations. To combat diarrheal disease from contaminated drinking water, water treatment technology and safe storage (HWTS) have been developed, researched, and deployed into resource-limited settings of developing countries for users to treat water at the household level. While household level purification technologies such as filtration have significantly reduced diarrheal illness, the majority of ceramic and granular media filters fail to remove viruses due to inability to physically retain them because of their small-size without sacrificing flow rate. In order to address this major shortfall in virus removal efficiency in household water treatment (HWT), we combine a promising natural coagulant as a form of chemical pretreatment with ceramic water filters (CWFs) to evaluate the coagulation and pretreatment capacity of chitosan. While CWFs have been a subject of continued research and are increasingly implemented and used around the world, critical performance deficiencies such as virus removals and knowledge gaps still exist. Chitosan is a natural organic polymer that is ubiquitous, inexpensive, widely commercially available, but has seen only limited use as a water coagulant. Chitosans are non-toxic and biodegradable polymers that are derived by simple chemical treatments from chitin, a major source of which are the leftover shells of crustacean seafood, such as shrimp, prawns, crabs, and lobsters. They have not been widely or systematically investigated as a water treatment chemical to remove microbes from water as a pre-treatment for point-of-use water filtration.

Objectives: The overall objective is to integrate chitosan use with the CWFs and determine the coagulation effects of chitosan through evaluating the removal of bacteria, virus, and turbidity. To evaluate effectiveness of chitosan coagulation we evaluated performance in two types of test waters: lake water spiked with known indicator bacteria, specifically Escherichia coli and viruses, specifically coliphage MS2, and lake water spiked with raw sewage. We allowed for chemical coagulation using chitosan at varied doses and sedimentation times, promoted flocculation and sedimentation of flocs, and subsequently transferred the pre-treated water (the supernatant water after coagulation and floc sedimentation) into the CWF for further treatment by filtration.

Methods: To evaluate microbiological removal in lake water spiked with indicator microorganism, test water was prepared by adding E. coli K011 and MS2 coliphages to lake water as surrogates for bacteria and virus pathogens. The spread plate colony count method was used to enumerate E. coli K011, and the Single Agar Layer (SAL) assay was used for MS2 enumeration. To evaluate microbiological removal of lake water spiked with raw sewage, test water was prepared by adding raw sewage to lake water. Membrane filtration with RAPID’ E.coli 2 Agar was used to enumerate Escherichia coli and other coliforms, and Enrichment Spot Plate (ESP) assay using E. coli Host CB390 to quantify both F male specific and somatic coliphages by the Most Probable Number Method. Other water quality parameters evaluated in test waters were Total Organic Carbon using Hach TOC test kit, turbidity using Hach 2001N Laboratory Turbidimeter, and chitosan level using Chitosan Residual test kit. Log10 values were calculated.
based on the microbiological reduction. Total organic carbon, turbidity, and chitosan on initial concentrations were quantified in influent water, before filtration, as compared to effluent water, after filtration. Results and Conclusions: Initial results indicate that chitosan is a promising coagulant that appreciably improves the removal of viruses, bacteria and turbidity. Based on WHO health based microbial reduction criteria for HWT, chitosan coagulation achieved the protective performance targets for both viruses (3 log10 reduction) and bacteria (2 log10 reduction). Therefore, these results support the use of chitosan to optimize water filtration processes for HWT to significantly reduce virus contamination while also decreasing the clogging of filters and thereby increasing their lifespan. While we did not evaluate the mechanisms of removal, it is suggested that chitosan promotes floc formation and sedimentation of viruses through two coagulation processes: interparticle bridging and charge neutralization. In conclusion, this is the first report investigating the potential of chitosan to enhance removal of viruses, other microbes and turbidity in natural waters by the dual treatment barriers of coagulation-flocculation-sedimentation and microporous ceramic filtration.

**Transitioning from Free Sanitation Provision to Sanitation Marketing-Lessons Learned from the Philippines After Yolanda**

John Akudago, Samaritan’s Purse

Gavin Gamstad; Janet Ausel; Lheneth Sarmiento; Marielou Realubit

Experiences from responding to disasters coupled with information shared at water, sanitation and hygiene (WASH) Cluster meetings have shown that transitioning from disaster relief to recovery has been very challenging. Immediately after disasters relief items are usually given freely to survivors without any requirement from the benefactor for beneficiaries to fulfill. This tends to create an attitude of "accepting without any responsibility". However, there appears to be challenges when nongovernmental organizations (NGOs) transition from the "free gift style" to participatory recovery or a model where beneficiaries are required to contribute a portion of the or full cost of facilities. This study considered transitioning from free sanitation provision at a household level in the immediate aftermath of Typhoon Yolanda to a market-based approach to sanitation where sanitation facilities are acquired at full cost. In this study, three municipalities in the Leyte Island, representative of those affected by Typhoon Yolanda, which struck The Philippines in 2013 were considered. Tanuan and Santa Fe Municipalities were considered for the free sanitation provision program whereas an adjacent municipality, Pastrana, was considered for the sanitation marketing program. As part of the disaster response and early recovery effort, households in Tanuan and Santa Fe municipalities who did not have, at the time, a functioning sanitary toilet with sealed septic tank, were offered an opportunity to participate in the free sanitation project by Samaritan's Purse (SP). Using appropriate behavior change communication (BCC) strategies, communities willingly agreed to be part of the program. All latrine materials and paid trained masons were provided by Samaritan’s Purse whereas households were responsible for labor for digging the septic tank. In Pastrana, the total cost of the sanitation facilities were borne by the individual households through a market-demand-supply approach where interested beneficiaries were provided loans from a microfinance institution that also worked with the trained masons. From the study, 95% of households were reached with access to household sanitation facilities resulting in 11,690 household latrines installed in Tanuan and Santa Fe over 12 months period. In Pastrana municipality, 1,300 households which represent 60% of total households have already accessed sanitation facilities through the sanitation marketing program within two months of the initiative. The study also revealed that factors such as dignity, access to loans, varieties of sanitation technologies to choose from and price affordability were key decisions in accessing sanitation facilities. The research concludes that transitioning
from disaster relief to recovery and development context could be smooth if the motivation factors for households are identified coupled with effective behavior change communication.

Management Capacity Index: a Participatory Method for Evaluating Local Water Service Providers and Authorities
Andrew Armstrong, Water Missions International

Of all the drivers of ongoing functionality of rural water supplies, the ability of local stakeholders to administer and manage the service is perhaps the most critical. Institutional failure almost always leads to technical, financial and social challenges. However, it can be difficult to measure management capacity in a manner that is participatory and constructive. Such aspects often go without being monitored as regulating agencies opt to track the more tangible elements of water service delivery such as finances, water quantity and quality. Water Missions International has developed a method for measuring the capacity of management personnel to carry out their responsibilities as planned for the anticipated life of the water service. The "Management Capacity Index" is intended to provide a collective measurement of these stakeholders' perceived capacity to oversee and respond to technical, financial and social elements that are deemed as critical to ongoing safe water service delivery. It considers their level of felt independence in ten key capacity areas: - Operating water treatment and supply equipment - Monitoring water quality - Promoting healthy water, sanitation and hygiene behaviors in the service area - Budgeting and setting fees to cover operating and replacement costs - Money handling and record keeping - Purchasing supplies and spare parts and performing minor maintenance - Saving funds to cover major maintenance, repairs and project expansion - Performing major maintenance, replacement, and expansion - Replacing and training management personnel - Resolving conflicts in the service area and within the management structure The index can be evaluated as often as necessary. Data collection involves focus group discussion during which stakeholders collectively determine the extent to which they are independent from external support in the specific capacity areas. Participants are also given an opportunity to identify additional capacity areas that they wish to monitor. Responses are quantified using the established Ten Seed Technique and contribute to an overall unweighted percentage-based index score. The index has been field tested and is currently being utilized in Water Missions International's programs in Peru, Honduras, and Mexico. Select case studies from these countries have indicated that the method, which intentionally promotes discussion among key stakeholders, is effective at identifying root causes of institutional failure and facilitating resolution. In fact, the insights gained through the participatory process are often more useful to the overall monitoring effort than the resulting index measurement.

Determinants of Behavior During the Ebola Virus Disease Outbreak in Lofa, Liberia
Janet Ausel, Samaritan's Purse

Bev Kauffeldt; John Akudago; Tom Wood; Keren Massey

In late 2013 what was to become a historic epidemic of Ebola Virus Disease (EVD) appeared in Miliandou, Gueckedou Prefecture, Guinea, in West Africa (New England Journal of Medicine, 9Oct2014). The index case appears to have been a 2 year old boy. In late March 2014 EVD crossed into Lofa, Foya County, Liberia. The outbreak was to grow beyond anyone's expectations, bringing normal life to a standstill in Liberia. Liberia has reported over 10,300 cases and 4,600 deaths (WHO, 29April2015) which are attributable to the disease. This outbreak is unique in many regards including the geographic distribution of cases, the number of
infections, and the fierce resistance in many communities to adopting interventions that would have curbed the spread of the virus. This presentation will discuss lessons learned during Samaritan's Purse's (SP) response to this epidemic. Specifically, we will discuss how educational messaging regarding infection prevention and control (IPC) measures aligned, or in many cases misaligned, with deeply held cultural practices and values and how dissonance contributed to explosive spread of the epidemic. Just days after the outbreak was confirmed in Liberia, mass public education campaigns were initiated. SP, along with other non-governmental organizations (NGOs) were required by the Ministry of Health and Social Welfare (MoHSW) to use messages and educational material which had been developed and approved by the ministry. The intent was to ensure that all messaging was accurate and unified. However, these messages were not always immediately or comprehensively effective. While messaging was spreading across the country, the tide of public perception did not seem to be turning. Families continued to care for loved ones at home and bodies of deceased were secretly buried following traditional practice. However, despite widespread resistance, we did note that some communities in acutely affected areas remained EVD free while sister communities separated by just a few kilometers were ravaged. It was notable that communities and their leaders heard the same IPC messaging but responded in markedly different ways. SP took a lead role early in the outbreak and reached over 1,147,500 individuals with EVD awareness messaging using educational flyers, radio adverts and other mass communication techniques. In addition SP established and managed Ebola treatment units (ETUs) and community care centers, training and participating in Rapid Isolation and Treatment of Ebola (RITE) responses which established mobile isolation units in locations where new chains of transmission were emerging, and supporting a significant number of contact tracers and active case finders. With the goal of facilitating Liberia’s recovery and in order to build resilience against future outbreaks of EVD and other infectious diseases, SP has now undertaken a program of extensive ethnographic research among traditional community leadership and community members with a goal of understanding their decision making processes during the EVD crisis. Framing research around elements of the health belief model, this investigation is focused on understanding how factors such as perceived severity, perceived susceptibility, and perceived benefits were understood by individuals, and how their perceptions aligned or misaligned with the Ebola awareness messaging, as heavily disseminated across the country. This study is focused on one of the hardest hit areas in the country, Lofa County, the original epicenter of the EVD outbreak in Liberia. SP has a well-established presence in Lofa and has worked closely with area communities for years prior to the outbreak. This history provided a base for our observation that, despite our long presence in Lofa, communities struggled, sometimes violently, to trust and accept the messages and health services offered by international and local staff. For example, messages from the MoHSW regarding safe burial practices were often rejected and safe burial teams met fierce resistance from communities while instructions from traditional healers on methods of how to prevent EVD infection, i.e., tying a thorn branch around your wrist or taking a bath in salt water in the early morning, were widely adopted. Understanding how communities perceived the EVD outbreak and the factors which deeply motivated their decision making during the crisis is essential, both to understanding how this catastrophic event unfolded as it did and to assist governmental and non-governmental actors in building resilience to future infectious disease outbreaks of though effective messaging and other public health strategies appropriate to the culture and context. This poster will present significant determinants of behavior in the context of the Liberian EVD outbreak.
**Convincing but Inconclusive: Using Results from a Systematic Literature Review and Expert Key Informant Interviews to Design a Study**

Kelly Baker, Safe Water Network/ University of Iowa

Francis Mawanda; Amanda Gimble; Jennifer Schmitzer

Safe Water Network seeks to build an evidence base that demonstrates our market-based model as a cost-effective way to improve the health and economic well-being of marginalized populations at scale. We aim to develop affordable, reliable and economically-viable solutions and standardize our model for broad scale replication by others, but must first ensure we are achieving our targets. The goal of our health impact research is to assess and quantify the comparative impact of Safe Water Stations, community-level pay-per-use integrated water treatment and point-of-sale systems, on the health of consumers and communities at large in low- and middle-income countries, and advance our understanding of the importance of various operational and program components in realizing health outcomes. Our hypothesis is that access to a Safe Water Station improves health compared to similar communities that have not yet received access to a Safe Water Station. This impact-based research will help us bring value to our operations – disaggregating our model’s chain of effects and identifying the most critical components, from screening a community for a Safe Water Station to a consumer drinking our water, that ensure intervention impact. This research helps us isolate and evaluate each of the steps to understand where there are issues that impact water quality - benefiting our model development at the same time as we position consumers and communities for positive health impact results. The four-phased approach allows us to build on outputs from early phases. The first phase, to be completed June 2015, summarizes available evidence of how effective different types of water interventions have been at improving human health and wellbeing, particularly for decentralized or community-level interventions versus other water source interventions, and why they may or may not have observed effects. This background research will be used to identify actionable implementation and/or evaluation strategies that can inform subsequent phases of the research. Our approach is holistic, bringing together traditional systematic literature review methods with a qualitative, structured Key Informant Interview (KII) process that leverages an often neglected source of information - wisdom built from human experience and intuition. To achieve our goal, the literature review will i) describe the range of strategies, including instrumentation, education, and level of delivery (household, community, municipal scale), that have been used to provide safe water sources in low or middle-income countries and the types of outcomes that were evaluated for each intervention; (ii) compare how effective various types of strategies were at generating improvements for a few common evaluation outcomes, such as diarrhea and household water quality; (iii) describe how many of these studies controlled for other behavioral and health-related factors that could be associated with health outcomes; and iv) summarize available evidence for how intermediate water-related behaviors (drinking, cooking, washing hands, bathing, and other rituals) might affect the impact of safe water source interventions on health outcomes. The KIIs will document the following information from water and health-related sector experts in conducting interventions and evaluations: goals and rationale for their project; study design; type of data collected and analyzed; challenges faced implementing and documenting study impacts; lessons learned during the project and opinions on why they did or did not observe impacts; how to adapt observations into a new study; and overall cost effectiveness of various strategies. Safe Water Network and Dr. Kelly Baker, Principal Investigator and Assistant Professor at the University of Iowa, will share results of Phase 1 of this collaborative effort.
As the proposed Sustainable Development Goals (SDG) illustrate, the sanitation sector aspires to deliver universal access by 2030. With slow progress during the Millennium Development Goals (MDG), it is clear that a step change is required to undertake this ambitious mission. But what does this step change look like? Is there a consensus on this within the sanitation sector? And a readiness to make it happen, including undergoing the internal shifts required? Trying to shed some light on these questions, I conducted an expert consultation, interviewing (semi-structured interviews) 18 sanitation thought leaders, including academics, sanitation experts in INGOs and agencies, and consultants. The interviewees were asked to identify the key blockages that explain the slow increase in access during the MDG era, the existing opportunities and the priorities and key issues they identify for the 2030 SDG challenge. Among the obstacles highlighted, political priority was the most frequently mentioned one, with specific concerns about the neglect of urban sanitation and about inadequate financing both in terms of quantity and quality. Some knowledge gaps were identified as important obstacles, including how to change behaviour and social norms (especially in rural areas), how to how to tackle sanitation in slums and small towns (urban) and how to reduce inequalities. Moreover a related common theme was the limited ability of the sanitation sector to learn, both from past experiences and from experiences of other institutions. Another aspect highlighted was that for different reasons transparency and reflexivity is many times limited and failures and challenges are not acknowledged, which leads to certain inertia, persisting in ways of working that are not optimal. Linked to that, another obstacle mentioned was the insufficient focus on scale; many sector actors are still doing small projects and working in ways that do not contribute to sector-wide progress. The opportunities identified were in many cases the reverse of some of the obstacles mentioned, which show that the sector has already started to tackle them. It was widely acknowledged that over the last 5 to 10 years, the political priority has increased dramatically, even if it is still not enough. A key aspect of this is the consolidation of Regional San Conferences and the Sanitation and Water for All Partnership. Similarly, the existing financing streams have improved over the last few years. Another opportunity mentioned by many interviewees is the consensus generated within the WASH sector around the SDGs, which has helped build a common understanding on what the sector should try to achieve. In the light of these obstacles and opportunities, the interviewees highlighted the following priorities: Sanitation services in institutional settings; Reaching the poorest and marginalized; Integrating learning and practice; Moving beyond fixed approaches to context-adapted flexible interventions; Addressing urban sanitation beyond the toilet (especially Faecal Sludge Management and engaging with planning processes); Engaging and integrating with the health sector; Improving collaboration among sector actors; Bringing about a step-change in capacity development of sanitation professionals. Overall, the interviewees seemed to agree in their diagnosis of the sector (obstacles opportunities), as well as around the priorities for the future, although there are nuances and differences in terms of focus amongst them. For instance, there is a more homogenous view on priorities among sanitation experts from NGOs and agencies -probable resulting from the SDG-related consensus building aforementioned, while some consultants and academics present more diverging perspectives. A clear example was one voice from the academia challenging the 2030 universal access goal, questioning its desirability, as it may lead to perverse incentives (rushing to meet the target), while the focus should just be to do always the best thing possible as a sector. Most interviewees mentioned collaboration as key to success and acknowledged that it needs to improve by tackling some of the institutional obstacles to it. An interviewee from academia shared a discordant and interesting perspective, namely too much collaboration is not good and within the sector there is a need to be more critical with each other.
Neighborhood Structure, Household Behaviors, and Their Effects on Spatial Clustering of Risk of Exposure to Fecal Contamination in Urban Flood Areas

David Berendes, Emory University

Daniel Beno; Julie Clennon; Ben Ghale; Annai Gunasekaran; Gagandeep Kang; Arun Kartikeyan; Amy Kirby; J. Senthil Kumar; Venkata Mohan; Suraja Raj; Sheela Roy; Habib Yakubu; Christine Moe

Risk of enteric infection depends on both the dose and the frequency of contact with a hazardous exposure. From a quantitative microbial risk assessment (QMRA) perspective, spatial variation in fecal contamination, behaviors, or both, may drive clustering of risk within urban settings. Flood areas tend to cluster spatially in urban environments due to neighborhood aspects geography/structure, but the associated risk may be due to structural, geographic, microbiological, or behavioral factors within those clusters. The goal of this study was to understand the potential drivers of spatial clustering of risk of exposure to fecal contamination in urban flooding areas. Surveys were conducted assessing household water/sanitation conditions, including flooding of the drain near the house and flooding in the house itself, in 100 households in each of two neighborhoods—Cinna Allapuram (CAP) and Old Town (OT)—in Vellore, India. Surveys also asked about frequency of household interaction with exposure pathways for fecal contamination. GPS points were collected for all survey households and also for potential sources of fecal contamination in public areas (e.g. open defecation fields and animal sheds). Open drains were mapped, with direction of water flow noted at the time of mapping. Environmental samples (open drains, swabs from households, and child hand rinse samples) were collected from fecal exposure pathways and tested for E. coli concentration using membrane filtration. Household survey responses were evaluated for local and focal clustering using Kulldorff’s spatial scans and Diggle’s method. Associations between survey responses and spatial data were assessed at the household- and cluster-levels. E. coli concentrations in environmental samples were evaluated for clustering via Getis G* statistics. Neighborhoods differed significantly in most household-level characteristics, including sanitation coverage (77% of households in CAP had toilets vs. 33% in OT). Of note, occurrence of drain and household flooding during the rainy season was not significantly different between neighborhoods (drain flooding: 47% (CAP) vs. 58% (OT); house flooding: 19% vs. 23%); however, reported contact with drain and flood water was significantly higher for all household members in OT, compared to CAP (78% vs. 55% among respondents and 86% vs. 62% among their children). Similar results were noted at the cluster-level, where household and drain flooding was clustered in both neighborhoods; however, contact with flood and drainage water was only clustered within flood areas in OT. No significant local clustering of E. coli concentration was noted within environmental sample types in either neighborhood. Clusters of drain and house flooding were compared between neighborhoods to assess factors affecting personal contact with drain/flood water. While OT had significantly more drains per survey household within a 50m radius (4096 m vs. 2561 m of drains per household in drain flooding areas, 3362 m vs. 2032 m of drains per household in house flooding areas), there was no significant difference in drains per person. OT had more drains per square meter than did CAP overall, as well as within flood areas specifically. However, flood areas within CAP were flatter and larger than those in OT, thus having more overall length of drains. In terms of non-structural characteristics, flood areas in OT had significantly higher household populations (6.6 vs. 4.9 people per household in drain flooding areas, 6.1 vs. 5.1 people per household in house flooding areas) and prevalence of open defecation among children under 12 years of age (87% vs. 46% open defecation in children under 5, 70% vs. 39% in children 5-12 years old) than those in CAP. Flood areas in CAP had significantly higher toilet coverage (72% vs. 46%), indicating that open defecation in the drains may be a key factor driving these differences in flood and drain water contact. Within the urban environment, our data suggest large heterogeneity, and correspondingly no spatial clustering, of E. coli contamination from different exposure pathways. From a QMRA standpoint, these results suggest spatial variation in risk is
driven primarily by frequency of exposure. While behavior is often thought of as an individual- or household-level 'decision,' significant clustering of behaviors suggest they may interact with local infrastructure as well. In flood areas, household behaviors (open defecation) may interact with aspects of a neighborhood that cause flooding to elevate exposure to fecal contamination through this additional flood/drain water contact. Thus, these behaviors should be viewed in the context of the neighborhood environment where they occur and both behavior change and structure interventions may be warranted. Such spatial analyses are a powerful tool for visualizing risk and prioritizing interventions to reduce exposure to fecal contamination in urban environments.

Expanding Ghana's Sanitation Coverage Through Business: Opportunities and Challenges

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African Sanitation Think Tank, Water and Sanitation for Africa, Accra, Ghana with support from the Bill and Melinda Gates Foundation and Government of Ghana’s Ministry of Local Government and Rural Development Ghana has one of the ten lowest rates of access to a sanitation facility in the world, but also well-developed policy in sanitation, renewable energy and agriculture that has attracted international attention. Innovative solutions are needed to substantially and sustainably increase sanitation access, and the Sanitation as a Business approach is increasingly gaining traction. This study sought to understand the opportunities and challenges in Ghana's sanitation industry through case-study interviews with businesses and their key nonprofit and government partners. Collectively, the business cases are representative of all stages of the Sanitation Value Chain and target a variety of socioeconomic groups, including the 'Base of the Pyramid'. The businesses and partners are optimistic about the existing demand and are leading efforts to meet this demand through innovations in technology, financing, and marketing. Government, nonprofit actors, and even other businesses serve as partners, contractors, and industry facilitators, providing critical support to the start and scale-up of sanitation businesses. While none of the businesses have yet to achieve substantial scale, business model development is an iterative process that demands time and patience. Sanitation businesses in Ghana have encountered a variety of challenges, including procurement of supplies and equipment, demand-side issues like willingness and ability to pay, insufficient capacity and resources, securing PPPs and other strategic partnerships, and navigating some restrictive policies and bureaucratic processes. However, several initiatives are in the beginning stages of addressing many of these issues. Further partnership opportunities remain untapped, especially for combining efforts to generate demand through public education and marketing. Partnership opportunities also exist with Ghanaian entrepreneurs, who could possibly reach greater scale with marketing support and business training. Given the necessity of sanitation access, the substantial international and domestic interest and support, and the innovative nature of the business approach, sanitation business appears to be a promising opportunity in Ghana. This study provides a picture of a growing sanitation industry and ideas for consideration in other contexts. We recommend that policy-makers and donors pay attention to how sanitation businesses can not only be supported to grow, but also how the benefits of such growth can reach the bottom of the pyramid.
Menstruation Management and WaSH Interventions: Development of Future Performance Indicators from Field-Based Case Studies

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Sarah Rhodes

Introduction: Menstrual management infrastructure is essential for continuous quality improvement of WaSH programs in developing countries and should be incorporated into standard monitoring and evaluation practice. The majority of case studies that have been conducted to characterize the landscape of menstrual management have focused on schools, especially in relation to absenteeism. Objectives: A systematic literature review was conducted in order to: (1) better characterize the quality and content of present peer-reviewed menstrual management case studies focused on developing countries, (2) synthesize the presence or absence of known enabling and disabling factors influencing management of menstruation in present research and (3) determine if lessons learned from prevalent, schools-based case studies can be applied to menstrual management in domestic and workplace environments. Methods: 82 articles were selected from multiple databases using Boolean search terms associated with WaSH infrastructure and menstruation. These articles underwent a multi-phase screening process following author-selected eligibility criteria, resulting in thirteen articles for final synthesis and analysis. The final articles were all case studies, of which eleven studied the status of menstrual management of girls (primarily ages 14-17) in schools. An additive index of study quality was created through analysis of study type, data type (qualitative/quantitative), number of study sites, rationale for selection of study site, prioritization of informed consent and specification of socio-economic status of participants. Each school case study was also analyzed for specification of WatSan infrastructure, hygiene practices, absorbent material type and mechanisms for disposal, as well as other essential determinants such as latrine distance, social support, sexual abuse, and health outcomes. Results: We found that studies incorporated a unique mix of quantitative and qualitative data collection methods. All eleven school-based studies mentioned absorbent materials; however, only eight specified a disposal mechanism. Only four school case studies mentioned the SES of their participants, seven specified whether participant consent was obtained, and six identified and described bias in their studies. Only two articles were identified that described slum and workplace environments, and both papers were hand-selected from reference sections of school-based studies. This systematic review has identified gaps in the current WaSH literature as it relates to menstrual management in developing countries. Additional studies must be conducted that follow schoolgirls post-graduation in order to better understand how menstrual management is maintained in the workplace and home environments. One suggested topic for future study is whether and how infrastructure such as disposal bins for absorbent materials, drying and washing spaces, and locks/stalls may play a role in the use of WaSH infrastructure by people who menstruate.

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Background The worldwide threat of reduced efficacy of antimicrobials that are used to treat infectious diseases in a regular basis and during outbreaks, represent an enormous challenge for the scientific and medical communities. The need for surveillance via the direct detection and quantification of ARB in clinical, community and environmental settings is growing. In response, UNC Chapel Hill and UNAN-Leon joined to collaboratively investigate the development of an indicator system that uses gram-negative bacteria that produce Extended Spectrum Beta Lactamase (ESBL) as well as Klebsiella Pneumoniae Carbapenemase (KPC). The goals of this research were to 1) compare a clinical medium, CHROMagar Orientation agar, to a standard environmental microbiological medium, Bio-Rad Rapid E. coli 2 agar to quantify E. coli and coliforms in wastewater and water, and 2) to evaluate CHROMagar media to detect ESBL and KPC resistant bacteria in clinical, community and environmental samples. Methods In Chapel Hill and Leon, parallel samples of hospital sewage, raw municipal sewage, secondary effluent and surface water upstream from the effluent discharge point were collected and analyzed using standard membrane filter methods on Bio-Rad Rapid E. coli 2 agar, CHROMagar Orientation, CHROMagar ESBL, and CHROMagar KPC media. Colony forming units (CFUs) were observed and recorded as discrete counts according to color guides provided by the manufacturer and concentrations were expressed as colony forming units (CFU)/100 mL. Results Both sites found no statistically significant differences in E. coli and coliform detection between the standard environmental medium, Bio-Rad Rapid E. coli 2 agar and the clinical medium, CHROMagar Orientation for all samples, including hospital and municipal sewage and surface waters. In hospital raw sewage 32% & 1% of all E. coli and 10% & 7.6% of all total coliforms (TC) were ESBL resistant as detected on CHROMagar ESBL compared to CHROMagar Orientation, in Chapel Hill and Leon respectively. Likewise, 22% & 0.5% of E. coli and 5% & 3% of total coliforms were KPC resistant as detected on CHROMagar KPC medium. In municipal raw sewage 3% & 0.7% of E. coli and 8% & 4.1% of total coliforms were ESBL resistant and 1% & 0.1% of E. coli and 1.3% & 0.1% of TC were KPC resistant, in Chapel Hill and Leon respectively. Similarly, in secondary treated effluent 1.2% & 0.4% of E. coli and 2% & 0.4% of TC were ESBL resistant and 0.4% & 0.5% of E. coli and 1% & 0.7% of TC were KPC resistant. In surface water samples taken upstream of the effluent discharge point of the wastewater treatment plant, 2% & 4.7% of E. coli and 1.0% & 4.7% of TC were ESBL resistant and 0.0% & 0.3% of E. coli and 0.2% & 49.8% of TC were KPC resistant. For both sites, additional studies have positively confirmed the identities and the antimicrobial resistance profiles of the E. coli and coliforms detected. Conclusions High levels of ESBL and KPC resistance were detected in E. coli and TC of hospital raw sewage. Additionally, high levels of ESBL and KPC bacteria were found in raw sewage from the hospital in Chapel Hill compared to Leon. Lower levels of resistant bacteria were detected in municipal raw sewage, while even lower but still detectable levels were found in environmental surface waters, with the exception of Leon, where levels of KPC resistant TC are disquieting. In summary, CHROMagar clinical media appear to be effective in directly quantifying ESBL and KPC E. coli and coliform bacteria in environmental samples of water and wastewater by standard membrane filter methods. These media and methods have promise as a candidate indicator system to detect and quantify ARB of great health concern in environmental media as a monitoring system to support environmental surveillance and during outbreaks.
My Water, My Business: Monitoring Self-Supply in Rural Ethiopia

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Self-supply relies upon households making their own investments in new and improved water supply facilities. Commonly, Self-supply involves digging traditional hand-dug wells to access shallow groundwater and a wide range of associated lifting devices, but it may also involve rainwater harvesting, and household water treatment and storage to improve water quality. Self-supply acceleration involves public (and development partner) investment in a set of activities that are intended to help trigger these household investments. In most of the country, Self-supply by households is unsupported with little or no planning, technical support, monitoring or regulation. While serving many households, its performance has been shown to be mixed with poor water quality a particular concern. Ethiopia has relatively recently recognised Self-supply as one of four rural water service delivery models in its national policy and seeks to improve the scale and performance of Self-supply. A key policy - the second Growth and Transformation Plan - also proposes higher rural water service levels including on-plot access and higher volumes of supply. Self-supply's role is expected to further evolve. The Millennium Water Alliance-Ethiopia Programme is supporting local (woreda) governments through its member INGOs to better plan for, promote and monitor Self-supply as part of mainstream water sector activities. This includes an integrated programme looking at both supply and demand of relevant products and services, and featuring activities intended to introduce new technology, build up local private sector capacity and supply chains and improve access to finance amongst others. By assessing the success factors and barriers to Self-supply acceleration the initiative is intended to help government strengthen systems for encouraging and monitoring the adoption of Self-supply. As part of initial activities, a baseline survey of household level water supply activities was initiated in 2014. This survey had multiple objectives including 1) to provide a baseline for monitoring subsequent changes e.g. construction of new or upgrading of wells 2) to provide information for planning Self-supply acceleration interventions and 3) to engage local government staff in taking the lead in Self-supply acceleration. The surveys were implemented using mobile-based data collection tools and were conducted by woreda water officials and other local staff, seeking to promote buy-in (and planning) at the local level. This paper presents results of the baseline survey in Omo Nada woreda, Oromia Region. This includes the results of 284 household-level facility surveys, and surveys of local enterprises and financial institutions. The facility survey included a modified sanitary surveillance assessment to accommodate the non-standard design of wells, and microbial water quality testing of a sub-sample of sources using the compartment bag test. Some of the key findings in this woreda were that: Self-supply was much more prevalent than had been expected; most wells are unprotected and microbial water quality poor; and almost all families buy some inputs or services to develop their supplies but only from the local informal private sector. Lessons are identified on how to use such surveys to trigger Self-supply acceleration activities and to monitor such NGO-supported programmes, as well as making recommendations on how Self-supply might be monitored at national scale as part of the One WaSH Plus National Program.
Performance of Intermittently Operated Slow Sand Filters in Rural Schools in Cambodia

Ray Cantwell, Samaritan’s Purse

Slow sand filtration has been used for municipal water treatment for over a century. Intermittently operated household-scale BioSand filters (BSFs) with surface area of 0.05 - 0.07 m² have been employed for over 20 years in many low income settings. This paper considered the performance of institutional-scale slow sand filters with surface area of 0.71 m². Such filters are being promoted for use in rural institutions without electricity and where water sources are unprotected. The filter considered is composed of a 1000-L capacity HDPE vertical tank that has a sand depth of 750 mm (ES= 0.15-0.20; UC: 1.5-2.5; silt content < 4%), a clean bed hydraulic loading rate of 0.2 m/h at a peak driving head of 25 cm for a maximum daily production of over 3,000 L/day. This study explored the effectiveness of the overall system (filtration and storage) by measuring the E. coli, turbidity, pH, nitrate, nitrite, ammonia, conductivity, total hardness, and calcium concentration for raw, filtered, and stored water. Samples were collected from 24 systems, each located at a different school employing different unprotected ground water sources. Water sources were not spiked with turbidity or challenge organisms. The purpose of this study was to document the performance the existing systems to identify opportunities for improvement in design, operation or implementation. Filtration resulted in an average turbidity reduction of 82% which is similar to that observed in field studies of household sized BSF. The average filtered water turbidity was 0.56 NTU with 96% (23 of 24) of filtered water turbidity values under 1 NTU, the WHO ideal turbidity target. The average E. coli removal was 89%, which is slightly lower than expected for slow sand filtration. The lower than expected removal rate may be due to the low E. coli count in the raw water (average= 27 cfu/100 mL), which inherently limited observed removal rates. An unexpected increase in calcium from a raw water average of 42 mg/L to a filtered water average of 71 mg/L warrants investigation. Calcium increases have been observed for concrete BSFs but not for sand filters in HDPE containers. The pH of the filtered water increased by an average of 0.7 units to a filtered water average pH of 7.4 which may indicate biological or electrochemical reactions that explain the increase in calcium levels. E. coli levels increased (or became positive) as compared with samples collected directly from the filter for 10 of 24 systems. The turbidity of the storage water increased by an average of 0.32 NTU in 16 of 24 systems. These results in terms of increase in E. coli and turbidity during storage are considerably lower as compared with household BSFs. Given that storage tanks were all found firmly secure with little cause to open the tank, the propagation of E. coli at ambient temperatures (23 to 32 °C) is as likely as post filtration contamination. In either situation, post- filtration disinfection would improve microbial water quality to ensure pathogen-free water. No nitrification was measured in the system (few raw water samples had any measurable ammonia) and no significant changes in conductivity, total hardness, or temperature were observed. In general, the results of this study show similar performance as compared with household BSFs. Improved performance was expected given the greater sand depth (750 mm vs 400-550 mm in typical BSFs) and decreased hydraulic loading rate (0.2 m/h vs 0.4 to 0.6 m/h for BSFs). During installation, sand is added to a tank containing water. If the fine sand is redistributed to the top of the filter during installation and subsequently removed during surface cleaning this could explain the under performance. This hypothesis warrants further study.
Costs and Services of Water in Humanitarian Context: Results of a Study Conducted in Two Refugee Camps

Mélanie Carrasco, IRC

The paper presents the results of a cost and service study conducted in emergency context in refugee camps in Ethiopia and Chad in 2014. The Life Cycle Cost Approach (LCCA) developed by IRC provides the methods and tools required to evaluate the costs of water and sanitation services and use that information to improve cost effective and equitable service delivery. This study initiated by UNHCR applies the methodology to the emergency context and in particular to refugee settlements. The approach consists of calculating the costs of providing a certain level of water service in a given area to a number of users. Costs are built up from historical financial expenditures on initial investment and recurrent activities such as operation and maintenance (O&M) of water systems and support to the water service provider. The levels of service are defined and scored against the prevailing national or local norms and standards for a service and can include scoring against other standards used in the emergency context such as Sphere. Indicators such as quantity and quality of water, and accessibility and reliability of service apply to most lower and middle income countries, and thresholds vary according to the types of technology and settlement. In the framework of this study, two refugee camps were selected; one in Ethiopia and one in Chad, and data were collected between July and November 2014. Two types of data were collected, expenditure data and service level data, using a mobile/web-based data collection tool. Expenditure data are collected where the expenditure was/is made whereas service level data are collected directly from users through water point technical surveys and household surveys. Findings on the study focuses on: how much investment per capita is needed to provide for the minimum standard of water? How much needs to be budgeted for operating and maintaining systems in the first 12 months? How much is needed to develop basic monitoring and coordination to ensure the standards are met in a cost-effective way? Unit costs are calculated (investment per technology and per capita, O&M and support per technology and per capita per year) factoring number of users, water resource availability and access to the camp.

