

## **Household Water Treatment and Safe Storage Abstracts – American Society of Tropical Medicine & Hygiene Conference 2012.**

Below are 21 abstracts on Household Drinking Water Treatment & Safe Storage from the 2012 ASTMH conference. There is also a [complete listing of conference abstracts](#).

### **1 - INTEGRATING DENGUE AND DIARRHEA CONTROL IN RURAL SCHOOLS IN COLOMBIA: A CLUSTER RANDOMIZED CONTROLLED TRIAL**

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Diarrheal diseases and dengue fever are major global health problems. Where provision of clean water is inadequate, water storage is crucial. Fecal contamination of stored water is a common source of diarrheal illness, but stored water also provides breeding sites for dengue vector mosquitoes. Poor household water management is therefore a potential determinant of both diseases. Little is known of the role of stored water for the combined risk of diarrhea and dengue, yet a joint role would be important for developing integrated control efforts. Even less is known of the effect of integrating control of these diseases in school settings. This trial investigates whether interventions against diarrhea and dengue can reduce diarrheal disease and dengue risk factors in rural primary schools in Colombia. This is the first trial investigating the effect of integrating dengue and diarrhea control interventions and it is also the first trial to do this in school settings. A 2x2 factorial cluster randomized controlled trial is being carried out in rural primary schools in La Mesa and Anapoima municipalities, Cundinamarca, Colombia. Schools were randomized to one of four study arms: diarrhea interventions (DIA), dengue interventions (DEN), combined diarrhea and dengue interventions (DIADEN), and control (C). Schools were allocated publicly in each municipality at the start of the trial. The objective of the trial is to investigate whether these interventions will significantly reduce diarrhea incidence and dengue entomological risk factors. The primary outcome for diarrhea is incidence rate of diarrhea in school children and for dengue entomological risk, *Aedes aegypti* adult density per school. A total of 873 pupils from 34 schools are enrolled in the trial. Here we report results from baseline and the first follow-up data collections.

### **2 - CRYPTOSPORIDIUM INFECTION IN CHILDREN LESS THAN FIVE YEARS OLD WITH MODERATE-TO-SEVERE DIARRHEA IN RURAL WESTERN KENYA, 2008-2011**

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Recent data from the Global Enterics Multicenter Study (GEMS), a 3-year case-control study of children <5 years with moderate-to-severe diarrhea (MSD) in seven countries, suggest that *Cryptosporidium* is a major contributor to infant diarrheal illness in Africa and Asia. GEMS cases were children <5 years who presented at a clinic with MSD (>3 loose stools in the last 24 hours, within 7 days of illness onset, with >1 of the following: sunken eyes, skin tenting, dysentery, IV rehydration, or hospitalization). Controls were age-, gender-, and village-matched, and diarrhea-free during the 7 days before enrollment. Stool samples were tested at enrollment; data on water, sanitation and hygiene were collected, and each child's health status was recorded at a 60-day follow-up interview. Presence of diarrhea was recorded by caretakers for 14 days following enrollment. From January 31, 2008 to January 29, 2011 in the rural GEMS Kenya site, *Cryptosporidium* was identified in 160 (10.8%) case children and 88 (4.7%) controls. Prevalence of *Cryptosporidium* was 10.6% among cases <6 months old, 16.2% among cases 6-11 months old, and 8.1% among cases 12-59 months old. Among cases with a single pathogen identified, those with *Cryptosporidium* had a significantly longer median duration of diarrhea than those with another diarrheal pathogen (7.0 vs. 5.0 days,  $p < 0.01$ ), and tended to need hospitalization more often than those with another diarrheal pathogen (17.8% vs. 12.3%,  $p > 0.05$ ). At follow-up, death within 60 days had occurred in 7 (4.6%) of 152 cases with *Cryptosporidium* compared with 45 (3.6%) of 1,267 cases without *Cryptosporidium* ( $p > 0.05$ ). Cases from homes that used rainwater as their main source of drinking water had lower odds of *Cryptosporidium* infection than cases who used other sources (Odds Ratio = 0.58; 95% CI: 0.40-0.85). *Cryptosporidiosis* causes a substantial burden of diarrheal illness in young children in Kenya. An intervention aimed at reducing the burden of this pathogen is warranted, such as ceramic filtration of household drinking water.

