A Bibliography on Point-of-Use Water Disinfection

Compiled by Environmental Health at USAID and CDC/Safewater

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INTRODUCTION

- This bibliography consists of published articles as well as project and/or research reports. It was compiled with assistance from CDC/Safewater.

- The bibliography is a work in progress and contains studies published through 2006. It will be updated on a regular basis. Links are included to abstracts or full-text for most of the studies.

- Full-text documents are in pdf format and the Adobe Reader can be downloaded free of charge.

OVERVIEW STUDIES

- CDC (2005). Preventing Diarrheal Disease in Developing Countries: Proven Household Water Treatment Options 1-page Fact Sheet. Atlanta, GA: CDC. - This one page fact sheet provides a snapshot overview of the benefits and drawbacks of each of the household water treatment options that are proven to reduce diarrheal disease incidence.


- Clasen T & Bastable A (2003). Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. J Water & Health 1(3): 109-115. - This study points to the need to extend drinking water quality beyond the point of distribution to the point of consumption. The options for such extended protection, including improved collection and storage methods and household-based water treatment, are discussed.

- Fewtrell L, Colford J (2004). Water, Sanitation and Hygiene: Interventions and Diarrhoea: A Systemic Review and Meta-analysis. Health, Nutrition, and Population Family of the World Bank Human Development Network. - This meta-analysis compares diarrheal disease reduction of various water and sanitation interventions. Handwashing (average 42% reduction) and household water treatment (39% reduction on average) were found to be the two most effective water and sanitation interventions.


- IRC. (2005). Household water treatment FAQs. Delft: IRC. - The focus of this FAQ is on options, suitable for developing countries, for treatment of microbiological contamination and treatment of chemical contamination.

- Jensen PK, Ensink JH, Jayasinghe G, van der Hoek W, Cairncross S, Dalsgaard A (2002). Domestic transmission routes of pathogens: the problem of in-house transmission of drinking water during storage in developing countries. Trop Med Int Health 7:604-609. - Even if drinking water of poor rural communities is obtained from a ‘safe’ source, it can become contaminated during storage in the house. To investigate the relative importance of this domestic domain contamination, a 5-week intervention study was conducted.


• Sobsey, M.D. (2002). Managing water in the home: accelerating health gains from improved water supply. Geneva: WHO. - This report describes and critically reviews the various methods and systems for household water collection, treatment and storage. It also presents and critically reviews data on the ability of these household water treatment and storage methods to provide water that has improved microbiological quality and lower risk of waterborne diarrheal and other infectious disease.


C. ECONOMIC ANALYSES

• Hutton G, Haller L (2004). Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. World Health Organization, Geneva. - This cost-effectiveness evaluation found that the Safe Water System was the most cost-effective water and sanitation intervention.

D. INTERVENTIONS/TECHNOLOGIES

1. Biosand filters


• Kaiser N, Liang K, Maertens M, Snider R (2002). Biosand Filter: Summary of all lab and field tests. - This summary details all of the microbiological laboratory data collected by various research organizations on BioSand Filtration.


• Stauber, CE; et al. (2006). Characterisation of the biosand filter for E. coli reductions from household drinking water under controlled laboratory and field use conditions (abstract). Water Science and Technology. 54(3): pp. 1-7.
2. Ceramic filters


3. Flocculant-Disinfectant


- Crump JA, Otieno PO, Slutsker L, Keswick BH, Rosen DH, Hoekstra RM, Vulule JM, Luby SP (2004). Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhea in areas with turbid source water in rural western Kenya: cluster randomized controlled trial. *BMJ* 331(7515):478-84. This paper documented a 25% reduction in diarrhea disease incidence in under-2’s and a 19% reduction in all age groups of users of PuR as compared to controls in turbid water in Western Kenya. In addition, this study documented a 17% reduction in diarrhea disease incidence in under-2’s and a 25% reduction in all age groups of users of the SWS as compared to controls in turbid water in Western Kenya. When the two arms were joined, there was a statistically significant reduction in all-cause mortality.
• Crump JA, Okoth GO, Slutsker L, Ogaja DO, Keswick BH, Luby S. (2004). Effect of point-of-use disinfection, flocculation and combined flocculation–disinfection on drinking water quality in western Kenya. Journal of Applied Microbiology 2004, 97, 225–231. This paper measured the effectiveness of PuR on microbiological contaminants in drinking water. In water from 30 sources, combined flocculant-disinfectant reduced Escherichia coli concentrations to <1 CFU100 ml⁻¹ for 29 (97%) and reduced turbidity to <5 nephelometric turbidity units (NTU) for 26 (87%).

• Rangel, J. M., B. Lopez, et al. (2003). A novel technology to improve drinking water quality: A microbiological evaluation of in-home flocculation and chlorination in rural Guatemala. Journal of Water and Health 01.1: 15-22. This study documented that the use of PuR with a traditional vessel (83% potable water), PuR with a CDC vessel (92% potable water), PuR with a covered bucket with spigot (93% potable water) led to an increase in potable water provision as compared to controls (5% potable water).


4. SWS and Chlorine

• CDC (2005). Preventing Diarrheal Disease in Developing Countries: The CDC/PSI/ Rotary Safe Water System Project in Western Kenya. Atlanta, GA. This fact sheet describes the SWS project, which includes social marketing with PSI linked to community groups, in Kenya.

• CDC (2005). Preventing Diarrheal Disease in Developing Countries: The CDC/PSI Safe Water System Program in Zambia. Atlanta, GA. This fact sheet describes the PSI social marketing SWS project in Zambia.

