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Household POU Pathogen Survey

Executive Summary

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Submitted by:

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Introduction

Waterborne disease outbreaks are documented annually in both municipal and private drinking water sources. Etiological agents include microbial and chemical contaminants and have been linked to a variety of causes, including inadequate treatment, external contamination in the distribution system, or premise plumbing bacterial regrowth.

Despite federal standards and routine monitoring of municipal water treatment facilities in the U.S., 42 drinking water outbreaks occurred from 2013-2014, resulting in 1,006 cases of illness, 124 hospitalizations, and 13 deaths.[1] Researchers estimate the true burden of waterborne disease to be closer to 19.5 million illnesses per year, resulting in 1,000 deaths.[2,3] In addition, more than 15 million U.S. households are served by private water wells that are outside the jurisdiction of federal regulations for monitoring and reporting.

Point-of-use (POU) water treatment devices offer a final barrier approach for the removal of contaminants at the consumer's faucet that may be introduced post-treatment or during distribution. POU systems may include nominal or absolute filtration mechanisms, either designed to remove microbial contaminants or as a pre-treatment to subsequent water purification steps. In a previous study, POU filters ranging from 5 µm to 30 µm pore size were collected from water vending machines with municipal tap water sources and evaluated as a tool for monitoring inlet water quality. In a sample of 48 filters, 13% were positive for total coliforms, 5% for *E. coli*, 19% for fecal enterococci, and 3% for infectious human enteroviruses.[4] This study served as a pilot for the use of spent POU filters from household devices to monitor tap water quality.

Aims

The goal of this study was to develop a method for improved monitoring of tap water quality at the household level, with respect to microbial contaminants of human health concern. Monitoring POU filters near the end of their life expectancy provides a method for directly detecting fecal bacteria and human viruses that may be present in large volumes of water over long time periods or following suspected contamination events that may occur after system maintenance, storm events, or general treatment failures. Another aim of this study was to develop a microbial risk assessment model to quantitatively estimate human health effects associated with source water contamination and the risk reduction associated with having a POU final barrier in place. In addition, we aimed to formulate an adjustable cost benefit calculator capable of relating POU treatment costs to risk mitigation benefits.

Methods

Filter Collection. In collaboration with a local household filter provider, spent 0.5 micron, nominal POU filters, utilized as pre-treatment to a reverse osmosis membrane, were collected from 75 households throughout Pima County, Arizona during scheduled annual maintenance and device exchanges. To minimize variability and the chance of cross contamination, filters were provided by a single, senior technician trained in proper handling. Hand sanitizer was used to cleanse technician hands and gloves were worn when handling the devices during removal and transfer to Ziploc bags for controlled temperature transport.

Microbial Assays. Within 72 hours, samples were eluted, assayed for fecal bacteria, and processed for future viral assays. Membrane filtration of half the eluate was used to concentrate coliform bacteria and *E. coli*, followed by culture on MI media where blue colonies indicate *E. coli* and total blue and fluorescent colonies represent total coliform counts.[5] Original sample equivalent volume estimates were calculated based on an estimated annual household use volume of 36,338,000 mL and final concentrations reported as *E. coli* and total coliform colony forming units (CFU) per original 100 mL and 2 L tap water volumes, representing typical monitoring grab sample volumes and consumer daily ingestion volumes, respectively. The remaining eluate was concentrated by organic flocculation for human viral assays using an integrated cell culture/polymerase chain reaction (ICC-PCR) technique previously shown to maximize detection efficiency of viable, infectious enteric viruses from concentrated and complex water supplies.[6]

Seeded Efficiency Studies. Filter recovery efficiencies were tested in the laboratory using MS2 phage and *E. coli* as viral and bacterial surrogates, respectively. Tap water was artificially contaminated with test surrogates and passed through new and spent POU filters, identical to those used in this study. Filter elution and microbial assays were completed as per described above.