### **3 - AN UNUSUAL PARTNERSHIP TO ENSURE SAFE DRINKING WATER TO THE RURAL POPULATION IN INDIA**

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Water treatment at the point-of-use (POU) can reduce diarrhea caused by waterborne pathogens by 30 to 50 % (WHO 2007). The goal of the project was to demonstrate a comprehensive strategy aiming at increasing use of POU water treatment methods among poor urban and rural populations and thereby reduce childhood diarrhea in the state of UP in India. The at-scale goal was to achieve 30 % rural and 40 % urban use of an effective POU method. By January of 2009, the partnership between POU manufacturers and NGO partners was formalized through MOUs. The project reached 674,064 households residing in 1120 urban slum areas and 1350 rural villages in UP. A quantitative study of 1400 households at baseline, showed only 2.5 % of households (4.1 % urban and 1.1 % rural) reported ever using a POU method promoted by the project (boiling, disinfection products, or filtration). In contrast, the outcome evaluation found very high rates of POU use in both the intervention and comparison areas, with 96.8 % of intervention households reporting they had ever used a recommended POU method, along with 71.0 % of households in the comparison areas. The biggest difference between intervention and comparison districts was in the use of chlorine liquid for disinfection (56.9 % versus 0.3 %). No difference was found in the use of water filters (about 7 % in both areas). Among urban households, 50% reported current use of chlorine tablets, vs. 3 % of rural households. Conversely, 60 % of rural households reported current use of liquid chlorine, vs. 11 % of urban households. This clear preference for different products cannot be explained by any difference in intervention approach, and bears further investigation. An engaged commercial sector was able to reach a substantial new market by partnering with NGOs and microfinance institutions. NGOs can be trained to become effective product demonstrators and micro-distributors. The long-term

viability of NGO POU product distribution should be monitored. Commercial partners are now expanding the model in other states in India.

#### **4- PRELIMINARY ASSESSMENT OF THE POTENTIAL EFFECTIVENESS OF WATER FILTERS TO REDUCE DIARRHEAL DISEASE BURDEN IN CHILDREN YOUNGER THAN FIVE YEARS OLD IN A PACIFIC ISLAND NATION**

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A novel household water treatment device was proposed for use in the Kiribati, a small, remote pacific island nation. In collaboration with the Kiribati Ministry of Health and the WHO (South Pacific) we conducted a field study to understand the extent to which water-borne diarrheal disease is an important health issue, and whether a domestic water filter used in this setting is likely to reduce the incidence of diarrhea. As far as we are aware, this is the first investigation of its kind in any pacific island nation. In this field study of 97 randomly selected households of 802 individuals we found that 7% of participants, and 25% of children under 5 years old had experienced diarrhea in the past month and 7% of children under 5 had experienced diarrhea in the past week. Participants reported high levels of open defecation (59% children) combined with low knowledge of the danger of childrens' feces and low levels of handwashing, especially after defecation and the handling of childrens' feces. It is highly likely that contamination from hands and flies goes on to contaminate food and individuals directly leading to high levels of 'waterwashed' (rather than water-borne) endemic diarrhea. Most individuals we interviewed (86%) reported that their household normally boils their water for drinking. Water samples were highly contaminated, and there was not a statistically significant difference in fecal coliforms between source water and drinking water. In households that boiled their drinking water, it was less contaminated than the source water in only half the samples, suggesting that significant recontamination occurs following boiling, this would likely happen following filtration. Almost all (91% of households) store drinking water and only 24% use safe storage containers, while the remainder access drinking water by dipping dirty cups, vessels, and hands into the water container. Information on behaviour and water quality indicates that the transmission of endemic diarrhoea is likely to be through many pathways other than drinking water, and even treated water is highly susceptible to recontamination. Filtration as a form of household water treatment is likely to have limited effect in this setting.

#### **5 - MOTIVATING CONTINUED USE OF POINT OF USE WATER TREATMENT IN RURAL BANGLADESH**

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Point of use (POU) water treatment can prevent diarrhea, though most interventions fail to achieve continued use in low income countries. In October 2010, we undertook a 13-month pilot POU water treatment intervention with sodium dichloroisocyanurate (NaDCC) tablets in 3 rural communities in Bangladesh. Trained local female community health promoters (CHPs) made 2 household visits and conducted 1 courtyard meeting per month. They encouraged water treatment by appealing to both health benefits and non-health values including convenience, nurture and modernity; addressed barriers; and provided a free supply of NaDCC tablets for daily use. At the last visit, CHPs gave study participants enough NaDCC tablets to last for two months. We assessed barriers to long term POU water treatment uptake and evaluated the effectiveness of the intervention in addressing these barriers during and at the end of pilot intervention activities. We assessed use by testing for residual free chlorine in stored drinking water in study households at the 2nd month (n=129) and 14th month (n=91). We also interviewed mothers of <5 children (n=30) and conducted group discussions (n=6) with both male and female study participants at 14 months. At months 2 and 14, 82% (106/129) and 62% (56/91) of households had detectable free residual chlorine in stored treated water, respectively. Respondents reported that they had become accustomed to the smell, taste and temperature of stored treated water and no longer perceived them as barriers. Respondents reported reduced episodes of illness, especially stomach aches, compared to the previous year, ease of dosing with provided storage vessel and clarity of treated water as factors that motivated continued use. Respondents welcomed regular household visits by CHPs whom they knew as neighbors. They emphasized that the encouragement provided by the CHPs motivated them to use NaDCC tablets in spite of their initial reaction to stored treated water, their heavy workload, and the reluctance of males to drink treated water. Despite initial concerns with smell, taste and temperature, the majority of study participants continuously treated their water for 13 months and at least one month after active promotion ended. Combining access to effective, easy-to-use water treatment technology with trained, confident and knowledgeable local community health promoters can help improve the uptake of POU water treatment.