• CDC (2005). Preventing Diarrheal Disease in Developing Countries: The Safe Water System Program. Atlanta, GA.

• CDC (2005). Preventing Diarrheal Disease in Developing Countries: The CDC/Jolivert Safe Water for Families Project in Rural Haiti. Atlanta, GA. - This fact sheet describes a community-based, rural Safe Water System project, where the chlorine solution is made and distributed through a faith-based clinic to the surrounding community.


• Crump JA, Otieno PO, Slutsker L, Keswick BH, Rosen DH, Hoekstra RM, Vulule JM, Luby SP (2004). Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhea in areas with turbid source water in rural western Kenya: cluster randomized controlled trial. BMJ 331(7515):478-84. - This paper documented a 25% reduction in diarrheal disease incidence in under-2’s and a 19% reduction in all age groups of users of PuR as compared to controls in turbid water in Western Kenya. In addition, this study documented a 17% reduction in diarrheal disease incidence in under-2’s and a 25% reduction in all age groups of users of the SWS as compared to controls in turbid water in Western Kenya. When the two arms were joined, there was a statistically significant reduction in all-cause mortality.

• Hutton G, Haller L (2004). Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. World Health Organization, Geneva. - This cost-effectiveness evaluation found that the Safe Water System was the most cost-effective water and sanitation intervention.

• Jensen PK, Ensink JH, Jayasinghe G, van der Hoek W, Cairncross S, Dalsgaard A (2003). Effect of chlorination of drinking-water on water quality and childhood diarrhoea in a village in Pakistan. J Health Popul Nutr 21:26-31. - This study found that there was no statistically significant difference between diarrhea in children using non-chlorinated water supply systems and children using chlorinated groundwater water supply systems, and concludes that "reduction of faecal bacteria in the public drinking-water supply by chlorination does not seem to be a priority intervention to reduce childhood diarrhoea.

• Luby, S., M. Agboatwalla, et al. (2004). Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. American Journal of Tropical Medicine and Hygiene 71(4): 420-427. This study documented a 71% reduction of diarrheal disease incidence in SWS users without a refrigerator not immediately, but after 1 year, indicating that houses of lower socio-economic status (as defined by ownership of a refrigerator) needed extra time to adopt the intervention. It also documented a 53% lower incidence of diarrhea in those who received soap initially, with a 35% reduction one year later.

• Luby, S., M. Agboatwalla, et al. (2001). A low-cost intervention for cleaner drinking water in Karachi, Pakistan. International Journal of Infectious Diseases 5: 144-150. This study documented a 99.8% reduction in the mean concentration of thermotolerant coliforms in users of hypochlorite solution and safe storage container as compared to controls. Two years after vessel distribution, 68% of the families were still using the safe storage container.

• Mahfouz AA, Abdel-Moneim M, al-Erain RA, al-Amari OM (1995). Impact of chlorination of water in domestic storage tanks on childhood diarrhoea: a community trial in the rural areas of Saudi Arabia. J. Trop. Med. Hyg. 98(2): 126-30. This study shows that children drinking water chlorinated with calcium hypochlorite had a 48% reduction of diarrhea as compared to controls, and that all water samples taken from participating families tanks were bacteriologically fit for drinking.

• Makutsa, P., K. Nzaku, et al. (2001). Challenges in implementing a point-of-use water quality intervention in rural Kenya. American Journal of Public Health 91(10): 1571-1573. This paper discusses and evaluates a SWS project implemented in communities CARE/Kenya was already working within. It was found 33.5% of families had residual chlorine in their drinking water, and 18.5% of families had and improved clay pot. This article discusses the way forward for the project.


• Mong, Y., R. Kaiser, et al. (2001). Impact of the safe water system on water quality in cyclone-affected communities in Madagascar. American Journal of Public Health 91(10): 1577-1579. After a hurricane, 11,700 kits containing chlorine solution and foldable jerry cans were distributed in rural Madagascar. Five months after distribution, 25% of those surveyed had chlorine residual in their jerry can at the time of an unannounced visit.
• Ogutu, P., V. Garrett, et al. (2001). Seeking safe storage: A comparison of drinking water quality in clay and plastic vessels. *American Journal of Public Health* 91(10): 1610-1611. This study found that chlorine residual can be maintained in both plastic jerry cans and ceramic containers for 24 hours above 0.2 mg/L.

• Olembo L, Kaona F, Tuba M, Burnham G (2004). *Safe Water Systems: An Evaluation of the Zambia CLORIN Program*. U.S. Agency for International Development (USAID) through the Environmental Health Project (EHP). - This extensive, population-based evaluation found that 42% of people in a random population-based survey reported current use of Clorin (the PSI SWS product) and 13% of the population had chlorine residual in their drinking water at the time of the unannounced visit.

• Parker AA, Stephenson R, Riley PL, Ombeki S, Komolleh C, Sibley L, Quick R. (2006). Sustained high levels of stored drinking water treatment and retention of hand-washing knowledge in rural Kenyan households following a clinic-based intervention. *Epidemiol Infect.* Jan 26: 1-8. - This study showed that two weeks after being recommended to use the PSI socially marketed WaterGuard solution by nurses when going to a clinic for diarrhea, 67% of patients had purchased WaterGuard and had chlorine residual in their drinking water at an unannounced visit, and 1 year later 71% of patients had chlorine residual. This study also found that patients trained in handwashing retained the knowledge 2 weeks and year out.