Factors Determining the Purchase of Drinking Water from Safe Water Kiosks in Kenya

Nadja Contzen, Eawag
Hans-Joachim Mosler

Background: In many sub-Saharan countries, including Kenya, the Millennium Development Goal on water supply will not be met. To increase access to an improved water source not only investments in piped water systems but also in small water enterprises, such as water kiosks, are indicated as the former often fail to provide service in rural areas and informal urban settlements. While there is some evidence on the positive impact of water kiosks on communities' water quality and childhood diarrhea, there is little knowledge on why some people use water kiosks as a drinking water source while others hold onto competitive, potentially unsafe sources. Insights into factors determining the kiosks' usage is essential to inform the kiosks' promotion so as to increase usage. Therefore, the present research project investigated factors explaining the (regular) purchase of drinking water from three water kiosks in Kenya, one located in an informal settlement in Nairobi and the two others situated in rural villages near Thika. The kiosks, constructed by a foundation, are owned by the respective communities and sell water at an affordable price covering the operational costs. They retrieve water from varying sources, including piped water and river
water, and treat it on-site by ultra-filtration. We tested the following factors as potential determinants of usage: socio-demographic characteristics of the households, contextual factors, psychological determinants of behavior change, sense of ownership and willingness-to-pay and demand for safe water. Method: Data were collected cross-sectionally in the catchment area of the three water kiosks by means of 45-minutes-long face-to-face interviews with the person in a household responsible for water fetching. A total sample of N = 430 was surveyed. Determinants of (regular) kiosk-use were tested by comparing users with non-users and main users with irregular users applying t-tests and χ2-tests. Results: User groups differed to some extent in socio-demographic factors with partly higher wealth and education levels in users compared to non-users. More relevant seemed the contextual factors distance and amount of consumed water with users consistently needing less time to get to the kiosk and fetching less water per week than non- and irregular users. As to psychological determinants of behaviour change, user groups did not differ in risk factors. In other words, whether someone (mainly) fetches water at a kiosk or not, depends not on whether the person knows about causes and preventive measures against diarrhoeal disease or not, whether the person feels vulnerable to diarrhoeal disease or not, and whether the person rates the consequences of diarrhoeal disease to be severe or not. However, user groups differed in (1) attitudinal determinants, i.e. perceived disadvantages and emotions - (main) users perceived the needed time and effort to fetch water at the kiosks and the water's expensiveness as lower and liked fetching water at the kiosks more than non- and irregular users, respectively; (2) normative determinants - among users more relatives or community members fetched their drinking water at the kiosk and more significant others approved and encouraged to fetch water at the kiosk than among non-users; (3) ability determinants - (main) users compared to non- and irregular users thought that it is easy to fetch water at the kiosk, to find the time and the money to fetch water there and to fetch all water there; and (4) self-regulation determinants - main users were more committed to fetch water at the kiosk and putted more effort into controlling their own fetching behaviour than irregular users. Further, user groups did not differ in their willingness-to-pay for safe water and the demand for safe water differed only between main and irregular users. Finally, user groups differed in their sense of ownership with (main) users feeling more as the owners of the kiosks than non- and irregular users.

Conclusions: The present study revealed that (regular) usage of water kiosks is rather independent of risk factors (i.e. health knowledge and risk awareness). Therefore, to increase the kiosks' usage, routinely applied approaches to increase healthy behaviour such as health and hygiene education or stimulation of fear of disease do not seem promising. Much more, promotion activities should lower the perceived disadvantages of the kiosks' usage, stimulate positive emotions and norms towards usage, increase the perceived ability to fetch water at the kiosk, strengthen self-regulation efforts related to usage and elicit a sense of ownership toward the kiosks'. The latter, in addition, should be initiated already prior to a kiosk's opening by means of participatory processes of a kiosk's establishment.

**Innovate or Die**

Tom De Blasis, Nike Foundation

Laura McLaughlin

Product and program innovation is becoming more important in WASH implementation programs, yet is still inhibited by program culture, alignment of key players, and availability of resources in development settings. Leveraging lessons from the private sector, we interviewed 40 organizations, identified the key barriers to innovation adoption in WASH settings, and developed a widely-applicable program, currently being piloted, to overcome these barriers. In the private sector, at companies like Nike and MSR (Mountain Safety Research), mantras like "Innovate or Die" are used without exaggeration in reference to their continued
success, as innovation is often the sustaining life-blood and fuel for growth. Nike formed in 1972, and is the world's leading athletic footwear, apparel and equipment company with over $25B in revenue, while MSR formed in 1969, and is one of the world's leading and most-respected backpacking and outdoor equipment companies. Both were born out of innovation and actively cultivate and create an environment that enables it to thrive - often leading to prestigious distinctions like Fast Company naming Nike as the most innovative company in the world in 2013. The public sector has a very different mission than private sector companies, but similarly has the need to leverage innovative new methods, ideas, and products to achieve impact and success. In the WASH space, precious few innovations have reached the scale and lasting impact that their potentials have promised. The lack of innovation infrastructure and process in the public sector, as well as the nature of innovation, make it difficult for innovators to demonstrate fitness for purpose or market demand, consequently blockading investor funding. Innovative companies like Nike have overcome this barrier by developing their own process and infrastructure, or engine of innovation, giving the company access and control of a robust pipeline of innovative ideas that are being simultaneously explored and invested in. Similarly at MSR, the innovation process is a highly tracked, deliberately interdisciplinary system that is linked to their supply chain, resource management, and the core of the company's decision making. MSR's design process is self-patrolled by strict approvals at various gates that MSR innovators must seek. In the WASH community the phrase "Innovate or Die" has a more literal and urgent meaning. Is it possible to leverage private sector innovation success and accelerate and deepen the impact and success of public sector efforts? In May 2014, MSR Global Health and the Nike Foundation both recognized the opportunity to advance public-sector innovation adoption and collaborated to carry out a survey of 40 WASH innovators, non-profit organizations, and funders that explored the innovation landscape opportunities and barriers to innovation adoption in WASH implementation scenarios. These barriers informed an active, problem-solving event called The Girl Effect Scrum with 20 of the surveyed organizations and experts participating - (a 'Scrum' is a term to describe a small, interdisciplinary design team that is assembled to solve a specific problem within a set amount of time. Both Nike and MSR commonly use Scrum teams to solve design challenges during innovation). The Girl Effect Scrum was a successful vehicle to enable an inclusive conversation and explore innovation adoption across a diverse group of stakeholders. One of the outcomes of the Scrum was the Innovation Adoption Process (IAP), a gated, inclusive and transparent product design process and tool, to be shared between implementers, funders, and innovators involved in innovation projects. The goal of the IAP is to apply successes from the private sector to meet public sector need. It improves communication and enables collaboration. The IAP concept is currently being proven out on MSR Global Health’s first product, the SE200TM Community Chlorine Maker, in collaboration with World Vision and PATH. While promising and encouraging as innovation tools in themselves, both the Scrum and IAP point more toward the potential for a broader and deeper discussion within the WASH community about innovation as a robust engine and vehicle for sustained impact at scale. Let’s explore how the public sector can successfully incorporate the innovation practices and mindset of leading private sector companies like MSR and Nike. This abstract is presented by: Tom De Blasis, Design Innovation Director for the Nike Foundation, who previously worked for 8 years as an innovation director for Nike and has over 25 years of innovation experience in the private and public sectors. Laura McLaughlin, MSR Director of Global Health, is leading the global health team toward innovating for impact. She has been with MSR for 7 years, previously working on market transformation efforts and health studies worldwide.
Department Level Changes in Pediatric Diarrhea and Mortality After a Large Scale WASH Program in Colón, Honduras

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Kristen Check

Using longitudinal data from records obtained from the Honduras Department of Public Health, pediatric diarrhea and infant mortality rates were tracked over a six year period during which a large scale WASH intervention occurred in the Department of Colón, Honduras. Rates of pediatric diarrhea and infant mortality from Colón were compared to national rates as well as a nearby department matched by using the Human Development Index. Both pediatric diarrhea and infant mortality dropped significantly faster in Colón than in the control department and the national rates, supporting local assertions of the impact of such large scale interventions on childhood health and survival. This study is an example of the use of public health data to track the impact of WASH interventions. Also the researchers will suggest a "clustering effect" whereby health impact appears greater when safe water points are concentrated in a smaller geographic area as opposed to being scattered across a larger landscape. This has significant implications for future planning and implementation of WASH projects everywhere.

Real Time Field Data Capture and Knowledge Diffusion via Protocols with FieldLogs

Jean-Marc Debaud, Trekea Mobile, Inc.

Ensuring that high quality data is systematically collected through field-based monitoring continues to pose logistical and financial challenges for many stakeholders and researchers in global health and development. Challenges include poor compliance in execution of protocols by field staff, inaccurately or incompletely reported data, and extended lag-times for delivering critical needs assessments to stakeholders to elicit response to public health problems. Additionally, errors can be introduced when linking field data assimilated by multiple devices, such as smartphone surveys, gps device, and camera. In the field, executing standard protocols or collecting survey data through digital means provides strong benefits. Among these, protocols and data surveys can include built-in info- or video-graphics documentation during execution for ease of understanding. Further, digital execution can provide geolocation, time-stamping, and media capture for stronger evidentiary purposes, as well as more advanced contextual analysis. In such digital form, protocols and surveys can be distributed and the collected results aggregated in near real-time. And ideally, the governance guiding their creation and update should be tailorable from both end of the spectrum: top-down or crowd sourcing efforts. FieldLogs is a Cloud-based web and mobile application designed to create digital field data capture surveys and protocols. Team-oriented, and with full on-and-offline capabilities it also supports real-time collaboration with field teams when needed. FieldLogs is to be piloted in several sanitation-poor communities in Kenya in early August by a team from the University of Iowa in the context of a web or data-based app for infectious disease spatial risk assessments. The FieldLogs team is also building a set of freely available protocols targeting diverse aspects of the Ebola epidemic. Material freely available from the CDC is being translated in digital form: For instance, this Protocol: http://www.cdc.gov/vhf/ebola/pdf/ed-algorithm-management-patients-possible-ebola.pdf becomes executable on the Web, iOS, Android, or Google Glass as: http://tinyurl.com/q4p2dyj. A simple URL allows access across those digital execution platforms. Built with a strong crowd sourcing community angle, FieldLogs can provide researchers, community health workers, stakeholder monitoring and evaluation professionals, educators, or field engineers with very affordable digital tools with which to rapidly survey issues of interest, as well as authoring and using protocols covering vast subjects in the domain.
To Pay or Not To Pay for Safe Water? Insights from Arsenic-Affected Communities in India

Caroline Delaire, University of California, Berkeley
Abhijit Das; Joyashree Roy; Susan Amrose; Ashok Gadgil; Isha Ray

Millions of people in rural West Bengal, India, use arsenic-contaminated groundwater as their primary water source for drinking and cooking. Arsenic ingestion can lead to various types of cancers, cardiovascular diseases and premature death. This situation has been called the worst case of mass-poisoning in human history. In addition, Bengal groundwater often contains high levels of iron responsible for bad color and taste, as well as fecal pollution potentially leading to diarrheal diseases. Alternatives to the direct use of contaminated tubewells are available in some areas, especially in the vicinity of cities. They can include (1) bottled water produced and sold by local mini-plants, (2) various types and qualities of domestic filters, (3) government tubewells, and (4) government-treated water accessible at free public taps. We present the results of a 501-household survey conducted in the arsenic-affected district of Murshidabad, West Bengal, India. We investigated household water behaviors in two areas: one cluster of villages where purchased water, government tubewells and domestic filters were the only alternatives available; and one village where public taps were available in addition to the other three alternatives. Our data allowed us to create 13 indices reflecting socioeconomic status, demographics and behavioral determinants such as peer behavior, external advice, arsenic awareness, risk perception of iron and gastric illness, and perception of purchased water. We used statistical regressions to determine the factors leading a household (1) to use alternatives to arsenic-contaminated groundwater, (2) to choose between the different alternatives available. We find that socioeconomic status and risk perception of gastric illness are the main factors driving the use of alternatives to contaminated groundwater, with arsenic awareness playing a secondary role and especially in higher-income households. Our results suggest that 3 factors -socioeconomic status, perception of purchased water and participation in women groups- determine the choice of alternative. Additionally, we observed different levels of adoption among households using alternatives ranging from “exclusive users” to “intermittent users” (alternating between private tubewells and alternatives), “partial users” (households where only a few members use alternatives), and “occasional users” (using alternatives on special occasions or when sick). Abandoning the traditional binary distinction between “users” and “non-users”, we use our data to formulate hypotheses about the factors leading households to move from one level of behavior change to the next. Overall, our results shed light on the dynamics of water purchasing in arsenic-affected areas. We found that arsenic awareness was not a driver for purchasing water. Rather, gastric illness, which is a much more salient and short-term concern for households, appeared to be the most determining factor. Consequently, the effectiveness of arsenic removal is not a criteria for selecting an alternative, and purchased water competes with domestic filters, which are sometimes preferred because they preserve the taste of groundwater. In addition, comparisons between our two survey areas allow us to discuss the impact of tap water introduction on the use of purchased water. We derive implications of our findings for behavior change campaigns in the region. Finally, interviews with water providers in our survey area revealed a complex competition between private mini-plants (both formal and informal), NGO-led mini-plants and government free public taps, which may complicate the introduction of new water businesses in the region. We propose that both our quantitative and qualitative findings can be used to inform the implementation of new efficient and low-cost water treatment technologies in West Bengal.
Learning from Practice- Case Study Topic: Facilitating Change in a Complex Environment: Delivering Rural Water Services in Ghana

Vida Duti, IRC

David Korboe; Veronica Ayi-Bonte


For rural populations to experience reliable access to safe water services, sector actors - policymakers, technical support agencies, regulators, service providers, facility owners, development partners and NGOs - need to work in harmony, guided by an approach that emphasises service delivery rather than simply extending the nominal 'coverage' of water infrastructure. Between 2009 and 2014 IRC, through the Triple-S project, supported Ghana's rural water agency, Community Water and Sanitation Agency (CWSA), to build consensus around a new vision of adequate water services that are sustained over time and develop an approach to make that vision a reality. The case study shares some lessons from how the Ghana CWSA, pilot districts and partners were supported to navigate the sector's complex realities. IRC supported CWSA to rethink its organisational systems and develop evidence-informed policy documents and tools needed for leading the drive towards service delivery. As the initiative aimed to influence sector dynamics and dialogue, continuous investments were made in mainstreaming the research conclusions into routine sector practice. Actors involved at the sector's multiple levels are beginning to cooperate more effectively, with CWSA, districts and partners jointly identifying areas needing improvement. Replication of successful solutions is occurring quite naturally because of the collective investment in defining and reflecting on the experiments to test them. High-level policy statements now routinely acknowledge a service delivery approach (SDA). CWSA has revised its mission statement and published revised service planning frameworks with relevant budgetary provisions. For the first time too, implementation guidelines include explicit requirements to budget for an extended life cycle beyond construction. A revised monitoring tool with agreed benchmarks on reliability, distance, coverage, quality and quantity has been adopted by the sector. Commitment to SDA is strong and growing, indicated by key sector donors (the Dutch Government, SNV, UNICEF and the World Bank) agreeing to resource CWSA to scale up the service monitoring model from an initial three to 131 of Ghana's 216 administrative districts. In 2014, Conrad Hilton Foundation also committed to extend the initiative with a three-year grant of US$3 million to support a knowledge transfer process to capacitate CWSA officials in 5 regions, 10 districts of operation and grantees (SWN, WVI, UNICEF, Water Aid) operating in Ghana to apply the successful tools developed under the Triple-S initiative to effectively manage the assets financed by the Foundation (and others). The case study presentation will describe the processes and actions undertaken by IRC and its partners to create large-scale change in Ghana's rural water subsector and offer an analysis of progress. It will also outline how change in sector thinking and practice is being achieved through a collaborative process of action research, reflection and on-going learning. References: Adank, M., Kumasi, T.C., Abbey, E., Dickinson, N., Dzansi, P., Atengdem, J.A., Laari Chimbar, T., and Appiah-Effah, E. (2013): The status of rural water services in Ghana: a synthesis of findings from 3 districts (Akatsi, Sunyani West and East Gonja Districts. Accra: IRC. Duti, V., Korboe, D., Ayi-Bonte, V., (2015): Facilitating change in a complex environment: delivering rural water services in Ghana. Accra IRC Government of Ghana, April 2010. The Ghana Compact - Sanitation and Water For All: A Framework of Action Government of Ghana (2012 & 2014): Sanitation and Water for All (SWA) Statement of Commitments presented at Washington DC during the High Level Meeting. Lockwood, H., and Duti, V. (forthcoming) Whole system change: capturing the change process in the Ghana rural water sub-sector, The Hague IRC RWSN, 2009. Handpump Data 2009: Selected Countries in Sub-Saharan Africa. St Gallen, Switzerland: Rural Water Supply Network.
Risk and Benefit Judgment of Excreta as Fertilizer in Agriculture

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Human excreta, faeces and urine generally evoke repugnance because they are marked with a negative image in people’s minds. This is part of the instinctive mechanism deterring people from getting in contact with substances or objects that can potentially contaminate and cause harm. Negative emotional reactions towards excreta, faeces in particular are so strong that they persist even after the substances have been properly treated and rendered innocuous. This plays a major role in influencing judgment and decision-making regarding the productive use of excreta. Moreover, uncertainties and unknowns regarding exposure especially to emerging pathogens and contaminants in excreta and the potential health threats exacerbate risk perception towards them. A combination of pathogen sensitivity and risk perception engender dread which fuels resistance to the use of excreta as fertilizer. This is, however, not the case among some individuals and within certain communities where unsafe use of untreated excreta prevails with concomitant health problems. This paper improves understanding of the above challenges, provides insights for understanding risk-benefit trade-offs and behavior, and makes suggestions relevant for sanitation, health, hygiene, and agriculture policies and practices. We explored the psychological mechanism underlying human judgment of excreta related activities including the use of excreta as fertilizer. Using psychometric techniques, we examined the role of affect i.e. risk as a feeling on the judgments of individuals from different backgrounds and settings in rural and urban Rwanda and Uganda, namely: environmental health students, smallholder farmers and petty traders. The finding reveals an inverse relationship between risk and benefit judgments. This relationship holds for the three groups of participants with significant risk-benefit correlations of p<.0001. This finding is in line with other studies showing that people use affect heuristic in making judgments and that affect plays a key role in risk perception. We found that smallholder farmers in communities where urine diversion dry toilets (UDDTs) have been introduced and where excreta are used as fertilizer, exhibit a slight preference for human manure. We have also shown from literature that animal manure, cow dung in particular also has high potential to contaminate and cause harm even though they are commonly used and, as our finding shows, are preferred by petty traders and environmental health students. Building on this finding, we conclude that individuals with high risk and low benefit judgment for excreta related practices would eschew them or emphasize strict standards. Also, individuals with a high benefit and low risk judgment would engage in excreta management practices regardless of the actual risks involved. This insight cannot be generalized given the type of sampling method we employed. However, the fact that we replicated the inverse relationship between risk and benefit judgments with the three groups from different backgrounds and settings is an indication of the validity of the finding and, therefore, an important contribution to the body of literature on risk perception and human behavior. The finding is relevant for risk communication and risk management as it indicates that individuals do not rely only on risk management information they receive concerning excreta and related risks but also depend to an extent on their feelings about these substances when making judgments and decisions regarding the purpose for using excreta as fertilizer and the level of exposure they can tolerate and manage when doing so. Thus, purpose and exposure are important factors to consider regarding the use of excreta as fertilizer. The finding also shows that students exhibit higher sensitivity for unsafe practices than the other two groups, hence supporting the assertion that risk means different things to different people. We attribute this difference to factors such as risk tolerance, practical experience, and knowledge of risk management. To get people to safely use excreta in agriculture requires an understanding of the risk and benefit trade-offs they make when they use excreta, the reasons why they engage in such practices, and the extent to which they understand the risks involved. This is important for risk communication as it enables risk information to be tailored and targeted to specific groups of individuals to address specific gaps. Furthermore, in communities where unsafe practices prevail, emphasis on negative framing methods may be useful in motivating preventive action and consequently changing behavior. Also,
high rates of compliance for practices such as washing hands with soap after using the toilet and handling human excreta and refraining from defecating in the open are unlikely where the targeted individuals lack material and cognitive resources needed to comply even if they are willing to do so.

**Determinants of Source and Stored Water Quality in Four Districts of Northern Ghana**

Michael Fisher, UNC
Katherine Shields; Jamie Bartram

Adequate quantities of safe water are critical to human health and development. Like many countries in West Africa, Ghana has made great strides in increasing access to improved communal water sources in its rural districts over recent decades. However, concern remains about the microbiological safety of water for consumption, both at the source and household level. In particular, the factors determining the microbiological quality of water actually consumed by households is of great interest. To address this question, a study of 230 communities was conducted in four districts of Northern Ghana. Water quality testing was conducted for a census of water sources (n = 562) and a sample of households (n = 527) in these communities, and data on several other potential explanatory and confounding variables were collected. Source water microbial quality was found to depend primarily on source type and location. Stored water quality was found to depend primarily on safe storage conditions and on observed handwashing practices in the household. These household-level factors were found to be stronger predictors of microbial water quality than the effects of source type for households using water from a communal source. The results suggest that in the study area, the effects of proper hygiene and safe management of water in the home on microbial water quality outweigh the effects of source type, and may represent key opportunities for improving the safety of water actually consumed in rural households in Northern Ghana, and potentially in other rural low and middle-income country settings as well.

**Anaerobic Digestion Pasteurization Latrine - Two Year Study of an Innovative Sewage Treatment System in Eldoret, Kenya**

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Patrick O’Meara; Wangare Mugo; Gelas Simiyu; Marc Deshusses

The overall objective of the Anaerobic Digestion Pasteurization Latrine (ADPL) is to develop and demonstrate the proof of concept a novel self-contained and energy neutral sanitation technology using anaerobic digestion of human wastes to generate biogas used to pasteurize the treated effluent. The concept was lab tested for over one year with a floating dome digester having a working volume of 17 liters for the anaerobic digestion of simulant feces and urine. Effluent flowed into a biogas-powered heater following a counter-current heat exchanger. Results from proof of concept study were presented at the 2013 UNC Water & Health Conference, and key findings were that anaerobic digestion of undiluted human waste yields 0.37 NL(biogas)/g(COD) (35-40 L(biogas)/person/day), which is sufficient to maintain continuous operation of the heating tank at 75 °C, within the 55-75 °C temperature range well known to provide several log reductions of bacteria, virus, and helminth ova. After finding successful operation in the lab, the concept was tested in field conditions. In June 2013 three systems were installed in a peri-urban area outside of Eldoret, Kenya. Each system was comprised of 3 toilets built above the digester and heating system, using gravity-induced flows. Site characteristics were shared compounds with 20-30 residents, pit
latrines, and borehole water well. Adoption at two sites was successful, and residents reported that the system compared to their pit latrines is easier to keep clean, has little to no odor or flies, and offers the possibility of excess biogas and effluent reuse. Use at the third site never reached a satisfactory level and is believed to be due to disinterest of site owner and perceived inconvenience of users to ascend stairs to the toilets. Average biogas production from sites with successful adoption was 270 and 317 L(biogas)/day. This production level was sufficient maintain the heating tank between 65-75 °C while having a surplus of biogas on most days. Lab analysis for organic and nutrient content and pathogen reduction is currently undergoing validation and finalization. The ADPL concept of using anaerobic digestion of human waste to power its own sterilization has been successful in both laboratory and field conditions. The system is simple, requiring no outside energy or moving parts, applicable in most contexts, and low-cost. All materials for installation were locally purchased or fabricated, and the total cost of initial installation and assumed maintenance expense is roughly $2000 for 20-30 users. With a 10 year life for the digester and 5 years for the heat sterilization system, cost comes to 1.8 to 2.7 cents per user per day (without factoring energy/fertilizer benefits). Up-to-date observations, lab results, and key findings of field operation of Kenya systems will be presented at the conference.

**Increasing Handwashing Effectiveness: Contextual and Psychological Determinants of Thorough Handwashing and Recommendations for Interventions**

Max Friedrich, Eawag

Hans-Joachim Mosler

Diarrhoea is one of the leading causes of childhood mortality. Handwashing has been shown to considerably reduce diarrhoea and is being intensively promoted worldwide. In this context, behavioural determinants of frequent handwashing at critical times have been in the focus of psychological research. In contrast, another dimension of handwashing has, until present, received few attention: The technique of handwashing. According to public institutions, such as the World Health Organisation (WHO) or the Centre for Disease Control (CDC), hands should be washed with running water and soap and by applying various scrubbing steps to remove germs effectively. Hands should be dried with a clean towel or air dried. Otherwise handwashing is less effective. But how can people be motivated to wash hands as recommended? And what are the barriers that prevent people from applying these handwashing techniques? In a cross-sectional survey in high-density suburbs of Harare, the handwashing technique of 494 primary caregivers was observed at their homes. The way of moistening hands, soap use, performed steps of hand scrubbing, duration of hand scrubbing and the hand drying technique were recorded and rated on a 12 point index with the CDC recommendations as a reference. For people to perform a behaviour, their attitudes have to be in favour of that behaviour. Attitudes regarding thorough handwashing were surveyed through structured quantitative interviews based on the Risk, Attitudes, Norms, Abilities and Self-regulation (RANAS) model.

Contextual factors were assessed using hygiene spot-checks at household level and additional standardized questions. The frequency of handwashing was obtained from self-report. A multiple linear regression analysis of the contextual and psychological factors of thorough handwashing and the self-reported handwashing frequency on the observed handwashing technique was performed. The knowledge of when and how to wash hands was the strongest predictor of handwashing thoroughness followed by the self-reported frequency of handwashing. Further psychological determinants of handwashing included having a detailed plan of the location and device for handwashing and the confidence to be able to maintain thorough handwashing even if circumstances were difficult. Availability of soap at the handwashing station and distance to the water source were significant contextual determinants. The predictors were able to
explain 40% of the variance in observed handwashing thoroughness. The results show that in order to improve handwashing thoroughness, interventions need to go above and beyond increasing the participants' knowledge of how to correctly wash hands. We propose the following interventions: (1) through personalized planning, participants shall be empowered to create and maintain an enabling environment in which a designated place for handwashing and sufficient amounts of soap and water are present. (2) The recommended handwashing technique shall be memorized, for example with a song that features all required steps. (3) Implementation intentions shall link the key situations for handwashing with the memorized technique to create situational cues for effective handwashing.

**Use of Cartography as a Tool to Develop WASH Strategies for Cholera Response, Prevention and Preparedness: Case Study for Kisangani and Kinkondja, DRC**

Giuliaserena Gagliardini, UNICEF

Brigitte Pedro

Democratic Republic of Congo is one of the country presenting most of the cases of cholera in West and Central Africa in the last years: 19305 cases in 2014, second position after Nigeria (Regional Update, UNICEF, 2015). In 2014, a study has been done in the country to update endemic and epidemic classification of Health Zones and better identify the dynamics and way of transmission of the diseases among different geographical areas based on the data of cholera case for the period 2009-2013. The results have been synthetized in a map that is currently used to design both preparedness and response strategies to cholera outbreak and middle-long term durable solutions. Moreover, within the framework of the Multi-Sectoral Plan for Elimination of Cholera 2013-2017, provincial and health zone operational and contingency plans have been developed, based on this cartography. Two study cases have been identified to illustrate this methodology and the partial results until the date both in non epidemic and endemic areas. Preparedness and response are focused on reinforcing local capacities to response to crisis. Kisangani was hit by a huge outbreak in 2011 that, through the river Congo, reached the city of Kinshasa 6 months later. In 2015, an outbreak also started in this city, in two health zone, and a local response, led by local authorities, allowed to contain and control the epidemic outbreak. Kinkondja in Katanga is an endemic rural health zone, from where the cholera easily spread to other epidemic areas until reaching the big cities in the South of the province. Based on this map, an action plan has been designed for this area with the aim to ensure a durable solution: the national programme healthy school and village is being implemented in this zone to improve access to water, sanitation and hygiene conditions. The programme is to cover all the health zone by 2018. This paper will present the impact of such strategy in the reduction of cholera cases in these 2 locations.

**Determinants of Ebola Preparedness and Evaluation of Implemented Promotion Activities in a Representative Sample of the Populations in Vulnerable Areas in Guinea-Bissau and Gambia.**

Anna Gamma, EAWAG

Hans-Joachim Mosler

The outbreak of the Ebola virus disease (EVD) in West Africa (Guinea Conakry, Sierra Leone, Liberia) is the largest and most complex Ebola outbreak since the Ebola virus was first discovered. In April 2015, there have been 10’704 reported deaths, and there are still new infections in these three countries. The vulnerability for an Ebola outbreak in Guinea-Bissau and Gambia is given due to several reasons: their geographical
location, the cross-border market activity, inadequate water and sanitation systems, poor hygiene practices in some communities and risky burial ceremonies, which are extremely conducive to conditions of contamination. The objective of this study was to find the relevant socio-psychological factors of behavior intentions related to the prevention of an Ebola outbreak and hand washing with soap in a representative sample of the populations in vulnerable areas in Guinea-Bissau and Gambia. In addition, several implemented promotion activities were evaluated. In each of the two study countries, 500 households were interviewed with a questionnaire based on the RANAS model (risk, attitude, norm, ability, self-regulation; Mosler, 2012). Structured face-to-face interviews were conducted with the primary care providers of randomly selected study households. By the mean of a multiple linear regression, the factors predicting hand washing with soap and water and the intention to call the Ebola hotline as well as the intention not to touch a suspected person anymore as long as this person is still in the household, will be revealed. The effectiveness of the implemented promotion activities will be analyzed using mediation analysis. A part of the study participants were men, despite that they are normally not responsible for the care of the sick. The goal of interviewing men was to detect differences with regard to the effects of the implemented promotion activities. The results will enable to identify the factors which enhance or hinder the chosen Ebola preparedness behavior or behavior intentions, separately for men and woman. Based on the results from this baseline survey, recommendations about how to adapt the promotion activities to change the influential socio-psychological factors with regard to the Ebola preparedness can be given.