## **6 - THE NEED FOR POINT OF USE WATER TREATMENTS IN AREAS OF PERI-URBAN POVERTY: CASE STUDY OUTSIDE IQUITOS, PERU**

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This study aimed to determine the water collection and home treatment methods in Belen, Iquitos, Peru to elucidate the cause of the high incidence of gastrointestinal diseases in this neighborhood. The results of this study emphasize the importance of point of use water treatment in the home. Belen is a sector of urban poverty on the outskirts of Iquitos, capital of the Loreto region of Peru, where people suffer from gastrointestinal diseases at higher rates than the rest of the city. While many previous studies have highlighted the prevalence of several specific pathogens in this neighborhood, there is little information regarding water-collection methods and treatment in this region. In July 2011, 50 households located in Belen were surveyed using stratified random sampling. Surveys were administered to the head of household in Spanish. In each house, a water sample was collected from the primary drinking water source in a sterile cup with an airtight screw cap then transported to the Universidad Nacional de Amazonica Peruana microbiology lab for fecal coliform (FC) testing. The American Public Health Association guidelines were used for FC testing. The

overall rate of contamination was 11.1%. Most of the water samples (92.5%) that were negative for FC were untreated in the home, suggesting that treatment methods used by the local water provider are sufficient at the point of treatment. The positive FC sample results most likely represent contamination during the time of storage or use in the home. No sample that had been treated at home had a positive FC test. Therefore, it will be critical to emphasize to residents of Belen the importance of home water treatment before consuming water. It is possible that water is contaminated during storage, so residents should be urged to keep their water storage containers disinfected as well. Iquitos boasts a water plant with treated water, but the amount of chlorine may not be adequate to cover contamination en route or in the home. Although a region may have access to treated water, residents should continue to practice point of use treatment to ensure the safety of their drinking water. Point of use contamination could be a substantial source for fecal contamination and therefore point of use treatment should be encouraged in the homes of communities of peri-urban poverty similar to Belen.

## **7 - DENGUE AND DIARRHEAL DISEASE RISK FACTORS IN RURAL AND SUBURBAN VILLAGES IN THAILAND AND LAOS**

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Diarrheal diseases and dengue fever are major global health problems. Household drinking water (DW) storage can be a determinant for both diseases if water is fecally contaminated and the storage containers provide breeding sites for dengue mosquitoes. The aim of this project is to assess health risks associated with household water storage practices by identifying relationships between household water management, contaminated DW, and mosquito production. In 2011 we collected entomological, bacteriological, and socioeconomic data from one rural and one suburban village in northeastern Thailand and southern Laos, respectively. In rural Thailand, almost 100% of the study population use rainwater as DW. In rural Laos 83% use unprotected wells in the dry season and 92% use rainwater in the rainy season. In the suburban settings DW sources are rainwater and bottled water. There was an average of 2.5 DW containers per household. Only 6% of households in rural Thailand and 43% in rural Laos treat their DW. These figures were higher for the suburban areas (Thailand: 65%; Laos: 84%). Water holding containers were found in >93% of the households, of which ~19% were positive for *Aedes aegypti* immatures. The most productive containers were cement tanks in both countries, representing 15-17% of all encountered pupae. The Breteau index (BI) was higher in Thailand than in Laos (140 vs 845,  $p < 0.01$ ). In Thailand the BI was higher in the rural area than in the suburban area (147 vs 134,  $p < 0.01$ ), whereas in Laos the opposite was observed (112 vs 56;  $p < 0.01$ ). In Thailand almost 10% of the *Aedes* positive containers were used for drinking, whereas in Laos as many as 25% were used for drinking. Of the *Aedes* infested DW containers 26% in Thailand and 51% in Laos were also contaminated with *Escherichia coli*. The results suggest an intricate relationship between water contamination and mosquito production in household water storage containers. This relationship and the role of domestic water management practices as risk factors for both dengue and diarrheal disease will be discussed.

## **8 - A COMMUNITY RANDOMIZED CONTROLLED TRIAL OF AN INTEGRATED HOME-BASED INTERVENTION IMPROVING HOUSEHOLD-AIR POLLUTION, DRINKING WATER QUALITY AND HYGIENE IN RURAL PERU**

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Diarrhoea and acute lower respiratory infections are leading causes of childhood mortality. Simple low-cost interventions have proven efficient in reducing diarrhoea and severe pneumonia; however, an integrated package provides opportunities for synergism. We conducted a community-randomised controlled trial in 51 rural communities in Peru to evaluate an environmental home-based intervention package (IHIP) in reducing acute lower respiratory infections, diarrhoeal disease and preventing malnutrition in children under 36 months of age. All homes used open fires and 80% had access to piped, untreated water supplies. E.coli was found in drinking water in 66% of the households. The proportion of stunted children was 55%. In the intervention arm an improved stove (OPTIMA) was installed and members were trained in the correct use and proper maintenances; a solar disinfection of drinking water (SODIS) method was established; and a water faucet with a kitchen sink was installed and handwashing practices were promoted. Diarrhoea, respiratory (weekly) and anthropometric (every two months) surveillance was done at home during a 12 months period. To reduce potential impact of non-blinding bias, the control arm received a psychomotor stimulation programme. We randomized 51 communities and enrolled 534 children. Baseline characteristics were balanced between study arms: The rate of diarrhoeal episodes in children in the intervention was 2.8 episodes per child per year as compared to 3.1 episodes in the control arm. The relative rate was 0.78 (95%CI: 0.58-1.05). Similarly, care takers in the intervention group reported fewer days of diarrhoea (mean 4.9 vs. 6.4 days per year; OR: 0.71, 95% CI: 0.47-1.06). No effect on acute lower respiratory infections or child's growth rates was observed. In conclusion we found no evidence for synergistic effects associated with the intervention package. Introducing several interventions and messages simultaneously may have overwhelmed the households and compromised use, operation and maintenance of all components.