• Quick, R. E., L. V. Venczel, et al. (1999). Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: A promising new strategy. *Epidemiology and Infection* 122: 83-90. - This study documented a diarrheal disease reduction of 44% and a significant reduction of E. coli in stored water of users of the Safe Water System.

• Rangel, J. M., B. Lopez, et al. (2003). A novel technology to improve drinking water quality: A microbiological evaluation of in-home flocculation and chlorination in rural Guatemala. *Journal of Water and Health* 01.1: 15-22. - This study documented that the use of the SWS led to an increase in potable water provision as compared to controls (92% in intervention users, 5% in controls).

• Reiff, F. M., M. Roses, et al. (1996). Low-cost safe water for the world: A practical interim solution. *Journal of Public Health Policy* 17(4): 389-408. - This advocacy piece advocates for the use of household water treatment to reduce diarrheal disease incidence until infrastructure can be established.

• Reller, M., Y. Mong, et al. (2001). Cholera prevention with traditional and novel water treatment methods: An outbreak investigation in Fort-Dauphin, Madagascar. *American Journal of Public Health* 91(10): 1608-1610. This case-control study in a Madagascar cholera outbreak found that patients were more likely than controls to have drunk untreated water, and that drinking heated water, water from a tap, or water treated with SWS was protective.


• Sobel, J., B. Mahon, et al. (1998). Reduction of Fecal Contamination of Street-Vended Beverages in Guatemala by a Simple System for Water Purification and Storage, Handwashing, and Beverage Storage. *American Journal of Tropical Medicine and Hygiene* 59: 380-387. This study documented a significant decrease total and fecal coliform in stored water and beverages sold by vendors using the SWS.
• Sobsey MD, Handzel T, Venczel L (2003). Chlorination and safe storage of household drinking water in developing countries to reduce waterborne disease. *Water Sci Technol.* 47(3): 221-8. This study evaluated point-of-use chlorination and safe storage in Bangladesh (reduction of diarrhea by 43%) and Bolivia (reduction of childhood diarrhea of 24%). E. coli, Clostridium perfringens, and heterotrophic plate count bacteria were lower in intervention households than in control households.


5. Solar Disinfection

• Acra A., M. Jurdi, H. Mu'allem, Y. Karahagopian, Z. Raffoul (1990). *Water Disinfection by Solar Radiation, Assessment and Application*, Technical Study 66e, IDRC. Sunlight with wavelengths of 315-400 nanometers (nm) on the ultraviolet (UV) range of the electromagnetic spectrum is most effective at destroying bacteria.

• Berney, M., Weilenmann, H.-U., Ihssen, J., Bassin, C., Egli, T. (2006). Specific growth rate determines the sensitivity of enteric bacteria to thermal, UVA and solar disinfection. *Applied and Env Microbio Vol. 72, No. 4*. Knowledge about the sensitivity of the test organism is essential for the evaluation of any disinfection method. In this work we show that sensitivity of *Escherichia coli* MG1655 to three physical stresses (mild heat, UVA light, and sunlight) that are relevant in the disinfection of drinking water with solar radiation is determined by the specific growth rate of the culture.


• Conroy R, Meegan M, Joyce T, McGuigan K, Barnes J (2001). Solar disinfection of drinking water protects against cholera in children under 6 years of age. *Archives of Disease in Childhood, 85(4):293-5*. Point of consumption solar disinfection can be done with minimal resources, which are readily available, and may be an important first line response to cholera outbreaks. Its potential in chlorine resistant cholera merits further investigation.

• Conroy R, Meegan M, Joyce T, McGuigan K, Barnes J (1999). Solar disinfection of water reduces diarrhoeal disease: An update. *Archives of Disease in Childhood. Arch Dis Childhood 81(4): 337-338*. 349 Maasai children younger than 6 years old were randomised by alternate household to drink water either left in plastic bottles exposed to sunlight on the roof of the house or kept indoors (control).

• Fujioka R.S., Yoneyama B.S. (2002): Sunlight inactivation of human enteric viruses and fecal bacteria. Water Science and Technology, Vol 46, No 11-12, pp 291-295. Three human enteric viruses (poliovirus, echovirus, coxsackievirus) suspended in seawater or buffer were stable for 6 hr in the absence of sunlight but were inactivated at the same rate in the presence of sunlight.


• Kehoe S.C, Barer M.R., Devlin L.O., McGuigan K.G. (2004). Batch process solar disinfection is an efficient means of disinfecting drinking water contaminated with Shigella dysenteriae Type I. Letters in Applied Microbiology, 38, 410-414. Phosphate-buffered saline contaminated with Sh. dysenteriae type I was exposed to simulated solar conditions and the inactivation kinetics of this organism was compared with that of Sh. flexneri, Vibrio cholerae and Salmonella typhimurium.


• Khaengraeng R., Reed R.H. (2005): Oxygen and photoinactivation of Escherichia coli in UVA and sunlight. Journal of Applied Microbiology 2005, 99, 39–50. Overall, the results indicate that future studies of bacteria exposed to UVA or sunlight should consider the effects of oxygen at every stage in the procedure, and especially during enumeration, where the inhibitory effects of ROS must be neutralized in order to obtain a valid count.


• Lonnen J., Kilvington S., Kehoe S.C., Al-Touati F., McGuigan K.G. (2005): Solar and photocatalytic disinfection of protozoan, fungal and bacterial microbes in drinking water. Water Research, 39, 877-883. A reduction of only 1.7 log units was recorded for spores of Bacillus subtilis. Both SODIS and SPC-DIS were ineffective against the cyst stage of A. polyphaga.

reflective (foil-backed) or absorptive (black-backed) rear surfaces, under a range of weather conditions in India.

