COST BENEFITS OF POINT-OF-USE DEVICES IN REDUCTION OF HEALTH RISKS FROM DRINKING WATER

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EXECUTIVE SUMMARY

Project scope

The goal of this project is to provide an assessment of the cost benefits of point-of-use (POU) water treatment at the tap in terms of protection from contaminants in drinking water. While POU water treatment benefits have been demonstrated, the cost benefit relationship has not been characterized previously. This study is novel in that a holistic approach was used to document individual and population benefits of single and multiple contaminant removal. Both chemical and microbial contaminants were considered.

Contamination risks exist in all water supplies no matter how well they are treated. This is because of treatment failures, post-treatment intrusion of microbes and chemicals, and regrowth of pathogenic organisms in the distribution system. The inability of treatment plants to remove all contaminants all of the time, require the use of a final POU treatment barrier to minimize exposure risks.

Risk of chemicals in water usually takes years or most of a lifetime to result in adverse effects. Municipal drinking water is typically regulated so that the level of cancer risk from a contaminant is less than one in a million per lifetime. Such rare events mean that the investment of lifetime POU costs to prevent an already small amount of illness must be considered in the routine cost benefit. However, occasionally accidental contamination of drinking water supplies occur, resulting in higher risk probabilities, such as with the recent lead contamination event in Flint, MI.

Exposure to waterborne microbes may cause acute, chronic or fatal effects, resulting in large associated costs. Unlike chemical risks, which usually take years or most of a lifetime of exposure to have an adverse effect, risk of illness from microorganisms are immediate. Thus, the benefit of a POU barrier is also immediate, ultimately resulting in greater benefits relative to POU investment costs. Since even one pathogen ingested is capable of causing disease, there is no level in water that is considered safe. Thus, the USEPA set the MCLG for pathogens in water at zero. To control waterborne disease pathogens in drinking water, the USEPA has set treatment standards to reduce the numbers of pathogens so the risk of infection is no greater than 1:10,000 per year.

Municipal water systems as well as unregulated private supplies are consistently linked to drinking water outbreaks. Even when water supplies meet regulatory standards and guidelines, additional POU treatment further reduces the risk of exposures and adverse outcomes since federal maximum contaminant levels (MCL) are based on acceptable risk limits and not elimination of risk.

Approach

Publically available data from various field water monitoring and treatment efficacy studies were used to determine risks of exposure pre- and post-POU treatment. Data was accessed from peer-reviewed literature and government or non-profit stakeholder websites, whenever possible. From these sources, optimal treatment and associated costs relative to target contaminants (arsenic, nitrates, lead, chromium, disinfection by-products, and microorganisms) and POU treatment technologies (reverse osmosis, activated carbon, UV treatment, adsorptive media, pour-through granular activated carbon pitcher filter, distillation, and ion exchange softeners) were examined. In addition, NSF/ANSI optimal contaminant efficacy requirements were evaluated.

Adverse health outcomes were also assessed from various publically available, peer-reviewed literature and government or non-profit stakeholder websites. Given that health outcomes vary based on population and regional variations, average risk values were considered in addition to 95% upper and lower confidence intervals.

Costs of POU devices were calculated from a number of sources in the public literature and are known to vary widely. Cost calculators are provided with this report so that the tools can be modified to reflect specific treatment and cost benefit analyses. For some contaminants (i.e., arsenic) calculating the cost benefit of a POU intervention included the cost of the POU (initial investment plus maintenance and unit replacement projections) compared to savings due to averted costs of disease burden. Costs per unit risk reduction were considered with a lifetime (70 years) POU investment and a 5 year replacement rate. For microbes, annual POU costs were averaged over a 5 year estimated product lifetime and compared with yearly associated health costs.

Costs and benefits were considered on both an individual and population level where appropriate and as permitted by theoretical estimates considering adverse outcome probabilities and evaluations of certain adverse outcomes (i.e., a 100% chance of occurrence).

Results

Arsenic. Individual and cumulative cost benefits were calculated for select chemical and microbial contaminants. Based on the available health information, the population savings related to POU usage and averted cancer due to arsenic totals $1.6B per year. The cost to implement a national POU intervention is estimated at $169.8B the first year. Thus, under water quality conditions that meet the USEPA arsenic MCL, it would not be cost-effective to supply a

POU device in every U.S. household for arsenic removal alone. However, for the individual who experiences the one in a million chance of cancer, preventing illness has the benefit of $36,388 for averting the costs of that cancer case.