## **9 - THE JOINT EFFECTS OF EFFICACY AND COMPLIANCE: A STUDY OF HOUSEHOLD WATER TREATMENT EFFECTIVENESS**

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The effectiveness of interventions to control infectious disease is related to the intrinsic efficacy of the interventions in removing pathogens, and how people comply with the interventions. However, little is known about the quantitative relationship between compliance and effectiveness, which is particularly important for household water treatment (HWT). Although many HWT methods are highly efficacious at inactivating pathogens, their effectiveness within actual communities is decreased by imperfect compliance. To assess the effectiveness of HWT on childhood diarrhea incidence via drinking water for three pathogen types (bacterial, viral, and protozoan), we developed a quantitative microbial risk assessment (QMRA) model. We examined the relationship between log<sub>10</sub> removal values (LRVs) and compliance with HWT for scenarios varying by: baseline incidence of diarrhea;

etiologic fraction of diarrhea by pathogen type; pattern of compliance; and size of randomly scheduled contamination spikes in source water. The benefits of increasing LRVs are strongly linked to compliance. For perfect compliance, diarrheal incidence decreases as LRVs increase. However, when compliance is incomplete in the scenarios we considered, there are diminishing returns from increasing LRVs at the community level. Higher LRVs are more beneficial if: contamination spikes are large; contamination levels are high in general; or the pattern of compliance includes some people who comply perfectly. The effectiveness of an HWT intervention at the community level may be limited by low compliance, such that the benefits of high LRVs are not realized. Therefore, patterns of compliance with HWT should be measured during HWT field studies and HWT dissemination programs. Studies of pathogen concentrations in a variety of developing country source waters should also be conducted. Guidelines are needed for measuring and promoting compliance with HWT, in addition to the recently published WHO HWT efficacy recommendations.

### **10 - THE RELATIONSHIP BETWEEN DISTANCE TO HOUSEHOLD WATER SOURCE AND MODERATE-TO-SEVERE DIARRHEA IN YOUNG CHILDREN IN THE GLOBAL ENTERICS MULTI-CENTER STUDY (GEMS), KENYA, 2009-2011**

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Water sources for rural households in the developing world are often located away from the home. Fetching water can be a substantial burden that can negatively affect household water quantity and quality, thereby increasing diarrheal disease risk. We visited households of 127 randomly selected pairs of case and age-, gender-, and village-matched controls enrolled in the GEMS study of moderate-to-severe diarrhea (MSD) in Kenya. We asked households to guide field teams from their home to their water source, and this path was captured as spatial data using GPS units. If no guide was available, we used GPS coordinates of the home and the water source to estimate distances. We compared GPS-sourced data to self-reported data in GEMS about round trip times spent to collect water, and evaluated each type of measurement as a predictor of MSD using conditional logistic regression. The paths recorded were a median of 1.18 (range 1.00 - 2.49) times the length of the straight line distances between their start and endpoints. Self-reported collection times were significantly correlated with the log-transformed distance measurements via GPS (Spearman correlation coefficient =0.80,  $p < 0.01$ ). The median recorded distance to water source was 196m (range: 1 - 1775m); 89 (35%) households were within 50m, all of which also reported the source to be in the household area. Collection times of 30 - 59 minutes were reported by households of 24 cases (median distance 561m, range 100 - 1775m) and 8 controls (median 562m, range 197 - 981m), and the odds of MSD were significantly higher vs. those with no travel ( $p < 0.01$ ). Collection times longer than 1 hour were reported for 12 cases (median distance 744m, range 148 - 1466m) and 3 controls (median distance 530m, range 460 - 1048m) and were significantly associated with MSD ( $p=0.02$ ). These

data suggest that distances traveled by households in rural Kenya to fetch water varied widely, that self-reported water collection times are correlated with measured distances, and that these may be useful in multivariate analyses of risk factors for MSD.