- McGuigan K.G., Joyce T.M., Conroy R.M., Gillespie J.B., Elmore-Meegan M. (1998). Solar disinfection of drinking water contained in transparent plastic bottles: characterizing the bacterial inactivation process. *Journal of Applied Microbiology*, 84, 1138-1148. The results confirm that, where strong sunshine is available, solar disinfection of drinking water is an effective, low cost method for improving water quality and may be of particular use to refugee camps in disaster areas. Strategies for improving bacterial inactivation are discussed.


- Oates, P., Shanahan, P., and Polz, Martin. 2003. Solar Disinfection (SODIS) Simulation of Solar Radiation for Global Assessment and Application of Point-of-use Treatment in Haiti. *Water Research* 37 (2003) 47-54. We have developed a mathematical model based on satellite-derived daily total energies to simulate monthly mean, minimum, and maximum 5-h averaged peak solar radiation intensities. This model can be used to assess if SODIS technology would be applicable anywhere in the world.


- Reed R.H., Mani S.K., Meyer V. (2000), Solar photo-oxidative disinfection of drinking water: preliminary field observations. *Letters in Applied Microbiology* 2000, 30, 432 – 436. These results demonstrate that solar photo-oxidation may provide a practical, low-cost approach to the improvement of drinking water quality in developing countries with consistently sunny climates.


limited environment, and can significantly decrease diarrhoeal morbidity in children.


7. Others

- Clasen T, Edmondson P (2006). Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. *Int’l J. Hyg. & Environ. Health*. Household water treatment using sodium hypochlorite (NaOCl) has been recognized as a cost-effective means of reducing the heavy burden of diarrhea and other waterborne diseases, especially among populations without access to improved water supplies.

- Colwell RR, Huq A, Islam MS, Aziz KMA, Yunus M, Khan NH, Mahmud A, Sack RB, Nair GB, Chakraborty J, Sack DA, Russek-Cohen E (2003). Reduction of cholera in Bangladeshi villages by simple filtration. *Proc. Nat. Acad. Sci. 100*(3): 1051-5. Effective deployment of this filtration procedure, from September 1999 through July 2002 in 65 villages of rural Bangladesh, of which the total population for the entire study comprised ≈133,000 individuals, yielded a 48% reduction in cholera (P < 0.005) compared with the control.

- Payment P, Franco E, Richardson L, Siemiatycki J (1991a). Gastrointestinal health effects associated with the consumption of drinking water produced by point-of-use domestic reverse-osmosis filtration units. *Appl. Environ. Microbiol. 57*(4): 945-948. During a prospective epidemiological study of gastrointestinal health effects associated with the consumption of drinking water produced by reverse-osmosis domestic units, a correlation was demonstrated between the bacterial counts on R2A medium incubated at 35 degrees C and the reported gastrointestinal symptoms in families who used these units.

- Rowe, A. K., F. Angulo, et al. (1998). Chlorinating well water with liquid bleach was not an effective water disinfection strategy in Guinea-Bissau. *International Journal of Environmental Health Research 8*: 339-340. This paper documents the fact that chlorinating well water with bleach, a common emergency response procedure, is not effective for water disinfection.

Venczel LA, Arrowood M, Hurd M, Sobsey MD (1997). Inactivation of Cryptosporidium parvum oocysts and Clostridium perfringes spores by a mixed-oxidant disinfectant and by free chlorine. *Appl. Environ. Microbiol.* 63:1598-1601. In this study, an alternative disinfection system consisting of an electrochemically produced mixed-oxidant solution (MIOX; LATA Inc.) was evaluated for inactivation of both *Cryptosporidium parvum* oocysts and *Clostridium perfringes* spores. The disinfection efficacy of the mixed-oxidant solution was compared to that of free chlorine on the basis of equal weight per volume concentrations of total oxidants.

### E. IMPLEMENTATION APPROACHES

#### 1. Emergency/Disaster Situations


#### 2. Handwashing

- Hutin, Y., Luby, S, et al. (2003). A large outbreak of cholera in Kano City, Nigeria: the importance of hand washing with soap and the danger of street-vended water. *Journal of Water and Health* 01.1: 45-52. This investigation of cholera transmission risk factors in an outbreaks found that cases were more likely than controls to have drunk street-vended water and less likely to have washed hands with soap before eating.
- Luby S, Agboatwalla M, Geikin DR, Painter J, Billhimer W, Altaf A, Hoekstra RM (2005). Effect of handwashing on child health: a randomized controlled trial. *Lancet* 366(9481):225-33. This study found that children younger than 5 that received plain soap had 50% lower incidence of pneumonia, 53% lower incidence of diarrhoea, and 34% lower incidence of impetigo. Results were not improved when children were given antibacterial soap.
- Luby, S., M. Agboatwall, et al. (2004). Effect of intensive handwashing promotion on childhood diarrhea in high-risk communities in Pakistan; A randomised controlled trial. *JAMA* 291(21): 2547-2554. This randomized, controlled trial found a 53% lower incidence of diarrhea in children washing their hands with soap as compared to control children.
- Luby, S., M. Agboatwalla, et al. (2004). Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. *American Journal of Tropical Medicine and Hygiene* 71(4): 420-427. This study documented a 71% reduction of diarrheal disease incidence in SWS users without a refridgerator not immediately, but after 1 year, indicating that houses of lower socio-economic status (as defined by ownership of a refridgerator) needed extra time to adopt the intervention. It also documented a 53% lower incidence of diarrhea in those who received soap initially, with a 35% reduction one year later.
- Luby, S., M. Agboatwalla, et al. (2003). The effect of antibacterial soap on impetigo incidence Karachi, Pakistan. *American Journal of Tropical Medicine and Hygiene* 67(4): 430-435. This study found a 23% reduction (as compared to controls who received placebo soap) and a 43% reduction (as compared to controls) of impetigo in children who used triclocarban-containing soap.
- Luby, S. P., M. Agboatwalla, et al. (2001). Microbiologic effectiveness of handwashing with soap in an urban squatter settlement, Karachi, Pakistan. *Epidemiology and Infection* 127: 237-244. This study found that providing soap and promoting hand washing measurably
improved mothers’ hand cleanliness in terms of bacterial reduction, even when the water used for washing was contaminated.