Nitrate. Nitrate exposures leading to documented adverse health outcomes are extremely rare. Even though POU devices remove up to 95% of nitrates from tap water supplies, exposures in the most high risk group (i.e., infants less than 6 months old) rarely exceed acceptable risk standards or measurable health effects. Given low risk, there is little benefit to POU applications for nitrate risk reduction and costs outweigh any anticipated benefits.

Lead. There is no safe level of lead in drinking water and any exposure results in unacceptable risks. However, lead is a common water contaminant at low levels. Reduction of lead exposures is always beneficial to health but may not always be cost beneficial. In this study we examined data that relates lead levels in water to human illnesses and cognitive development impacts considering typical U.S. concentration scenarios and also levels reported in the Flint, MI outbreak, where a change in source water and treatment protocols resulted in a dramatic spike in lead exposures for the local community. Increased benefits of POU removal of lead relative to costs are dependent on initial water lead concentrations. In general, the economic breakeven points occur when the initial water lead concentrations are $\geq$37.4 µg/L. While more than 3% of the population is estimated to drink water that exceeds the lead action level of 15 µg/L, exceeding the breakeven cost concentration is considered rare. Recently, the breakeven point was exceeded for the community of Flint, MI. Cost associated with this case study approaches a lifetime economic loss of $269M or $2,695 per person. A community wide POU intervention for lead removal would have cost just $52M.

Little information is available relative to costs and benefits of POU water treatment for the many emerging contaminants identified in water. Chromium VI was evaluated for cost benefit reduction in this study. While the literature was reviewed and background and discussion presented, the lack of reported adverse health outcomes stemming from hexavalent chromium due to drinking water consumption in humans makes it difficult to calculate POU risk reductions or cost benefit. Cr^6 exposures are considered higher via the inhalation route, suggesting the need for future studies on POE/POU interventions targeting showerhead filtration.

Similar to arsenic, carcinogenic effects from disinfection by-products are rare in the U.S. population and occur over long periods of time. Researchers estimate THM exposure cancer risks to be 29 per million resulting in a total medical cost of $108.8M per year for the U.S. population. In this study we considered reported and NSF/ANSI certified POU removal efficacies for disinfection by-products in water. Cost per POU risk reduction was ≥$260M. With such small risks and associated POU benefits for THM removal, costs outweigh the benefits on a population level. On an individual level and assuming a certainty of cancer occurring, the savings related to POU usage and averted cancer (bladder and colorectal) due to disinfection by-products in water averages $197,284 per case compared to the individual's lifetime costs for a POU intervention at ≥ $7,644.

Microorganisms resulted in the greatest cost benefit in this study, considering gastrointestinal illnesses, chronic sequelae and mortality caused by drinking water contaminants. Risk assessment and epidemiological studies indicate that more than 9M cases of acute gastrointestinal illness, 618,047 sequelae cases, and 1,470 mortalities associated with drinking water occur annually. POU treatment is expected to reduce these outcomes by at least 35% and a single POU device may remove a variety of viruses, bacteria and protozoa from water, increasing the cost benefit. Thus, the highest cost-effectiveness is seen when the totality of disease burden (acute, chronic sequelae, and mortality) from all pathogens is considered, resulting in an overall cost per averted disease case of $3,784 annually. The commonality of waterborne disease makes it cost-effective to prevent such illness with the relatively low-cost purchase of a POU device ($380 per year per household).

Conclusions

Consideration of all contaminants listed in this study shows that POU device use in the U.S. is cost beneficial given the wide range of contaminants potentially present in drinking water. Much of the economic benefit is driven by reduction of microbial pathogen exposures. However, POU devices with the capability to remove multiple contaminants offer the greatest benefit.

Some of the data presented here may be an underestimation of risk and benefit since random events or unmonitored private water supplies- where high level exposures might occur unnoticed- are not always captured. Further, risk is non-linear throughout an individual's life. Therefore, the cost benefit from operating a POU device would be even greater for a household with young, immunocompromised, or elderly residents.