### **11 - RELATIONSHIP BETWEEN USE OF WATER FROM COMMUNITY-SCALE WATER TREATMENT REFILL KIOSKS AND CHILDHOOD DIARRHEA IN JAKARTA**

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In developing countries, safe piped drinking water is generally unavailable, and bottled water is unaffordable for most people. Purchasing drinking water from community-scale decentralized water treatment and refill kiosks (referred to as *isi ulang* depots in Indonesia) is becoming a common alternative. This study investigates the association between diarrhea risk and water kiosks. We monitored daily diarrhea status and water source for 1,000 children aged 1--4 years in Jakarta, Indonesia, for up to 5 months. Among children in an urban slum, rate of diarrhea per 1,000 child-days varied significantly by primary water source: 8.13 for tap water, 3.60 for bottled water, and 3.97 for water kiosks. In multivariable Poisson regression analysis, diarrhea risk remained significantly lower among water kiosk users (adjusted rate ratio [RR] = 0.49, 95% confidence interval [CI] = 0.29--0.85) and bottled water users (adjusted RR = 0.44, 95% CI = 0.21- -0.94), compared with tap water users. Purchasing water from low-cost water kiosks is associated with a reduction in diarrhea risk similar to that found for bottled water.

### **12 - OUTBREAK OF MULTI-DRUG RESISTANT SALMONELLA TYPHI, LUSAKA, ZAMBIA, 2011-2012**

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*Salmonella enterica* serovar Typhi causes approximately 22 million typhoid fever infections worldwide each year and outbreaks are increasing across southern Africa as urban population growth overwhelms aging water and sanitation systems. In December 2011, clusters of suspected typhoid cases were identified at two city hospitals in Lusaka, Zambia. From December 2011 - February 2012, 416 suspected cases were reported through hospital-based surveillance. We conducted a retrospective review of laboratory records and a case-control study using hospital-identified cases and matched controls from a highly affected neighborhood reporting an attack rate of 59.1 cases per 100,000 per month to identify risk factors for typhoid fever. A suspected case was defined as a hospitalized person having fever  $\geq 3$  days and one or more of the following: abdominal pain, vomiting, diarrhea, constipation, headache, joint pain, muscle pain, malaise, negative malaria parasite test or lack of improvement with antimalarial medication from the affected neighborhood. Laboratory record review revealed 145 *Salmonella* Typhi isolates recovered from January 2011 - February 2012. Among isolates tested locally for antimicrobial sensitivity, 7/71 (9.9%) were resistant to ciprofloxacin, 9/27 (33.3%) resistant to nalidixic acid, 66/108 (61.1%) resistant to chloramphenicol, and 34/112 (30.4%) resistant to cefotaxime. Of 248 neighborhood households tested, only 20% demonstrated residual chlorination in their drinking water at a level of at least 0.2mg/L. Neighborhood public drinking water sources



tested negative for residual chlorine, and one sample was positive for Escherichia coli, an indicator of fecal contamination. Recommended control measures included emergency point-of-use water treatment interventions and community education about sanitation and hygiene until long term repairs in water and sanitation systems are made. Antibiotic resistance indicates the need to reassess treatment recommendations and strengthen laboratory surveillance.

### **13 - EVIDENCE THAT MULTISECTOR FOOD SECURITY INTERVENTION PROGRAM IN RURAL PANAMA REDUCES HOOKWORM INFECTION IN PRESCHOOL CHILDREN**

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Since 2007, a multisector food security program in rural Panamanian communities has attempted to improve food security and health through agriculture extension, training in maternal-child nutrition and hygiene, and community organisation. Although gastrointestinal parasites are recognized as a health problem among young children, they have been outside the scope of the program. Our objective was to compare prevalence and intensity of intestinal parasitic infection among preschool children (6-60 mo) not yet involved in the program and those involved for 1 or 5 years. Fecal samples from 153 children were examined for Protozoa (direct smear) and helminths (FLOTAC), and household demographics, hygiene behaviours, and sanitation and water infrastructure were noted. An improved household water source was found in 43% of households and was more common where the program had begun in 2007 ( $p = 0.0003$ ). Latrines were found in 82% of homes and 59% of caregivers reported that their child always wore shoes. Hookworm was found in 31% of children, Giardia in 28% and Ascaris in 16%. Stepwise multiple regression models revealed that hookworm epg was higher in older children, households with more preschool children, and households without an improved water source ( $p = 0.0001$ ). Ascaris epg was higher in children with younger caregivers and in households with more children 12 years and younger ( $p = 0.02$ ). Presence of Giardia was not correlated with any of the measured demographic, behaviour or infrastructure variables. The number of years involved with the program did not emerge as a factor contributing to either prevalence or intensity of any of the infections. Our results show that that improved water source is associated with reduced hookworm infection but that long-term participation in this multisectoral program alone is not sufficient to protect against gastrointestinal parasites. Our future work will explore whether specific aspects of this multisector intervention are effective in reducing transmission of gastrointestinal parasite infections.