• Parker AA, Stephenson R, Riley PL, Ombeki S, Komolleh C, Sibley L, Quick R. (2006). Sustained high levels of stored drinking water treatment and retention of hand-washing knowledge in rural Kenyan households following a clinic-based intervention. *Epidemiol Infect.* Jan 26: 1-8. This study showed that two weeks after being recommended to use the PSI socially marketed WaterGuard solution by nurses when going to a clinic for diarrhea, 67% of patients had purchased WaterGuard and had chlorine residual in their drinking water at an unannounced visit, and 1 year later 71% of patients had chlorine residual. This study also found that patients trained in handwashing retained the knowledge 2 weeks and year out.

F. DISEASES

1. Arsenic related studies

• Meng X, Korfiatis GP, Christodoulatos C, Bang S (2001). Treatment of arsenic in Bangladesh well water using a household co-precipitation and filtration system. *Water Res* 35:2805-10. Laboratory and field tests were conducted to evaluate the effectiveness of a household filtration process and investigate the effects of phosphate and silicate on the removal of arsenic from Bangladesh groundwater by ferric hydroxides.


• Yuan T, Hu JY, Ong SL, Luo QF, Ng WJ (2002). Arsenic removal from household drinking water by adsorption. *J Environ Sci Health* 37:1721-36. Geogenic inorganic arsenic contamination in drinking water has been raising public health concern especially in developing countries. Cost-effective and stopgap arsenic removal method for household use (cooking and drinking) is very urgent.
2. Cholera

- Besser RE, B. Moscoso Rojas, et al. (1995). Prevencion del la transmission del colera: Evaluacion rapida de la calidad del agua municipal en Trujillo, Peru. Boletin de la Oficina Sanitaria Panamericana 119(3): 189-193. This study documented variable chlorine levels (0-1.5 mg/L), with 17% of samples with no free chlorine in water associated with the 1991 cholera epidemic. This data supports the promotion of point-of-use water treatment.


- Colwell RR, Huq A, Islam KMA, Yunus M, Khan NH, Mahmud A, Sack RB, Nair GB, Chakraborty J, Sack DA, Russek-Cohen E (2003). Reduction of cholera in Bangladeshi villages by simple filtration. Proc. Nat. Acad. Sci. 100(3): 1051-5. Based on results of ecological studies demonstrating that *Vibrio cholerae*, the etiological agent of epidemic cholera, is commensal to zooplankton, notably copepods, a simple filtration procedure was developed whereby zooplankton, most phytoplankton, and particulates >20 μm were removed from water before use. Effective deployment of this filtration procedure, from September 1999 through July 2002 in 65 villages of rural Bangladesh, of which the total population for the entire study comprised ≈133,000 individuals, yielded a 48% reduction in cholera (P < 0.005) compared with the control.

- Conroy RM, Meegan ME, Joyce T, McGuigan K, Barnes J (2001). Solar disinfection of drinking water protects against cholera in children under 6 years of age. Arch. Dis. Child. 85(4): 293-5. Results confirm the usefulness of solar disinfection in reducing risk of water borne disease in children. Point of consumption solar disinfection can be done with minimal resources, which are readily available, and may be an important first line response to cholera outbreaks.

- Daniels, N., S. Simons, et al. (1999). First do no harm: Making oral rehydration solution safer in a cholera epidemic. American Journal of Tropical Medicine and Hygiene 60: 1051-1055. This study found high levels of fecal contamination in ORS solution prepared with tap water in a clinic. The use of Safe Water System treated water to prepare the solution significantly reduced the microbiological contamination of the ORS solution (to 0 col/100 mL of E. coli).


- Swerdlow, D., G. Malenga, et al. (1997). Epidemic cholera among refugees in Malawi, Africa: Treatment and transmission. Epidemiology and Infection 118: 207-214. This case-control study of a cholera outbreak in Mozambique found that risk factors for illness included drinking river water and placing hands into stored household drinking water.

unboiled water, drinking water for a household water storage container in which hands had been introduced in the water, and going to a fiesta.


- Weber, J. T., E. D. Mintz, et al. (1994). Epidemic cholera in Ecuador: multidrug-resistance and transmission by water and seafood. *Epidemiology and Infection* 112: 1-11. This case-control study of a 1991 cholera outbreak in Ecuador found that drinking unboiled water, drinking a beverage from a street vendor, eating raw seafood, and eating cooked crab were associated with illness. The presence of soap in the home and drinking boiled water were protective against cholera.

### 3. Diarrhea

- Brooks, J., R. Shapiro, et al. (2003). Epidemiology of sporadic bloody diarrhea in rural Western Kenya. *American Journal of Tropical Medicine and Hygiene* 68(6): 671-677. This study investigated bloody diarrhea in Western Kenya, and found that drinking Lake Victoria water and sharing latrines increased the risk of bloody diarrhea, while washing hands after defecating was protective.