Sustainability of Household Water Treatment Practices: Findings from a Market Assessment

Roshini George, Sera Global Health Practice

Sustainability of Household Water Treatment Practices: Findings from a Market Assessment A market assessment of household water treatment (HWT) products in Asia and sub-Saharan Africa was conducted as part of the International Scheme to Evaluate Household Water Treatment Technologies (HWT). The intent of the assessment was to create a robust understanding of availability and regulation of HWT products, scale of use, and enabling and constraining factors. The findings from the market assessment are to be used to inform the activities of the Scheme. The methodology for the assessment included a desk review, email discussions, phone interviews, and in country interviews with stakeholder groups. Stakeholders included ministries and agencies involved in HWT regulation, manufacturers, distributors, NGOs, and academic experts. Interviews were designed to better assess HWT products being distributed, primary channels of distribution, extent of regulation, monitoring, and evaluation, and enabling and constraining factors influencing uptake. The prevalence of HWT practice has not increased significantly over the last several years and there has been some discussion in the literature about why this is the case. The market assessment supports some of these prior discussions and adds findings from the assessment to highlight systemic demand and supply side factors impeding the sustainability of HWT products. Demand side factors impacting the long term market sustainability of HWT products include: NGO focused initiatives that provide products for free or at highly subsidized prices thereby limiting commercial possibilities; consumer, government, and NGO perceptions of HWT products as associated with emergencies and disease outbreaks; and the lack of understanding of true product costs and long term benefits of HWT use. The presentation will also explore supply side issues such as barriers impacting consistent supply, challenges with distribution networks, and the difficulties created for production due to lack of consistent demand. Recommendations to address the sustainability and scalability of HWT products will be presented along with examples of innovative approaches to establish commercially viable markets for HWT products while providing access to vulnerable populations.
Groundwater Potential Evaluation Based on Integrated GIS and Remote Sensing Technique in Bilate River Basin, South Rift Valley of Ethiopia

Tesfaye Tessema Gintamo, Ethiopian Kale Heywet Church Development Program

Groundwater is occurring within different hydrogeology environment, geologic formations and topographic settings that the factors mainly control the groundwater distribution and development for different purposes. A systematic evaluation of groundwater is essential for the proper utilization and management of this precious natural resource. Integrated GIS (geographic information system) and remote sensing are efficient techniques in groundwater studies; in facilitate better data analysis and their interpretations of groundwater potential controlling parameters. In the present study, an attempt has been made to delineate and classify possible groundwater potential zones in the Bilate River catchment of the south Ethiopian rift escarpment, found in SNNPR using integrated remote sensing and GIS techniques. The thematic layers considered in this study are lithology, geomorphology/landform, drainage density, lineament density, rainfall, soil, slope and land use/land cover were prepared using the Landsat ETM+ imagery and ArcGIS software. All the thematic layers were then assigned weights according to their relative importance in groundwater occurrence and the corresponding normalized weights were obtained based on the Saaty's analytical hierarchy process. These weights were applied in linear summation equation to obtain a unified weight map containing due weights of all input variables. The thematic layers were finally integrated using ArcGIS and IDRIS software to produce a groundwater potential zone map of the study area. Thus, four different groundwater potential zones were identified, namely 'high', 'moderate', 'low' and 'poor'. The high potential zones correspond to alluvial plains, lacustrine sediments, the fracture valleys, and valley fills, which coincide with the low slope and high lineaments density areas. The eastern portion and some small patches in the northern and valley escarpment of Bilate River of the study area fall under moderate groundwater potential zone. The low zones mainly comprise structural hills and escarpments which contribute high run-off. On the other hand, Poor groundwater potential zones are present in the mountain peaks, plateaus and escarpments with steep cliff, where low fractured undifferentiated peralkaline Dino formation, obsidian and pitch stone exist. The resulted groundwater potential zoning map validated based on existing water sources point data of the study area. Finally, it is concluded that the integrated GIS and remote sensing techniques are very efficient and useful for the identification of groundwater potential zones. Key words: Bilate River, Groundwater potential, GIS and remote sensing, western escarpment, thematic maps

Fecal Contamination on Produce from Wholesale and Local Retail Food Markets in Low-Income Communities of Dhaka, Bangladesh

Angela Harris, Stanford University

Mohammad Aminul Islam; Leanne Unicomb; Jennifer Davis; Alexandria Boehm; Stephen Luby; Amy Pickering

Fresh produce items can become contaminated with enteric pathogens along the supply chain before harvest (e.g., irrigation water, soil, fertilizer) or after harvest (e.g., vendor conditions or consumer handling). In this study, we measured the extent and sources of fecal contamination on produce items sold in food markets in Dhaka, Bangladesh. Carrots, eggplants, red amaranth (a leafy green or purple vegetable), and tomatoes were collected from vendors at the city’s largest wholesale market, as well as from four neighborhood retail markets. Along with produce collection, information was collected from vendors on produce handling practices, and field staff recorded observations of market conditions. Produce items (n=96) were rinsed in bags of sterile water; the rinse water was processed using IDEXX defined substrate
assays to enumerate the fecal indicator bacteria E. coli and enterococci. Molecular microbial source tracking assays were also used to detect the presence of ruminant-specific fecal contamination, as well as general fecal contamination (from any animal host), in the produce rinses. We compared quantitative levels of fecal indicator bacteria and the molecular markers found in produce rinses between wholesale and neighborhood markets using multivariate regression and Poisson regression models that control for produce type. E. coli was found in the majority of produce rinses, including 100% of carrot and red amaranth rinses, 92% of eggplant rinses, and 46% of tomato rinses. Concentrations of E. coli per 100 cm2 surface area ranged from a low of 0.87 log-mean MPN on tomatoes to a high of 2.3 log-mean MPN on eggplants. Enterococci was detected in 100% of eggplant and red amaranth leaf rinses, 75% of carrot rinses, and 50% of tomato rinses. The concentration of enterococci also varied by produce type, from 2.5 to 3.4 log-mean MPN per 100 cm2. The molecular target of general fecal contamination, GenBac3, was detected in 100% of eggplant, amaranth, and carrot rinses, and in 94% of tomato rinses. Concentrations of the GenBac3 target varied between 4.0 and 4.5 log-mean target copies per 100 cm2. Evidence of ruminant fecal contamination was found in 32% of produce rinses using the BacR ruminant-specific assay. The BacR target was detected on 22% of carrots, 28% of eggplants, 39% of red amaranth leaves, and 39% of tomatoes. Rinses of produce obtained from neighborhood retail markets had higher mean concentrations of all general fecal indicators as compared to rinses of the wholesale market produce. Retail market produce had significantly greater GenBac3 target copies compared to the wholesale market produce (p=0.03); the mean difference was 0.4 log GenBac3 copies per 100 cm2 higher (equivalent to a 2.5-fold increase in contamination). E. coli was 0.52 log MPN per 100 cm2 higher (p=0.07) and enterococci was 0.36 log MPN per 100 cm2 higher (p=0.09), in retail versus wholesale market produce. The ruminant fecal target was detected in rinses of produce from both neighborhood and wholesale markets (i.e., target detection not associated with market type, p>0.10). The results of this study suggest that fecal contamination of produce markets in Dhaka is common, and that food market conditions may contribute to produce contamination. The detection of the ruminant marker on one-third of produce items indicates that at least a portion of fecal contamination on produce originates from ruminant sources. There are several plausible mechanisms for produce contamination within the markets enrolled in this study. For example, vendors reported rinsing or spraying produce with water (32% of produce items), which may be contaminated. Consumers and vendors often handled produce during inspection and sale; animals were often tethered or allowed to walk in close proximity to produce. Most markets had open concrete drainage systems that were filled with water and food waste. Future research could evaluate the effects of improving sanitary conditions and vendor produce handling practices in markets to reduce fecal contamination of produce.

 Associations Between Meteorology and Waterborne Disease: a Spatial and Temporal Study in North Carolina State

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It has been well-documented that water in general and floodwaters specifically can spread pathogens within watersheds (Curriero et al. 2001). Excessive or heavy rainfall events can mobilize pathogens in the environment and contribute to an increase in runoff from livestock or other agricultural fields, as well as transport pathogens into rivers, coastal waters, and wells (Semenza, 2009). This study focuses on the public health implications of heavy precipitation with a localized focus on North Carolina State. Although waterborne disease outbreaks are frequently associated with heavy precipitation events, this study monitors baseline levels of waterborne disease infections that may not be classified as "outbreaks" but can still be associated with rainfall patterns. As such, the results of this study may be able to inform health officials of a potential increase in number of waterborne disease infections given a
set of meteorological variables. As many as 900,000 cases and 900 deaths from waterborne disease occur annually in the United States (Rose et al. 2000). More than 100 different types of pathogenic bacteria, viruses, and protozoa can be found in contaminated water (Patz, 2008). Gastroenteritis and acute gastrointestinal infection (AGI), the disease outcomes of this study, are the primary diseases associated with contaminated water exposure (Patz, 2008). A positive association has been found between diarrhea and meteorological variables (Curriero et al. 2001). Several articles document increases in diarrhea or outbreaks following dry periods, which might suggest an interaction between the accumulation of pathogens in the environment during dry periods and heavy rainfall (Adkins, 1987; Carlton et al. 2014; Effler et al. 2001; Nicholas et al. 2009; Smith et al. 1989; Willocks et al. 1998). In summary, there is mounting evidence that heavy precipitation and runoff events add to the risk of waterborne disease outbreaks (Curriero et al. 2001). This study utilizes ICD-9 codes 1.00-9.00 ("Specified Gastrointestinal Infections") from Emergency Department (ED) discharges in North Carolina hospitals. This ED data is made available via NC-DETECT (North Carolina Disease Event Tracking and Epidemiologic Collection Tool). NC-DETECT is North Carolina's statewide syndromic surveillance system. ED data have been used as a uniform sentinel for community-wide events of gastrointestinal illness in similar contexts before (Drayna et al. 2010; Tinker, S. 2014). In addition, daily, monthly, and seasonal rainfall totals will be collected from 2008-2013 (the period of record for which NC-DETECT data is available). The precipitation data is collected from weather stations maintained by various government organizations (i.e. ASOS, AWOS, EcoNet). NC-Detect data also includes 2010 Census information, allowing for patients' zipcode of residence to be identified. For this study, ArcGIS is utilized to produce county maps that display the precipitation in a county as well as incidence of gastrointestinal infection. These maps (seasonal, monthly, and annual) explore the relationships between dry periods (which can lead to pathogen accumulation) prior to heavy precipitation events, the presence of private wells vs. community sewer systems, and the abundance of livestock by area. Due to the fact that the NC-DETECT data is only ED visits, the data could be skewed based on multiple factors, such as gender, severity of illness, skin contact with floodwater, and private water supply (Lowe, 2003). Other limitations on the study could include, but are not limited to a lack of individual data regarding disease etiology, clinical course, drinking water source and habits, and recreational water exposures (Drayna et al., 2010). Furthermore, since the data is only ED visits, there is a possibility that the results could reflect an underestimation of the true incidence of rainfall- associated disease (Drayna et al., 2010). Hypothesis: The hypothesis for this study is that there is an association between rainfall and ED visits in North Carolina State for acute gastrointestinal enteritis (AGI) over spatial and temporal ranges that may represent an unrecognized, endemic burden of disease (adapted from Drayna et al. 2010). A baseline precipitation and waterborne disease monitoring system of this nature for the state of North Carolina has not yet been published. I hope that this work will provide data that can drive public health initiatives in North Carolina communities that may be at high risk for waterborne disease outbreaks during given periods of the year.

Incentives for Home Water Quality and Supply Reliability: a Results Driven Approach

Adam Harvey, Whave Solutions
Joel Mukanga

Although the existence of a crisis in clean water supply, sanitation and hygiene in developing countries is recognised universally, its causes and character are generally not well understood, nor its significance for the
global health burden. Scientific research and field studies indicate that 30 to 40% of clean water sources are not functional at any one time and there is agreement that the health benefits expected from clean water supply investments are not being delivered in practice. The problem of endemic unreliability is compounded by the prevalence of contamination of water during transport and storage. This paper describes a practical strategy adopted by Whave Solutions in Uganda to address the twin problem of unreliability of clean water supply and poor hygiene. Results are presented from two years of pilot work in 170 communities in five districts. The approach taken to incentivise reliability through performance-payment of local micro-utilities was successful (99% reliability was recorded), and the strategy for promotion of community self-financing of WASH service agreements shows early promise. The paper also discusses incentives for transformation of hygiene and sanitation conditions, which are combined with incentives for daily operational reliability. Both are integrated into a public-private partnership structure for self-sustaining WASH services. The paper concludes by promoting practical methods of driving this transformation through results-based finance (or "outcome-based aid"), which operates both at local level, by professionalising the local private sector, and at international level as a mode of generating aid assistance.

Electrochemical inactivation of E. coli

Brian Hawkins, RTI International

Katelyn Sellgren; Christopher Gregory; Michael Hunt; Ethan Klem; Jeffery Piascik; Brian Stoner

Electrochemical water disinfection is a cost-effective means of neutralizing enteric pathogens via production of oxidants from naturally occurring chloride. Chloride is the second most abundant chemical species in human urine, making electrochemical treatment a possible mechanism for waste water disinfection. Our research is focused on developing a free-standing disinfection system for human waste that requires no added water, chemical reagents, or energy in excess of what can be produced at the point of use. In this study, we examined the energy efficiencies of two electrode materials, boron-doped diamond (BDD) and mixed metal oxide (MMO), in the inactivation of cultured E. coli added to a solution consisting of ~25% human urine in water to simulate wastewater effluent. The experimental apparatus consisted of a 10-L reaction vessel containing 8 L of simulated effluent solution, into which either BDD or MMO electrodes were submerged and run without agitation. Samples were collected over the course of each experiment and analyzed for E. coli number (most probable number [MPN] method), total and free chlorine content, oxidative reduction potential, pH, total dissolved solids (TDS), and conductivity. Starting MPN in the experimental effluent was typically on the order of 10^7 per ml. The energy required to achieve a 97% kill ratio was three times greater using the BDD electrode compared with the MMO electrode, despite the fact that the MMO electrode required twice as long to achieve this benchmark. Subsequent optimization experiments were performed on the MMO electrode to examine the effects of varying voltage and current on disinfection efficiency; while increased voltage and/or current increased the rate at which energy was consumed, this was largely made up for by significant decreases in kill time. Interestingly, kill time was largely unaffected by variations in starting MPN across different runs. Since the current density at a given voltage is determined by the composition (TDS) of the effluent, more saline solutions should enable more energy-efficient production of chlorine and thus more efficient disinfection. Electrochemical disinfection is expected to provide an efficient means of disinfecting high-TDS solutions such as effluent composed principally of urine, making it an ideal approach to treat wastewater and reusing it at the point of use.
Thermotolerant Coliforms in Drinking Water as Predictors for Diarrhea: an Analysis of Combined Data from Multiple Studies

James Hodge, Rollins School of Public Health, Emory University

Thomas Clasen; Sophie Boisson; Simon Collin; Rachel Peletz; Howard Chang

Background: Inadequate access to microbiologically safe water is a major contributor to the global burden of diarrheal disease and a leading cause of mortality among young children. Water quality interventions have been found effective at reducing fecal contamination in drinking water and reducing risk of diarrhea. Thermotolerant coliform (TTC) bacteria are a WHO-approved indicator of fecal contamination of drinking water. However, there is conflicting evidence on the association between the quantity of TTC in drinking water and the risk of diarrhea.

Methods: Individual level data were obtained from seven field studies that measured TTC levels in household-drinking water and prevalence of diarrhea among household members during the seven days prior to the visit (7-day period prevalence). Data from the seven studies were combined into one data set for analysis. We explored the association between diarrhea prevalence and TTC levels in household drinking water using multilevel logistic regression with diarrhea prevalence as the dependent variable and log10 TTC/100ml as the predictor variable, adjusting for age, season, and study location. Odds ratios were calculated for TTC as a continuous variable to evaluate whether increases in log10 TTC/100ml are associated with an increased risk of diarrhea and as a categorical variable to evaluate whether there is evidence of a threshold level at which the odds of diarrhea become significantly elevated.

Findings: The combined data set included data for 4,017 households and 26,518 individuals. The odds of diarrhea increased by 12% (95% CI: 8-18%) for each log10 increase in TTC/100ml. For children under five the association was larger with an 18% (95% CI: 11-26%) increase in odds of diarrhea per log10 increase in TTC/100ml. The results suggest a threshold with increased odds of diarrhea at 11 TTC/100ml level and above in both all age populations and children under five. Conclusions: This study found evidence of an association between TTC levels and risk of diarrhea. These results challenge recent studies and provide support for health-based WHO guidelines that limit TTC levels in drinking water. At the same time, these results provide some evidence that increasing the minimum threshold to 10 TTC may have a minimal effect on diarrhea. Furthermore, the association between fecal contamination and odds of diarrhea found here provides further support to suggest that improving drinking water quality is an effective method of reducing the risk of diarrheal disease.

A Hybrid Approach to Monitoring and Evaluation: the Case of Dipina Esperanza in Waslala, Nicaragua

Iain Hunt, Villanova University

Nora Reynolds

Millennium Development Goal 7, Target 10, reads: "halve, by 2015, the proportion of people without sustainable access to safe drinking water" over the 1990 baseline level. Despite this goal having been achieved ahead of schedule in 2010(i), research finds troubling statistics related to water system failure rates (ii). These findings call for attention to the importance of more in-depth understanding of three key terms in the goal's statement: safe, access, and most ambiguous, sustainable. Specifically, how can we define, operationalize, and measure these terms in local contexts? In this paper, we utilize a specific case in rural Nicaragua to explore these terms and propose a hybrid approach to monitoring and evaluation that incorporates both technical performance and project outcomes, assessed by both quantitative and
qualitative methods. This paper draws on Water for Waslala’s 10 years of experience working in water supply and development in the particular context of Waslala, Nicaragua. Waslala, a region of northern Nicaragua with a population of 62,828 inhabitants, includes 12 neighborhoods in town and 72 villages in rural areas(iii). Using the case of Dipina Esperanza, a rural community with a gravity-driven water supply network serving 80 households and four schools, this paper explores lessons learned from a decade in the field. Our work in Dipina Esperanza incorporates quantitative methods for physical measurement of the technical performance of the installed infrastructure in terms of both water delivery and water quality coupled with both quantitative (household surveys) and qualitative (ethnographic home visits with observations of health and hygiene behavior) methods to deepen our understanding of project outcomes. This experience has coincided with the evolution of institutional frameworks for WaSH in Nicaragua and collaboration with local actors including the municipal government. We highlight the following characteristics of our approach as important considerations in the work for "sustainable access to safe drinking water": -We have adopted a set of key performance indicators (KPIs) that collectively fall into three categories we expect our interventions to positively influence: health and hygiene, educational attainment, and economic well-being. -Instrumentation installed in storage tanks to record water levels over time served to both evaluate performance with respect to water availability, and to estimate actual volumes of water supplied and consumed via changes in tank water levels. We view monitoring of technical performance as an essential complement to impact evaluation, as desired outcomes are predicated on a desired level of technical performance. -A water quality testing program drawing upon field methods researched by Chuang, et. al (2011)(iv) and modeled after the WHO’s Rapid Assessment for Drinking-water Quality(v) was also piloted in the community. -We also supplement this quantitative process with a more ethnographic approach, in which one of our staff members visits a sample of beneficiary houses after a project is implemented to observe how families use the intervention. We view this approach to be as critical in monitoring impact as our quantitative surveys, as it allows us to more deeply understand the extent to which families are using the water system correctly and following proper health and hygiene practices. - After third party evaluation of the system along with all others constructed in the municipality by the Nicaraguan Social Fund, FISE(vii), the municipal government started using the water system in Dipina Esperanza as a model system in the municipality. We argue that our hybrid approach to monitoring and evaluation coupled with partnerships with local and national actors provides a pathway to better understand the terms safe, access, and sustainable in the context of Dipina Esperanza that can be applied in other settings. i WHO and UNICEF Joint Monitoring Program (2012). Progress on Drinking Water and Sanitation, 2012 Update. iii https://improveinternational.wordpress.com/handy-resources/sad-stats/ iii Municipalidad de Waslala (2012). Diagnóstico municipal de agua y saneamiento de municipio de Waslala, Región Autónoma de Atlántico Norte. iv Chuang, Patty, Stephanie Trottier, and Susan Murcott. "Comparison and Verification of Four Field-based Microbiological Tests: H2S Test, Easygel®, Colilert®, PetrifilmTM." Journal of Water, Sanitation, and Hygiene for Development 01.1 (2011): 68-82. Web. v Rapid Assessment of Drinking-water Quality: A Handbook for Implementation. Rep. World Health Organization and UNICEF, 2012. Web. 14 Aug. 2014. vi http://www.fise.gob.ni/contenido.asp?idcnt=1

Acceptability and Effectiveness of Smaller Biosand Filters in Nicaragua

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Background: The biosand filter (BSF) is a household-scale, intermittently-operated slow sand filter promoted globally for household water treatment (HWTS). BSFs have been shown to effectively remove bacteria,
protozoa, and some viruses in the laboratory, and improve the microbiological quality of household water and reduce diarrheal disease among users in field trials. BSFs are typically constructed with a concrete casing and 54-cm high sand layer, which renders them difficult and costly to build and transport. Alternate designs, including commercially-available plastic-casings, and BSFs constructed inside a 10-inch PVC pipe, maintain similar dimensions but are lighter and easier to transport. A smaller BSF, with a 15-cm sand depth housed in a 5-gallon bucket, has demonstrated comparable turbidity, Escherichia coli (E. coli), and protozoan cyst removal rates to traditional concrete BSFs tested in parallel in the laboratory. To our knowledge, smaller BSFs have not been evaluated in users' homes. The goal of this field study was to compare acceptability and microbiological effectiveness of this smaller 5-gal BSF design to that of full-size PVC casing BSFs in Nicaraguan households. Methods: Fifty-two households in three rural Nicaraguan communities were enrolled by local partner Fundacion Tierra. We completed a baseline demographic survey; trained users on BSF installation and use; distributed and installed 23 large filters (in one community) and 29 small filters (in two communities); and visited households at three unannounced follow-up times: two months, six months, and fifteen months after distribution. At each visit, we administered a survey on BSF use, and collected three water samples: 1) untreated (UT), 2) directly from the filter outlet (DF), and 3) stored, treated water (ST). Samples were collected in sterile WhirlPak bags, placed on ice, and analyzed within twelve hours using Standard Methods' membrane filtration method for simultaneous detection of total coliforms and E. coli with m-ColiBlue24 media. Household survey acceptability questions (self-reported responses: still using filter, like water taste, plan to keep using; and observation of treated water at time of visit) were analyzed. Percentages of responses were calculated for small and large filters at each follow-up. Chi-squared or Fisher's exact tests of independence comparing filter types were performed at 0.05 significance. Geometric mean E. coli concentrations in UT, DF, and ST samples were calculated for small and large filters at each follow-up. Percent reductions were calculated between UT and DF means, and UT and ST means. Difference in median E. coli removal between large and small filters considering data at all follow-ups was assessed by Wilcoxon rank sum tests at 0.05 significance. Results: At all follow-ups, 85-100% of small and 86-91% of large filter users reported still using the filter; 100% of small and 94-96% of large filter users liked filtered water taste; and 88-100% of small and 94-96% of large filter users reported they will continue to use filters. BSF-treated water was observed in 83-100% of small, and 91-94% of large filter households. No differences were observed in any acceptability measure between small and large filter households (p>0.05). For small filters across all follow-ups, geometric mean E. coli ranged from 53.8-411.2 CFU/100 mL for UT, 4.5-12.8 CFU/100 mL for DF samples, and 7.9-11.3 CFU/100 mL for ST samples. Mean percent reductions ranged from 90-97% for DF samples, and 80-91% for ST samples. For large filters across all follow-ups, geometric mean E. coli ranged from 82.4-156.4 CFU/100 mL for UT water, 3.6-8.2 CFU/100 mL for DF samples, and 3.6-20.7 CFU/100 mL for ST samples. Mean percent reductions ranged from 92-96% for DF samples, and 75-96% for ST samples. Considering all follow-ups, median percent E. coli reduction between small and large filters did not differ for DF samples (small: 93%, large: 95%, p=0.62) or ST samples (small: 86%, large: 86%, p=0.36). Discussion and Recommendations: For both filter designs, acceptability measures were high and bacterial removal rates were consistent with previously-published BSF field data. As BSFs operate with size exclusion, we would expect protozoan cyst removal also to be comparable between small and large filters. Viral removal depends on filter pore volume and pause time between operation, which varies with filter size and usage, and thus viral removal efficiency may vary. Water recontamination from filter outlet to storage has been previously identified, and remains a challenge with both BSF designs. While limited by small sample size, we did not observe differences in user acceptability or microbiological effectiveness between large and small BSFs. Smaller BSFs built from local materials may be cheaper and easier to build and transport than traditional designs, and could be promoted as a viable HWTS alternative.
Sanitation Technology Platform - STePs to Launch High-Tech Sanitation Solutions

Jamie Jones, RTI International

Sonia Grego

Successfully transitioning technologies from the laboratory to market is challenging, but early field testing that is integrated with business model development can increase the likelihood that a technology reaches its full potential for scale and thereby impact. Countless efforts are underway to address the massive and mission critical challenge of global sanitation. To date, most efforts have focused on scaling basic biological solutions such as composting and leach pits. Despite their technical simplicity, scaling these solutions in a financially sustainable way has been challenging and slow yielding only moderate success stories. With new innovations beginning to emerge from the Bill & Melinda Gates Foundation (BMGF) Reinvent the Toilet Challenge, methods for field testing and validating the technology, the outputs thereof, as well as linking the technology to new business models that can promote scalability must be developed. Unlike previous attempts to address sanitation, the Reinvent the Toilet program resulted in the development of sophisticated technologies that physically and chemical treat waste with the expectation of completely pathogen-free outputs. But, like their less technically sophisticated predecessors, successfully deploying and scaling these new technologies will not be easy. The Sanitation Technology Platform (STeP) has developed a process for systematically transitioning sanitation technologies from lab to market in such a way that ensures end-user needs are appropriately considered, outputs are guaranteed pathogen-free, and technical specification are met in such a way that also facilitates commercially-viable and thereby scalability. This robust field testing practice codifies the transition of sanitation technology innovations from the laboratory to field testing to commercial launch. The STeP approach is unique in its integration of technology, market, and nonmarket factors throughout the testing process ensuring that all elements impacting successful launch, as well as their points of interdependence, are identified and addressed early in the learning process. The STeP program supports field testing of sanitation technologies developed by the BMGF Water, Sanitation & Hygiene grantees by managing test sites, defining sample analysis protocols, identifying laboratories to carry out data collection during the field test, and aggregating and synthesizing collected data. The objectives of the field testing program include: determining technical feasibility, assessing the safety of the technology and ensuring compliance with all regulations, and evaluating the usability of the technology. Field testing is expected to occur initially in three countries: India, South Africa and Senegal. Simply focusing on the novelty and productization of these sophisticated technologies is a recipe for a failed launch, as is the omission of nonmarket influences. Through a refined process, STeP assists the entity commercializing the technology with field testing support, helping identify and address key questions that relate the technology to the market and nonmarket environment in which it will be deployed. STeP employs a user-centered field testing research approach, to gain insights into the customer, market opportunity, important policy and regulatory frameworks, and socio-cultural influences which are then integrated with the work of the product development team. As the product moves closer to launch a target customer segment is selected and potential business models are tested and validated through prototyping. This holistic and iterative approach allows the commercializing agent to align the technology development with the market opportunity and thereby increase the chance of developing a sanitation product that meets the needs of the customer and effectively leverages policy and regulation to create a business model that can grow and scale. This approach is underway with the California Institute of Technology's Reinvent the Toilet technology; this example will be used as a case study for the broader conceptual model and shared during our presentation. As other sanitation technologies mature and commercialization partners seek a means by which to move the technology from the lab to the field, the STeP framework may provide an actionable guide for field testing, long term success, and scalable impact.
Improving the "Improved Sources" Metric: Construction of a Modified Water Poverty Index in Coastal South India

Luke Juran, Virginia Tech
Morgan MacDonald; Nandita Basu; Shane Hubbard

An estimated 780 million individuals lack access to improved (i.e., assumed safe) drinking water (Gleick et al. 2014). However, this figure surges when measures such as quantity, distance traveled, and quality are considered. The inclusion of these parameters—contrary to the improved-unimproved metric utilized by the United Nations, World Health Organization, and others—generates a more holistic characterization of a waterscape. Furthermore, such measures problematize the definition of improved water, which is in fact not always safe (Bain et al. 2014). Thus, this poster presents a modified Water Poverty Index (WPI) that captures several attributes of a waterscape in order to identify and compare complex issues of water poverty at various scales. This research makes use of original data collected at the household level from 14 newly constructed post-tsunami settlements in Nagapattinam, Tamil Nadu, and Karaikal, Puducherry (India). Data were collected with a survey instrument (n = 300), water quality tests (n = 375), and through qualitative interviews (n = 74) and focus group discussions (n = 14). The resultant data were leveraged to develop a WPI that is relevant to both the Indian and post-tsunami contexts. The construction of this WPI addresses principal critiques of the classic WPI, namely: a) robustness of data; b) representativeness; c) scale; d) weighting; and e) substitutability of indicators and their human values across space. Moreover, this study is novel because it incorporates new indicators that are not included in the classic WPI but were articulated by study participants as creating hazards in water provision, and because it employs three weighting schemes—one dictated entirely by study participants themselves.

Infusing Capital to Activate the Supply Chain for Sanitation Financing in Rural Bihar, India

Genevieve Kelly, Population Services International
Arunesh Singh

In India, the estimated economic impact of diarrhea and inadequate sanitation amounts to an annual loss of US$38.5 billion to the country. Within India, the state of Bihar has some of the poorest sanitation indicators in the country: 88% of rural households have no toilet facilities. The vast majority of the population of Bihar (89%) lives in rural areas, and of these rural families, 68% belong to the poorest two wealth quintiles, where access to improved toilet facilities is the lowest. There is high need for toilets in Bihar exists—84% of households in the 3SI target districts stated a desire to own a toilet, and 33% were found to have seriously considered a purchase, and had conducted some form of pricing and product research. However this has not historically translated into demand and ultimately into purchase. This is due to three main challenges—(1) Broken supply chain for toilets - while there are some locally available materials for toilet construction, the final products are often expensive, of poor quality, difficult to acquire and unsuitable for a household’s needs; (2) Low demand for toilets - need is not translated into demand and is very nascent among consumers; and (3) Limited financing - Expensive and unorganized financing to meet working capital needs among private enterprises to expand their business, as well as limited financial liquidity among consumers in the market to convert household needs into demand and purchase. To address these challenges, PSI, with funding from the Bill and Melinda Gates Foundation (BMGF) has been working since 2012 in partnership with Monitor Group (now Deloitte), PATH and Water For People to implement the Supporting Sustainable
Sanitation Improvements (3SI) Project to address the market shortcomings on both the demand and supply side to achieve sustainable and scalable solutions to meet sanitation needs among consumers in Bihar. To date, the 3SI project has made tremendous progress in the design and development of components for a standard toilet product; training and hands-on support to sanitation-related enterprises to enhance their skills to produce quality toilets; and marketing and sales efforts to assist households with the purchase decision and process of acquiring a quality toilet to meet their sanitation needs. In addition to these demand and supply activities, scale cannot be achieved without addressing the financing needs of both consumers and enterprises. This includes improving access to credit to facilitate the purchase of toilets by low-income households, and for sanitation enterprises to support business expansion. Although the 3SI project identified a gap in the market and developed a high-quality toilet that was both affordable and desirable within the price range of INR 8,000-20,000 (US$160-400), market research based on household income levels and savings practices found that only 6-8% of households have the cash on hand to purchase a product within this range outright, despite the strong preference indicated for the 3SI product over other options. Approximately 88% of households in rural Bihar will require loans for purchasing toilets. As demand increases through the availability of financing, enterprises must similarly access financing to build their capacity and ensure supply. However, financial inclusion and penetration of micro-finance institutions (MFIs) that could provide both consumer and enterprise sanitation loans in Bihar is poor. Fewer than 3% of households in Bihar have accessed loans of any type from an MFI and consumption loans such as those for sanitation are considered high risk and rarely offered. As such there is a need to activate the sanitation finance supply chain in Bihar. To ensure a viable solution for sanitation financing in Bihar, PSI has helped introduce a risk-free, capital infusion that will activate the supply chain for sanitation financing and result in an increased rate of uptake of toilets among rural households. Since January 2015, PSI is working in close collaboration with a fund manager, Friends of Women’s World Banking India (FWWB) and with various MFIs for the development and promotion of a sanitation loan product for both consumers and enterprises. Over the course of the project, PSI aims to infuse over $1.5 million into the supply chain to spark demand and facilitate enterprise growth. Initial results are extremely promising, with over 600 consumer loans and 30 enterprise loans already disbursed within 4 months of the launch, with 100% repayment rates. More than 70% of households have constructed their toilets within 30 days of loan disbursement and nearly all 30 enterprise loans were used for bulk purchases of input material for toilet construction and stock management.

Efficiently Identifying and Addressing Market Failures in Urban Sanitation in West Africa

Genevieve Kelly, PSI
Katharine McHugh; Steve Poyer

Since 1990, there has been little progress towards increasing coverage of improved sanitation in Benin, Cote d’Ivoire and Ghana. If current trends continue, these three countries will be far from meeting their 2015 MDG sanitation targets by even 2030. Transformational approaches are needed to accelerate progress in urban areas within these countries, where population coverage of improved sanitation is no greater than 36% (Cote d’Ivoire) and more than a quarter of urban Beninoise (27%) practice open defecation. The Sanitation Service Delivery Program (SSD) is a USAID/West Africa regional urban sanitation project implemented in Benin, Cote d’Ivoire and Ghana by PSI in collaboration with PATH and Water and Sanitation for the Urban Poor (WSUP). The goal of SSD is to improve urban sanitation outcomes through developing and testing scalable, market-based models that contribute to structural change within the region’s sanitation sector, with an initial focus on Cotonou (Benin), Abidjan (Cote d’Ivoire), and Accra and Kumasi
Over the course of five years the project aims to reach 1 million people with access to improved/adequate sanitation and 1 million people with access to safe management of fecal waste. These ambitious goals and transformative change more broadly, will only be achieved through systemic changes supporting a developed market for urban sanitation products and services. SSD will facilitate sanitation and fecal sludge management market development by influencing levers in the market system to create an effective, efficient, and more inclusive sanitation market for the urban poor that will contribute to project results. A critical element of SSD project planning and learning is an intensive formative (and then ongoing) market landscaping to inform potential market development activities and to better understand the target markets. Building on the Making Markets Work for the Poor (M4P) approach, SSD will develop an in-depth understanding of the urban sanitation markets in Ghana, Cote d'Ivoire and Benin. Insight gathering for the market landscaping will fill gaps identified through secondary research and involve in-depth interviews with actors along the production to use spectrum (i.e. from manufacturers and importers to service providers and end users) of the sanitation service chain. Interviews will also be conducted with actors in the financing market. Markets will be categorized by (1) core functions (products, prices, places and promotion); (2) supporting functions (such as coordination and information); and (3) rules functions (including policy, regulation, tax and tariffs). The project will pilot fresh approaches to interpret and analyze results from the market landscaping. Using a root-cause analysis and traffic light system for ranking and prioritizing market failures, the project will seek to identify the underlying causes of market failures within each function category and prioritize high-potential areas for interventions that will deliver the most impact for the target group. Through the project partnerships, including supportive donor relations, SSD is equipped to design focused interventions that will influence key market players to efficiently address failures in each market system for each country context. Furthermore, where the analysis identifies patterns of market failures across the region, successful models can be replicated and tested elsewhere. Results of the marketing landscaping will be presented alongside potential pilot interventions based on landscape findings. Most importantly, all pilots will aim to inform more efficient and inclusive sanitation market systems for the urban poor that ensures better access to sanitation via better performing commercial enterprises. Methods for tracking and assessing each pilot will be briefly introduced before the presentation is opened for discussion.