### **14 - EVALUATION OF HOUSEHOLD LEVEL INTERVENTIONS DURING A LARGE, URBAN TYPHOID FEVER OUTBREAK - HARARE, ZIMBABWE 2011-2012**

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Between October 2011 and March 2012, ~2,750 suspected cases of typhoid fever in two high-density suburbs of Harare (Dzivaresekwa and Kuwadzana) were reported to the Harare City Health Department (HCHD). To prevent outbreak spread, HCHD and non-governmental organizations conducted door-to-door health and hygiene education and distributed point-of-use water treatment (PoUWT) products beginning in October 2011. To evaluate the effectiveness of these interventions, we conducted cross-sectional household surveys in these two affected suburbs in March 2012, including free chlorine residual (FCR) testing in stored drinking water. Reported intervention coverage was high, with 351 (77%) of 458 randomly selected households having received both typhoid fever prevention information and at least one PoUWT product. Of 368 households that received at least one of the three types of chlorine tablets distributed, 326 (89%) reported ever using them, 160 (43%) reported using them daily, and 98 (27%) had stored water that was treated and had FCR  $\geq 0.2$ mg/L when tested. Only 169 (55%) of 310 household respondents who had chlorine tablets on the day of the survey knew the correct volume of water to treat with their tablets. In univariate analysis, respondents who had higher income, were older, had received PoUWT products or typhoid fever prevention information, and who reported household water treatment before the outbreak were more likely, and respondents who reported boreholes as the primary source of drinking water were less likely, to report water treatment during the outbreak or on the day of the survey, and to have treated stored water with FCR  $\geq 0.2$ mg/L ( $p < 0.05$ ). The findings highlight: 1) relatively low uptake of PoUWT after free distribution (consistent with other research); 2) the need to improve coordination of NGO response activities through consistent PoUWT product choices and communication about product use; and, 3) the need to emphasize treating drinking water from all sources daily to control and prevent typhoid fever and other waterborne disease outbreaks.

## **15 - PROGRESS ON MDG 7.C IN THE MILLENNIUM VILLAGES AFTER THREE YEARS: IMPROVED HOUSEHOLD WATER AND SANITATION**

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Benefits of improving water and sanitation can influence health, educational, employment, economic and social domains. Since 1990, there have been significant global gains in access to improved water, and slower gains in sanitation. Despite commendable improvements, global progress has been uneven, with sub-Saharan Africa, and rural areas in particular, carrying a disproportionate burden of poor access. This mixed methods implementation study assesses progress towards MDG 7.C across nine sites in rural sub-Saharan Africa in the first three years of the Millennium Villages Project (MVP), a 10-year multi-sector development project. Details of costs, variability between and within sites, challenges and lessons learned are explored in the study. Across nine MVP sites, the proportion of households not using an improved household water source reduced from 87.3% at baseline (2006/07) to 22.7% at year 3 (2009/10) (64.6% percentage-point change, 95% CI = 60.7-68.6%,  $p$ -value  $< 0.0001$ ). This represents a 74% reduction in the proportion of population without access to improved water, and exceeds the MDG target for water at a local level, as well as meeting the sub-Saharan African regional target of less than 25% of the population without coverage by 2015. The proportion of the population reporting not using an improved sanitation facility reduced from 98.1% at baseline to 71.4% at year 3 (26.7% percentage

point change, 95% CI 24.6%-29.0%, p-value <0.0001). This represents a 27% reduction in the proportion of the population without access to improved sanitation facilities. Although not yet meeting the MDG for sanitation, if the same rate of change were to continue from today to 2015, sanitation would also be on track to meet local and regional MDG targets. These data provide promising evidence suggesting that with MDG-focused interventions, significant gains can be made in household access to improved water and sanitation facilities in a rural sub-Saharan African setting.

## **16 - POST-IMPLEMENTATION EFFECTIVENESS OF FOUR HOUSEHOLD WATER TREATMENT TECHNOLOGIES IN TYPICAL-USE CONDITIONS IN RURAL KENYA**

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Household water treatment technologies are used by about 18 million of the 884 million people without adequate access to safe water. The efficacy of household water treatment technologies has been demonstrated in controlled situations such as laboratory and field trials. However some authors query the sustainability of the efficacy of HWT technologies under real-life situations after the field trials have ended. In view of the dependence of rural communities on highly polluted surface water sources; the sectoral promotion of household watertreatment (HWT) systems and the lack of data on their post-intervention effectiveness, it is necessary to evaluate the effectiveness of household water treatment technologies within a real-life context. This study was carried out one and two years after the two implementing organizations had ended their intervention. It examined the microbial efficacy of Aquatab, PUR, Waterguard and ceramic filters by carrying out three unannounced visits between March and April 2010 to each of the 37 HWT user households in five villages in the Nyanza province of Western Kenya. A total of 247 samples were collected from study households' collection and storage containers in order to determine the efficacy of the technologies on water from the 11 unimproved and improved water sources used by the study households. The findings indicate that the four HWTS technologies assessed are able to improve microbial quality of the improved and unimproved water sources. However, based on the observation of inconsistent performance, none of the technologies achieved the minimum expected reduction value or can be classified as a highly protective or protective technology. It is recommended that the drinking water supply and sanitation sector should address the reasons for their reduced effectiveness in the typical-use conditions when compared to laboratory efficacy. These include incorrect usage and inappropriate selection of HWT options for water source characteristics.