### 4. HIV/AIDS

- Dunne, E. F., H. Angoran-Benie, et al. (2001). Is Drinking Water in Abidjan, Cote d’ Ivoire, Safe for Infant Formula. *Journal of Acquired Immune Deficiency syndromes* 28(4): 393-398. This study documented the presence of E. coli in 41% of stored water samples and 1% of source water samples in water that was given to infants to drink in households where the mother is HIV positive. It also documented widespread practice of giving infants stored water to drink (90% of households).

- Lule, J.R., J. Mermin, et al. (2005). Effect of home-based water chlorination and safe storage on diarrhea among persons with Human Immunodeficiency Virus in Uganda. *Am J Trop Med Hyg* 73(5): 926-933. This study documented that persons with HIV who use the SWS had 25% fewer diarrhea episodes, 33% fewer days with diarrhea, and less visible blood or mucus in stools than controls. Use of cotrimoxazole prophylaxis in addition to SWS reduced diarrhea episodes by 67%, and days with diarrhea by 54%.


5. Others


G. COUNTRY STUDIES

Bangladesh

- Colwell RR, Huq A, Islam MS, Aziz KMA, Yunus M, Khan NH, Mahmud A, Sack RB, Nair GB, Chakraborty J, Sack DA, Russek-Cohen E (2003). Reduction of cholera in Bangladeshi villages by simple filtration. Proc. Nat. Acad. Sci. 100(3): 1051-5. Based on results of ecological studies demonstrating that Vibrio cholerae, the etiological agent of epidemic cholera, is commensal to zooplankton, notably copepods, a simple filtration procedure was developed whereby zooplankton, most phytoplankton, and particulates >20 μm were removed from water before use. Effective deployment of this filtration procedure, from September 1999 through July 2002 in 65 villages of rural Bangladesh, of which the total population for the entire study comprised ≈133,000 individuals, yielded a 48% reduction in cholera (P < 0.005) compared with the control.

- Meng X, Korfiatis GP, Christodoulatos C, Bang S (2001). Treatment of arsenic in Bangladesh well water using a household co-precipitation and filtration system. Water Res 35:2805-10. Laboratory and field tests were conducted to evaluate the effectiveness of a household filtration process and investigate the effects of phosphate and silicate on the removal of arsenic from Bangladesh groundwater by ferric hydroxides.


- Sutherland D, Swash PM, Macqueen AC, McWilliam LE, Ross DJ, Wood SC (2002). A field based evaluation of household arsenic removal technologies for the treatment of drinking water. Environ Technol. 23:1385-403. Seven household treatment technologies for the removal of arsenic (Alcan, BUET, DPHE/DANIDA, Garnet, Sono, Stevens, Tetrahedron) were each evaluated using water from 63 different tube wells taken from 3 different regions of Bangladesh.

Bolivia


- Quick, R. E., L. V. Venczel, et al. (1999). Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: A promising new strategy. Epidemiology and...
Infection 122: 83-90. This study documented a diarrheal disease reduction of 44% and a significant reduction of E. coli in stored water of users of the Safe Water System.

**Colombia**


**Cote d’Ivoire**

- Dunne, E. F., H. Angoran-Benie, et al. (2001). Is Drinking Water in Abidjan, Cote d’ Ivoire, Safe for Infant Formula. *Journal of Acquired Immune Deficiency syndromes* 28(4): 393-398. This study documented the presence of E. coli in 41% of stored water samples and 1% of source water samples in water that was given to infants to drink in households where the mother is HIV positive. It also documented widespread practice of giving infants stored water to drink (90% of households).

**Dominican Republic**


**Ecuador**

- Weber, J. T., E. D. Mintz, et al. (1994). Epidemic cholera in Ecuador: multidrug-resistance and transmission by water and seafood. *Epidemiology and Infection* 112: 1-11. This case-control study of a 1991 cholera outbreak in Ecuador found that drinking unboiled water, drinking a beverage from a street vendor, eating raw seafood, and eating cooked crab were associated with illness. The presence of soap in the home and drinking boiled water were protective against cholera.

**Ghana**

- VanCalcar, JE. (2006). Collection and Representation of GIS Data to Aid Household Water Treatment and Safe Storage Technology Implementation in the Northern Region of Ghana (pdf, full-text). MIT.

**Guatemala**


- Rangel, J. M., B. Lopez, et al. (2003). A novel technology to improve drinking water quality: A microbiological evaluation of in-home flocculation and chlorination in rural Guatemala. *Journal of Water and Health* 01.1: 15-22. This study documented that the use of PuR with a traditional vessel (83% potable water), PuR with a CDC vessel (92% potable water), PuR with a covered bucket with spigot (93% potable water) led to an increase in potable water provision as compared to controls (5% potable water).

• Sobel, J., B. Mahon, et al. (1998). Reduction of Fecal Contamination of Street-Vended Beverages in Guatemala by a Simple System for Water Purification and Storage, Handwashing, and Beverage Storage. *American Journal of Tropical Medicine and Hygiene* 59: 380-387. This study documented a significant decrease total and fecal coliform in stored water and beverages sold by vendors using the SWS.

**Guinea-Bissau**

• Daniels, N., S. Simons, et al. (1999). First do no harm: Making oral rehydration solution safer in a cholera epidemic. *American Journal of Tropical Medicine and Hygiene* 60: 1051-1055. This study found high levels of fecal contamination in ORS solution prepared with tap water in a clinic. The use of Safe Water System treated water to prepare the solution significantly reduced the microbiological contamination of the ORS solution (to 0 col/100 mL of E. coli).