The Impact of Improved Community Water Sources on Water Quality at Point Of Use, Household-Level Water Consumption, Health and Income: Evidence from Ghana

Lila Khatiwada, University of Notre Dame

We rigorously examine the link between an improved community water system and household-level changes in water quality, water collection time, water consumption, income and health outcomes. Our impact evaluation will test the hypothesis that an improved water system at the community level will lead to household level outcomes such as improved water quality at point of use and reduced prevalence of illness, particularly diarrhea. It will also test the hypothesis that increased access to clean water will result in a substitution of time formerly reserved for collecting water to income producing activities. Finally, our analysis will include a component of willingness to pay for the improved water source. We examine these indicators using data from a five year Millennium Challenge Corporation (MCC) funded water project in Ghana. Three types of improved water systems were implemented by the project in rural communities in Ghana: boreholes, small town water systems, and pipe extensions of municipal water project. Baseline data was gathered in 2010. Three years after the completion of the community water project, a final survey was done in Feb/March 2015. We also test the water quality in the household using the IDEXX water test to see
the relationship between water quality in the household and self-reported diarrheal disease incidence. A sample of 1,200 households was selected at the baseline for the evaluation and the same households were followed in the final evaluation. We employ a pretest-posttest with matched-pair comparison groups with 100 communities (50 treatment and 50 controls). We use a difference-in-difference estimate to estimate the impacts of improved water system. Our paper will focus on quantifying the impacts of an improved community water source on household-level water quality, health, time savings, monetary savings. Our findings are relevant to the conference theme of water supply and quality. This analysis will fill a gap in the research on improved community-level water supply on household level indicators. In particular, the data provides us a unique opportunity to analyze the impact of improved water sources at catchment and relevant indicators such as water quality at point of use, income, time use, prevalence of diarrhea, and willingness to pay. Policy-makers will find this data useful for the valuation of the benefits of provision of an improved community-based water source, through the quantified impact of those sources on the indicators listed above.

**Latrine Best Practices at Engineers Without Borders**

Joshua Knight, Engineers Without Borders USA

Latrines used to meet household sanitation needs is an ancient technology with many analyses reviewing how it improves health and hygiene. These reviews have mostly been on performance and usage in case study applications. Some studies have looked at diarrhea reduction links to latrine use. What is not in many of these reviews is an in-depth look at how the high level program was developed and implemented by the organization responsible for the latrine projects. This presentation will analyze some of the factors used in the planning and implementing phases of village-sized latrine projects done by Engineers Without Borders USA between 2005 and 2014. It includes a large data set of latrine projects in many geographic regions and different socio-economic backgrounds, which shows key features of successful and unsuccessful projects for all of us to learn from.

**Monitoring Progress Towards Sustainable Sanitation and Hygiene for All**

Antoinette Kome, SNV Netherlands Development Organisation

Since 2008, SNV and its partners have been working to develop the Rural Sustainable Sanitation and Hygiene for All (SSH4A) approach, which aims to strengthen the capacity of local government, private sector and others to achieve district with sanitation coverage in their area. The approach combines insights from sanitation demand creation, governance, sanitation supply chains and finance as well as BCC. At the moment the approach is implemented in 13 countries, in over 70 districts. While strengthening local government capacities to monitor progress is part of the SSH4A programme in all countries, it was clear that an additional source of (high quality) monitoring data was needed to learn how access develops over time in the context of large scale programmes. Therefore a shared monitoring system was developed among the countries, not only to measure progress in access and use of sanitation and hygiene, but also to assess progress in enabling environment and capacity together with partners. The latter were called "sustainability indicators". Outcome indicators are measured through a household questionnaire mobile phone application, whereas the sustainability indicators are measured in dialogue with the concerned stakeholders in each district. At this moment, the programme has managed to test and standardised the household questionnaire and measurement of sustainability indicators across all 12 countries. This paper aims to share the key features, experience and some of the initial findings. The SSH4A programmes measure 3 main outcome
indicators, being: 1. Access to a sanitary toilet 2. Hygienic use and maintenance of toilets 3. Hand washing with soap at 2 critical moments A 4th indicator on safe final disposal of human waste was added last year. The inclusion of DHS asset based wealth questions (country specific) in the questionnaires, allows for wealth disaggregated information. Moreover, disaggregation is done for district, gender of the household head and disability. Each outcome indicator is a ladder consisting of 5 scenarios or levels. For example for the first indicator this means that the quality of access is not linked to toilet technology options, but to functionality or different degrees of separation of human waste from human contact. Questions and syntaxes to define these levels have been extensively tested and discussed in the different countries, so that now one consolidated questionnaire is used across all. As mentioned above, sustainability indicators are measured in dialogue with local partners trying to capture both capacities as well as enabling environment. Sustainability indicators range from the affordability of sanitation technology options for the two poorest wealth quintiles, to capacity of the local government to steer good quality demand creation in their area. Sustainability indicators are score cards with 10 items which do not only guide the discussion, but also provide an opportunity to identify improvements with partners. The shared monitoring system has helped to track progress and gaps, while reducing the burden on countries. The idea is not to replace local government led monitoring, but to have a source to contrast data and also to help learning between countries. Now reflections are emerging about the pace of progress in different countries, the level of disparities and possible causes. In particular the wealth disaggregated access data at district level are furthering reflections on how to reach the last mile and the need to make focused efforts to include this group.

Making Toilets More Affordable for the Poor Through Microfinance: Lessons Learned from Introducing Microfinance Loans for Sanitation in Rural Cambodia

Phyrum Kov, World Bank

Susanna Smets

From 2000 to 2012, access to sanitation in Cambodia's rural areas increased by only 1% per year. By 2012, 66% of population practiced open defecation which is the highest in the region. Though open defecation rates are highest among the poorest rural Cambodians at 86%, they are still quite high even among the richest at 32%. Extensive previous experience with sanitation marketing approaches illustrates there is strong household demand for sanitation and the domestic sanitation market is capable of meeting it. At the same time, challenges remain in reaching low-income households that do not have the cash to meet upfront payment costs to purchase sanitation products. While there is strong demand for improved latrines in Cambodia amongst the rural poor, this demand goes unmet largely because these consumers cannot afford to pay upfront for a latrine that meets their preferences. Having access to microloans could help alleviate this challenge; however, microfinance institutions (MFIs) often perceive non-productive loans as high-risk, particularly when the borrower is not a trusted existing business client. A 13-month pilot (July 2012-2013) was conducted to introduce microfinance for sanitation on top of an ongoing sanitation marketing program to help cash-constraint households gain access to sanitation. Two MFIs participated in the pilot offering group loans and individual loans without requiring hard collateral. Loan financial database of the two MFIs was used for the analysis to understand the average loan size for a latrine, characteristics of customers (existing vs. new customers), socio-economic of customers (poor vs. non-poor customers), loan sufficiency ratio, loan acquisition cost, and revenue. The results after the pilot have generated a number of insights that are useful for WASH practitioners and MFIs. Firstly, it is learnt that there is demand for latrines even among poor households and a sanitation loan program offered by socially-oriented MFIs helps to increase uptake of sanitation among the poor. The key success factor to this is attributable to a small loan size and a poor-
inclusive application process offered by MFIs. Secondly, MFIs can increase the number of loans offered, reduce loan processing time, and increase a household's likelihood of committing to a sanitation loan by dedicating loan officers to the sanitation portfolio. Thirdly, allowing borrowers to repay loans close to where they live increases the likelihood of interest in this loan product. Borrowers will hesitate if they have to travel long distances, especially for small loans. Fourthly, a close partnership between an MFI and a latrine business that has the motivation and capability to produce and deliver on time is needed to maximize commitments from customers and avoid losing latrine orders. Fifthly, a poor-inclusive sanitation loan program is financially viable and sustainable given the right support, and if loans are managed carefully.

Cost Effectiveness of Hygiene Promotion in Bhutan

Ingeborg Krukkert, IRC

Thinley Dem

This paper will look at hygiene interventions in Bhutan and will describe if and how these interventions are successful in encouraging safe hygiene practices; and how much they cost. This study is part of the second phase of the Sustainable Sanitation and Hygiene for All (SSH4A) programme, a four year rural sanitation and hygiene programme running from 2013 - 2017. Why looking at hygiene cost effectiveness? Since hygiene, and more broadly behaviour change, is seen as a core component of the SSH4A programme, it seemed logical to look more in-depth into the hygiene activities and its costs and see if people increase their hygiene practice levels when hygiene interventions are taken place. The study aims to guide the programme for improvements and to support decisions on where to adapt or refine hygiene interventions and where best to allocate money to. It also aims to support decision makers at the Ministry of Health by providing more insight on current costs and effectiveness of Behaviour Change Communication interventions. From the baseline findings we have seen that more than half of the sample households have no effective or limited hygiene practice levels. Key reasons were flies having access to human waste and toilets that were not properly designed. To encourage these households to climb to basic or improved levels, the programme can work on emphasizing covering the pit; and cleaning and maintenance; or it can focus on upgrading the toilet. This way, the findings provide insight in where to adapt or refine hygiene interventions; or where best to allocate money to. The study captures behaviour change using a ladder for effectiveness: from not effective and limited to basic and improved and it also captures the costs of hygiene interventions - from costs of soap at household level to the costs of implementers and government institutions for training and transport. Finally, these costs are compared against behaviour changes. Three key hygiene behaviours were observed for the purpose of this study: 1. Toilet & toilet use; 2. Handwashing with soap; and 3. Safe drinking water management. Findings Looking at the three indicators at a glance we see that for all three indicators more than 50% of the households practice hygiene behaviour that is below the basic level. Within this group, the households with lower income are doing worse than others. At the moment costs are collected from implementers and government institutions to see how much money was allocated and what was achieved in behaviour change with that money. In this presentation we will go into the costs, affordability and service levels and how this can be used for improvement of the programme, for improving hygiene interventions globally and how it can be used for advocacy purposes. The focus can also be on how the framework is developed and how it has evolved since the first hygiene effectiveness study was tested in Mozambique under the WASHCost programme executed by IRC. The angle can depend on what is best suited for the audience. Note: DfAT has provided funds for two countries: Bhutan and Nepal to follow-up on phase one.
Just How Much Household Water Insecurity do Pregnant Kenyan Women of mixed HIV status experience?: The Need for a Validated Scale

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Background: Household food insecurity has emerged as a very powerful predictor of poor health among people living with HIV (PLHIV). Although water is arguably more fundamental than food, the role of water security in the health of PLHIV has been almost entirely overlooked. Therefore, we sought to describe experiences of household water insecurity in a region of high HIV prevalence. Further, because water acquisition and water intensive chores are primarily the domain of women, we focused on women’s experiences. Methods: Pith Moromo (Luo for "enough feeding") is an ongoing cohort study in western Kenya, in which 371 women (51% HIV positive) were enrolled at less than 30 weeks gestation, and will be followed until 9 months post-partum. At the second study visit, women were surveyed about their experiences with water acquisition using a modified UNICEF WASH questionnaire. They were also asked questions about their experiences of water sufficiency and how that influenced activities within economic, nutrition, disease, and psychosocial domains. Those who reported experiencing the phenomenon either "sometimes" (3-10 times) or "often" (>10 times) in the last month were considered to be experiencing some sort of household water insecurity. Results: Approximately 88.1% of participants did not have access to water in their households. Of these, 76.9% bore the primary responsibility of acquiring water, even in the late stages of pregnancy [mean (SD) gestational age of 33.1 (2.1) weeks]. Women spent 4.6 ± 5.7 hours per week traveling to a water source - long trips during which 42.3% felt "strongly concerned" for their physical safety. In addition to the burden of acquiring water, women reported a variety of negative impacts of water insecurity on their daily activities. Economic effects included decreased agricultural and livestock productivity due to insufficient water for gardens/crops (14.1%) or animals (12.6%). Nutrition was impacted when insufficient water resulted in changes in food being cooked (18.4%) or women reported going to sleep thirsty (12.6%). Lack of water also influenced sanitation and hygiene behaviors, including preventing women from washing clothes (35.6%), washing their children (28.4%), and washing their hands after contact with feces (35.2%). Even more strikingly, over one third (35.6%) reported drinking unsafe water sometimes or often, with a larger proportion of HIV positive women than HIV negative women doing so (44.1% v. 28.9%, p=0.012). Psychosocial impacts included worrying about accessing sufficient water (40.2%), and getting into arguments with neighbors (17.2%) or within their own households (12.6%) over water. Conclusion: The frequency of household-level water insecurity experiences suggests that there are many ways by which household water insecurity may be harmful. However, without a validated scale, we are unable to 1) characterize the prevalence of household water insecurity; 2) elucidate the various economic, nutrition, disease, and psychosocial health impacts of household water insecurity; or 3) identify those at greatest risk of deleterious consequences of water insecurity, and intervening accordingly. We conclude that a validated scale for household water insecurity would be a powerful monitoring and evaluation tool that is long overdue.
Water Use Patterns and Community Engagement in Identifying Indicators of Utilization and Sustainability of Improved Water Infrastructure in the Eastern Region of Ghana

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BACKGROUND: Rural Ghanaian communities rely on a combination of rain, surface and groundwater to meet their water needs. Small town pipe systems (STPS) with shared stand pipes (SP) and private household connections are an example of a groundwater provision scheme. In this manuscript, spatial and temporal patterns in water use, perceived and measured water quality and revenue recovery are examined as potential indicators of utilization and sustainability using four towns with STPSs in the Eastern Region of Ghana as case examples. METHODS: Data streams for this study, collected between February 2014 and January 2015, included geographical locations of all public water sources in the four communities; 2-3 years of daily water use records (volumes sold and revenues, aggregated monthly) from every public SP; physicochemical water quality (WQ) in the STPS via two grab samples; daily rainfall data (aggregated monthly) from the nearest meteorological station; and qualitative interview responses from 5-6 community members per town. Temporal and spatial patterns in monthly water use and revenue recovery were explored using mapping tools and mixed effects regression models conducted in ArcGIS and R software, respectively. Multiple spatial attributes of SPs were explored using a regression tree model to develop a classification scheme. Perceived and actual water quality was assessed qualitatively due to small sample size. RESULTS: Water use patterns vary temporally and spatially within the study towns. There is a clear seasonal variation in monthly water use, which is inversely correlated with rainfall. Each millimeter of rainfall contributes a 0.12 cubic meter (CI95% -0.14; -0.10) decrease in monthly water use, however dependence on rainfall varies between individual SPs. In the spatial context, the size of the SP service area and proximity to the edge of town affect SP utilization. Largest service area (>7.5 ha) and being on the town edge is associated with the lowest monthly average water use (37.54±28.18 cu.m.) and medium service area (>4 and ≤7.5 ha) and not being on the town edge is associated with the highest monthly average water use (101.17±68.43 cu.m.). Presence of alternative water sources (streams or shallow wells) and how the perceived WQ in these sources compares to the STPS in terms of local preferences for drinking and clothes washing, is an important predictor of STPS utilization. Revenue stream is highly seasonal; however, revenue recovery is not affected by rainfall patterns or spatial SP characteristics. It is more likely that town-wide dissatisfaction with STPS WQ or maintenance and poor accounting are responsible for low revenue recovery rates. CONCLUSIONS: High temporal and spatial variation in water use and dependence on rainfall are indicative of people's general preference for alternative water sources (e.g. rainwater or surface water) as compared to groundwater in the Eastern Region. Metered STPSs and availability of water use records are an important step forward in rural water supply, providing opportunities for accountability and future planning. However, providing good quality water that users prefer and improving revenue recovery remain important challenges in ensuring financial sustainability of these systems.
Residents of fragile and conflict-affected states are less likely to have access to safe drinking water than those in stable developing countries; establishing and maintaining public water services in these states is a significant development challenge. In Port Harcourt, Nigeria, which is recovering from political and economic instability that severely degraded their public water infrastructure, less than 10km of the roughly 190km of piped water distribution network that was installed in the 1950s currently functions. The risk of contamination of non-piped sources by pathogens and harmful chemicals is high due to increasing population densities, lack of adequate sanitation infrastructure, and poor construction. Our research objective was to generate representative information on drinking water sources and their quality in Port Harcourt and to explain observed differences in quality. We developed a simple stratified sampling method for urban areas without water supply inventories that is applicable to other studies. We also examine intra-urban and seasonal variations in water quality, including settlement type (planned vs. unplanned), population density, sanitation status, and flooding. Since there were few data available on drinking water sources in Port Harcourt, we randomly selected locations for sampling, stratified by population density and areas identified as unplanned settlements. We first allocated a set number of samples to each of 17 hydraulic zones in proportion to their estimated populations. We then randomly assigned sampling locations within each zone, allocating half in each zone to unplanned settlements (we had identified these settlements by manually digitizing contiguous areas of densely packed small structures visible in satellite imagery). We took samples from the structure closest to each location, with separate samples of drinking and domestic water. Water had often been stored before sampling. We tested samples for fecal coliform, pH, electrical conductivity, turbidity, nitrate, fluoride, arsenic, and refined oil (petroleum contamination is a concern since Port Harcourt is an oil-producing zone). Preliminary results presented in this abstract are based on data collected during the dry season (Nov 2013-Feb 2014). We will also present data collected during the rainy season (Apr-Sep 2015). The random selection of water sources in Port Harcourt identified low access to treated piped water, forcing residents to rely on multiple alternative water sources. Out of the 637 water samples we collected from 386 locations (including households, small businesses, and institutions), 55% came from boreholes, 32% from sachet water, 6% from vended water, 5% from bottled water, and <1% from open dug wells and the piped network. Fecal coliforms exceeded regulatory requirements in 25% of the sources, though, when it was detected, concentrations were generally low (5% of samples had >100 CFU/100mL). Fewer than 2% of samples exceeded standards for nitrate and fluoride and no samples had detectable concentrations of arsenic or refined oils. Sachet water showed fewer samples positive for fecal coliforms (15%, n=180) than bottled (26%, n=27), borehole (29%, n=317), or vended water (32%, n=34). The majority (67%) of the surveyed residents reported using a different source of water for drinking than for cooking or washing (n=386). Water used for drinking was of significantly better microbial quality than water used for cooking and washing, reflecting that many respondents drank sachet and bottled water. Water quality did not differ significantly between planned and unplanned settlements or between highly populated and less dense areas. Notably, a similar percentage of residents in unplanned areas drank sachet water as in planned settlements (58% in unplanned vs. 53% in planned). The only spatial variations we identified were in nitrate and TDS concentrations, which were lower at the periphery of the city and higher closer to the waterfront, respectively. In addition, we will explore the impact of flooding during the rainy season as well as proximity and type of sanitation on water quality, and whether they have different effects in planned and unplanned settlements. This study was conducted in advance of planned improvements in municipal piped water supply. However, there is already extensive reliance on self-supply...
of groundwater. Municipal services may therefore have a limited impact on water quantity or ease of access. High quality drinking water could increase household willingness to pay for piped water. However, utilities in developing economies often do not monitor and communicate their water quality to customers, promoting reliance on commercial water marketed as safer. To ensure safe water delivery and build consumer confidence in new services, sector investments should include adequate attention to ongoing water quality monitoring and consumer awareness.

Hand and Object Mouthing of Rural Bangladeshi Children 3-18 Months Old

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Background: Children are exposed to pesticides, pathogens, and other environmental contaminants by placing hands or objects in their mouths. Exposure models are based on mouthing frequencies of children in high-income countries and may be inappropriate in different cultural and domestic settings. We sought to quantify hand and object mouthing frequencies of Bangladeshi children and determine if they differ from U.S. children's mouthing frequencies. Methods: Trained observers recorded five hours of mouthing behaviors of 49 rural Bangladeshi children aged 3-18 months. We compared the data with a meta-analysis of U.S. children's mouthing frequencies. We modeled mouthing frequency using 2-parameter Weibull distributions. Results: Younger children had higher hand mouthing frequencies (children 3-6 months: median 41.7 contacts/hr; 6-12 months: 35.5 contacts/hr; 12-18 months: 26.8 contacts/hr). Children <1 year had higher object mouthing than children >1 year (3-6 months: 231 contacts/hr; 6-12 months: 28.2 contacts/hr; 12-18 months: 9.8 contacts/hr). Frequency was not associated with behavior location (indoor/outdoor). Mouthing frequency of Bangladeshi children is higher than in same-age U.S. children, except for object mouthing of children >1 year, which is similar to that of U.S. children (U.S. indoor hand mouthing by age group: 23.0, 14.0, and 14.0 contacts/hr; object mouthing 9.3, 19.0 and 12.3 contacts/hr). Outdoor mouthing frequencies for U.S. children were lower than indoor frequencies. Conclusions: These results imply that exposure models should account for location-specific exposure behaviors.

Applied Research on Disinfection of Hands, Surfaces, and Wastewater to Prevent Ongoing Transmission of Ebola

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Introduction The current Ebola Virus Disease (EVD) outbreak in West Africa is the largest to date. The primary transmission risk for Ebola is in direct contact, particularly in caring for patients in late-stage disease and in unsafe burials. Indirect contact with fomites or a contaminated surface also carries some risk. Historically, health professionals have led EVD response, and water, sanitation, and hygiene (WASH) responses focused on transmission prevention in Ebola Treatment Centers (ETCs). ETC WASH recommendations are: 1) to use 0.05% liquid chlorine solution for cleaning living things (washing hands, people) and 0.5% for disinfecting non-living things (surfaces, personal protective equipment, dead bodies); and, 2) to chlorinate controlled and uncontrolled excretions of liquid wastes (vomit, soft stools, urine, blood) with 0.5% chlorine for 15 minutes, followed by disposal in a soak pit or latrine. The combination of high caseload and urban transmission in the current outbreak have led to the ETC WASH recommendations being inadequate and extrapolated for use in the community setting. As soak pits have overflowed, organizations have turned to alternative treatments for liquid Ebola wastes, including superchlorination or lime addition.
In the community, 0.05% chlorine solution is widely promoted for handwashing, despite not being recommended for widespread use due to the potential for developing dermatitis. Additionally, there has been debate and confusion about the benefits and drawbacks in terms of manufacturing, expiry, and efficacy with the three commonly used chlorine sources - HTH, NaDCC, and NaOCl - at Ebola-relevant concentrations. The current situation is that: 1) the largest Ebola outbreak to date is ongoing (albeit currently less intensely); 2) due to the outbreak’s scale, previous WASH recommendations are no longer adequate; 3) there is a disconnect between recommendations and field practice; and, 4) we lack the information necessary to make evidence-based recommendations for this and potential future Ebola outbreaks. Tufts University - in collaboration with University of Brighton and Partners HealthCare - has received a commitment of funding from USAID/OFDA to complete five research investigations to address these gaps, including: 1. Accuracy, precision, ease-of-use, and cost effectiveness of methods to test Ebola-relevant chlorine concentration solutions; 2. Comparison of expiry and efficacy of HTH, NaDCC, and NaOCl chlorine solutions at Ebola-relevant concentrations in cleaning surface and hands; 3. Comparison of soap, hand sanitizer, and 0.05% NaDCC, HTH, and NaOCl chlorine solutions in the development of dermatitis during frequent handwashing; 4. Evaluating the potential of on-site chlorine disinfection of excreta; and, 5. Evaluating the potential of simple on-site physiochemical disinfection of excreta. Methods In October, data from the first investigation, and two of the three sub-parts from the second investigation, will be available (described below). Data from the remaining investigations will be available June 2016. Investigation 1 - With widespread community use, chlorine solution quality control testing has been recommended. Responders have experience testing water treatment relevant chlorine concentrations, but there is a gap for which methods are accurate, precise, easy-to-use, and cost-effective for 0.05% and 0.5% solutions. We will: gather information from responders; obtain testing equipment; manufacture 0.05% and 0.5% solutions using HTH, NaDCC, NaOCl, and neutral NaOCl; test each method with each type of chlorine solution in quintuplicate; analyze data for accuracy, precision, ease-of-use, and cost; and, develop a decision-making tree for which method is most appropriate in various contexts. Investigation 2a - In an ETC, chlorine solution is generally made daily, so expiry is not considered. However, with community use it has been recommended to determine expiry. We will: manufacture 0.05% and 0.5% solutions using HTH, NaDCC, NaOCl, and neutral NaOCl; place duplicate solutions in opaque HDPE plastic containers at 25, 30, and 35°C; measure chlorine concentration and pH daily for 30 days; and analyze and compare results to theoretical models. Investigation 2b - It is unknown if the liquid waste cleaning recommendations are effective. We will: manufacture 0.5% solutions using HTH, NaDCC, NaOCl, and neutral NaOCl; place spiked E. coli and bacteriophage on plastic and metal surfaces; clean surfaces as recommended with each of the solutions; rinse the surfaces and measure E. coli and bacteriophage in rinse water; and, repeat this procedure with organic material present. Results To be determined. Discussion will focus on recommendations for field practice generated from the research.

**The role of WaSH and Infection Prevention Control (IPC) in an Ebola Treatment Center (ETC), Sierra Leone**

Jean-Marc Leblanc, SOLIDARITES INTERNATIONAL

Andrea Angioletti

Since February 2014, an Ebola Virus Disease (EVD) outbreak has been affecting West Africa. First appearing in Guinea, the epidemic subsequently spread to Sierra Leone and Liberia. Since the beginning of the outbreak, and during the first phase of the response, the emphasis has been placed by most national and international actors, on the containment of the epidemic by enhancing the case management and isolation of patients. This strategy was in line with the priorities identified by the United Nations Mission for Ebola Emergency Response (UNMEER). In the first two pillars: 1. Stop the outbreak and 2. Treat the infected) the role of Infection Prevention Control (IPC) activities is crucial. In EVD outbreak contexts, the World Health
Organization (WHO) advises establishing a "case management" committee in each health center and naming a professional in this committee to be in charge of supervising adherence to IPC measures. In the current EVD outbreak, the role of supervising IPC measures has been assigned to the WASH actors of the Ebola Treatment Centre (ETC) management. In November 2014, SOLIDARITES INTERNATIONAL (SI) a WaSH NGO for more than 35 years, started an intervention in the Ebola Treatment Center of Moyamba, in Sierra Leone, focusing on the WASH and IPC management of the center. This intervention is implemented in partnership with the Spanish medical NGO "Medicos del Mundo", which is in charge of the overall management of the programme and the medical management of the ETC. The unique nature of this partnership and the coordination system adopted between Medical and WASH actors in this project highlights the role of a WASH actor in the management of an ETC and more generally, in the fight against Ebola. This poster will present the specific roles and responsibilities that WASH actors can undertake in the management of an ETC during an EVD outbreak. The isolation of patients in safe facilities is the primary manner to interrupt the transmission of the disease. The main objectives of the WASH response are: - To ensure that all staff members stay safe whilst carrying out their duties at the site; - To limit the risk of contamination from the ETC to the outside; - To limit the risk of cross-contamination among patients inside the ETC. To achieve these goals, the WASH actor has to ensure: - Adequate quantity and quality of water supply and adapted sanitation systems; - Adequate and safe dead-body management and burial practices for deceased patients; - Clear and effective Infection Prevention and Control (IPC) activities IPC in an ETC is based on the reinforcement of standard precautions applied in regular health care centers (basic hygiene, hand washing, use of Personal Protective Equipment) and the application of specific measures for EVD. In the ETC, the roles of IPC activities are: establishing physical barriers, establishing rules, establishing Standard Operating Procedure (SOP) and critical support to medical activities.

Comparative Study of Financing of Operations and Maintenance of WASH Facilities in Schools

Seung Lee, Save the Children

Mohini Venkatesh; Murat Sahin

In 2013, UNICEF conducted a bottleneck analysis in 10 countries and found that 20% of what is required for WASH in Schools (WinS) is currently allocated by national budgets and that only 20% of schools had a budget for maintenance of WASH facilities and purchase of soap (1). In 2012, Save the Children conducted a study to identify the key conditions that promote the continued management of school toilets in rural Bangladesh. The study concluded a combination of on-going financial support for operation and maintenance (O&M) and incentivizing conditions are needed to realize long-term management of school sanitation investments (2). Acknowledging the need for a better understanding of financing systems for the O&M of WinS facilities, how much is allocated, and how well it works, UNICEF and Save the Children USA partnered to undertake a study on the financing of operations and Maintenance of WASH Facilities in Schools. In 2014, UNICEF and Save the Children collected data through a literature search, desk reviews by Save the Children country offices, school visits, and key informant interviews of 23 countries including in-depth case studies of 10 countries with over 120 schools observed. Desk review was used to collect the following information: National policies and standards on WinS; Government institutions responsible for schools and WinS and their national government allocation; Other sources of funds for schools; WinS costs and expenditures for the past year; WinS monitoring; Opinions on WinS O&M Eighteen Save the Children country offices that implement WinS interventions contributed country-specific information to the desk review. In depth case study data was collected using: - Questionnaire for government official interviews - Observation checklist for WinS facilities at schools - Questionnaire for school representatives - Materials and equipment cost survey for shop visits
The case studies used qualitative and quantitative data to evaluate financing and expenditures for WinS O&M and the condition of WASH facilities in schools. Ten (10) Save the Children country offices contributed data for the case studies. A purposive sampling technique was used to identify schools for visits and for selecting which WASH facilities to observe. The process for selecting schools included these steps: 1. Identify a Save the Children project site where schools can be visited easily during the active school year. 2. Within the project site(s), identify schools with WASH facilities constructed at least 1-2 years ago (be it by Save the Children, government or another organization). 3. Select 10 schools, half of which are considered to have good WASH O&M (based on Save the Children staff's professional judgment) and the other half of which do not. Armenia, Bolivia, Guatemala, Honduras, Indonesia, Kenya, Nepal, Pakistan, Philippines, South Africa programs participated in the in depth case studies. The observation checklist and questionnaire on WinS O&M were used to gather information on WinS facilities, budgets, costs, and finances for WinS operations and maintenance. Semi-structured interviews were held with key informants, who were selected by Save the Children staff in consultation with school representatives. Challenges during the data collection indicate that some of the preliminary findings will indicate that there is very little support for O&M for WinS in general. Most governments did not recognize the need for these recurring costs that allow for durability of the installations and sustainability of WinS interventions. In some cases, the misunderstanding about responsibilities between government and communities results in disused of facilities instead of rehabilitation. In cases where there are clear budget allocations, the actual expenses are much higher than what is budgeted so school communities are left with the burden to meet the financial gap - inadvertently increasing the cost of schooling for some. More global conclusions will be developed as all data are cleaned and verified. Save the Children and UNICEF hope to be able to present key findings from the desk review and case studies that provide new insights to the policy and financial needs of sustainable WinS intervention. We also hope to present a few key country cases to highlight different contexts represented by the 10 countries.

Climate Disasters and Water Shortages - How Local Adaptation is Being used to Develop Resilience to Extreme Weather Events in Pacific Island Countries

Morgan MacDonald, Griffith University

Wade Hadwen; Terry Chan; Mark Elliott; Annika Kearton

Acute water issues, exacerbated by climate change, threaten the health and well-being of people living in Pacific Island Countries (PICs). Resource limited rural communities in the South Pacific face severe freshwater shortages caused by intensifying extreme weather events and increasingly variable seasonal rainfall. This presentation reports on a multidisciplinary investigation of water and sanitation systems in eleven different communities of the Solomon Islands (n=5) and the Republic of the Marshall Islands (n=6). We use in-depth household interviews and community focus groups to examine the social and biophysical contexts of modern and traditional adaptation options designed to mitigate the effects of cyclones, floods, and droughts in coastal, floodplain, and atoll settings. Over 87% of households surveyed in the Marshall Islands, a nation of low-lying coral atolls, reported dependence on seasonal rainfall for drinking water. During times of drought, marked by months without rain, this number remains largely unchanged with 80% of respondents reporting long term storage of rainwater in private tanks and austere usage behaviours. Similar adaptive capacity is found in the Solomon Islands, a country with routine experience of high magnitude tropical storms and devastating floods. The challenge for many rural communities is, therefore, not in finding freshwater, but finding water that is free of pathogens and safe for human consumption. During heavy rainfall events, wells and surface water bodies are inundated by flood waters that contain debris and biological contaminants, including human faeces that can accumulate from open defecation.
Significantly, despite the fact that 79.1% of households felt that their drinking water was unsafe to drink, only 13.4% reported using any kind of treatment. The proportion of households drinking rainwater increased from 46.6% under normal conditions to 70.4% during floods, with equivalent reductions in the number of households drinking from rivers and natural springs. This systematic cycling of water sources and practices according to season and climate-related hazards is a form of local adaptation. Rural communities in both countries have learned to cope with climate disasters and harsh environmental conditions by optimizing available water resources and modifying consumption behaviour. Climate change adaptation in the Pacific is evolving as the confluence of traditional knowledge and contemporary technology. The ancient knowledge of village elders has transcended generations of Islanders, with teachings of disaster response and freshwater conservation. Modern adaptation options including donor funded treatment technologies, such as reverse osmosis for the desalination of brackish water, are comparatively new to PICs, with unknown long-term impacts with respect to community-level resilience. This presentation will focus on the impact of extreme weather events in rural Pacific Island communities, local adaptation used to mitigate the effects of climate change, and the need to integrate traditional and modern knowledge in order to strengthen community resilience in light of climate threats.

Experiences Training Volunteers in Emergencies to Build Resiliency in Water, Sanitation and Hygiene

Laura Macdonald, Centre for Affordable Water and Sanitation Technology

Lee Boudreau

Introduction: On 25 April 2015, Nepal experienced a magnitude 7.8 earthquake which killed approximately 9,000 and injured more than 23,000. It left hundreds of thousands of people displaced or homeless and flattened entire villages. Major aftershocks followed, the most significant of which occurred on 12 May with a magnitude of 7.3. Of considerable concern post-earthquake are the potential health impacts of the damage to the water and sanitation facilities and networks and the spread of cholera and other diarrhoeal diseases which often follow disasters. Methodology: The Environment and Public Health Organization (ENPHO), a Kathmandu-based non-governmental organization, collaborated with the Centre for Affordable Water and Sanitation Technology (CAWST), a Canadian education, training and consulting NGO, to develop a training program for volunteers to respond to water, sanitation, and hygiene needs as part of earthquake relief efforts. The focus of this training was to help ENPHO volunteers educate those affected by the disaster about local WASH issues, their link to health, and their increased importance in the aftermath of emergency situations. Results: The training program was developed and first deployed within two weeks of the earthquake. Initially, the scope of the training was limited to a one day program, but it was found during the development process that more was necessary in order to give the volunteers the core knowledge necessary. The objective of the training was not simply to provide the volunteers with information, but rather to ensure that volunteers understood the material, be able to train others, and be equipped to use the knowledge they gained to formulate useful advice in the unanticipated circumstances they would encounter. In the end, two workshops were developed: a 2-day "WASH Volunteers in Emergencies" training package as well as a 1-day follow-up module "Cholera Prevention and Preparedness." From 7 May to 16 June 2015, more than 291 volunteers were trained by ENPHO on WASH awareness in the context of emergencies. The volunteers distributed hygiene kits, produced and distributed chlorine, and facilitated health messaging and WASH awareness activities in camps and affected communities. The volunteers extended ENPHO’s reach, enabling it to conduct relief and outreach activities in 11 of the 14 earthquake affected districts. In one particular project with ENPHO and UN Habitat, 119 trained WASH volunteers reached 3320 people in Sindhupalchowk and Dolakha districts. Conclusion: ENPHO and CAWST found that despite the personal tragedy that local populations faced, they were willing to volunteer to do what they
could to help those who were even more impacted than themselves. Providing coordination and training in a timely manner empowered residents to quickly respond and assist others. By delegating the bulk of the initial workshop production to CAWST in Canada, ENPHO staff was freed up to focus on emergency response in the days immediately following the earthquake. In addition, by training community members in basic WASH concepts, ENPHO and CAWST have been able to link immediate emergency relief to long-term developmental goals.