Risk Assessment. A risk assessment model was developed to relate microbial concentrations to exposure probabilities and estimated health outcomes using a standard, published dose response curve.[7] The following exposure assumptions were also considered:

a. Filter recovery rates
b. Indicator to pathogenic bacteria ratios
c. Annual filtered volumes
d. Daily consumption rates[8]

Multiple scenarios were run for 10,000 model iterations, each over defined variable distribution ranges. This *in silico* method allowed testing over plausible yet changing exposure conditions.

Cost-Benefit Analysis. A cost-benefit calculator, developed as part of a previously funded WQRF project "Cost benefits of point-of-use devices in reduction of health risks from drinking water", was modified to include values defined within the current project relative to health outcomes and costs associated with use or absence of POU devices. The calculations assumed that the assayed filters represented the water quality in municipally treated water, the population exposed to this water was 1,193,737 (based on regional southern Arizona census data from collection area), an annual infection rate for *E. coli* O157:H7 of 3.96E-06), and POU device illness reduction efficacy of 35%.[9]

Results

Microbial Assays. Seventy-five POU filter samples were collected during routine filter replacement and system maintenance. *E. coli* and total coliforms were detected on 53 filters. Average daily consumption, average Tucson household size, and the EPA's default exposure frequency for residents (350 days) were all factors utilized to determine an equivalent volume for calculations. Quantifiable concentrations of *E. coli* and total coliforms ranged from 5.50E-06 CFU/100 mL to 1.70E-03 CFU/100 mL and 5.50E-06 CFU/100 mL and 1.71E-03 CFU/100 mL, respectively. Lower and upper detection limits were <5.45E-06 CFU/100 mL and >4.95E-03 CFU/100 mL, respectively. Unlike the original pilot study, no samples (n=75) tested positive for enteric viral pathogens.

Seeded Efficiency Studies. Most of the seed organisms were not captured by the filters. The overall recovery efficiency including seed that passed through the filter was 0.15% on new and used filters (MS2 virus) and 1.65% and 0.20% on new and used filters, respectively (*E. coli*).

Risk Assessment. Annual risk estimates ranged from a high of 2.39E-03 (probability of infection equal to 2.93 per thousand persons per year) under the worst-case scenario to a low of 7.93E-07 (probability of infection equal to 7.93 per ten million persons per year). Using microbial risk assessment tools with consideration of health targets, the USEPA originally developed maximum contaminant levels or treatment technology standards based on an acceptable risk of 1.00E-04 or a probability of infection equal to one infection per ten thousand persons per year.[10]

Cost-Benefit. Given estimated risk scenarios, five acute *E. coli* O157:H7 infections are expected in the region resulting in 1 case of chronic impact or sequelae. Given POU efficacy assumptions, a reduction from five to two acute *E. coli* O157:H7 infections is expected in the region resulting in <1 case of sequelae. For the acute cases, the cost without and with a POU intervention for the community would be $1,985 (n=5 cases) and $695 (n=2 cases), respectively. For such low infection risks, POU intervention costs for the community outweigh benefits.

Conclusions

Results indicate household water treatment filters can be used for large volume monitoring of drinking water quality at the point-of-use, however, retention of introduced pathogens on the tested filter is low and may still underestimate risk. Based on the results of this study and the given risk assumptions, exposure and infection from *E. coli* in these tap water supplies is probable, but the health risk estimate is low and generally acceptable based on current regulatory guidelines of one in ten thousand annual infection risk. Absolute cost benefit for a community-wide POU intervention was high but our assessment was limited to the pathogens targeted whereas the true benefit of POU treatment would involve a wide variety of microbial, physical and chemical contaminants.

Significance and Impact

This study is the first to our knowledge to design and evaluate a tap water monitoring scheme at the point-of-use using POU filters from households. We determined the method is feasible for monitoring large volume tap water supplies over extended time periods. Further, the development of a risk assessment model and scenario simulation experiments provides a quantitative context for health outcome probabilities that can be adjusted for additional contaminants and exposure scenarios. The methods developed in this study will be useful in evaluating changes in tap water quality following suspected contamination events where targeting consumption sites and a wider array of contaminants is possible.

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