• Rowe, A. K., F. Angulo, et al. (1998). Chlorinating well water with liquid bleach was not an effective water disinfection strategy in Guinea-Bissau. *International Journal of Environmental Health Research* 8: 339-340. This paper documents the fact that chlorinating well water with bleach, a common emergency response procedure, is not effective for water disinfection.

**Haiti**

• CDC (2005). *Preventing Diarrheal Disease in Developing Countries: The CDC/Jolivert Safe Water for Families Project in Rural Haiti*. Atlanta, GA. This fact sheet describes a community-based, rural Safe Water System project, where the chlorine solution is made and distributed through a faith-based clinic to the surrounding community.


• Oates, P., Shanahan, P., and Polz, Martin. 2003. Solar Disinfection (SODIS) Simulation of Solar Radiation for Global Assessment and Application of Point-of-use Treatment in Haiti. *Water Research* 37 (2003) 47-54. We have developed a mathematical model based on satellite-derived daily total energies to simulate monthly mean, minimum, and maximum 5-h averaged peak solar radiation intensities. This model can be used to assess if SODIS technology would be applicable anywhere in the world.

**India**


conditions in India.


Kenya

- Brooks, J., R. Shapiro, et al. (2003). Epidemiology of sporadic bloody diarrhea in rural Western Kenya. American Journal of Tropical Medicine and Hygiene 68(6): 671-677. This study investigated bloody diarrhea in Western Kenya, and found that drinking Lake Victoria water and sharing latrines increased the risk of bloody diarrhea, while washing hands after defecating was protective.

- CDC (2005). Preventing Diarrheal Disease in Developing Countries: The CDC/PSI/Rotary Safe Water System Project in Western Kenya. Atlanta, GA. This fact sheet describes the SWS project, which includes social marketing with PSI linked to community groups, in Kenya.

- Conroy RM, Meegan ME, Joyce T, McGuigan K, Barnes J (2001). Solar disinfection of drinking water protects against cholera in children under 6 years of age. Arch. Dis. Child. 85(4): 293-5. Results confirm the usefulness of solar disinfection in reducing risk of water borne disease in children. Point of consumption solar disinfection can be done with minimal resources, which are readily available, and may be an important first line response to cholera outbreaks.


- Crump JA, Okoth GO, Slutsker L, Ogaja DO, Keswick BH, Luby S. (2004). Effect of point-of-use disinfection, flocculation and combined flocculation–disinfection on drinking water quality in western Kenya. Journal of Applied Microbiology 2004, 97, 225-231. This paper measured the effectiveness of PuR on microbiological contaminants in drinking water. In water from 30 sources, combined flocculant-disinfectant reduced Escherichia coli concentrations to <1 CFU100 ml )1 for 29 (97%) and reduced turbidity to <5 nephelometric turbidity units (NTU) for 26 (87%).

- Crump JA, Otieno PO, Slutsker L, Keswick BH, Rosen DH, Hoekstra RM, Vulule JM, Luby SP (2004). Household based treatment of drinking water with flocculant-disinfectant for preventing diarrhea in areas with turbid source water in rural western Kenya: cluster randomized controlled trial. BMJ 331(7515):478-84. This paper documented a 25% reduction in diarrheal disease incidence in under-2’s and a 19% reduction in all age groups of users of PuR as compared to controls in turbid water in Western Kenya. In addition, this study documented a 17% reduction in diarrheal disease incidence in under-2’s and a 25% reduction in all age groups of users of the SWS as compared to controls in turbid water in Western Kenya. When the two arms were joined, there was a statistically significant reduction in all-cause mortality.

• Makutsa, P., K. Nzaku, et al. (2001). Challenges in implementing a point-of-use water quality intervention in rural Kenya. *American Journal of Public Health* 91(10): 1571-1573. This paper discusses and evaluates a SWS project implemented in communities CARE/Kenya was already working within. It was found 33.5\% of families had residual chlorine in their drinking water, and 18.5\% of families had and improved clay pot. This article discusses the way forward for the project.

• Ogutu, P., V. Garrett, et al. (2001). "Seeking safe storage: A comparison of drinking water quality in clay and plastic vessels." *American Journal of Public Health* 91(10): 1610-1611. This study found that chlorine residual can be maintained in both plastic jerry cans and ceramic containers for 24 hours above 0.2 mg/L.

• Parker AA, Stephenson R, Riley PL, Ombeki S, Komolleh C, Sibley L, Quick R. (2006). Sustained high levels of stored drinking water treatment and retention of hand-washing knowledge in rural Kenyan households following a clinic-based intervention. *Epidemiol Infect*. Jan 26: 1-8. This study showed that two weeks after being recommended to use the PSI socially marketed WaterGuard solution by nurses when going to a clinic for diarrhea, 67\% of patients had purchased WaterGuard and had chlorine residual in their drinking water at an unannounced visit, and 1 year later 71\% of patients had chlorine residual. This study also found that patients trained in handwashing retained the knowledge 2 weeks and year out.


**Liberia**


**Madagascar**


• Mong, Y., R. Kaiser, et al. (2001). Impact of the safe water system on water quality in cyclone-affected communities in Madagascar. *American Journal of Public Health* 91(10): 1577-1579. After a hurricane, 11,700 kits containing chlorine solution and foldable jerry cans were distributed in rural Madagascar. Five months after distribution, 25\% of those surveyed had chlorine residual in their jerry can at the time of an unannounced visit.