**Socio-Demographic Determinants of Type of Domestic Water Use by Rural Households in Southern Ghana**

Alfred Manyeh, Dodowa Health Research

Vida Kukula; David Akpakli; Elizabeth Awini; Sefiamor Baah; Emmanuel Darkwah; Gabriel Odonkor; Solomon Narh-Banah; Margaret Gyapong

Introduction: Safe drinking water is a basic necessity for good health and the benefits related to an improved water supply, such as effects on health, time savings and high productivity, are quite immense. Unsafe drinking water can be a significant carrier of diseases such as trachoma, cholera, typhoid, and schistosomiasis. Drinking water can also be tainted with chemical, physical and radiological contaminants with harmful effects on human health. In addition to its association with disease, access to drinking water may be particularly important for women and children, especially in rural areas, who bear the primary responsibility of carrying water, often for long distances for use in their homes. Despite the critical need for clean water to improve child and population health, simple provision of portable water through piped systems has not yielded the expected result in most developing countries. This study examines the determinants of type of domestic water used by households in rural southern Ghana. Methods: This study comprises of 100,634 household heads from 2006 to 2013 whose information were extracted from the Dodowa Health and Demographic Surveillance System, which since 2005 has been following households and individuals in two districts (Ningo-Prampram and Shai-Osudoku districts) in southern rural Ghana. The univariable and multivariable associations between exposure variables (determinants) and household’s type of water were explored using logistic regression. Results: While the percentage of household having access to portable water increased from 64.43% in 2006 to 80.22% in 2013, household without portable water reduced from 35.37% to 19.78% within the same period. The result shows a remarkable influence of gender of household head, level of education, socioeconomic status, marital status, household size and occupation of household head on type of domestic water used by households. Conclusion: Socio-demographic variables of household heads are strong determinants of type of water used by households in southern rural Ghana. Keywords: Water, Household, Determinants, Dodowa, Ghana

**Evaluation of Effectiveness of Household Filters in January 2015 Malawi Floods**

James McGill, Church of Central Africa, Presbyterian, MALAWI

Kirsten Fagerli; Reinier Veldman

Safe water in flooded areas with low-cost water filters An experience with Siphon filters after the floods in Malawi. On 16th January 2015 the Southern districts of Malawi and neighbouring districts in Mozambique were struck by flooding, as a result of days of excessive rainfall. Over 230,000 people were displaced and more than 270 people were killed by the floods. The displaced people have been housed in a number of temporary camps, where access to water and sanitation have proven to be difficult due to shortage of clean
water sources and the temporal nature of the camps. As a result there has been an outbreak of Cholera in one of the camps in February 2015, with over 50 cases of Cholera. All bridges were washed away on roads accessing the eastern side of the Shire River such that the only access to those camps and communities was by helicopter. Large community water systems would not fit into the available helicopters. Training staff flew in with 500 low-cost Tulip Siphon Filters, distributing and educating the use of the filters to the Osiyana camp in Nsanje District, providing an estimated 5000 people with clean and safe water. To learn from the intervention and the distribution, the filters have been monitored and evaluated in follow-up visits. This has provided valuable insights in effective strategies for the distribution and use of these filters in emergency situations and the potential for future use of these filters. Some lessons learned from this intervention are: 

- Maximum efforts must be made to insure ample training time from the onset of the intervention. Multiple interventions for displaced communities occur in too short periods of time, decreasing the effectiveness of the initial trainings 
- Give extra training to key people like early adaptors, community leaders and people who are more technical, so they in turn can explain and assist families to use and maintain the filters 
- Proper follow-up is imperative, otherwise filters and buckets are not used for the intended purpose. 
- Using the filters in an emergency setting can potentially open a market for this or other Household Water Treatment options. 
- Simple usage and storage of the filtered water resulted in more adherence to use water treatment than the use of additives 
- The low-cost of the filter allows many people to be reached with safe and clean water in an emergency situation. 
- Infrastructure is needed to distribute the filters and to reach the most needy, and to insure proper usage. 
- An emergency like this can start the supply chain of filters and spare parts; this supply chain is needed for sustainable and long term use of filters. 

Keywords: Disaster, Flooding, Household water treatment, Low-cost water filter, Malawi, Safe drinking water

Early Results from iDE Ethiopia's SanMark Project

Blake McKinlay, iDE

iDE has a proven history of implementing innovative Sanitation Marketing (SanMark) approaches that enable poor, rural households to rapidly adopt hygienic latrines. In Vietnam and Cambodia, iDE has catalyzed markets for sanitation that have reached more than 900,000 people to date, and continue to thrive. This success inspired iDE to create the Global WASH Initiative, which now oversees SanMark programs in 7 countries (Vietnam, Cambodia, Bangladesh, Nepal, Ethiopia, Burkina Faso, and Ghana). iDE’s SanMark effort in Ethiopia is young, however, the country presents an enormous opportunity as there is a market of at least 50 million people. iDE is confident a vibrant sanitation market can be developed in Ethiopia where businesses are able to sell affordable, desirable, and hygienic latrine products that households are eager to buy. In 2013, iDE launched the 1st SanMark pilot project in Ethiopia in partnership with UNICEF. This 12 month effort assessed the market opportunity in 4 regions and used the Human Centered Design methodology to gather user insights to inform product and business model designs. The project ended with the MOST SUCCESSFUL sales test in iDE WASH history, surpassing even the flagship iDE Cambodia program, confirming there is a strong latent demand for improved latrines and that customers are willing to pay for a latrine (with a deposit). In 2015, with funding from the Vitol Foundation and WASHplus, iDE launched a short project to build on the lessons from the SanMark pilot and create the foundation needed for large scale. This project allows iDE to further iterate upon the product/business model and build the necessary infrastructure of trained latrine business and sales agents. iDE will: (i) Refine the product to balance customer preference for a ‘heavy’ latrine with need to decrease transport costs; (ii) Use Human Centered Design to explore how to overcome pit collapse; (iii) Determine the best price to optimize affordability and cash flow for supply actors; (iv) Develop financing options; (v) Develop a sales process and tools to fit the new product/business model; (vi) Design a recruitment, training and commission structure;
(vii) Recruit & train existing/additional businesses and sales agents; and (viii) Introduce a 1x1 coaching system. iDE Ethiopia proposes to share the good practices, lessons learned, and remaining challenges in developing a sanitation marketplace in Ethiopia at the 2015 UNC Water and Health Conference. Examples of the insights iDE could share include: (i) The essential role of Sales Agents and a site seller; (ii) How to secure a deposit; (iv) Suggestions for which businesses to engage; (v) The importance and challenge of developing an effective commission structure; (vi) How SanMark can work with the government; and (vii) Lessons learned from latrine and pit lining product prototypes. SanMark is now an accepted approach to improving rural sanitation; however, it has not yet been demonstrated at scale in Africa. This presentation would provide an excellent platform for the sector to hear tangible insights about the opportunity and challenges of scaling SanMark in Ethiopia and learn from the most experienced SanMark implementer in the sector.

Epidemiology of Diarrhea among Refugees under Five Years of Age; and Water, Sanitation and Hygiene (WaSH) Intervention In Ethiopia

Getachew Kabew Mekonnen, Addis Ababa University

Bizatu Mengiste

Background Most refugees are people under 5 years old, women and the elderly who escaped from very difficult and traumatic situations. The UN refugee agency reported on World Refugee Day that the number of refugees for the first time in the post-World War II era exceeded 50 million people. Refugees may be in a weak physical state, under stress and vulnerable to communicable diseases. Much of the burden of disease in complex emergencies is in children. The highest mortality rates in refugee populations are in children younger than 5 years of age. Child mortality rates are highest during the acute or early phase of a complex emergency. Early on, when a refugee camp is being established, public health problems such as rubbish control, sanitation and hygiene may seem less important than immediate day-to-day needs - for food, water supplies and curative health services. However, the longer a camp is in existence, the greater the risk that the environment will become polluted unless prompt action is taken. Diarrhoeal diseases, acute respiratory infection, measles, malaria and malnutrition are the most common causes of death in destabilized people. More than 25 % of the deaths are due to diarrhea and all these causes of death are preventable. Malnutrition and micronutrient deficiencies following diarrhea contribute substantially to child morbidity and mortality in refugee camps particularly in developing countries. Children are especially at high risk because of their poor resistance and they are getting more contact with contaminated things through eating or playing something like water and ground. Undernourished children are at higher risk of suffering more severe, prolonged and often more frequent episodes of diarrhea. Infants who are not breastfed have a six fold greater risk of dying from infectious diseases in the first two months of life, including from diarrhoea, than those who are breastfed. In developed countries about 70% of diarrhoea cases are of viral (40% rotavirus), 10-20% of bacterial and less than 10% of protozoal origin. Although it may not be representative 50-60% of cases of diarrhea in developing countries are bacterial (Enteropathogenic E. Coli 25%, Campylobacter jejuni 10-18%, Shigella spp and Salmonella spp 5% each), 35% of viral(15-25% rotavirus) origin, and in most cases the cause is unidentified or mixed. Moreover, some diarrhea cases like cholera, Typhoid fever, Drug resistant shigellosis and Plague cause devastating regional and global health consequences as refugees cross borders. A number of rigorous studies over the past two decades have confirmed that a large proportion of child deaths are preventable through basic WASH interventions. However, these studies also make it clear that such interventions must be implemented in an integrated way, not as stand-alone projects, or the impact will be muted. Addressing the health needs of children in complex emergencies is critical to the success of relief efforts and requires coordinated and effective
interventions. Therefore, assessing the actual burden of diarrhea, prominent pathogens and risk factors followed by demonstration of potentially effective WASH interventions in refugee camps of developing countries is mandatory. Aim of the study: evaluating burden of diarrheal diseases among children, identifying the major responsible pathogenic organisms, risk factors for, seasonal variation of diarrhea and demonstrating potential effective interventions which are relevant in reducing incidence of diarrhea. Methodology: The study subjects are children age of under 5 years with diarrhea, defined by the passing of three or more loose or watery stools in the 24-h period prior to presentation. Controls will be healthy children who will not fulfill this case definition during the two weeks preceding entry to the study. Cases and controls will be matched for their sex and full year age group. Children having taken antibiotics in the previous 2 weeks will be excluded from the study. Stool specimens will be examined to investigate enteropathogens via standard laboratory procedures (Microscopic, Culture and Molecular techniques) as part of an ongoing acute diarrhea case-control study. Quantitative data will be collected though interviewing parents of children using structured and pre tested questionnaire. Information about children's demographic characteristics, risk factors and parent's knowledge about interaction between WASH and diarrheal disease will be collected, entered (double data entry) and checked for consistency and missing values using epi-data version 3.1. The data will be exported to statistical package for STATA version 14.0) software for data cleaning and analysis. Prevalence will be determined, statistical tests such as \( \chi^2 \) for association of attributes and t-test for difference in the mean for independent samples and Logistic regression to show the relationship of Diarrhea with WASH will be used. All \( P < 0.05 \) will be co

**Establishment of WASH Governance in Urban Informal Communities: Lessons from Fiji**

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Dani Barrington; Asenaca Vakatalai; Regina Souter; Kate Sheilds

The emergence of urban informal settlements in Fiji (about 12.5% of the urban population) is a manifestation of broader social, economic, environment, health and other development challenges that affect quality of life and wellbeing. There is some understanding of the reasons for the rapid growth of these settlements and a high degree of certainty that this influx of informal settlers is inevitable. Consequently, there has been a recent a shift of government and donor focus towards the long term development of these settlements. One of the foundations for the functionality and cohesiveness of informal communities is the development of some form of governance to oversee development. Leadership structures vary based on the ethnic make-up and preferences of individual settlements. The informal settlers in Fiji are multi-racial, comprising of the I Taukei (Indigenous Fijians), Fijians of Indian descent, Fijians of Polynesian descent and a minority of others. Amongst the I Taukei faction there are different ethnic groups based on the provinces or islands from which they originate. Religion is also embedded into traditions and the construct of religious units diversifies the forms of governance in communities. Inhabitants are challenged because, despite their heterogeneous cultural and religious makeup, they will need to proactively work together toward the development and security of the community for the future. They need to organize themselves so that they are able to identify disturbances and collectively make decisions for their community and household so that their livelihood is enhanced. The focus of this study is to highlight how governance in urban informal communities can facilitate the implementation of Water, Sanitation and Hygiene (WASH) actions. In general, the growing informal settlements in the urban areas of Fiji do not have systematic development plans nor a formalised WASH policy hence the enabling actors are limited to reactive and ad-hoc WASH management. There is currently a lack of government involvement in WASH issues in informal settlements, and improving WASH is often a minor priority of settlers who struggle to feed their families each day and live with the
insecurity of not having land tenure. Communities and external actors tend to react to WASH after an outbreak of waterborne or water-based disease (e.g. typhoid, dengue, diarrheal diseases, and skin diseases). Yet it would be in the best interest of governments and communities to take a preventative, rather than reactive, stance towards WASH issues. Effective governance is necessary to take a preventative approach to WASH issues. Within Fijian communities there are traditional forms of governance, as well as contemporary governance systems implemented through various development programs. For example, the use of traditional social capital between I Taukei factions can bring together the multi-ethnic groups in a community. Comparatively, government and civil society organisations (CSOs) often promote committee systems for development discourses, a contemporary governance mechanism that serves efficiency. A governance system that leverages the strengths of the two approaches and can produce useful WASH outputs could be a practical way forward. This study has used Participatory Action Research (PAR) to facilitate sharing within and between informal communities so as to understand their WASH skills and aspirations and to plan future action. We present a case study on how two informal communities of Fiji established their WASH management bodies through this PAR process, and how these WASH management bodies are positioned within existing governance structures. The management bodies have been strengthened by considering the bonding social capital values that already exist within the community, as well as essential bridging values to connect with units outside of their communities which can assist the committee in performing its duties. The two communities have also agreed on the inclusion of a new management body that oversees WASH issues and actions and also works to maintain the sustainability of this initiative. In the process of empowering their newly established WASH governance body, the communities are partnering with WASH enabling actors (e.g. government departments and CSOs) in order to effect change. Institutionalisation of WASH into informal community governance structure is necessary because it provides the fundamental base with which solid partnerships can be established beyond the community level.

Comparative Study of Modeled and Experimental Flow in Disk and Full Size Ceramic Water Filters for Household Water Treatment in Developing Countries

Kyle Monahan, Tufts University

Ebenezer Annan; Justine Rayner; Wole Soboyejo; Daniele Lantagne

Background: Household water treatment and safe storage (HWTS) technologies can be cost-effective interventions to improve household drinking water quality and reduce the burden of diarrheal disease. Locally manufactured ceramic water filters are considered a promising HWTS technology, as they are effective, durable items. Filters consist of a silver-treated ceramic filter element suspended in a storage container fitted with a tap for dispensing treated water. In laboratory investigations, these filters remove 90-99.99% of bacterial organisms from drinking water. In the field, filter use has been associated with a 49% reduction in diarrheal disease. The potential for ceramic filters has led to an extensive research base, including research on: 1) predictive theoretical flow rate models, as flow rate is the main quality control indicator in decentralized production facilities; and, 2) the impacts of manufacturing variables (as each facility uses different recipes to make the filters) on flow rate and bacterial removal efficiency. Although flow rate literature is extensive, it remained unknown: 1) how accurate theoretical flow-rate models are in predicting actual full-size filter flow rates as confirmatory experimental testing had not been completed; and, 2) how well the flow-rate models developed for full-size filters can be adapted to disks used in laboratory testing. Methods: We specially manufactured three sets of matched full-size filters and disks (in triplicate), varying the burn-out material sieve size and firing temperature to manufacture representative
A Baseline Understanding of WaSH in Schools for Achieving Universal Access Post-2015

Camille Morgan, UNC Water Institute

Georgia Kayser; Michael Bowling

Adequate water, sanitation, and hygiene (WaSH) infrastructure can reduce mortality and morbidity rates. In low and middle-income counties, WaSH research has focused primarily on household settings. More recently, WaSH in school settings, a place where children spend much of their day, has received some attention, yet little to no cross-country population based research on WaSH access, quality, quantity, and continuity of service in rural schools has been conducted. In addition, water quality has direct impact on diarrheal disease. Diarrheal disease impacts uptake of valuable nutrients, decrease energy levels, and can cause wasting and stunting which decreases cognitive performance. Most especially, however, diarrheal disease decreases school attendance, which impacts educational outcomes, developmental progress, and gender parity. Microbiological water quality in rural school drinking water in Sub-Saharan Africa has received...
little attention and the factors associated with drinking water contamination in schools are understudied. To gauge current levels of WaSH access, quality, quantity, and continuity of service in rural schools, 2270 rural schools were randomly sampled from lists of schools across a diverse set of geographic regions in Ethiopia, Kenya, Mozambique, Rwanda, Uganda, and Zambia. In each school selected, confidential surveys developed from internationally established indicators were conducted with head teachers, and field- and lab-based microbiological water quality tests were conducted of the drinking water in each school. To study the factors associated with water quality contamination in rural schools, we used regression models. We found: 78% of schools in the rural areas sampled have access to an 'improved' water source, 41% percent safely store their water, and 74% have low-risk water quality. While 80% of schools in the study areas have improved sanitation facilities, fewer than 25% of schools met the World Health Organization's (WHO) recommended student-to-latrine ratio. While 44% of rural schools in the study area reported access to handwashing facilities, fewer than 10% had hand-washing materials (water, soap or ash, and drying materials) on the day of the survey. While 35% of schools reported access to menstrual hygiene but fewer than 20% had at least 4 of the 5 recommended menstrual hygiene facilities, which include separate-sex washrooms, clean water at the sanitation facility, door, a lock on the door, and a waste disposal mechanism. We found that improved water sources and schools with less than 30- minute collection times for drinking water had significantly lower E.coli contamination in Mozambique. Results from Kenya reveal that water treatment is associated with significantly higher rates of water quality contamination. In rural schools in geographically diverse areas of Ethiopia, Kenya, Mozambique, Rwanda, Uganda, and Zambia, we found low access to adequate sanitation and hygiene, relative to drinking water. Specifically, student to latrine ratio and presence of handwashing materials was very low in the study areas. While most schools have access to low-risk microbiological water quality, we found that factors associated with microbiological water quality in rural schools in the study areas differ across countries. Water access and less than 30 minute collection time decrease microbiological water contamination in Mozambique. In Kenya, further training may be needed in rural schools in the study area so that water treatment that improves microbiological water quality is conducted. This research is especially important as the Sustainable Development Goals are launched this year and target universal access in schools. The results from this research show the substantial progress that must be made in the areas of sanitation and hygiene to reach universal access by 2030.

Urban Sanitation in India: Preferences and Valuation of Innovative Sanitation Features under the Gates Reinvent the Toilet Technology Program

Laura Morrison, RTI International

Myles Elledge; Brent Rowe; Sumeet Patil; Brian Stoner

Worldwide, a large portion of urban populations lack access to the demonstrated benefits of improved sanitation. Under the Gates Foundation's "Reinvent the Toilet Challenge", novel strategies for conservation and recovering of resources from human waste have emerged in the projects' sanitation technologies. The challenge additionally emphasizes the importance of user adoption in technology development. This presentation focuses on individual preferences related to novel aspects of the RTI Toilet, including uses for water recycled from human liquid waste, menstrual hygiene product disposal, and hand-washing amenities. The presentation suggests which combination of novel features hold promise to promote user adoption among potential customers in India, findings which will serve as an input to the technology's development. Experimental willingness-to-pay data is drawn from a survey conducted in 2015 of 1200 households in slum communities of Ahmedabad, India. The results provide important insights into development of the RTI sanitation system's technology and user adoption strategy, as well as hold broader implications for understanding of market preferences for sanitation in high-need populations.
Measuring the Effects of Sodium Thiosulfate on E.coli Counts in Drinking Water Samples: How Important is Dechlorination?

Anna Murray, Tufts University

Emily Kumpel; Rachel Peletz; Ranjiv Khush; Daniele Lantagne

Background: Standard methods for microbiological water quality testing include collecting chlorinated water samples in bottles containing sodium thiosulfate (Na2S2O3), a dechlorinating agent. Dechlorination is recommended to prevent ongoing disinfection during sample holding and analysis, to ensure that microbiological test results reflect the actual water quality at sample collection. Previous literature indicates that sampling chlorinated water without sodium thiosulfate could result in artificially low indicator bacteria counts, although quantitative data of this effect is lacking. Through the Monitoring for Safe Water (MfSW) program, the Aquaya Institute collaborates with 26 water utilities and public health agencies in six sub-Saharan African countries to evaluate microbiological water quality practices and build capacity for improved monitoring. Many of these partners collect drinking water quality data, including free chlorine residual (FCR) and indicator bacteria, but do not add sodium thiosulfate to dechlorinate water samples collected for microbiological analysis. The purpose of this laboratory investigation was to determine if there was a difference between Escherichia coli (E. coli) levels in spiked, chlorinated water samples stored with and without sodium thiosulfate, in order to quantify the impact of sample dechlorination in drinking water quality monitoring. Methods: E. coli (ATCC 25922) was inoculated into phosphate-buffered water to attain three target doses: 1x10^5 colony forming units (CFU)/100 mL (low), 1x10^6 CFU/100 mL (medium), and 1x10^7 CFU/100 mL (high). The entire protocol, as follows, was repeated twice for each E. coli dose. 1) E. coli spiked water and unspiked buffered water were chlorinated at each of five target FCR doses (0.0, 0.1, 0.2, 0.4, 0.6 mg/L) with liquid sodium hypochlorite. 2) Five seconds after chlorination, samples were collected in sterile 4-oz glass bottles with and without sodium thiosulfate, and immediately placed on ice in a cooler stored at 4 degrees C. 3) FCR was measured in all samples within five minutes of dosing, and again after holding for 3.5-6.5 hours. 4) Spiked samples were processed for microbiological analysis by membrane filtration with m-lauryl sulfate media within 5-8.5 hours, colonies were counted after incubation, and E. coli concentrations calculated in CFU/100 mL. A Wilcoxon signed rank test for paired samples was performed to determine if E. coli concentrations differed between samples collected with and without sodium thiosulfate at 0.05 significance. Results: FCR results were as expected, as: 1) FCR readings for samples without sodium thiosulfate started near the target dose and declined during the holding time; and 2) FCR readings for samples stored with sodium thiosulfate were nearly zero, indicating a sufficient amount of sodium thiosulfate was added to quench chlorine. At the low E. coli level, all chlorinated samples collected without sodium thiosulfate had no detectable E. coli after the holding period; however, E. coli was present in four of eight samples collected with sodium thiosulfate (range 5-1300 CFU/100 mL). At the medium E. coli level, samples chlorinated at ≥0.2 mg/L and collected without sodium thiosulfate had no detectable E. coli after the holding period. E. coli was present in seven of eight chlorinated samples collected with sodium thiosulfate (range 17-5.2x10^5 CFU/100 mL). At the high E. coli level, E.coli was present in all samples, with and without sodium thiosulfate, with the exception of one sample chlorinated at 0.6 mg/L and collected without sodium thiosulfate (range 1.4x10^6-8.6x10^6 CFU/100 mL). E. coli concentrations for all chlorinated samples collected with sodium thiosulfate were greater than or equal to concentrations of equivalent samples collected without sodium thiosulfate, and this difference was statistically significant (p < 0.0001). No significant difference was seen between unchlorinated (control) samples collected with and without sodium thiosulfate (p=0.56). Discussion: Our results, the first we know to quantify sodium thiosulfate's effect on E. coli enumeration in spiked laboratory water, demonstrate that unquenched chlorine can continue to disinfect during holding time and analysis. This evidence highlights the importance of adhering to existing...
guidelines for dechlorinating samples collected for microbiological analysis. More research is needed to confirm these results with natural waters; MfSW partners are currently analyzing paired field samples collected with and without sodium thiosulfate, and we will present these alongside laboratory results. An extension of these findings is that water utilities and public health agencies in Africa may require additional training and quality control to ensure effective water quality testing and management.

The Use of Time Series Analysis in Water Quality and Health Research

Elena Naumova, Tufts University
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Many water related diseases (WRDs) exhibit strong seasonal patterns, which contribute substantially to the overall temporal fluctuation in disease counts. WRD seasonality has been demonstrated for various causal pathogens, populations and geographic locations. Seasonality has also been demonstrated in many surface and ground water quality (WQ) parameters. Understanding temporal fluctuations WQ and WRDs provides insight into patterns of disease transmission and potential interventions. The aims of this presentation are to illustrate the utility of time series analysis on measuring associations between WQ and WRDs, designing WQ interventions to reduce disease risk, and considering results of epidemiological studies in meta-analyses. For illustrative purposes, examples from community-based longitudinal studies of waterborne enteric infections conducted in Ecuador and India will be used. Changes in seasonality in both WQ and WRD counts are reflective of complex human-environment interactive processes. Man-made catastrophic events and natural disasters that cause deaths, population displacement, contamination of source water and infrastructural damages affecting availability of potable water, and pathogen ecology, may trigger long-term alterations in seasonal profiles of WRDs. The timing and intensity of WRD outbreaks can also be affected by these disturbances in human-environment interactions due to emergence of novel pathogens, viral mutations, drug resistance and severe weather events. Successful intervention programs aiming to improve water, sanitation and hygiene (WASH) conditions and to prevent disease transmission can result in changes of temporal patterns manifested by the reduced intensity of seasonal spikes. Associations between microbiological drinking WQ as assessed by indicator bacteria and WRD risk are currently largely inconclusive. This is due in part to the performance of indicator bacteria as well as the limitations of the analytical methods currently employed in epidemiological studies. Time series analysis, applied to longitudinal data collected in prospective cohort studies and by surveillance systems, takes advantage of the temporal characteristics of the observations, which is not possible with traditional cross-sectional study designs. It allows for comprehensive analysis of temporal fluctuations in WQ and health outcomes, including synchronization, lead and lag times. Additionally, considering the seasonal pattern of the disease in question during study design helps anticipate and reduce biases by properly selecting the study start and end dates, study duration, and staggered enrollment.

Menstrual Hygiene Management: A Hidden Barrier that Impacts Education of Female Students in Traditional Societies

Aftab Opel, SNV Netherlands Development Organisation

Introduction: Growing literature suggest that menstrual hygiene is an issue central to young girls which leads not only to their current development through contributing to their education but also lack of facilities at schools mean that their rights are violated to a great extent. Despite menstruation being a natural aspect of
health and life, the social stigma and silence surrounding the topic means that women and girls have to find ways to manage their menstruation with limited means and support every day, impacting their productivity, privacy and well-being. A recent global level estimate suggests that four school days are missed in every four weeks by girls because of menstruation. In Africa, 1 in 10 school-age girls do not attend school during menstruation. In India, 23% girls drop out of school after reaching puberty. Although it is difficult to attribute the effects of menstruation; however, studies show that girls seriously lack knowledge about menstruation which must have an effect. In South Asia, 32.5% of female students had never heard of menstruation prior to menarche and 97.5% of female students do not know that menstrual blood come from uterus. This has a long-term effect on school attendance, thereby their educational attainment, health and well-being, and socio-psychological life. Rural society in Lao PDR is socially isolated and culturally rigid which contribute to sustain taboos and behaviour about menstruation hygiene practices. 22.6% of its female population in Laos belongs to the age group between 10 to 19 years who are severely affected by lack of programme. This study aimed to increase understanding about the extent and magnitude of the problem to inform policy and programme and contribute to intervention design. Methodology: Data for this paper was collected in November 2014 from 38 schools in three districts in a rural province in Laos. Water, sanitation and hygiene facilities at the schools were audited and Head Teachers of all the selected schools were interviewed. One female student from each of the grades in the schools were randomly selected and interviewed using a semi-structured questionnaire. A total of 174 students were interviewed for this study which provides the basis of this paper. Findings: A high percentage of school have functional water supply (84.2%) and sanitation (76.3%) but only a few schools provide privacy for its female students (23.7%) and required materials for hygiene management (5.3%). Although school curriculum in Laos included menstrual hygiene management, 31.6% teachers did not know about it. This study also shows that inclusion in the curriculum does not necessarily mean that Menstrual Hygiene Management is properly taught in the schools. Despite that, half of the students interviewed knew about menstruation before their menarche but only 8% students mentioned ‘teacher’ as their source of information. For the rest, mothers, friends and female kin were the main source of information which is considered to be the main route to cultural learning. 25.8% girls interviewed were either at school or somewhere outside of their home when they experienced their first bleeding. Thus, for most of the girls stepping into the womanhood was scary (66.7%), embarrassing (16.1%) or annoying (15.5%). Although, almost all the girls interviewed (97.1%) used disposable products, but 67% girls do not feel comfortable at schools. They don’t feel comfortable sitting next to boys (82.7%) and many can’t maintain privacy (75.9%) at school. Although most of the girls declined to miss school during menstruation but 40.8% girls mentioned that many of their friends do not come to school during menstruation. This indicates high level of absenteeism related to MHM. Over one-third of the girls mentioned that menstruation affects their school performance since they cannot fully concentrate in the classes during menstruation. Girls also mentioned about a range of social restrictions on them including restrictions on social movement, dietary intake, and religious activities. Poor MHM also caused to them some health effects that include itching, smelly discharge, unusual discharge, redness and swelling.

Conclusions: Although WASH facilities at school and access to disposable products are considered to be the most important components of menstrual hygiene management but this study indicates that knowledge and social restrictions deserves equal attention. On the other hand, inclusion of menstrual hygiene lessons in the curriculum does not necessarily mean that they are taught properly in the classes that may help the girls to prepare to step into the womanhood. Unless formal education systematically provides improved knowledge, social and cultural constructs related to menstruation will remain dominant. It is therefore important to design and implement comprehensive programmes to address this hidden barrier that affects women development.
Assessing Faecal Matter Flows in a CityScale: Preliminary Results of Implementing the SFD approach in 50 Cities

Arne Panesar, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

It is widely acknowledged that despite timid progress, at current rates the Millennium Development Goal (MDG) related to sanitation will not be reached by over half a billion people (WHO/UNICEF JMP 2014). Even against the backdrop of higher chances for urban populations to have improved sanitation than for rural ones, urban settings still pose substantial challenges to the sanitation crisis. Population growth in cities outpaces gain in access to sanitation, with 750 million urban dwellers in continuously growing cities still lacking access to safe and hygienic toilet facilities that ensure health and dignity. Also, the MDG target does not take account of the sustainable management of excreta from containment and conveyance to treatment and final safe disposal or end-use for resource recovery, thus hiding a much larger problem. In 2013, the World Bank - Water and Sanitation Program (WSP) commissioned a study to examine global trends in Fecal Sludge Management (FSM) using 12 city case studies as a basis. The desk-based study was a rapid assessment based on secondary data sources supplemented with interviews with key informants, resulting in new tools for assessing the context and outcomes relating to the flow of fecal matter through the city, namely the shit-flow diagram (SFD) and service delivery assessment. The SFD summarizes and presents how excreta is or is not contained as it moves along multiple pathways in the sanitation service chain, while the service delivery assessment looks at the enabling environment in the city concerned. SFDs focus the discussion on where the real sanitation gaps are, therefore guiding priorities and interventions. The diagrams are an easy-to-understand advocacy and decision support tool, understandable and suitable also for non-technical people and have since become widely used to illustrate and visualize excreta flows in urban settings. Building on this study, an initiative of six international institutions active in the sanitation field has been working collaboratively over the last one year to establish consistency in the methods and procedures, to achieve a greater level of confidence and credibility for the development of SFDs and analysis of the service delivery context. The SFD Promotion Initiative consists of the World Bank - Water and Sanitation Program (WSP); the Global Sector Program on Sustainable Sanitation of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ GmbH); the Department of Water and Sanitation in Developing Countries (SANDEC) at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG); the water@leeds research group of the University of Leeds (UoL); the Water, Engineering and Development Centre (WEDC) of Loughborough University and the Centre for Science and Environment (CSE). The outcome will be a standardized approach to two different levels of data collection to produce city-wide SFDs: desk-based and field-based. The methodology is currently being implemented by the SFD Promotion Initiative in 50 cities and will enable drawing lessons from the field. In this presentation the preliminary findings from the field test of the methodological approach are introduced and key lessons based on first results are discussed.

Understanding Perceived Access to Water in Uganda: Associations with Established Measures of Access and Health

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Objective: Access to water has been associated with myriad health concerns. However, measures of access vary and cross-study comparisons can be difficult and may not reflect the differing priorities of users. It is not known whether there is a close relationship between the established measures of access and perceptions of access to household water. This study aimed to: 1) measure five aspects of access to household water (reliability in access, reliability in source, distance, time, ownership); 2) examine the
The relationship between perceived level of access to water and other measures of access; and 3) compare the ability of one established measure of access (minutes to source) versus perceived access to predict percentage time spent ill. Methods: Households in Uganda’s semi-arid savannah (n=100) were recruited, as this region involves an annual extended dry season and few government-provided water sources. Baseline anthropometric measurements and repeat morbidity histories every two weeks were collected for all household members. A survey was conducted after four months of health data collection. Separate linear regression models were fitted to test which aspects of access to water were associated with self-reported access. Next, hierarchical linear regression models were fitted to test the relationship between self-reported level of access and percentage time ill. Results: During the four-month study period, participants were observed for an average of 102 days. In comparing the ability to predict percentage time ill between an established measure of access (minutes to source) versus perceived level of access, only perceived level of access was significantly associated with percentage time ill but the effect was small (β = -0.83, p < 0.10).

Conclusions: A better understanding of the drivers of perceptions of access to water and differences within communities may provide useful insights into social dimensions of access, which either help or hinder health, especially in areas with very poor access by typical standards. These social structures may be particularly salient to avoid conflict into the future, with projected water shortages across sub-Saharan Africa.