## **17 - EVALUATION OF THE MICROBIOLOGIC SAFETY OF STORED RAINWATER AS AN IMPROVED DRINKING WATER SOURCE FOR COMMUNITIES IN KHON KAEN, THAILAND**

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Rainwater (RW) is considered an improved source of drinking water (DW) by the WHO and UN agencies tracking progress towards achieving the safe water access target of the

Millennium Development Goals. There are, however, a paucity of data on the microbial quality of RW, making uncertain its safety as a DW source. The objective of this work was to evaluate the microbial quality of stored RW collected in a rural village in Thailand using the WHO DW quality guideline value of  $<1 E. coli/100\text{mL}$  as the basis for safety. In 2011, 59 households in Khon Kaen province, all of which used RW as their primary source of DW, were visited twice, once during dry season and once during rainy season. Observational data related to the physical/sanitary conditions of RW harvesting systems (RWHS) were collected during visits. Sampled containers included each household's main RW collection tank and the refillable container used to store RW for daily consumption. Samples were assayed for *E. coli* by the Colisure Quantitray 2000 method and results were scored as present if *E. coli* was  $\geq 1/100\text{mL}$ . Of all samples processed (collection tank, refillable container), 39% and 82% of households had *E. coli* present in at least one container during the dry and wet seasons, respectively. *E. coli* was present in 21% and 66% of RW collection tanks during the dry and wet seasons, respectively. Initial analysis suggests that no single factor related to RWHS setup (roof, pipe, or tank material) had a statistically significant impact on the presence of *E. coli* in RW collection tanks. These results suggest that stored RW microbiologic quality may be highly seasonal, may not always meet WHO guidelines for safe DW, and that deterioration of the microbiologic quality of stored RW is likely due to a combination of collection and use practices. These results document that the UN Joint Monitoring Program's use of access to improved water supplies as an indicator of progress towards the MDG safe water target results in overestimation because improved sources, like harvested RW, may be microbiologically unsafe.

## **18 - REDUCTIONS IN DIARRHEA AND CLINIC VISITS FOR DIARRHEA AMONG CHILDREN UNDER THE AGE OF FIVE ASSOCIATED WITH A SCHOOL-BASED WATER SUPPLY, SANITATION AND HYGIENE INTERVENTION IN WESTERN KENYA: A CLUSTER-RANDOMIZED TRIAL**

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While many studies have documented reductions in diarrhea incidence in children under five associated with improvements in water, sanitation, and hygiene (WASH) in the domestic environment, the effect of institution-based interventions are not well understood. We conducted a cluster-randomized trial of school-based WASH interventions in 185 public primary schools in western Kenya. Enrolled schools with a nearby water source ( $<1\text{KM}$ ) were randomized into a handwashing promotion and water treatment intervention [HP&WT], HP&WT plus an additional sanitation component [San + HP&WT], or a control group. Schools without a nearby water source were randomized to receive a water supply intervention in addition to the San + HP&WT intervention components or to a control group. Interviews were conducted in a systematic selection of households in the catchment areas of all enrolled schools. Parents reported diarrhea episodes in the past week and clinic visits for diarrhea or vomiting in the past two weeks were recorded for all children under the age of five. Data were collected at baseline (March-April 2007) ( $n = 4,549$ ) and two years after the start of the interventions ( $n = 4,392$ ). There was a non-significant 33% reduction in the relative risk (RR) of diarrhea and 51% reduction in the RR of clinic visits among children under five living in the catchment areas of schools receiving water supply improvements compared to control areas ( $p = 0.185$  and  $0.075$ , respectively). Restricting analysis to those children under five living with at least one child attending a school enrolled in the trial

increased both the magnitude and significance of this effect (RR diarrhea: 0.53,  $p= 0.049$ ; RR clinic visits: 0.39,  $p= 0.03$ ). The HP&WT and San + HP&WT interventions showed no effect on either outcome in both unrestricted and restricted analyses. Our findings suggest that an integrated school WASH intervention that includes the provision of improved water supply at the school can result in substantial reductions in child morbidity even among those children too young to attend school.

### **19 - PERSISTENT, WIDESPREAD OUTBREAK OF TYPHOID FEVER ASSOCIATED WITH INTESTINAL PERFORATIONS - BUNDIBUGYO AND KASESE DISTRICTS, UGANDA, 2009-2011**