• Reller, M., Y. Mong, et al. (2001). Cholera prevention with traditional and novel water treatment methods: An outbreak investigation in Fort-Dauphin, Madagascar. *American Journal of Public Health* 91(10): 1608-1610. This case-control study in a Madagascar cholera outbreak found that patients were more likely than controls to have drunk untreated water, and that drinking heated water, water from a tap, or water treated with SWS was protective.

**Malawi**
• Swerdlow, D., G. Malenga, et al. (1997). Epidemic cholera among refugees in Malawi, Africa: Treatment and transmission. Epidemiology and Infection 118: 207-214. This case-control study of a cholera outbreak in Mozambique found that risk factors for illness included drinking river water and placing hands into stored household drinking water.

Nepal


Nicaragua


Nigeria

• Hutin, Y., Luby, S, et al. (2003). A large outbreak of cholera in Kano City, Nigeria: the importance of hand washing with soap and the danger of street-vended water. Journal of Water and Health 01.1: 45-52. This investigation of cholera transmission risk factors in an outbreaks found that cases were more likely than controls to have drunk street-vended water and less likely to have washed hands with soap before eating.

Pakistan

• Jensen PK, Ensink JH, Jayasinghe G, van der Hoek W, Cairncross S, Dalsgaard A (2003). Effect of chlorination of drinking-water on water quality and childhood diarrhoea in a village in Pakistan. J Health Popul Nutr 21:26-31. This study found that there was no statistically significant difference between diarrhea in children using non-chlorinated water supply systems and children using chlorinated groundwater water supply systems, and concludes that “reduction of faecal bacteria in the public drinking-water supply by chlorination does not seem to be a priority intervention to reduce childhood diarrhoea.
• Luby, S., M. Agboatwalla, et al. (2004). Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. American Journal of Tropical Medicine and Hygiene 71(4): 420-427. This study documented a 71% reduction of diarrheal disease incidence in SWS users without a refrigerator not immediately, but after 1 year, indicating that houses of lower socio-economic status (as defined by ownership of a refrigerator) needed extra time to adopt the intervention. It also documented a 53% lower incidence of diarrhea in those who received soap initially, with a 35% reduction one year later.

• Luby, S., M. Agboatwalla, et al. (2004). Effect of intensive handwashing promotion on childhood diarrhea in high-risk communities in Pakistan; A randomised controlled trial. JAMA 291(21): 2547-2554. This randomized, controlled trial found a 53% lower incidence of diarrhea in children washing their hands with soap as compared to control children.

• Luby, S., M. Agboatwalla, et al. (2003). The effect of antibacterial soap on impetigo incidence Karachi, Pakistan. American Journal of Tropical Medicine and Hygiene 67(4): 430-435. This study found a 23% reduction (as compared to controls who received placebo soap) and a 43% reduction (as compared to controls) of impetigo in children who used triclocarban-containing soap.

• Luby, S. P., M. Agboatwalla, et al. (2001). Microbiologic effectiveness of handwashing with soap in an urban squatter settlement, Karachi, Pakistan. Epidemiology and Infection 127: 237-244. This study found that providing soap and promoting hand washing measurably improved mothers’ hand cleanliness in terms of bacterial reduction, even when the water used for washing was contaminated.

• Luby, S., M. Agboatwalla, et al. (2001). A low-cost intervention for cleaner drinking water in Karachi, Pakistan. International Journal of Infectious Diseases 5: 144-150. This study documented a 99.8% reduction in the mean concentration of thermotolerant coliforms in users of hypochlorite solution and safe storage container as compared to controls. Two years after vessel distribution, 68% of the families were still using the safe storage container.

Peru

• Besser RE, B. Moscoso Rojas, et al. (1995). Prevencion del la transmission del colera: Evaluacion rapida de la calidad del agua municipal en Trujillo, Peru. Boletin de la Oficina Sanitaria Panamericana 119(3): 189-193. This study documented variable chlorine levels (0-1.5 mg/L), with 17% of samples with no free chlorine in water associated with the 1991 cholera epidemic. This data supports the promotion of point-of-use water treatment.


Saudi Arabia


South Africa

• Gundry, S. et al. (2006). Contamination of drinking water between source and point-of-use in rural households of South Africa and Zimbabwe: implications for monitoring the

Uganda

Lule, J.R., J. Mermin, et al. (2005). Effect of home-based water chlorination and safe storage on diarrhea among persons with Human Immunodeficiency Virus in Uganda. Am J Trop Med Hyg 73(5): 926-933. This study documented that persons with HIV who use the SWS had 25% fewer diarrhea episodes, 33% fewer days with diarrhea, and less visible blood or mucus in stools than controls. Use of cotrimoxazole prophylaxis in addition to SWS reduced diarrhea episodes by 67%, and days with diarrhea by 54%.


Uzbekistan


Zambia

CDC (2005). Preventing Diarrheal Disease in Developing Countries: The CDC/PSI Safe Water System Program in Zambia. Atlanta, GA.


Olembo L, Kaona F, Tuba M, Burnham G (2004). Safe Water Systems: An Evaluation of the Zambia CLORIN Program. U.S. Agency for International Development (USAID) through the Environmental Health Project. This extensive, population-based evaluation found that 42% of people in a random population-based survey reported current use of Clorin (the PSI SWS product) and 13% of the population had chlorine residual in their drinking water at the time of the unannounced visit.


**Zimbabwe**