**Linking the Environment with Humans: Evidence of Global Spread of Extended Spectrum Betalactamase Escherichia coli Producers.**

Claudia Perez Rodriguez, University Of Nicaragua

Kathleen Brown; Erick Erick Amaya; Daniel Reyes; Sylvia Becker-Dreps; Elizabeth Ryan; Samuel Vilchez; Mark Sobsey

Background: The emergence and spread of antimicrobial resistance bacteria (ARB) has become a major global public health concern. While there is scientific evidence supporting that national and global surveillance is essential for understanding which bacteria may ultimately generate outbreaks, limited data exist from shared ARB in environmental and human sources. As such, co-evaluation will be critical to positively impact surveillance methods and interventions geared towards protection of both environmental and human health.

Methodology: We conducted a cross-sectional study during April to July 2015, in different peri-urban and rural areas among defined communities of Leon, Nicaragua and Chapel Hill, NC, USA. Approximately 500 isolates of suspected ESBL and KPC Escherichia coli producers (detected in ESBL and KPC Chromogenic media) were analyzed from different waste and surface waters, and including stools of one year old healthy kids living in Leon near the sources of exposure (IRBs No.: 14-5233H & ACTA-129). All samples were deeply characterized by similar phenotypic and molecular methods (e.g. Kirby Bauer, Hodge, PCR and PhP) to determine their relatedness and clonality in these two geographically distinct, coastal regions.

Results: Our results showed that 95% of the suspected ESBL E.coli were real ESBL producers of the TEM, SHV and CTXM betalactamases families. The remaining 5% were characterized as broad spectrum betalactamases producers of the Amp-C types. Also, 90% of the suspected KPC E. coli were confirmed by the Hodge modified assay to be KPC producers. In terms of clonality between ESBL E. coli from Leon and Chapel Hill, we found 32 common clones that cluster more than 2 isolates and 18 unique isolates. The most interesting to this point is that out of these 32 clones we found 4 clones clustering Chapel Hill and Leon isolates, of which 3 of them were recovered from Hospital, raw and secondary sewages. The other clone
cluster isolates were from Hospital, raw and secondary sewages of Chapel Hill and Leon and from the stools of healthy kids of Leon. Conclusions To our knowledge, this is the first report linking circulating environmental ARB isolates and those present in the gut microbiota of young healthy kids. Given these findings that the same ARB clone was detected in healthy kids from Nicaragua and treated sewage water from Leon and Chapel Hill, the essential roles for UNICEF WASH strategies for the control of ARB was sub-optimal. Global spread of ARB merits evaluation across other geographic regions in US and abroad using parallel, matching methods that may reduce future threats and outbreaks.

**Water and Public Health in Chiapas, Mexico**

Rebecca Peters, UC Berkeley

Two intersecting concerns in development studies include gender inequality and inaccessibility to safe and affordable drinking water; these are issues prevalent in rural communities of Chiapas, Mexico. In five small-scale rural communities of Chiapas where NGO initiated and community managed water systems seek to address these concerns, this research asked how the gender composition of the management of water services influences people's perception of the quality of a given water service. This question was influenced by the need for research on perceptions of water quality in developing countries and the importance of understanding and promoting gender equity as a process involving men and women, as identified by Doria (2010) and Cornwall (2000). Using ethnographic tools including focus groups, semi-structured interviews, and participant observation, data was gathered at each of the five water systems, two of which are managed by committees made up entirely of women and three with mixed-gender committees. The communities' experiences demonstrated gender inequalities and uneven access to water. The results suggest that the gender composition of the management carries greater influence over a person's perception of the drinking water service in communities where the gender composition and distribution of responsibilities among committee members challenge the gender norms in that community. These findings suggest that organizations dedicated to developing safe water services should consider factors such as gender norms and community dynamics as a way to improve access to safe drinking water sources.

**Economic Gains from Good Water and Sanitation**

Lesley Pories, Water.org

Water.org has been pushing the boundaries of microfinance with WaterCredit, a program that uses microfinance to empower the world's poor to access water and sanitation. The primary hurdle that this program encounters is the general assumption that loans for water and sanitation are too risky because they are perceived as consumptive rather than income generating. This presentation seeks to prove that assumption wrong by using quantitative data that measures time saved as a result of improved access to these important assets and calculates the economic gains to a household based on these time savings in India. Data will be collected from interviews with current and past WaterCredit borrowers across India that measures time saved by construction of the WASH asset as well as data collected about how that time saved was utilized. Economic values will be extracted based on indicators such as: extra income generated from extra hours available to work per day, extra income generated from days not missed due to water-borne illness or the need to collect water, school and education-related impacts of not being sick or not missing school for water collection, and increased household income due to reduced medical bills. The positive correlation between water, sanitation and economic development is understood in certain circles but remains to be proven and communicated globally. The data mentioned above is under collection with nearly

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all borrowers interviewed to date able to point out the economic advantages the household water connection or toilet has had upon the lives of their families. All results will be collected by August 2015, leaving several months for analysis and recommendations. A key recommendation will be that lending institutions review this data and, based on the findings, reassess their reluctance to lend for these "consumptive" assets. Another recommendation specific to India will be to use this information to encourage the Reserve Bank of India to include Water and Sanitation as part of nationally-promoted "Priority Sector Lending" sectors.

AquaPak Solar Thermal Water Pasteurizer for use in Emergency Situations

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Emergency is any upland event that poses immediate risk to health, life, environment or property. One of the most important factors in a crisis, especially after experiencing an earthquake is the extreme need for water. The need for safe water is a threat to the public health during and after incident. Destruction of water sources such as springs, wells, aqueducts, broken sewage pipes and no power are the main reasons for water cut off or water pollution during emergency situations. Lack of water can lead people to use contaminated water for survival. Even water from mobile tankers or stationary tanks installed in the affected areas won’t be completely safe due to the lack of protection from harvest to consumption. During these crises the public will need to use and transport safe water until a long term drinking water supply is available to the population. AquaPak is one of the options suggested in this paper as a highly reliable method to pasteurize water by only using sunlight. According to World Health Organization, Pasteurization has the highest rank of biologically removal efficiency (99.9999%) for all pathogens among alternate household water treatment options. AquaPak is a single batch unit, designed for individual use. With the aim of improving health and sanitation for poor people in rural area of developing countries or people deal with water shortage in emergency situation, AquaPak is able to pasteurize maximum of 5 liters of water within 3 to 5 hours depends on sun radiation. The AquaPak is a ready-to-use product constructed of The Food and Drug Administration (FDA) approved Ultra Violet inhibited polyethylene which is quite durable. The current size is about 14 inches square (0.35 meters). The AquaPak is comprised of several layers of materials that can easily, reliably, and inexpensively be assembled using a sealing machine. The sealing process bonds the edges of the plastic tightly enough for the AquaPak to pass a 10-foot (3 meter) drop test when filled with 3 liters of 80°C water. The AquaPak includes a glass indicator known as the WAPI (Water Pasteurization Indicator). The WAPI is filled with an orange-colored wax that melts at 65°C to indicate the start of the pasteurization process. The WAPI can be removed and inverted for reuse after the wax has resolidified. The WAPI is made of glass and is hermetically sealed. In experiments conducted by BioVir Laboratories, San Francisco, CA, on water contaminated by viral pathogens and by Environmental Engineering Laboratories, San Diego, CA, on water contaminated by bacterial pathogens, the AquaPak eradicated over 99.99% of the pathogens present. The AquaPak also includes a roughing filter, charcoal filter, and final filter. These accessories take out larger debris and help to improve the taste of the water. The AquaPak can be used on any relatively flat surface including roofs, the ground, or even strapped to someone’s back or also carried by hand. The bubble pack front insulation allows the unit to be placed in various locations without concern of maintaining a proper air gap for insulation. Other advantages of AquaPak: Easy to use and easy to transport, especially for refugees who are always in move; Has a detector to prove if water reached pasteurization and safe to drink, it is called WAPI (Water Pasteurization Indicator) and invented by Dale Andreatta; There is no need for pre filtering of water as the effectiveness of pasteurization is not influenced by turbidity, however in case users wanted to have better looking water a rough filter is provided with each AquaPak; Has its own storage which prevents post contamination; Has chlorine tablet in case weather is cloudy or rainy
Evaluation of Household Drinking Water Filter Distributions in Haiti

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Background Household water treatment and safe storage (HWTS) can be cost effective at improving drinking water quality where access to water and sanitation infrastructure is limited. In Haiti, 52% of rural and 12% of urban populations do not have access to an improved water source. In a 2012 national survey, 71% of households self-reported treating their water, only 1% of which reported using filtration-based technologies. However, household filter promotion in Haiti has increased since the earthquake and cholera outbreak in 2010, with more than 140,000 biosand, ceramic, Sawyer, and Lifes straw filters distributed. There is currently little evidence on the effectiveness and sustainability of filtration-based HWTS programs in Haiti. In this research, we evaluated five programs that distributed filters in Haiti since 2010 to identify and share lessons learned about implementing household filtration programs in Haiti.

Methods: Programs that distributed filters in Haiti between 2010-2014 were identified and invited to participate. Each participating program provided distribution lists, from which 50 households were randomly selected to carry out surveys and water sampling. The two-part survey included 48 background questions, followed by 46-48 technology-specific questions. Three water samples - untreated, direct-from-filter, and stored treated - were collected steriley, placed on ice, and analyzed within 12 hours using membrane filtration for simultaneous detection of total coliforms and Escherichia coli (E. coli) using m-ColiBlue24 media. Effective use was calculated as the percent of target households that improved their water quality from contaminated (in untreated sample) to uncontaminated (in stored treated sample).

Results: Four of six organizations identified elected to participate in the study. The participating organizations implemented five filter programs: two biosand, two ceramic, and one Sawyer. Biosand and ceramic filters were locally-manufactured, at four different manufacturing facilities; Sawyer filters were imported. Regular follow-up was completed only in the biosand programs; and recipients paid a subsidized price for the filters in both biosand and one ceramic filter program. The average time since filter distribution was <6 months to 1.3 years. A total of 223 household surveys were carried out (44-46 per program). Overall, 98-100% of biosand, 82-89% of ceramic, and 96% of Sawyer households surveyed reported receiving the filter; and 78-80% of biosand, 27-50% of ceramic, and 57% of Sawyer filter households were provided a filtered water sample on the day of the unannounced survey visit. Breakage was the primary reason for disuse in one ceramic filter program. Safe storage was observed in 7-100% of biosand, 95-100% of ceramic, and 66% of Sawyer filter households. Across all respondents, 77% reported sometimes drinking untreated water. For biosand filters, the geometric mean E. coli was 29.3-691.3 CFU/100mL in untreated, 1.1-1.5 in direct-from-filter, and 2.3-6.1 in stored treated waters. In ceramic filters, the same results were 6.6-78.5 in untreated, <1-21 in direct-from-filter, and 1.2-16.4 in stored treated waters. For Sawyer filters, results were 12.6 in untreated, 1.0 in direct-from filter, and 2.2 in stored treated waters. The effective use (using a breakpoint of 1 CFU/100 mL E. coli) was 20-34% in biosand, 0-29% in ceramic, and 27% in Sawyer filter programs. Using 10 CFU/100 mL as the breakpoint, the effective use was 37-54% in biosand, 9-22% in ceramic, and 23% in Sawyer filter programs.

Discussion: Our results suggest potential for sustained and effective use of filtration-based technologies in Haiti, although we identified themes and challenges consistent and expanding upon previous literature. These include: 1) a greater percentage of households had filtered water where organizations provided regular follow-up; 2) disuse of ceramic filters was high where no follow-up or supply chain existed to replace broken filters; 3) the percent of respondents that reported sometimes drinking untreated water was high
Diarrheal disease is a leading cause of mortality in children < 5 years of age, yet it can be prevented through safe water, sanitation and hygiene conditions. Access to sanitation facilities that safely contain waste is fundamental for preventing environment transmission of infectious fecal pathogens. Current global sanitation monitoring tools measure household access to "improved" or "unimproved" sanitation facilities based on facility design. Households that share an otherwise-improved facility are not considered to have improved access. These indicators focus primarily on the "contain" part of this equation - the capacity for facilities to minimize the risk of exposure to human excreta in a facility and to install barriers between excreta and the environment. Facility-level design is important for preventing infectious disease transmission, but fecal exposure often occurs outside a sanitation facility from environments impacted by open defecation. It is unclear whether shifts from unimproved to improved design reduce exposure via environmental pathways. Also unclear is how poor use of available facilities modifies the effect of access to an improved sanitation facility. Compared to households with private toilets, households that depend on public toilets are particularly inconsistent at using a facility by all members of the household, especially by children. Thus, these households may experience greater levels of within-household fecal contamination compared to households with private or compound toilets. This study analyzed the association between a household sanitation access and use score and the presence and concentration of fecal indicators on household surfaces and hands. Surveys, environmental sanitary inspections and collection of handrinse and swab samples were conducted in 71 households in four neighborhoods of Accra, Ghana, a city with low overall household sanitation access. A sanitation score was developed based upon sanitation access level, the defecation location for children between 5-12 years and < 5 years of age, the feces disposal practices of other mothers in the compound, and the observation of human waste in the compound. Swab and handrinse samples were tested for E. coli and human adenovirus. Hierarchical linear and logistic regression models adjusting for random household effects were used to estimate the association between the sanitation score and the presence and concentration of E. coli and human adenovirus. Public latrine access (n=49) was not associated with household E. coli or human adenovirus contamination compared to a private or compound access (n=22). The sanitation score that adjusted for household- and compound-level defecation practices improved model fit and was associated with increased human adenovirus concentrations on surfaces (Prevalence risk ratio (PRR)=1.2; 95% Confidence Interval (CI)=1.1-1.4). The score was not significantly associated with E. coli log concentration on hands (PRR=1.0; CI=0.9-1.2) or surfaces (PRR=1.0; CI=0.9-1.1), although animals observed in the household did decrease E. coli log concentration on surfaces (PRR=0.5; CI=0.3-0.7). Our study demonstrates a score that combines sanitation access and use, and accounts for within-household practices, is a valuable indicator of environmental exposure to human feces in the household. Adoption of this score could improve global indicators of access to safe sanitation.
A Rapid and Simple Metric for Assessing the Sustainability of Safe Water Provision in Healthcare Facilities

Kate Robb, Center for Global Safe Water at Emory University
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In the developing world, significant barriers exist to ensuring sustained safe water provision in healthcare facilities (HCF). The 2015 Sustainable Development Goals include a provision (Goal 6) to "provide universal access to safe drinking water in health centers." An estimated 38% of HCF in the developing world lack an improved water source. The adoption of Sustainable Development Goal 6 not only impels over a third of HCF to gain access to an improved source, but also necessitates better tools to assess conditions, track improvements, and measure sustainability of safe water provision. The Center for Global Safe Water (CGSW) at Emory developed a sustainability metric to measure the ability of HCF to maintain water treatment systems and provide safe water over time. The metric uses mobile data collection, allowing rapid data visualization and dissemination between stakeholders. The metric builds off a previous sustainability metric designed by the CGSW and incorporates lessons learned through literature review and three years of fieldwork evaluating sustainability of safe water in HCF in Honduras and Ghana. Sustainability is measured using four domains: Technical feasibility, On-Site Capacity, Financial and Operational Accountability, and Institutional Engagement. Each domain is divided into four subdomains and evaluated based on indicators. The indicators are scored (0-4) by a pre-programed algorithm using inputs from surveys with HCF personnel, observations, and water quality results. The total sustainability score (also 0-4) is based on the domain and subdomain scores derived from the indicator scores. The higher the score, the greater the evidence of an enabling environment for sustainability. A score of 2 is defined as the cut-off below this score, there is not evidence of an enabling environment for sustainability. The sustainability score, and the breakdown of its parts, allows for a nuanced understanding of sustainability in the context of a particular HCF. The score is used by a HCF and/or donor organization to target efforts toward specific domains of sustainability. For example, the previous version of the metric was deployed in 10 hospitals in Honduras and Ghana at 3 time points between 2012 and 2015. At baseline, the average sustainability score was 2.1 in Honduras and 1.4 in Ghana, indicating that the Honduran hospitals were vulnerable to becoming unable--and the Ghanaian hospitals were unable--to sustain safe water provision. Through capacity strengthening and infrastructure improvements guided by results from the sustainability evaluations, the scores improved to an average of 3.3 in Honduras and 2.0 in Ghana. In summer 2015, the new version of the sustainability metric will be deployed in 20 hospitals in Cambodia and Uganda. The new version of the metric differs from the previous version in that it 1) uses mobile data collection, 2) can be used in healthcare facilities of various sizes and with various water treatment technologies, and 3) uses a pre-programed analysis for real-time results. Results from the summer 2015 assessment will be used to make recommendations for improved sustainability and examine how sustainability threats and opportunities vary by site and country. The sustainability metric is an important step toward the assessment of barriers and the development of mitigation strategies to attain universal and sustained safe water provision in HCF. Furthermore, the findings contribute to the evidence-base for promoting safe water in HCF as a priority within the global water sector.
Evaluation of WASH Infrastructure and Resources in Healthcare Facilities in Cambodia and Uganda

Kate Robb, Center for Global Safe Water at Emory University

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The 2015 Sustainable Development Goals include a provision (Goal 6) to provide universal access to safe water, sanitation, and hygiene (WASH) in healthcare facilities. Currently, little is known about the status of WASH in healthcare facilities in low and middle income settings. Safe water, sanitation and hygiene in healthcare facilities play critical roles in infection prevention and control. The adoption Goal 6 necessitates better tools to assess WASH conditions in healthcare facilities and track improvements. To meet this need, the Center for Global Safe Water (CGSW) at Emory University developed a tool to assess WASH infrastructure and resources in healthcare facilities in low and middle income countries. The tool utilizes survey data, observations, and water quality indicators. Researchers at the CGSW developed the tool drawing from over four years of experience evaluating WASH in healthcare facilities in Rwanda, Ghana, and Honduras and through discourses at global meetings regarding the key gaps and indicators needed to advance the status of WASH in healthcare facilities. The tool includes modules on water, sanitation, hygiene, infection control, medical waste management, waste water, electricity, and accessibility of WASH resources. The WHO Guidelines for Environmental Health in Healthcare Facilities and the proposed indicators for the 2015 Sustainable Development Goals were used as a guide to develop many of the survey questions and observations. Survey questions and observations were also adopted from several large-scale hospital assessments including the Service Availability and Readiness Assessment (SARA), the Service Provision Assessment (SPA), and the Service Delivery Indicators (SDI). The tool will be deployed in April-August 2015 in at least 20 district-level healthcare facilities in Cambodia and Uganda. All provide both inpatient and outpatient services for adult and pediatric patients. Surgical care is available but the complexity of surgical services varies. Hospitals included in this study will be part of a scoping exercise to identify hospitals that meet selection criteria for the donation of water treatment systems by the General Electric Foundation.

Preliminary pilot data collected by the CGSW in Cambodia and Uganda suggest that while the majority of the district-level healthcare facilities assessed do have access to improved water sources, the reliability and availability of water is limited due to power outages, dry seasons, aging infrastructure, and unpaid water bills. None of the sites had water that met WHO guidelines for safe drinking water and no water quality monitoring system was in place. Most hospitals had water distillation equipment for preparing water for laboratory and surgical purposes; however, not all distillation equipment was functional. No other hospital-level water treatment occurred at the sites but some caregivers were observed boiling drinking water and many patients and staff purchased bottled water for drinking. Toilet facilities were rudimentary and access to sanitation and handwashing facilities was limited for patients and their families. Most toilet facilities were not designed to be accessible for patients with disabilities. Soap was not available for patients at any of hospitals, while the majority of handwashing stations for doctors and nurses did have soap. Most hospital waste was disposed of in on-site, unlined pits or burned. By September 2015, we will have a comprehensive dataset on the status of WASH infrastructure and resources in at least 20 healthcare facilities in Cambodia and Uganda. The data will help to identify where monitoring could be improved to drive investment in operation, maintenance, and facility upgrades. The data will also contribute to the evidence-base for advocacy and action in the areas of WASH, healthcare facilities, and improving health outcomes.
Characterizing Determinants of Hand Contamination Across Public and Private Domains in Low-Income Neighborhoods of Accra, Ghana

Kate Robb, Center for Global Safe Water at Emory University
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An estimated 72 percent of the urban population of Africa now lives in slums, which are often characterized by poor access to sanitation and hygiene services and high rates of diarrheal disease. There are limited data on the relationship between fecal contamination in the environment and fecal contamination of hands in low-income, urban settings. The SaniPath study examined sources and movement of fecal contamination and risks of exposure to fecal contamination in four low-income neighborhoods in Accra, Ghana. This analysis assessed the relationship between environmental fecal contamination and hand fecal contamination in these study neighborhoods. Handrinse samples and other environmental samples (stored drinking water, surface swabs, and soil) were collected from children and adults in four settings: households, public latrines, schools, and nurseries, and analyzed for fecal indicator organism concentrations (Escherichia coli and enterococci). Hand contamination levels were characterized by neighborhood and demographic factors using analysis of variance (ANOVA), and linear regression models were constructed to predict hand contamination from fecal contamination of environmental samples. Handrinse samples had a mean E. coli concentration of 2.53 log10 colony forming units (cfu)/pair of hands (range: no detectable E. coli (<1 cfu/pair of hands) to 5.19 log10 cfu/pair of hands) and a mean enterococci concentration of 3.08 log10 cfu/pair of hands (range: no detectable enterococci (<1 cfu/pair of hands) to 5.85 log10 cfu/pair of hands).

Handrinse samples from public latrines had the highest concentrations of E. coli, while handrinse samples from nurseries had the highest concentrations of enterococci. After normalizing E. coli and enterococci concentrations by average hand surface area, children under five had the highest levels of E. coli and enterococci hand contamination per cm² of hand surface, while adults had the lowest levels of hand contamination per cm² of hand surface. There was a moderate, positive correlation between E. coli and enterococci handrinse concentrations (r=0.33), with higher enterococci concentrations across all settings. The correlation between E. coli and enterococci concentrations was highest for handrinse samples from nurseries and children under five, while there was no correlation between E. coli and enterococci concentrations in the handrinse samples from schools and children 5-12 years old. These differences could support previous reports that enterococci has a longer survival time on hands than E. coli and that there is better correlation between these two measures in settings where there is frequent, recent fecal contamination of hands. E. coli concentrations on swabs of surfaces were a significant predictor of handrinse E. coli concentrations (p-value<0.0001). Neighborhood and setting were also important predictors of E. coli hand contamination in this population, because they reflect socioeconomic status, access to sanitation and hygiene facilities, daily activities, and age category. Measures of fecal indicator bacteria on children’s hands may be a useful surrogate for exposure to fecal contamination in their immediate environment - especially in settings where handwashing is infrequent and children typically eat with their hands. Future studies should focus on determining the strength of the association between fecal contamination of environmental surfaces and hand contamination in different settings and the implications for pathogen transmission.
Reuse of Grey Water within Households and Communities: Benefits, Risks and Guidance

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Introduction: By 2050 more than half of the world’s population is expected to live within water-stressed regions. Increasingly, more water users will be competing for limited water supplies. On-site reuse of greywater is seen as a means of reducing water consumption in homes and communities. As part of a suit of solutions, water recycling innovations are being explored to augment domestic and community water needs; here we review enteric and water-based pathogen risks to manage when considering novel options that utilize household greywater for intimate use in home and personal care. Objectives: To identify microbial hazards of potential concern when using greywater within homes and community facilities without regular centralized water services, and propose, through application of a screening-level risk assessment, possible management and required research strategies. Methods: International literature was reviewed and conceptual diagrams developed to identify possible greywater reuse options suited to rapidly developing urban environments within India. Current criteria were assessed for context and suitability, noting that nearly all relate to greywater generated within developed regions resulting from supply of centralized drinking water. In particular, reference was sought for skin/wound/aerosol pathogens given local production of washing waters and the interest for reuse within homes or communal facilities. Hence, key hazards were identified based on likely exposures and a reverse QMRA to ascertain critical reference pathogen densities to achieve < 1 DALY/y. A qualitative assessment of relative risks was undertaken to inform risk management/options to consider for further evaluation, including possible levels of treatment required. Results: In addition to current greywater reuse for household hand cleaning as currently practiced in Indian slum areas for floor and general cleaning purposes, we identified four additional scenarios for more communal application (Figure 1). For either of these general application areas, current greywater criteria appear to only address possible enteric pathogens, not water-based pathogen growth within greywater, nor skin/wound infecting pathogens. Enteric hazards are dominant risks when using greywaters generated from body or clothes washing, and in the potential presence of high pH soaps are enteric viruses and Cryptosporidium. These enteric risks would need to be controlled to minimize accidental hand-to-mouth or splashing of recovered greywaters when mopping floors. Missing data here are volumes of accidental ingestion during floor hand-mopping. Of particular concern however, is the growing incidence of opportunistic and antimicrobial-resistant bacterial pathogens; such as those from skin infections (S. aureus, P. aeruginosa) and that many (e.g. Legionella, P. aeruginosa, NTM) will naturally grow in stored water in the absence of a disinfectant residual. These skin and aerosol pathogens are of particular concern if recirculating communal showers are considered (Figure 1, scenarios 3&4). Furthermore, if water-recirculating surfaces are not cleaned and drained of free water on a daily basis, biofilms will form, potentially allowing the development of various pathogenic amoebae and amoeba-resistant bacteria such as Legionella pneumophila. Dose-response data is urgently needed to better describe risks from these water-based pathogens, and ultimately determine log-reduction requirements for safe reuse. Conclusions: Current international greywater reuse criteria appear inadequate to address risk pathways relevant to the greywater applications considered likely for developing urban slum situations in warm/hot climates. Critical data required to reduce uncertainties in estimating pathogen risks via the greywater scenarios considered include: faecal loads from food preparation and dish washing waters; accidental ingestion and skin abrasions during hand washing with greywaters; growth of water-based pathogens within greywater storage containers; and the general impacts of high pH or detergents on enteric and water-based pathogen fate under local conditions.
Impact Evaluation Of Urban Water Infrastructure Upgrades In Urban Tanzania: Midline Results from a Two-Year Follow-Up

Danae Roumis, Social Impact, Inc.

Olga Rostapshova; Jeff Alwang; John Feighery

Rigorous impact evaluations of water infrastructure programs in urban areas are in short supply. To date, efforts to evaluate safe water interventions in the developing world have emphasized smaller-scale programs in rural settings. Urban water projects operate in a distinct environment, with more densely and increasingly populated areas, greater socioeconomic and access disparities, and the existence of a multiplicity of sources that are available for use by households for drinking and other domestic consumption. In addition, efforts to evaluation urban water projects must account for existing levels of supply, and varying levels of supply intermittency. In order to improve the reliability and safety of water supply in urban Tanzania, the US Millennium Challenge Corporation (MCC) and the Government of Tanzania (GoT) are implementing a water sector infrastructure project in two urban centers: Dar es Salaam and Morogoro. This presentation presents results from an analysis of a panel dataset of over 5000 households in Dar es Salaam and Morogoro, focusing on how dimensions of water access including water supply availability, reliability, consumption, and expenditures, affect household level health and human capital outcomes. The objective of this presentation is to (1) report on any changes in these indicators and outcomes at midline in these urban areas, as well as (2) share key learnings on implementing data collection, measurement, and identification of impact in this context. Both objectives address key knowledge gaps in WASH research and evaluation in urban areas, where water access, supply problems, and all of the outcomes of interest vary substantially within cities, as much as between them. A rich set of data was assembled as part of an impact evaluation baseline in 2013, using household surveys, follow-up phone calls, direct water quality measurement, spatial data, secondary utility data, and supplemented by a host of qualitative interviews among residents of each city and other water sector stakeholders. Findings from the baseline showed that 14% and 54% of Dar es Salaam and Morogoro residents, respectively, have tap connections to the public distribution network on premises. However, access varied significantly according to wealth with only 3% of the bottom socioeconomic quintile connected in Dar es Salaam compared to 31% of the top quintile, and 24% among the bottom quintile in Morogoro compared to 70% among the top. In both cities, water shortages were common, with about half of connected households reporting a water shortage in the past 7 days and irregular supply hours. In both cities, the vast majority of households relied on multiple sources of water, regardless of their tap connection, for all domestic uses, including drinking. Residents in both cities were concerned about the adequacy of water supply in the past 30 days (19% and 30% in Dar and Morogoro, respectively). About one quarter of water samples from household taps tested positive for fecal coliform contamination. The midline results will report on two-year follow-up on these indicators and outcomes, and provide practical advice on implementing rigorous impact evaluations of large-scale water infrastructure projects in urban areas. Note as data collection is ongoing, findings are not reported here but will be updated prior to conference presentations.

Danae Roumis, Social Impact, Inc.
Olga Rostapshova; John Feighery; Jeff Alwang

In urban Tanzania, piped water networks are limited and water supply is irregular. The Millennium Challenge Corporation (MCC) and the Government of Tanzania (GoT) are implementing a water sector infrastructure project in Dar es Salaam and Morogoro, to improve the reliability of supply in terms of both quantity and quality. On behalf of MCC, Social Impact is conducting an independent, rigorous, multi-year, quasi-experimental impact evaluation of the MCC Tanzania Water Sector Project (WSP), aimed at measuring how the interventions, though increased supply quantity and quality, affect health and human capital outcomes in each city. Key to this impact evaluation is a precise measurement of the level of water supply and quality available to households across each city. However, existing research and evaluation of water supply often categorizes this important variable as binary (piped vs. unpiped) or in categorical terms (0-6 hours, 6-12 hours, etc.). Efforts to measure water supply delivered through public distribution networks quantitatively and directly have been limited, which means that continuity (and intermittency) of supply is often approximated instead of precisely measured. Water quality across the entire distribution network system in a given city is also often not comprehensively measured or reported in the same analysis. The objective of this presentation is to report on both the implementation and results of an innovative combination of direct measurements of water supply quantity and quality. This combination of methods involves the use of pressure logging devices (a reliable proxy for availability and reliability of supply), installed at household taps and rotated on a weekly basis across a sample of piped households in both cities one week in advance of an in-person household survey which includes questions with seven-day recall; and water quality measurements that include system level (intake and outlet), household point of collection (taps), and household point of consumption (tap or storage, etc.), to provide a more comprehensive, system-representative picture of water quality variation across the distribution network, testing for E. Coli, chlorine residual, and turbidity. Combining these measures enhances the accuracy of supply continuity measurement, and water quality measurement across the entire network, both of which are important in the context of large-scale upgrades to the system. We present the results of these supply and quality measurements, and the results of a spatial analysis examining their relationship in each city, combining these analyses with survey data from baseline and endline (2013 and 2015). To our knowledge, there is no existing work demonstrating the spatial relationships between supply and quality that are both measured directly, quantitatively, and continuously (rather than binary or categorical), especially those that are able to connect such data with survey data from a household panel tracked over time, including survey-based measures of similar indicators (supply and quality) plus other demographic variables that can be used as controls in such analyses. We will also report on fieldwork logistics and lessons learned regarding the implementation and combination of these direct measurement methods in practice. Note as data collection is ongoing, findings are not reported here but will be updated prior to conference presentations.

Danae Roumis, Social Impact, Inc.
Olga Rostapshova; Jeff Alwang; John Feighery

Rigorous impact evaluations typically rely heavily on quantitative survey data, often supplemented with qualitative information to provide in-depth contextualization, answer "how" and "why" questions, or to help identify case studies for further investigation. Often, impact evaluation results are presented without much discussion of question wording, and respondent interpretation of this wording. However, the ability of surveys to measure constructs accurately depends to a great extent on good question design and the ability for the researchers' intent to be adequately understood by respondents, and on the ability of respondents to provide the information requested. In the case of urban water supply evaluations, validated indicators related to continuous or intermittent water supply availability, reliability, and other aspects of access are not readily available. Cognitive interviewing (CI) is one technique used to improve question design, by allowing evaluators to assess respondent comprehension and response patterns, and test alternate question wording. CI is especially useful when survey questions have not been thoroughly validated in similar contexts, and when questions require respondents to do some "cognitive work" - e.g., recall behavior, events, or calculate quantities - to help evaluators assess construct validity and reduce response error. In this presentation, we report on our use of another qualitative method - Cognitive Interviewing - as part of an impact evaluation in the urban water sector in Tanzania, and demonstrate its value in helping to refine survey-based measurement of these important indicators. This presentation will highlight how CI has been successfully embedded in the midline data collection phase of a quasi-experimental evaluation of water infrastructure in Tanzania, to refine novel survey measures of water access, availability, quality, seasonality, and security, including questions considered for future rounds of WHO/JMP monitoring. Through this application, this session will demonstrate how evaluators can implement CI within surveys and impact evaluations, with application to the WASH sector, to improve the accuracy and construct validity of survey questions, and reduce response error. We will present not only on the findings of our own exercise in Dar es Salaam and Tanzania, but also provide useful insights into how this method can be successfully implemented in practice. Note as data collection is ongoing, findings are not reported here but will be updated prior to conference presentations.

Household Water Treatment and Safe Storage in Haiti: Report of Stakeholders Consultations

Ryan Rowe, The Water Institute at UNC
Frantz Chrispin

Background: In Haiti, diarrhea is a leading cause of death among children under the age of five. Unsafe drinking-water and sanitation place them and others at risk for water-related diseases such as cholera, which has killed nearly 9,000 people and sickened hundreds of thousands since an outbreak began in late 2010. Household water treatment and safe storage (HWTS) offers a potential solution to improve the quality of drinking water just prior to the point of use or consumption, normally in the household. When practiced correctly, HWTS methods such as chlorination and filtration can maintain and improving drinking water quality and substantially reducing the risk of diarrhea. Introduction: In Haiti, there have been successes in implementing HWTS including high levels of awareness and use of chlorine products, many committed and
engaged stakeholders, and proven and sustained uptake of HWTS under different conditions. However, many practical and policy-related issues remain, which if addressed, could optimize the impact of this intervention. In order to address the issues, the Government of Haiti through the National Directorate for Water Supply and Sanitation (French acronym: DINEPA) and the Ministry of Public Health and Population (French acronym: MSPP) prioritized the development of a national strategy and a product certification protocol. The US Centers for Disease Control and Prevention provided funding to undertake the efforts and engaged the Water Institute at the University of North Carolina at Chapel Hill (UNC) to support DINEPA in this process. Methods: DINEPA and the Water Institute conducted stakeholder consultations with the following three objectives: - To identify organizations implementing HWTS in Haiti; - To consult with them on the lessons they have learned; and - To identify issues to be addressed in the forthcoming national strategy. We identified stakeholders from a list of organizations and individuals contained in DINEPA's existing documentation and knowledge on HWTS in Haiti, as well as through desktop research and referrals from interviewees. Stakeholders were consulted by email, phone, face-to-face meetings, and a stakeholders' workshop, using an open-ended, and informal questioning format to gain insight into lessons learned. Results: Between July and November 2014, DINEPA and the Water Institute at UNC identified over 60 individual organizations. In total, 32 stakeholders were interviewed and a workshop was held, which enabled the identification of lessons learned and recommendations for action by the government and stakeholders in eight categories: Institutional roles, responsibilities, and regulations; Stakeholder coordination and priority-setting; Engagement of community leaders; Technology selection; Community promotion to generate demand: Correct, consistent, and continued use of HWTS; Program improvement; and Knowledge and information-sharing. Conclusion: Household water treatment and safe storage, when practiced correctly, consistently, and on a continued basis, is shown to reduce diarrheal disease. It offers significant potential for the Government of Haiti to improve water quality and improve health. However, many policy-related and practical challenges remain in improving sustainability and achieving scale. This paper identifies eight categories of action by government officials and implementing stakeholders and will help inform the development of a national strategy on HWTS.