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*Salmonella enterica* serovar Typhi causes approximately 22 million typhoid fever infections worldwide each year; among these, 1-3% of patients develop intestinal perforation (IP). In 2008, an outbreak of typhoid fever with a high rate of IP was reported in Kasese, a rural district in western Uganda. A 2009 investigation of this outbreak identified 577 cases through July 15, 2009; 249 had IP. A high rate of IP was sustained in Kasese through 2011 and the neighboring district of Bundibugyo reported a typhoid fever outbreak in August 2011. We gathered information about cases through enhanced surveillance and hospital and district health office (DHO) records. A suspected typhoid case was defined as diagnosis of IP or symptoms of fever, abdominal pain, and one or more of the following: vomiting, diarrhea, constipation, joint pain, headache, general body weakness, clinical suspicion of IP, or failure to respond to antimalarials in a Kasese resident from July 16, 2009-December 31, 2011 or in a Bundibugyo resident in 2011. Among Kasese residents, 658 suspected cases were identified; 519 were diagnosed with IP. Among Bundibugyo residents, 330 suspected cases were identified and 56 were diagnosed with IP. Laboratory surveillance from October - December 2011 isolated *Salmonella* Typhi by blood or stool culture from 9 Kasese and 15 Bundibugyo patients. Among 19 isolates tested for antimicrobial sensitivity, 1 had intermediate susceptibility to ciprofloxacin, 15 were multidrug resistant but sensitive to ciprofloxacin, and 3 were pan-susceptible to all antimicrobials tested. Several pulsed field gel electrophoresis patterns were shared by isolates from both districts, suggesting that the outbreak spread from Kasese to Bundibugyo. Untreated drinking water was suspected as the chief transmission route. Drinking water sources in areas of high typhoid incidence in both districts yielded *Escherichia coli*, an indicator of fecal contamination. Recommended control measures included emergency point-of-use water treatment interventions and community education about sanitation and hygiene.

### **20 - THE IMPACT OF IMPROVED SCHOOL WATER, SANITATION AND HYGIENE ACCESS ON PUPIL DIARRHEA: A CLUSTERRANDOMIZED TRIAL**

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Numerous studies have assessed the impact of improved access to water, sanitation, and hygiene (WASH) at the household level in reducing diarrheal disease, but few have rigorously assessed the impact of WASH in the school setting. Lack of access to improved WASH facilities and behaviors at school may increase risk of diseases due to the vulnerable age of children, increased opportunity for transmission of infectious agents, and lack of an immune response to organisms circulating in the public domain. We conducted a cluster-randomized trial to assess the impact of a school-based WASH intervention on diarrheal disease among primary school pupils. The study was carried out among 4,665 pupils in 185 public primary schools in Nyanza Province, Kenya. Two study populations were used: schools with a dry season water source within 1KM and those without. Schools with water nearby were randomly assigned to receive hygiene promotion and water treatment (HP&WT), HP&WT + sanitation, or no intervention (control). Schools without a nearby water source were randomly assigned to receive HP&WT, sanitation, and water supply improvements or no intervention (control). Our primary outcome was pupil-reported seven-day recall of diarrheal symptoms. At endline, pupils in schools with nearby dry-season water sources that received improvements in HP&WT and sanitation demonstrated similar measures of diarrhea period prevalence (RR 0.88, 95% CI 0.60-1.28) and diarrhea illness duration (IRR 0.85, 95% CI 0.57-1.24) compared to pupils attending associated control schools. Similar results were noted for pupils attending schools with HP&WT interventions only. Pupils attending schools without a water source in the dry season that received a water supply improvement followed by HP&WT and sanitation showed a 66% reduction in diarrheal disease (RR 0.34, 95% CI 0.17-0.64) and 70% reduction in days of illness (IRR 0.30, 95% CI 0.15-0.60) compared to associated controls. In settings with no water supplies in the dry season, an integrated school-based intervention to improve water supply, water quality, sanitation, and handwashing can reduce diarrheal illness among pupils. Since many schools in low-income settings function without year-round water supplies, these should be a priority for implementing WASH interventions.

## **21 - EVALUATION OF EDUCATION THROUGH LISTENING, A COMMUNITY ENGAGEMENT METHODOLOGY, TO PROMOTE THE ADOPTION OF SAFE HOUSEHOLD WATER TREATMENT BEHAVIORS IN COMMUNITIES IN WESTERN KENYA**

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Household water treatment has been shown to reduce diarrhea risk by nearly 40%, but relatively low rates of adoption of these interventions have limited the scale at which they are being used. New behavior change approaches are needed to accelerate adoption. In 2010, we evaluated the impact of Education through Listening (ETL), a behavior change methodology, on the adoption of household chlorination. ETL is a community engagement technique that is a person-centered way of communicating and giving feedback to promote behavior change. We randomized 12 villages in Vihiga District, Kenya into an intervention group in which ETL was used to motivate home water chlorination and a comparison group that used the standard village-based social marketing approach promoted by the Safe Water

and Aids Project, a local Kenyan non-governmental organization. Over a 6-month period, during biweekly home visits mothers were interviewed about reported water treatment and diarrheal disease in children <2yo; water treatment was confirmed by testing stored water for residual chlorine. A higher percentage of households in ETL villages than comparison households had reported (14% versus 11%, Pearson's chi-square,  $p = 0.03$ ) and confirmed (7.5% versus 3.6%, Pearson's chi-square,  $p < 0.0001$ ) household water treatment with chlorine products. There was no difference in the proportion of children <2yo reported to have diarrheal disease between the intervention (6%) and comparison (6%) groups. However, the percentage of children with reported diarrheal disease was significantly lower in households that reported treating drinking water by any method than non-treating households (4% vs 7%, Pearson's chi-square,  $p = 0.027$ ). Although use of ETL appeared to increase the reported and observed use of chlorine products, adoption was modest. Further study of barriers to water treatment is needed.