Multi-Track and NonSubsidy Approach to Achieve Healthy Behaviour in Indonesia

Maaike Schouten, Simavi

Dinnia Joedadibrata

Indonesia is working towards the universal access to water and sanitation in 2019. To do this, the government issued a national policy of 'STBM five pillars'. STBM is the Indonesian adaptation of CLTS (Community Led Total Sanitation), and consists of five hygiene practices ('pillars') which are key to proper healthy behaviour: 1 no practicing of open defecation 2 hand-washing with soap and running water at critical moments 3 treatment and safe storage of water 4 adequate management of household solid waste 5 adequate management of household liquid waste Many actors in the (development) sector interpret the policy in terms of highly subsidised physical infrastructure of building toilets to stop open defecation. However due to the lack of sanitation education, the communities often slip back to their unhealthy behaviour despite having toilet facilities and water supply. In its 5-year program 'Sanitation, Hygiene and Water' (SHAW), Simavi supports the government's policy to implement STBM in nine districts of Eastern Indonesia. The difference with this program is that it does not focus on hardware but entirely on behavioural change. SHAW engages the communities to practice the five STBM pillars without providing any initial subsidy, which in turn creates demand for improved WASH facilities. Parallel to this, we actively advocate the local government to ensure they respond to this demand. Simavi and five local implementing partners
follow a multi-track approach. In this approach, we work on four different tracks with government structures as well as the communities: district, sub-district, village, and hamlet level: - At the community level, we reach out to each household and encourage them to want and maintain a healthy living environment - including paying for services. We work with around 20,000 village volunteers who go house to house to motivate the communities and monitor the improved behaviour and practices. All this activities require no cost from SHAW. Once the communities practice an improved behaviour and demand some facilities to support this (i.e. running water for hand-washing), the SHAW’s partners will then hold discussions to find an appropriate solution. This might include possibilities for some assistance from SHAW. - At the government level , we work with the local government to put STBM agenda into their strategic plan and budget for the institutionalisation of STBM in the long run. We also involve other government institutions such as the community health centres and schools to adopt STBM. In the end the approach adopted by SHAW is an example of how a community-based non-subsidy WASH programme has successfully reached around 1.5 million people and 1,000 villages to be declared 100% STBM. Through this approach, we aim to achieve maximum impact and establish an environment which facilitates and encourages sustainable routines of improved behaviour. In this presentation, we will present the experiences gained in the SHAW program, explaining why this approach has been successful in the targeted districts (rural and peri-urban), even without an initial subsidy. Several evidence-based results will be highlighted through testimonials from the end-beneficiaries, a cost-benefit analysis and our replication strategy.

Social Accountability in Three Case Studies

Maaike Schouten, Simavi

Saskia Geling

Social accountability is an interactive process that aims to increase citizen’s influence in policy- and budgeting processes and to ensure inclusion of their needs in policies and budgets by decision-makers and service providers. Simavi applies different social accountability strategies at community level to give voice to marginalised communities. Work on this is needed, because in many developing countries there are adequate national policies for water and sanitation, but implementation at- and trickling down of budgets to the local level is insufficient. In all the social accountability approaches applied by Simavi and its partners, citizens are sensitised on their Human Right to safe water and sanitation, and mobilised to express their needs. Knowing their rights and being capable of voicing their demands to the right stakeholders, and having a platform to interact, helps communities to hold the government and service providers accountable for provision of equitable WASH facilities. In this presentation, we quickly present three case studies where Simavi successfully applied different social accountability approaches, and finish with the lessons learnt covering all three. The case studies are: (1) In Bangladesh Simavi applied the 'WASH Budget Tracking' method, which resulted in improved transparency and a 12 to 18% increase of local public WASH budget within two years. (2) In Tanzania, the 'Community Engagement' approach resulted in improved Water Governance, where local government is taking its responsibility to manage the water source properly; the private company recognizes the right of people to access the water source and all the water users pay their share to ensure proper operation and maintenance of the water source. (3) In Kenya, the completion of 'Citizen Report Cards' by local communities showed that 75% of the population did not receive water from the private service provider. This evidence was presented to different stakeholders including the Kenyan Government and local water service providers, as a means to push them to improve the delivery of WASH services. All three approaches facilitated meaningful dialogue among stakeholders and led to increased equitable WASH services. Other lessons learnt were: - Most people in the communities are not aware of their WASH rights, nor of the national policy and -budget available. Therefore they are not holding their
government accountable for insufficient WASH service delivery. Another handicap is the lack of clarity and overlap of roles and responsibilities among duty-bearers, which makes it difficult for citizens whom they should address. - Local government authorities often lack knowledge on how they can collaborate more with the citizens under their administration and incorporate them structurally in decision-making procedures. - Endorsement of the 'Right to Information' by countries is an important step to start meaningful dialogues between different stakeholders, where communities can voice their demands and hold service providers accountable. - Facilitating stakeholder dialogues, empowering communities and making them aware of their rights, ensuring access to information and using evidence-based methods in advocating for equitable WASH services are necessary to realize increased transparency and improved WASH governance.

**Development of Ceramic Disk Filters for Household Water Treatment in Guatemala**

Christopher Schulz, CDM Smith

Philip Wilson; Tesfa Yacob

In recent years, household water treatment and safe storage (HWTS) has progressed from an unproven concept to a widely accepted water, sanitation and hygiene (WASH) intervention in developing countries. HWTS can provide clean drinking water in areas that are poor and rural; have limited ground water; have piped water of questionable quality; are in emergency response mode; and in numerous other situations. One of the most effective HWTS technologies is the ceramic pot filter, which is now manufactured and sold by some 52 filter factories in 32 countries in the developing world--including the Ecofiltro factory in Antigua, Guatemala, which has the capacity to produce some 120,000 pot filters annually. However, several limitations of this technology have been reported by Ecofiltro and in the literature: - Low filtration rates (1 to 2 liters per hour) - Uncertain virus removal capability - Limited raw and filtered water storage capacity - Requires hand cleaning by the user when the filter clogs - The bottom storage receptacle is not sealed and subject to recontamination - The filters are bulky, fragile and expensive to ship over long distances. The purpose of this paper is to present the research results and commercialization of a new type of HWTS system called the ceramic disk filter, which was developed in partnership by Ecofiltro, CDM Smith and the University of Colorado. It is a simple, effective, and affordable treatment system that meets World Health Organization guidelines for drinking water quality and addresses all the limitation of ceramic pot filters noted above. The disk filter could eventually replace traditional ceramic pot filters as the technology of choice for serving low-income rural communities in Africa, Asia and Latin America. The CDF includes the following innovative features which allow higher flow rates through the disk, while maintaining high turbidity, bacterial and virus removal rates. ?X Clay mix recipe with a higher percentage of sawdust (burn-out material) which leaves behind large "reservoir pores" to improve flow permeability. ?X Iron oxide microparticles added to the clay mix to improve bacterial and virus reduction. ?X Sealing method between the disk and plastic bucket walls to force all water through the disk ?X A stacked sealing two-bucket design with the ceramic disk embedded in the top bucket and a spigot connected to the bottom bucket. Preliminary laboratory testing results indicate that ceramic disk filters can achieve flow rates of 2 to 3 l/hr, or 2-3 times higher than ceramic pot filters, with excellent filtered water treatment performance, even approaching water quality standards for turbidity (< 0.3 NTU) and disinfection (> 4-log E. coli reduction) in the United States. Additional MS2-coliphage challenge tests will be performed at the University of Colorado in Spring 2015 to evaluate the effectiveness of embedded iron oxide particles for achieving 4-log virus reduction. The CDF system will also be field tested in four to six Mayan Indian villages in Guatemala for a 6-month period, beginning in May 2015. The laboratory and field results will be presented in the paper, together with plans by Ecofiltro to modify their factory production methods to commercialize and distribute the CDF system to low-income communities in Guatemala and for export to other developing countries in the region.
Relating the Financial Management Skills of SILC Groups with Water Management Committees in the DRC

Christopher Seremet, Catholic Relief Services

Catholic Relief Services is exploring relationship models between the financial management skills of Savings and Internal Lending Communities (SILC) with the financial responsibilities of Water Management Committees (WMC) in its project areas in the Ototo Health Zone, Democratic Republic of the Congo. WMCs fail to sustain their community water system due to their weak transparency and weak financial management skills of the Treasurer, the tariff amount paid by water users is often not sufficient to pay for life-cycle costs, the tariff is not regularly collected, and the collected money is not properly stored. SILC groups which have gone through at least three cycles of deposit, borrowing and dividend payout are transparent, have developed strong financial management skills, and can usually address the financial challenges they typically face. This paper presents findings from several relationship models, including WMCs depositing their money into SILC groups, and SILC group members participating in WMCs.

Involving Children for Better Sanitation in Schools: Case from Nepal

Neera Sharma, Save The Children

WASH in Schools is a first step towards ensuring a healthy physical learning environment. In Nepal, the National Framework of Child Friendly School 2010 (NFCFS) has set the minimum and expected indicators for the infrastructures and physical condition of the schools. The availability of a tap with potable water within school premises is one of the important indicators for the same. But the data shows that although 79% of schools have access to drinking water, the presence of actual safe drinking water out of that available water is unknown. Save the Children started interventions to improve water and hygiene in schools in their working district. Raising awareness on the health and sanitation in the schools and communities through young children was an approach that was used as a way of influencing large groups of people. Involving children in activities that emphasize learning about health and sanitation is a methodology that Save the Children is being using in coordination with its partners where it is implementing a School Health and Nutrition program. While celebrating school health and nutrition week, Save the Children facilitated mass awareness campaigns to reach the wider audience of the district. Mass awareness campaigns were conducted through local FM stations and TV stations to disseminate health and sanitation messages. As a continuity to mass awareness child club members, initiated street dramas and rallies in the local periphery along with demonstrating dance and songs related to health and sanitation for raising awareness on the need for sanitation in schools and community. The event was witnessed by nearly more than 350 people including local journalists and the event was broadcasted in local TV channels of the district. School Level Program Activities such as inter school Speech Competition on "Role of Students in keeping the healthy school environment" and "Importance of Safe drinking water in schools" and art events like the inter schools drawing competition was conducted on the topic "Clean and Hygienic My School Environment". Children from the schools took the initiative to advocate for and initiate testing of water quality in 80% of schools in district. Testing quality of water sources in 295 public schools of the district was conducted for the first time by District Education Office in partnership with Save the Children and District Water Supply and Sanitation Division. The test result showed that different water sources in 99 schools (almost 33.55%) were contaminated with E.Coli bacteria and therefore were unsafe for drinking purpose which needed immediate action for purification. The test result highlighted the urgency to further explore the grave situation of drinking water conditions in community schools which was directly associated with the wellbeing of children in schools and the community at large. Government and non-governmental agencies expressed the need to
support this initiative of DEO for ensuring every school has access to safe drinking water. As a result of the interventions, the need to focus on having safe drinking water in schools was highlighted and commitment to form a drinking water safety committee in every school was made. The committee was required to have a school water safety plan to ensure availability of safe drinking water in schools. An action plan for addressing the problem was developed for each school in the district. School Led Total Sanitation (SLTS) could be one important approach for changing community through the schools and involvement and participation of children in advocating for water testing could be the starting point for such approach. This could be achieved through effective involvement and active participation of children in water and hygiene related activities.

**Household Stored Water and Communal Source: the Impact of Geography on the Determinants of Microbial Water Quality in Rural Ethiopia**

Kate Shields, The Water Institute at UNC

Elizabeth Christenson; Argaw Ambelu; Kaida Liang; Jamie Bartram

Many studies have explored determinants of microbial contamination in water, both at the source and in household stored water. Relatively few studies have compared source and stored water quality. These analyses tend to focus on proximal determinants, like storage characteristics or water treatment in the household and sanitary inspections and leakage at the source. A few have focused on more distal determinants such as household sanitation or affordability of household water treatment. However, while these studies seek compare source and stored water quality, they do not explicitly consider the differing geographic scales (household and community) of these determinants, nor how they may impact each other. In addition, while these analyses incorporate space to some extent through sanitary inspections (i.e. no latrine within 10 meters of the water point), spatial analysis provides insight into not just which determinants are important, but which determinants are important where. Understanding these spatial and scalar dimensions of water quality will allow for the creation of more targeted interventions to improve water quality. Our work on a quasi-experimental study of water quality in Ethiopia is ongoing. The study employs a multi-stage cluster randomized sampling approach with a sample size of 400 communities and 2,400 households. Our analysis of previous monitoring data from 132 water points and 770 households in the study area indicate that half of water points (51%) had high risk water (10-100 colony forming units (CFU) per 100 mL), while about one third (31%) had low risk water (<1 CFU per 100 mL). Three quarters of household stored water samples (78%) fell into the high risk category. Low risk water from the source was significantly associated with ODF communities, while low risk water in the household was significantly associated with clean storage containers, presence of a household latrine, and handwashing knowledge. We anticipate that data from the current study will validate these determinants of water quality both at the source and at the household. In addition, collection of spatial data allows community level variables to be assessed and integrated into the multi-level regression including land use characteristics or elevation, variables less pertinent to field surveyors. Spatial analysis allows better quality control and will allow us to better understand patterns and determinants of water quality at two scales: the community and the household. In our study, water sources are mapped through discussions with the WaSH committee or other community leader. Households identify their most recently used water source through a "water walk" and geographic positioning system (GPS) data are collected for each household location, water walk route, source water location, and all sanitation facility locations in each community. We are testing source and household stored water for E. coli using Compartment Bag Tests. Smart phone based surveys are used for collecting survey, observational, geographic and water quality data. Data are analyzed using multi-level regression techniques and spatial analysis.
Mental Health in the Context of Emergencies and Violence: Does Depression Impair Handwashing in Children?

Jurgita Slekiene, EAWAG - Swiss Federal Institute of Aquatic Science and Technology
Hans-Joachim Mosler

Background. Mental disorders, particularly depression and post-traumatic stress disorder (PTSD), are common long-term psychological outcomes in emergency contexts associated with conflict or natural disaster. Further sources of negative health outcomes, with the highest rates in developing countries, are violence and abuse towards children. According to the WHO (2014), depression is a common mental disorder characterized by sadness, loss of interest or pleasure, feelings of guilt or low self-worth, disturbed sleep or appetite, feelings of tiredness, and poor concentration. Depression can be long-lasting or episodic, substantially impairing an individual's ability to function at work or school or cope with daily life. For our study, we expected that depressed children would i) wash their hands less often, ii) have weaker behavioral determinants, iii) exhibit less influence of behavioral determinants on behavior, iv) have different behavioral determinants, and v) demonstrate an impaired influence of behavioral determinants on handwashing.

Methods: In a cross-sectional design study, face-to-face interviews were carried out with primary school pupils in Harare, Zimbabwe (N=556). We used the quantitative questionnaire developed for children and based on the RANAS (Risk, Attitudes, Norms, Abilities, Self-Regulation) approach and the Center for Epidemiological Studies Depression Scale for Children (CES-DC). The CES-DC is a reliable, valid, and, in many countries, well-established 20-item depression screening instrument used to identify groups in which children are at risk for developing depression.

Results: More than half of the assessed children were depressed, which is in line with the findings of other studies in Zimbabwe. Self-reported handwashing with soap among depressed children at school was significantly lower than among nondepressed children. Almost all RANAS behavioral determinants were significantly lower in depressed children. Depressed children indicated more often that they forgot to wash their hands, experienced less pleasure from handwashing, felt less guilty when not washing their hands, and had less of an intention to wash their hands with soap. They also perceived themselves as less vulnerable to getting diarrhea and believed that it was not that severe a condition. Additionally, they cared less about what others thought when they did not wash their hands than did nondepressed children. In depressed children, behavioral determinants were less indicative of the handwashing behavior. This is due to the fact that the behavioral determinants of the RANAS model provide a better explanation of the handwashing behavior in nondepressed than in depressed children. Detailed analysis revealed that the behavioral determinants worked differently in the depressed than in the nondepressed children's group. Among depressed children, the expected results of costs and benefits (instrumental beliefs), social norms such as the behavior of important people (injunctive norm), belief in the ability to organize and execute certain behavior (action self-efficacy), remembering, and habits were significant predictors of handwashing. In contrast, in nondepressed children, we identified two behavioral determinants associated with handwashing: the belief in the ability to organize and execute handwashing (action self-efficacy) and habitual behavior. The behavioral determinant of action self-efficacy exerted twice as strong an influence on nondepressed as on depressed children. These findings indicate that depressed children have weaker confidence or belief in their ability to organize and execute the handwashing behavior at critical times. Behavioral determinants that were impaired in depressed children were health knowledge, instrumental beliefs, affective beliefs, and commitment. These findings imply that depression interrupts the relationship between several behavioral determinants and handwashing. In depressed children, the following beliefs do not apply: the more they know about the health effects of handwashing, the more they wash their hands;
the more positive results they expect, the more they wash their hands; and the more they like handwashing, the more they are committed to it and the more they perform it. These beliefs hold true only for nondepressed children.

Implications for a handwashing campaign: These results imply that in a population with a significant proportion of depressed children, interventions mitigating depression should precede behavioral change interventions for handwashing. There is evidence that physical exercise has a positive effect on the mental well-being of a person, and it has been successfully applied in the treatment of anxiety and affective disorders such as depression. Research on this topic is especially relevant in emergency contexts, as it involves conducting depression-relieving measures before or in parallel with any WASH interventions to make them more effective.

**WASH and Disabilities in Bangladesh**

Marielle Snel, IRC

In 2014, the London School of Hygiene and Tropical Medicine and IRC obtained a grant from the Australian Development and Research Awards Scheme to research accessibility to sanitation in relation with disabilities in Bangladesh and Malawi. The project, aims to obtain prevalence of disability related problems on access and accessibility to sanitation and reflect on a mitigation strategy to be rolled out beyond the project. This paper specifically focuses on Bangladesh where the project is led through a collaboration between BRAC and IRC in collaboration with local disability organisations. In order to address disability in a strategic and cost-efficient way, basic data has been collected. The paper is to reflect on some of the results of a baseline study conducted by IRC and BRAC to measure access and accessibility to and practice of water, sanitation and hygiene (WASH) services for persons with a disability. Initial findings based on the survey are: (1) to address the problem of adapted sanitation facilities, a general mobility problem needs solving first; and (2) to discuss solutions, social barriers around both sanitation and disability need to be lifted by all relevant stakeholders. To address suitable solutions in a cost-effective and up-scalable way, a dialog between provider and user seems to be the best way forward in Bangladesh. At the same time, self-assessment by the disabled does not always result in the most appropriate solution.

**Untouchability, Casteism, and the Persistence of Open Defecation in India: New Quantitative Evidence from the IHDS**

Dean Spears, Princeton University & r.i.c.e.

Amit Thorat

Most of the world's remaining open defecation is in rural India, and this fraction increases each year. Continuing open defecation in rural India is a special challenge both because high population density translates into especially high costs to health an human capital (Hathi, et al. 2014), and because aversion to use of internationally normal pit latrines increases the challenge to sanitation programs and policy-makers (Coffey, et al. 2014). Why does open defecation persist in rural India? A growing literature points to the importance of a set of cultural beliefs and practices rooted in Hindu meanings of purity and pollution, of public and private space, and of the caste system and untouchability. Qualitative evidence for this explanation is explored in the "switching study" of Coffey, et al (2015), as well as in recent research in rural Orissa. However, none of these studies have been able to apply quantitative methods to test for an
association between open defecation on the one hand and cultural practices associated with casteism on the other. We are able to offer new evidence using a special survey question included in the newest round of the India Human Development Survey, a nationally representative demographic panel survey of Indian households. The 2012 round of the IHDS asked households whether or not they practice untouchability (meaning, for example, not letting a Dalit into their kitchen). Villages in which more households report practicing untouchability have importantly higher rates of open defecation, a result which is robust to controlling for a large set of economic, social, and demographic properties of villages and households, as well as for state or district fixed effects. States where more rural households practice untouchability experienced a smaller decline in open defecation between the 2005 and 2012 survey rounds; after accounting for untouchability, economic differences do not further explain variation across Indian states. These robust associations are not merely due to spurious correlation between practicing untouchability and household education, modernization, or exposure: practicing untouchability is positively associated with correctly answering a range of questions about health and health production (such as causes and treatment of diarrhea). These results add important quantitative evidence to a literature suggesting that the Indian puzzle of exceptional open defecation is associated with the culture of purity, pollution, and casteism.

**Access to Water Does Not Explain Exceptionally Common Open Defecation in India**

Dean Spears, Delhi School of Economics & r.i.c.e.

Manish Kumar; Rinku Murgai

Open defecation is exceptionally common in India. According to Joint Monitoring Programme data, 60 percent of all people worldwide who defecate in the open live in India. In policy discussions, one commonly cited candidate explanation for the puzzle of Indian open defecation despite economic growth is access to water. We report two analyses, comparing internationally and within India, which suggest the same conclusion: exceptional open defecation in India is not, in general, able to be explained by lack of access to water, on average. Internationally, India has much more open defecation than cross-country trends would predict for its level of water access, and four of every five countries with worse access to water have lower levels of open defecation. Within rural India, in data from the 2011 Census of India, almost half of households with piped water in the home defecate in the open. Open defecation rates between households with water near and water far are very similar, and this slight difference is entirely accounted for by differences in asset wealth: at the same level of wealth, open defecation has no association with this difference in water access, on average.

**Citizen-Administered Water Quality Tests: a Mechanism for Information Transparency and Government Accountability? A Case Study from Ahmedabad, India**

Jonars Spielberg, Massachusetts Institute of Technology

Reecha Das; Ashish Ranjan; Ankur Sarin

Despite its vibrant civil society, India’s poor, disadvantaged urban communities are often excluded from socio-political processes that would otherwise help them secure basic needs. As a result, and in breach of a constitutional guarantee, 91 million people continue to lack access to an improved water source [1]. In this paper, we seek to explore the role of citizen monitoring—via low-cost, decentralized water testing—as a tool for enhancing individual agency and government accountability in polities characterized by weak governance
structures. Our case study considers the introduction of a water quality test in low-income neighborhoods in Ahmedabad. Ahmedabad has experienced rapid urbanization and redevelopment since 2000, which has led to increased low-income and resettlement government housing. Though an estimated 85% of the city is serviced by municipal piped water supply, specific areas are systematically neglected [2,3]. Further, poor infrastructure and increasing demand inflate contamination risk between distribution and collection points, and an intermittent supply necessitates water storage, causing further contamination [4]. In such an environment, it is paramount that citizens possess means for testing their water as desired, with the goal of bolstering personal agency and state accountability by extension. This paper draws upon a larger study that required participants to complete a hydrogen sulfide (H2S) test: a simple, cheap procedure that detects the presence of H2S-producing bacteria, which includes some coliforms. We use a mixed methods approach to gather qualitative and quantitative data based on surveys administered to 234 low-income households in February 2015; unstructured individual interviews and focus group discussions (FGDs) will be conducted in May and June. Analysis of the survey data shows high ease of use, ease of understanding and willingness to use and pay for the H2S test in the future. Initial test results suggest that 37% of water samples were contaminated, corroborating recent research [5]. Though survey respondents reacted positively to the test, its ability to substitute for substantive structural and institutional changes remains dubious. While the test helps overcome the information asymmetry that is at the core of citizens’ inability to monitor authorities and demand accountability, it may also be inimical to the citizen-state social contract by increasing the disillusionment of citizens with their government [6]. We are in the process of interviewing individual respondents and conducting FGDs to understand responses to the test results and how these are affected by social, institutional and economic factors. For instance, in one government-relocated area, we do not observe any corrective action despite high levels of water contamination. Residents report disillusionment with the system, believing it futile to approach public officials, and show limited awareness of administrative and political avenues for redressal. To understand the governance challenges better, we plan to take test results to local officials responsible for water supply and quality and document their perceptions and responses to the use of self-administered technology. Though still in the process of completion, we believe our study contributes to the literature on water policy by probing efforts to improve citizen agency via the use of low-cost technology. Our analysis so far suggests that, in the absence of effective governance mechanisms, citizens are unable to translate increased information available to them into enhanced government accountability and improved tangible outcomes. The central role of effective governance, predicated on sound policy and its implementation, in securing access to clean, safe water cannot be overstated. [1] WHO/UNICEF. 2012. Joint Monitoring Program. http://bit.ly/1zR2AU7 (accessed 4-8-2015). [2] AMC. n.d. "Slum Free City Action Plan Under Rajiv Awaaz Yojana: Ahmedabad." Volume I Final Draft Report. http://bit.ly/1Jfhk9c (accessed 5-1-2015) [3] Patel S, Sliuzas R, and Mathur N. 2015. "The Risk of Impoverishment in Urban Development-Induced Displacement and Resettlement in Ahmedabad." Environment and Urbanization 27.1 (April): 231-256. [4] Kumpel E and Nelson KL. 2013. "Comparing microbial water quality in an intermittent and continuous piped water supply." Water Research 47: 5176-5188. [5] CITE. Forthcoming. Water Filter Evaluation Integrated Report. 3Ss: Suitability, Scalability, Sustainability. Cambridge, MA: MIT. [6] Bauhr M and Grimes M. 2014. "Indignation or Resignation: The Implications of Transparency for Societal Accountability." Governance 27.2 (April): 291-320.

**A Survey of Past Water Point Functionality at Living Water International**

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Executive Summary At some point, almost everyone working at Living Water International has been asked a question about how many of our pumps are still functioning. This study was undertaken to help improve the answer. The results were also deemed to be of interest to the broader WaSH community. Introduction in
2014, Living Water International conducted a survey to estimate the proportion of historical water points that were still functional. Because precise location data (GPS coordinates) were only available for projects starting in 1999, the population chosen for the study could only span 15 years (1999-2013). A search of Living Water's monitoring database revealed GPS coordinates for 3770 new-installation projects. Rather than visiting all of the identified project sites or pulling a simple random selection, this study incorporated a proportional stratification sampling method to accomplish its desired objectives. The sampling frame included all new-installation projects completed within the time frame. The sample was chosen to allow for statistical significance in each of 12 Countries within a 10% margin of error. The other 10 operational countries could not complete the study because of security concerns, medical emergencies or logistical challenges. At its most basic level, an observer would need only to visit a project and record a yes or no to the simple question - 'is water flowing'? But, since getting to the project site was a significant investment, it was also decided to find out if whether the water was clean, drinkable, odorless, colorless, uncontaminated, produced in sufficient quantity, sited properly, being used a primary source and so on. Also, if no water was flowing then we wanted to find out how long it had been out of service, why it failed, when it would be back in operation and the like. The questionnaire contained a set of questions designed to capture observations by the person conducting the survey in addition to a few questions to be asked of a local water point user. Samsung smart phones were used to collect the information for same-day transmission to a global dashboard. GPS coordinates and a photo were captured for verification. Approaches Sites identified in the sample were visited and surveys completed by staff in each of the 12 countries from August-December 2014. Of 837 projects identified in the sample, visits were made to 792 water points (visits could be made to 95% of sites in the sample). All of the actual water point photos were viewed to verify, wherever possible, whether water was actually flowing or not. Results Research always requires difficult choices between scope, efficiency and precision in light of intended objectives. With that in mind, results of this study must always be presented as being accurate within a 10% margin of error and also within boundaries of two additional limitations: (1) GPS coordinates were not being recorded in the database for all projects starting in 1999 - rather, GPS use gradually increased over the years covered by the study; (2) a minimum number of projects had to be sampled from each country to ensure significance within 10% margin of error. So factoring in these two limitations, the reader should be aware that even though the study covered a 15-year horizon, that almost 83% of the sampled projects had been installed during the most recent five-year period (2009-2013). Other survey variables included: Who is responsible for water point management? Is it a primary source of drinking water? Do users pay for water and, if so, how much do they pay? For projects without flowing water, what happened and how long since it last functioned? Because an observation that water was flowing might not provide a robust picture, there were questions that probed for perceived problems. In addition to recording her/his own observations, each interviewer found one locally-available user to participate. The local users reported that 154 (154/667=23%) of the water points (the ones with flowing water) had at least one problem - some had more than one problem. Several categories of problems were identified by observers or local users, including: objectionable taste, color, smell; limited flow; poor siting; and potential contamination. Using the most basic definition of functionality, a primary finding is that 83% of data collectors reported that, yes, water was flowing. A stricter definition of functionality (one that required both a yes, water is flowing and limited flow NOT mentioned by either the observer or interviewed local user) indicated a 77% functionality rate. Conclusion Now that Living Water International has a functionality percentage and additional robust data to use for reflection; an internal dialogue is underway to find out how the results of this study should improve the way we work.
Willingness-to-Pay for Automated Chlorination at Shared Water Points among Urban Slum Landlords in Dhaka, Bangladesh

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Yoshika Crider; Amy Pickering; Nazrin Akter; Atonu Rabbani; Leanne Unicomb; Stephen Luby; Jenna Davis

Background and research objectives: This study estimates demand among Bangladeshi slum landlords for a novel water treatment device that is attached to shared water points drawing water from the public water network. More than 130 million people living in urban areas of developing countries are classified as lacking access to improved water or use improved water points that may not supply safe water. In Dhaka, Bangladesh, almost one third (3.4 million) of the population lives in slums and obtains water through shared water points among which approximately 80% are contaminated with fecal indicator bacteria, suggesting increased risk for waterborne illnesses. The two most common approaches to water treatment in low-income cities (centralized disinfection at a water treatment plant, and point-of-use treatment by individual households) have both consistently failed to provide safe water in Dhaka. In this study we evaluated a passive chlorine doser that was developed by Medentech (Ireland), adapted by Stanford University (USA), and tested through a partnership with icddr,b (Bangladesh). The device is designed to deliver a dose of 0.5-2.0mg/L of chlorine. It has no moving parts, and requires no electricity or behavior change on the part of users, except for refilling the device with chlorine. We targeted landlords and property managers of low-income rental housing for marketing the device. The study tests the hypothesis that landlords perceive installation of the device as an amenity that confers competitive advantage in recruitment and retention of tenants. Specifically, landlords were offered the opportunity to have the device installed on the water point in their compound and pay a monthly subscription fee for its maintenance and operation, including chlorine refills. Methods: 127 compounds with rental housing units were identified in purposively selected neighborhoods of Dhaka. Each compound consists of 5-30 households; has as its principal water source a shared water point with an underground or overhead tank; and has a legal, billed connection to the public water network. Field staff approached each eligible compound and if the landlord was willing; they conducted a baseline survey with the landlord, and with 3-5 households in the compound. Next, a one-on-one marketing session was conducted with the landlord, in which two disinfection service packages were offered. If the landlord was interested in the service, s/he was asked to bid for the package in a Becker-DeGroot-Marschak (BDM) auction. The BDM auction elicits maximum binding bids in a way that incentivizes participants to reveal their true willingness to pay (WTP). If a landlord?s bid exceeded the service price, s/he won the auction and the chlorine device was installed in his/her compound. The landlord?s first subscription fee was collected during the day of installation; additional payments will be collected on a monthly basis. In the event of non-payment, the device will be removed. Our goal is to provide 6 months of service to compounds who make timely payments. Preliminary results: During the period 8th February-17th April, 2015, we enrolled 76 compounds in the study. Among the 76 landlords completing baseline surveys, 60 (79%) agreed to participate in the marketing session. Of these, 55 (92%) participated in the auction. Fifty-nine percent (n=32) of the landlords who placed bids in the auction won and had the chlorine device installed in their compounds. Assuming that WTP for the device is zero among landlords who refused to participate in marketing or the auction, mean monthly WTP for the in-line chlorination technology was 270 BDT (approximately US$3.5). Among landlords with non-zero bids, mean monthly WTP was 294 BDT (approximately US$42). The current estimated cost for the service is 600 BDT (approximately US$8) which is twice the mean WTP. Compound enrollment in the study continues, with a goal of installing 40 devices. By the time of the UNC conference, we expect to have updated our preliminary results with data from an estimated 100 compounds. We will report findings on the share of landlords with installations who have continued to pay for the device maintenance over time. Finally, we will add an analysis exploring variation in
willingness-to-pay as a function of landlord, household, and compound characteristics. Conclusion: The findings from this study suggest that, in Dhaka, point-of-collection water disinfection strategies may address both the technical challenges of centralized treatment, and the low effective demand for point-of-use treatment approaches. In addition, the study generates insights regarding the viability of a landlord-targeted business and marketing strategy for water treatment that is relatively unexplored in the literature to date.

**Measuring and Mitigating the Risk of Contaminant Intrusion in Water Distribution Networks with Household Booster Pumps**

David Taylor, MIT

Alexander Slocum

Indian water utilities supply low pressure water (7 psi at the customer connection) for an average of only 4.3 hours per day. To make the most of the available water and to supplement the low pressure, some customers use residential booster pumps. When these pumps are directly connected to the utility's water pipe, they often induce negative pressure in the pipe between the distribution main and the customer's residence. This induced negative pressure increases the flow rate to the customer's house, but also increases the risk of contaminant intrusion. This work developed a method for estimating the significance of this distributed source of contaminant intrusion and assessed the performance of a new type of safety valve invented to mitigate this risk. The intrusion of contaminants into water distribution systems has caused significant public health concerns and several historical crises. Contaminant intrusion can only occurs when there is a pathway for contamination, when contaminants are present, and when there is a pressure gradient that allows contaminants into the pipe. Whenever there is negative or low pressure in a pipe, the protective positive pressure barrier is removed and the intrusion risk increases. Previous studies have assumed that since intermittent systems are unpressurized for such long periods of time, other sources of negative pressure pose negligible risk. To test this assumption, the intrusion risk was quantified at a convenience sample of 19 houses which used booster pumps in New Delhi, India in January and March 2014. At each customer connection, the pressure history was recorded immediately upstream of customers' booster pumps and the fraction attributable to booster pumps was considered. The data contained three distinct groups: continuously-supplied households (taken to include houses with supply hours longer than 22 hours/day; N=9); frequently-supplied households (12-22 hours/day; N=3), and briefly-supplied households (0-12 hours/day; N=7). Of the average of five hours per house per day of negative pressure, the mean duration of booster-pump-induced negative pressure was found to be 38 minutes [99% CI (27, 54)]. More significantly, booster pumps were found to contribute over 60% of pressures observed that were less than -1.5 psi. To prevent this contamination risk, a new type of back-pressure reducing valve (BPRV) was invented and tested. The risk at each participating household was measured with and without the BPRV installed and this paired difference was considered as the outcome variable for this crossover study. A paired randomization test of the duration of negative pressure with and without the valve showed that the valve reduced the duration of pressure less than -0.9 psi by a mean of 4.5 hours per day [99% CI (0.4, 10)]. The total reduction in negative pressure, however, was not found to be significantly affected by the BPRV. Since the briefly-supplied houses included in the study experienced such a large and varying duration of negative pressure during non-supply hours, changing the booster-pump-induced fraction of negative pressure had a small signal to noise ratio and was therefore not detected as significant. To the knowledge of the authors, there have been no published attempts to quantify or mitigate the intrusion risk posed by booster pumps. This work therefore represents an extremely important first step towards not only estimating the size of this contamination risk, but also pointing towards a solution.

Belen Torondel, LSHTM

Sada Siva; Wolf Schmidt; Parimita Routray; Thomas Clasen

An estimated 2.5 billion people lack access to improved sanitation. India represents a particular challenge, accounting for a third of the world's population without improved sanitation and two-thirds of those practicing open defecation. Governments have responded need by creating or supporting large-scale campaigns to improve sanitation coverage. Recent studies have shown that India's rural-focused Total Sanitation Campaign (TSC) left large proportions of villages without functioning latrines. There are also concerns about the extent to which the program provided sufficient promotional support to encourage latrine use and to provide householders with necessary information about faecal sludge management.

Methods: We conducted a cross-sectional study from September through December 2014 among 50 villages in Orissa, India that received latrines in accordance with the TSC between March 2011-February 2012. TSC subsidized latrines only for households that were below poverty line, which was around 70% in these villages. The 50 villages comprised the intervention group of a RCT to assess their health impact over the ensuing 21 months. In accordance with the TSC program, the pour flush latrines were designed for dual pits, though the program only constructed the first pit. We conducted surveys and spot checks to assess latrine coverage, use and attitudes or practices on faecal sludge management. All households in the villages were eligible for participation in the study, whether or not they were eligible to receive a latrine under the TSC.

Results: Latrine Construction, Coverage and Use: Data was collected from 4398 households. Of these, 53% had some type of latrine. Among these, only 32% were complete, with the balance 68% either under construction or otherwise incomplete. The mean age of the completed latrines was 4.8 years and for under-construction latrines 3.6 years. More than 99% of the latrines had only a single pit. Most latrine pits were constructed with 3 rings and had an estimated depth of 3-4 feet. We obtained use data from 97.8% of households that had some type of latrine (2285/2336). A total of 33% reported their latrines were not in use at all. Of the 1521 households that reported latrines being used, reported use was highest among women (97%) followed by men (78%) and children 6-14 years (40%); only 11% of households with young children (<6) reported that those children used the latrines or that their faeces were deposited in latrines. When households with latrines reportedly in use were asked about the frequency of latrine use, 78% (1185/1518) responded "always", while the balance responded "usually" (4.4%), "sometimes" (8.8%) or "never" (8.5%). Married women were most likely to report using the latrine always, while men were most likely to use it never or sometimes. Faecal Sludge Management. Data was collected from households which latrines presented signs of used assessed by spot-checks. Only 2.3% (35/1494) reported that the pit had filled up after this 2-3 year period following construction. Among these, 23 reported emptying it and only 2 reported diverting waste to a second pit as intended by the latrine design; 5 households simply stopped using the latrine and reverted to open defecation. 27 households emptied their latrine once and 8 emptied twice or more. 18 households reported they emptied their latrines, 13 hired private scavengers and 4 used municipality services. A minority of persons emptying pits used gloves or boots. Householders generally reported that the pit contents were left in open places (38%) or used on crops (24%); only 24% reported burying the sludge in a hole. As so few latrines had actually been emptied thus far, we also asked a selected number of householders about their expectations regarding pit filling and emptying. 36% (160/446) of the respondents reported that when the pit was filled they would empty it, 26% reported that they would build a new second pit and divert the waste into it, 12% said they would build a new latrine and 3% said they would stop using the latrine altogether. Most expected that they would hire manual scavengers to empty it (52%); others that they would call the municipality (24%) and others that they would empty it themselves
(13%). About a third (34%) reported that they would dispose the pit contents in cultivation fields; others would bury it in a hole (30%) or leave it in the open (23%).

Conclusion: Two years after completion of the intervention in these villages, only half of households had a latrine at home. Only a third of these latrines were completed and 44% were functional. A third of the households with latrine reported never using them. Evidence suggest that faecal sludge management will be a major challenge, with most households expecting to empty fresh pit contents (or stop using the latrine) using uncertain or unsafe methods rather than building a second pit. Disposal of the sludge in open space or used on crops was the most frequent practice reported.

Assessing the Promotion of Urine-Diverting Dry Toilets through School-Based Demonstration Facilities in Kalisizo, Uganda

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Ecological Sanitation (Eco-San) systems are designed to improve sanitation while recovering nutrients and organic matter from human excreta for use as agricultural amendments. Wider implementation of these systems could help to address trends in countries such as Uganda, where declining soil fertility is jeopardizing the nutritional security of a rapidly growing population. Eco-San systems, especially Urine-Diverting Dry Toilets (UDDTs), have been promoted in Uganda as an alternative to pit latrines, which are becoming less feasible in growing urban areas with limited space. However, uptake of UDDTs has been slow, suggesting a need for improved promotion strategies. In general, sanitation promotion through hardware subsidies has proven to be an ineffective and unsustainable strategy. The necessary behavior changes and willingness to maintain the supplied facilities often do not result. Promotion efforts have now shifted to focus on self-respect, marketing, and the creation of demand for sanitation products available in the private sector. In the specific case of UDDTs, demonstration facilities have been reported to function as effective targeted subsidies, helping to convince local stakeholders of the benefits of UDDTs and increasing long-term uptake of the technology in the surrounding community. However, an unresolved question concerns whether these facilities should be installed in household or institutional settings. This study evaluated the initial effects of a promotion strategy involving school-based demonstration UDDTs and incorporating community-influenced design, installation, training, and monitoring. The research goal was to determine the strategy’s success in encouraging local acceptance and uptake of UDDTs through the influence of students and the example of well-functioning demonstration units. Specifically, knowledge and attitudes within school communities were assessed before and after the introduction of demonstration systems, and facility operation was monitored to gauge success. Demonstration UDDTs were introduced at two primary schools located in Kalisizo, Uganda, a small town with an urban population of approximately 10,400 residents. UDDTs are extremely uncommon in Kalisizo. Knowledge and attitudes regarding UDDTs were assessed in the school communities through focus group discussions and key informant interviews conducted in two phases. The first phase occurred before facility installation, while the second took place after several months of operation. Additional focus groups and interviews were conducted in Kasensero, a nearby fishing village where UDDTs had previously been installed due to adverse soil conditions hindering the construction of pit latrines. Kasensero functioned as a control community, allowing for comparisons between the knowledge and attitudes expressed at the schools and those exhibited by a group of experienced UDDT users. Prior to the introduction of demonstration facilities, Kalisizo school community members knew very little about UDDTs and confused them with other types of systems, such as flushing toilets. After participants were provided with some basic information, attitudes were mixed, with negative perspectives outweighing
positive ones. After installation, students exhibited a marked increase in knowledge regarding these facilities and their benefits, and opinions were strongly positive. These changes were seen in users of the facilities as well as non-users, suggesting that students were discussing the facilities amongst themselves and informally teaching their peers, and that direct observation of the facilities may have been improving knowledge among students. In other words, the facilities were functioning as effective demonstrations, and students may have already been acting as advocates for UDDTs within the schools. The introduction of an improved sanitation system at the schools also appears to have sparked other improvements related to sanitation and hygiene, such as the provision of hand-washing stations and facilities for the disposal of used menstrual pads. In the future, it is likely that students will be compelling representatives for UDDTs within their households and communities. Substantial increases in local uptake of UDDTs may not materialize for several years, but the possibility of increased uptake seems more likely after this school-based demonstration program. Through these units, students have been empowered to act as ambassadors for UDDTs. School-based demonstration facilities are recommended as effective tools for UDDT promotion, with the understanding that additional considerations, including local community involvement, education and monitoring programs, the incorporation of continuous training and promotion, and a general atmosphere of respect and trust, are also critical components of any UDDT project.

**Sustainability of Community Managed Rural Water Supply in Post-Conflict Regions of Northern Uganda**

Julie Truelove, Self-Employed

Kevin Sansom

Numerous challenges of sustainability with the community based management method are widely recognized however it remains a predominant methodology in rural water supply especially in regions where few, if any, alternatives exist. Criteria for community management have generally not been realized as anticipated and outcomes are compounded by post-conflict conditions and other transitions from crisis or emergency. In this study, factors of institutional, financial and service delivery sustainability of community-managed water supply are assessed in post-conflict regions of rural northern Uganda. The study region is an area facing both post-conflict stresses and aspects of rural disparity. Achieving sustainable rural water supply remains elusive even within the well-developed national policy for the water sector in Uganda that integrates community management methodology into the government framework. The research objective is to determine the extent to which reliance on the community based management method has supported sustainable water supply in this post-conflict environment and identify factors of success and failure. Research was carried out in 2011 to 2013 with qualitative and quantitative data collection, including field surveying of 45 community well sites and interviews with experts, NGOs and government stakeholders. Review of existing literature on the community management model, influence of post-conflict conditions, sustainability and rural water supply policy and process in Uganda set the context of the research and identified areas for further study. Use of the Uganda Water Supply Atlas and the "WATSUP" Database of the Ministry of Water and Environment provided a vast source of data specific to the region with which to triangulate collected data. Literature sources that examined the interconnectedness of sustainable rural water supply and post-conflict conditions were limited at the time of the study. The study region is comprised of eight neighbouring, rural sub-counties within Oyam, Kole and Lira Districts of the northern region of Uganda. Point sources in the region include protected springs, rainwater harvesting tanks, shallow wells and deep boreholes. Communities served by shallow wells and deep boreholes, all with the Ugandan standard India Mark II handpump, are the focus of this study. Results of the research indicate that 40% of community managed well sites surveyed were fully functional with another 24.4% either semi-functional
needing minor repairs or minimally functional needing major repairs. Of the 45 surveyed sites, 42% reported having fully operational and responsible management committees. Based on targets for the "golden indicators" of the Ministry of Water and Environment, results from the study region are below expected outcomes. Analysis of repair data at 1, 3 and 5-year intervals since construction illustrates technical challenges that are often beyond the capacity of one community to manage and fund themselves. Post-conflict conditions in the region including population movement, changing administrative boundaries and timelines for transition are factors in these results. A tendency in the literature to reflect post-conflict recovery in Uganda from the 1980's understates the impacts of more recent regional transition in the north since 2008. While each post-conflict situation comes with unique characteristics, some comparison can be made with neighbouring Rwanda where, in recovery from conflict, national water policy moved away from community management to promotion of public-private partnerships. Research conclusions indicate that community management is viable for a relatively short time until repair and maintenance of handpumps becomes a limiting factor. It is viable in the short-term as no other management option exists in this region of transition. Institutional capacity to create a supporting environment is lacking, the financial means does not exist within communities under abject poverty and service delivery struggles with lack of a spare parts supply chain. There is value in exploring ways to enhance the institutional framework through private sector development, strengthening capacity of local government, and engaging civil society to balance both support and pace of post-conflict transition collaboratively. Bridging well-developed water sector policy in Uganda into improved practice and exploring alternative self-supply or private sector options would benefit constituents of the study region. By the nature of a transitional environment, communities in areas like northern Uganda are required to be somewhat self-sufficient and there is value in community autonomy. Creating a supporting environment, exploring options for future management methods of rural water supply and defining further measures of regional equity are vital steps forward. Full text http://rural-water-supply.net/en/resources/details/537

Wait Wait? Don’t Drink It! Public Compliance of Boil Water Advisories

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Kyra Spotte-Smith; Susan Riha

Globally, many water utilities providing continuous and reliable service to its customers provide advisory notifications when the services are interrupted or water is likely to be contaminated. When the contamination is biological, utilities or the local public health agencies issue a 'boil water advisory' (BWA). The public health effectiveness of a BWA depends strongly on an implicit public understanding and compliance. In this study, a meta-analysis of 11 articles that investigated public compliance to BWA notifications was conducted. Awareness of BWA was moderately high, except in situations involving extreme weather. Reported rates of compliance were generally high, but when rate of awareness and non-compliant behavior such as washing dishes and brushing teeth were factored in, the average effective compliance rate was found to be around 64 percent. This does not include situations where people forgot to boil water for some part of the duration, or ingested contaminated water after the BWA was issued but before they became aware of the notification. The two-thirds compliance rate is thus an over-estimate. Results further suggest that timeliness of receipt, content of the advisory, and number of sources reporting the advisory have a significant impact on public response and compliance. This analysis points to improvements in the phrasing and content of BWA notices that could result in improved compliance.
Growing Taller Among Toilets: Evidence from Changes in Sanitation and Child Height in Cambodia, 2005-2010

Sangita Vyas, Research Institute for Compassionate Economics
Phyrum Kov; Susanna Smets; Dean Spears

Child height is an important indicator of human capital and human development, in large part because net nutrition early in life shapes both child height and adult economic productivity and health. Recent evidence suggests that exposure to poor sanitation - and specifically to widespread open defecation - can pose a critical threat to child growth. We study the effect of open defecation on child height in Cambodia, where more than half of the population defecated in the open and 40 percent of children under 5 were stunted in 2010. The primary contribution of this paper is to econometrically identify an effect of open defecation on child height by studying changes over time within geographic areas of Cambodia. This paper seeks to investigate whether the geographic areas that experienced a decrease over time in open defecation also experienced an increase in child height. If so, how much of the increase in child height between 2005 and 2010 in Cambodia can be statistically accounted for by the decrease in open defecation? In this analysis, we use Cambodia’s two most recent Demographic and Health Surveys (DHS), conducted in 2005 and 2010. These nationally representative datasets collected data on approximately 3,600 children under 5 in each year. Using multi-variable regression analysis with fixed effects, we identify an effect of open defecation on child height from within-province changes in the fraction of households defecating in the open in the primary sampling unit, a measure of a child’s exposure to fecal pathogens. This fraction, rather than household open defecation alone, proves to be more important for predicting changes in child height, underscoring the negative externalities that make reducing open defecation a policy priority where it is common. Our econometric analysis finds that a decrease from 1 to 0 in the rate of open defecation in a child’s locality is linearly associated with an increase in children’s height by 0.43 standard deviations, after controlling for household open defecation, local area electrification, mother's height and body-mass index, household socio-economic characteristics, child demography, and indicators for engaging with healthcare systems. This estimate is numerically very similar to a recent randomization-based estimate by Gertler, et al (2015), to an observational estimate in Bangladesh by Lin, et al (2013), and to Spears’ (2013) estimate of the effect size needed to account for the India-Africa height gap. In order to explore the contribution of changing exposure to open defecation to the difference in child height observed between 2005 and 2010, we use three decomposition methods. Using simple pooled regression, Blinder-Oaxaca decomposition, and non-parametric re-weighting, the decline in exposure to open defecation can statistically account for a large and important fraction of the increase in height-for-age. The average child under 5 in Cambodia was 0.13 standard deviations taller in 2010 than in 2005, and our econometric analysis finds that reductions in the amount of open defecation to which the average child was exposed are able to account for much of this difference, and widespread open defecation could be a critical constraint for human development.

Understanding Latrine Adoption in Rural India: a Mixed-Methods Analysis

Sangita Vyas, Research Institute for Compassionate Economics
Dean Spears

According to WHO/UNICEF Joint Monitoring Programme estimates for 2012, 60 percent of the world's open defecation occurs in India. While the practice of open defecation is steadily decreasing in many other countries of the world, it remains stubbornly persistent in India. In the 2011 Indian Census, 53 percent of
households reported not owning a toilet or latrine, and the vast majority of these households were in rural areas. Sanitation has important implications for health and human capital development. An accumulating body of research links open defecation to intestinal diseases which reduce the absorption of calories and nutrients, and lead to malnutrition and impaired cognitive development among children. Considering the negative effects of poor sanitation on health and human capital, researching strategies for speeding the adoption of safe sanitation is a policy imperative. This paper seeks to inform this pursuit by investigating the cultural, economic, geographic, and demographic characteristics of households that built latrines between 2005 and 2012, and the motivations for adopting latrine use. We use two datasets for this mixed-methods analysis. Nationally representative panel data from the India Human Development Survey, which interviewed a sample of approximately 40,000 households across India in 2004-2005 and 2011-2012, offer sparsely available statistics on latrine adoption, and provide a unique opportunity to explore how changes in individual household characteristics are associated with latrine adoption. We supplement this quantitative analysis with qualitative data from 100 semi-structured interviews conducted in 2013-2014 in Gujarat, Haryana, Uttar Pradesh, and Nepal, exploring the motivations behind latrine construction and adoption of latrine use. In 2011-2012, 65 percent of rural households did not have a latrine, representing a 10 percentage point improvement from 2004-2005. Over the panel period, 21 percent of rural households who did not have a latrine in the first survey built one before the second. The states in which the greatest fraction of rural households adopted latrines over the panel period include Himachal Pradesh (45 percent), Haryana (38 percent), and Meghalaya (37 percent). Multi-variable regression analysis of the panel data finds that the likelihood of latrine adoption by households that did not own a latrine in 2005 is significantly associated with religion, caste, literacy, initial consumptions levels, changes in consumption, changes in household demographics, and improvements in housing. Hindu households were significantly less likely than non-Hindu households to have constructed a latrine over this period. In fact, the difference in adoption rates between Hindus and non-Hindus is about the same as the difference in adoption rates between households that were in the 25th percentile of consumption in 2005 and in the 75th percentile of consumption in 2012. The qualitative interviews indicate that rural Indian Hindus commonly consider latrines as polluting and do not want to build one near the home. Latrine adoption is also significantly more common among households that gained additional elders and adult women, either by aging over the panel period or by the arrival of new household members. In our qualitative interviews, respondents who had recently built latrines often cited ailing elderly as a reason for doing so because it is difficult and degrading to clean their feces daily. Similarly, young daughters-in-law, who have low intra-household status in rural India, are commonly kept from leaving the private space of the home, and building a household latrine is sometimes used to enforce this norm when new daughters-in-law become a part of the household. Contrary to popular belief, gaining access to piped water was not associated with latrine adoption after controlling for a range of economic, cultural, demographic, and geographic characteristics. This finding is consistent with the qualitative research, in which no household mentioned water as a reason to build or not build a latrine. This study employs new nationally representative panel data and qualitative interviews to shed light on the characteristics associated with latrine adoption. Understanding the household characteristics and motivations that are associated with latrine adoption can help policy makers focus efforts more effectively, either by targeting sanitation programming on households that are more likely to adopt latrines, or by experimenting with methods to convince those who are less likely. While further work is needed to investigate how to change attitudes and beliefs towards latrine use, this study represents an important step towards this goal.
Associations Between Access to Sanitation and Violence Against Women: a Multi-Country Study

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Robert Dreibelbis

Violence against women (VAW) is not only a violation of human rights, but also a serious public health concern around the globe. VAW has extensive health consequences that affect women’s physical, sexual, mental, emotional, and reproductive well-being (Campbell 2002; Ellsberg et al. 2006). Academic, media, and organizational reports focused on sanitation coverage in developing countries frequently suggest that lack of access to sanitation may also be a risk factor for VAW (Khosla 2000; Cairncross 2003; Pearson & McPhedran 2008; United Nations Human Settlements Program 2008; Amnesty International 2010; Massey 2011; World Health Organization & United Nations Children’s Fund 2013; Sommer et al. 2014). Yet, quantitative investigations of the association between VAW and access to sanitation are nearly absent in the scholarly literature. We utilized Demographic Health Survey (DHS) data from 27 countries to examine the association between access to sanitation and women's experiences of physical and/or sexual violence by a non-partner. We restricted our analysis to DHS surveys completed in the last eight years that contained sufficient information on recent violence and its known determinants (alcohol use, intimate partner etc). Self-reported, non-partner violence within the last 12 months was the binary outcome variable for our analysis. We developed a series of country- and region-specific multilevel logistic regression models assessing recent experiences of non-partner violence against self-reported access to sanitation. Access to sanitation was represented by a three-level categorical variable—(1) open defecation (2) shared sanitation facility, and (3) private facility. Private facilities served as the referent group for our analysis. All models controlled for several demographic characteristics and violence-related variables including, age, education, wealth, experiences of physical/sexual intimate partner abuse, physical/sexual family violence, partner alcohol use, and urban/rural location of residence. Logistic regression results were translated into average marginal effects to assess the (relative/absolute) probability of recent, non-partner violence associated with differing levels of sanitation. Country level-results suggest that lack of access to sanitation is strongly associated with women’s recent experiences of non-partner violence in countries in east and western Africa. Findings indicate that the probability of a woman who defecates in the open having experienced recent non-partner violence is double that of women who have access to a private facility in several of these countries. In addition results suggest that women with access to shared facilities in parts of west Africa have higher probabilities of having experienced non-partner violence than those who have access to private facilities. We did not, however, find significant associations between women’s recent experiences of non-partner violence and their levels of access to sanitation in countries in south Asia or southeast Asia. It should be noted that these are preliminary findings. Women substantially under report experiences of violence, so results may be an underestimate of the true magnitude of the problem.

WaterCredit in East Africa - A Sustainable Solution through Private Sector Partnership

Nozomi Witherspoon, Water.org

Madeleine Dy

This presentation will discuss Water.org’s experience of implementing the innovative WaterCredit model in East Africa, specifically around both the challenges and successes of partnering with private sector players. Empowering people in developing countries with sustainable access to water and sanitation (WASH), and
still reaching the base of economic pyramid (BOP) is possible by partnering with private sector stakeholders. In economic terms, the BOP is a socio-economic segment of the world’s population living on less than USD $2.50 a day. An estimated 3 billion people comprise the BOP, of which 2.5 billion people lack access to improved WASH services. As things stand, there will never be enough charity in the world to reach everyone in need. In response to this global challenge, Water.org developed its WaterCredit model based on the belief that a private sector, market driven approach is critical to achieving universal access to sanitation and safe water. The WaterCredit model revolves around partnerships with private sector players such as financial institutions (FIs) and WaSH suppliers to promote access to credit for household-based WASH improvements. The model encourages FIs to partner with WASH manufacturers and suppliers to streamline the value chain so that the households can receive the products in a timely and affordable manner. To date, WaterCredit has leveraged US$10.9 million in loan capital in East Africa, supporting all stakeholders in the WaterCredit ecosystem - FIs, suppliers, and beneficiaries. Water.org began its five year partnership with The MasterCard Foundation in 2010 to launch WaterCredit in Kenya, expanding to Uganda in 2013. In East Africa, Water.org partnered with seven private sector FIs with different market characteristics ranging from large commercial bank to a small WASH NGO with microfinance arm. The program has resulted in a number of lessons learned and achievements. Key achievements to date include: - As of April 2015, 6 partners in Kenya and Uganda had disbursed 21,109 WaterCredit loans serving 137,417 people. - As of April 2015, Water.org has invested USD $1,139,352 in WaterCredit and leveraged additional USD $10,979,265 in loan capital in East Africa. - FIs mainstreaming water and sanitation lending into their core business practices. - FI reaching scale in number of beneficiaries by making larger community based loans in addition to typical household approach. - FIs partnering with suppliers, local government and WASH NGOs to achieve mutual WASH goals. Key lessons learned include: - Multiple factors contributed to sanitation loans being less popular than water loans in Kenya. - Customized loan products and WASH technologies should meet the demand of the market (clients). - Support in terms of financial and human capital is needed at FIs. - Additional strategic partnerships with cross-sectoral private sector players should be developed. Based on these accomplishments and learnings, Water.org is seeking ways to reach more families at the BOP in East Africa through scaling-up WaterCredit in Kenya and Uganda, expanding WaterCredit in new markets in Ethiopia and Tanzania, and exploring additional innovative approaches to reach more people in Kenya.

**Adsorption and Biofiltration Based Odor Treatment for Improving FSM**

Tesfayohanes Yacob, University of Colorado

Jiele Xu; Stewart Farling; Kate Stetina; Marc Deshusses; Karl Linden

The provision of sanitation services is being accelerated as part of the Sustainable Development Goals (SDGs) with increasing focus put on fecal sludge treatment and re-use. The one common constraint in the sanitation value chain is the malodor present within human waste. Finding cost-effective ways to minimize odor nuisances from the latrines to the end point of use facilities is critical. Adsorption and biofiltration studies are being conducted as part of a project funded by the Bill & Melinda Gates Foundation to control and mitigate malodors derived from human waste. Biochars derived from wood, manure (human feces, horse, poultry), and Norit ROZ 3 activated carbon are being used to evaluate adsorption of the malodors. A reconstitution of fecal malodors was used, which comprised a mix of 7 compounds including carboxylic acids, sulfur and nitrogen containing compounds shown to be responsible for human fecal odor. Both static and dynamic type adsorption tests were performed. Odor was quantified using olfactometry (dilution to threshold or D/T) and an H2S meter. Breakthrough capacities of the adsorbents for both odor reduction (odor units per g of adsorbent) and H2S reduction (mg/g of adsorbent) were determined. It was shown that
odor breakthrough for most cases occurred prior to H2S breakthrough. Initial results show manure based chars (horse and human feces) having capacity of > 4.2 mg H2S/g char and an odor reduction of 2550 odor units per g char. In addition, specific compounds representing adsorption challenges and contributing to the earlier odor breakthrough were identified. Biofiltration tests are also being conducted with various biochar packed columns and odor removal determined as a function of operating conditions (flow, odor loading, biochar type, and moisture content). Overall, the results provide baseline engineering data on possible ways of applying adsorption and biofiltration to the various fecal sludge management approaches such as drying, combustion, and pyrolysis. Preliminary design information will be developed to aid in applications.

Systematic Reviews on Hygiene Interventions in Emergencies

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Background: Hygiene interventions are widely implemented to reduce the risk of disease in populations affected by emergencies. Despite their ubiquity, evidence on the effectiveness of these interventions has not yet been systematically reviewed. To address this research gap, 3ie and Humanitarian Evidence Programme (HEP) have recently awarded grants to conduct systematic reviews on the effectiveness of hygiene interventions in emergencies. Objective: The objectives are to determine the effectiveness of: 1) short-term hygiene interventions in reducing the risk of disease in non-protracted emergency response situations (funded by 3ie); and, 2) WASH interventions in reducing the risk of outbreaks (funded by HEP). We identified eight interventions for systematic review and impact analysis, including: increasing water access; source-based water treatment; household water treatment; promotion of hand hygiene at critical times; distribution of soap and/or hygiene kits; environmental hygiene; installation of temporary or permanent sanitation facilities; and, distribution of latrine alternatives. Methods: The review protocol has been developed, beginning with mapping the causal chain for the eight interventions. Due to the expected lack of experimental-design manuscripts, experimental, quasi-experimental, non-experimental, mixed-methods, and qualitative peer-reviewed and gray literature will be eligible for inclusion. A formal search engine and gray literature solicitation will be completed, and title, abstract, and full paper review will be used to access papers against inclusion criteria and for quality. Data from included papers will be synthesized for outcomes, including improvements in water quality, reduction of disease, and qualitative contextual factors. Results: By October, we will have completed our search engine searching and a majority of gray literature searching. The presentation in October is intended to: 1) share and receive comments on our protocol; 2) create awareness of the systematic reviews among influencers; 3) share initial results from the review; and, 4) solicit additional gray literature and references from attendees.

Improving the Sustainability of WASH Capacity Building Through Mobile Technologies

Candice Young-Rojanschi, CAWST
Clarke Foster

The Centre of Affordable Water and Sanitation Technology (CAWST) and Seeds of Hope International (SHIP) partnered together in Zambia to create a community health promoter (CHP) training and volunteer program in 2010. SHIP offers a one-day workshop introducing to water, sanitation, and hygiene (iWASH) from which interested participants are identified and given the opportunity to continue their training with the three-day
CHP A course, followed one month later with a three-day CHP B course. A recent evaluation of the program was able to contact 710 of the approximately 900 active CHPs. Together, the survey respondents have reached approximately 27 000 community members since 2010. One finding of the evaluation was that a key threat to the program is the reduction of motivation over time for volunteer CHPs. It was determined that keeping a close relationship with trainers was critical to sustaining the program. However, there is a great difficulty in maintaining contact with the large number of past trainees while still attempting to expand the program. CAWST and SHIP have worked together to develop a strategy for maintaining contact with CHPs using mobile technologies. Automated messages will be sent to the CHPs every four months. The messages will request information from the CHPs, such as how many households they have visited over the previous period, and offer additional support from SHIP, including the number of an assigned relationship manager. The goal of this project is for CHPs to continue to feel valued and connected to SHIP and to the larger program, and to periodically boost the motivation of CHPs. An additional benefit will be to assist SHIP and CAWST in monitoring the effectiveness of the CHP program by keeping track of CHP activities. CAWST worked with students at the University of Cambridge to investigate existing mobile technology options including advantages, costs, and limitations. This will assist in the selection of the appropriate software for the project. In June 2015 CAWST and SHIP will continue to pilot the mobile project by sending out automated messages to all CHPs on file, then again in October. The number of CHP responses, their activities, and the time required for staff to respond to requests generated by the project will be monitored. This paper will be presented as a case study focusing on what will be learned during the pilot of the mobile technology this summer.

**Sustainable Water, Sanitation and Hygiene Services: Community Health Promoters in Ndola, Zambia**

Candice Young-Rojanschi, CAWST

Clarke Foster

Introduction: Seeds of Hope (SHIP)'s community health promoter (CHP) program in Ndola, Zambia was developed in partnership with the Centre for Affordable Water and Sanitation Technology (CAWST) in 2010. The program consists of an initial community-wide workshop introducing the importance of water, sanitation, and hygiene (WASH) for health. Community members with further interest are encouraged to become volunteer community health promoters (CHPs). These volunteers participate in a three-day workshop about water-related disease transmission, volunteerism, and methods for approaching households. After one month the volunteers participate in a second three-day workshop addressing any questions or concerns the participants have, providing further information on safe water and sanitation, and reviewing skills to assist in their role. CAWST partner organizations in Afghanistan, Cambodia, and Nepal have modified the program for use in their respective countries. The goal of this study was to evaluate the project in Zambia to assist with identifying areas for improvement. Methods: Interviews were conducted by CAWST staff with SHIP and with active CHP groups. CHPs were surveyed either in person or by phone. In-person interviews were conducted in 17 geographical areas over 6 days. Senior CHPs in various neighbourhoods were contacted over the phone by SHIP trainers ahead of time, in order to disseminate the date and time of the interview to the remaining CHPs; all CHPs were also contacted by SMS to provide the date and time of interview information. Interviews were paper-based and conducted by SHIP trainers. Results: Of the 1400 CHPs trained in the previous five years, 900 were estimated by SHIP staff to still be active, of whom 710 were able to be reached. Together, the 710 CHPs reported having trained 27 000 community members over the previous five years. Several challenges to the program were identified, including knowledge dilution and maintaining motivation. The relationship that CHPs felt they had with the
Baseline Predictors of One Week Prevalence of Diarrhea within a Large Cluster-Randomized Controlled Trial of Point-of-Use Water Filters and Improved Cookstoves in Western Province, Rwanda

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Diarrheal and respiratory diseases are the leading contributors to childhood mortality in Sub-Saharan Africa. Despite Rwanda's rapid gains in childhood mortality reduction since 2000, most rural households still lack access to safe water, and unsafe water exposures in Rwanda may be exacerbated given recent population displacements from neighboring Democratic Republic of Congo and Burundi due to ongoing conflict and election violence. To address this environmental exposure, DelAgua Health initiated the large-scale distribution of point-of-use water filters (in addition to improved cookstoves to address household air pollution) with an aim to eventually reach 600,000 of Rwanda's poorest households. In Phase 2 of this program, DelAgua distributed this dual intervention to 100,000 households in 72 administrative sectors in Western Province between September and December 2014; the remaining 24 sectors in the province, containing about 40,000 target households, are currently serving as controls. This cluster-randomized controlled trial will evaluate the health impact of DelAgua's program. During the baseline phase of this study, an average of approximately 9 households were enrolled from each of 174 randomly selected villages, evenly split between intervention and control sectors. At baseline, all potential confounders related to education level, wealth status, livestock presence, water sources, sanitation factors and housing construction were balanced between our intervention and control arms. Overall, 1582 households were enrolled across all 174 villages and 2179 children under 5 years-old from these households were assessed for various health conditions, including diarrhea and pneumonia, through respondent reporting and by diagnosis using the WHO's Integrated Management of Childhood Illness (IMCI) criteria. Baseline seven-day prevalence of diarrhea in children under-5 years-old was 13.97%; seven-day prevalence of diarrhea with blood in stool, representing dysentery, was 1.98%. Overall, 60.92% of households had a pit latrine or open pit with no slab; 33.82% had a pit latrine with a slab and 2.45% had a composting toilet; the remaining houses either had a ventilated pit latrine or had access to no toilet. No toilet type observed presented excess risk of diarrhea over any other. The majority of households obtained their water from a protected spring (52.78%), unprotected spring (17.19%) and a public tap or standpipe (19.72%). After controlling for age in months and presence of livestock or poultry in the compound, the odds of reported diarrhea in children under-5 were higher in households that accessed water through a hand pump/borehole (OR=3.04, 95% CI: 1.51-6.12) or from a pond or lake (OR=2.46, 95% CI: 1.08-5.59) compared to households that accessed water through a protected spring. Presence of livestock or poultry in a household compound appeared to reduce the odds of childhood diarrhea by 30% (OR=0.70, 95% CI=0.55-0.89) after controlling for age, which could reflect the development of protective immunity or increased socioeconomic status. In addition to analyses presented here, thermotolerant fecal coliform membrane filtration analyses will be available on household drinking water samples and seroprevalence analyses against common enteric pathogens will be performed from blood samples collected from children 6 to 12 months of age at baseline.