Study Report

Efficacy of Point-of-Use Nephros Filter in Removing Nosocomial Infection-Associated Waterborne Pathogens

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I. **Background**

The presence of waterborne pathogens in hospital water systems has been epidemiologically linked to nosocomial infections in Intensive Care Units (ICUs). These pathogens include *Legionella, Pseudomonas, Stenotrophomonas, Acinetobacter, Klebsiella*, and *Mycobacterium* species. Nosocomial infections associated with these pathogens increase patient mortality and healthcare cost. Disinfection of hospital water systems has been an alternative in prevention of nosocomial infections caused by waterborne pathogens. Hyperchlorination, copper-silver ionization and chlorine dioxide have been implemented for Legionnaires' disease outbreaks (Lin et al. 1998; Sidari et al. 2004). The capital expenditures for treating the entire hospital potable water system may not be cost effective if the risk of nosocomial infection is limited to critical high risk areas (eg. ICUs).

The efficacy of point-of-use filter (POU) has been documented in controlling *Pseudomonas* species and *Legionella* species (Trautmann et al. 2004; Sheffer et al. 2005; Vonberg et al. 2005; Harpel et al. 2006; Vianelli et al. 2006; Trautmann et al. 2008). However, the current point-of-use filters have some limitations in field application. POU filters are approved for either 14 days (faucet) or 30 days (shower) before they must be replaced. The filters may have to be replaced sooner due to blockage caused by high suspended solids, thus increasing the cost of filter replacement.

The Nephros Inc. uses a different technology to design a dual stage ultra-filter which increase the usage life to 3 months or longer. The company manufactures the filter with pore size of 0.005 μm membrane offering additional filtration capability including viruses. The objective of this study is to evaluate the efficacy of this new water filter for removing waterborne pathogens in a laboratory model plumbing system.

II. Hypotheses

Nephros water filter can remove waterborne pathogens from a laboratory model plumbing system.

III. Materials and Methods

A. Model Fixture

Test and control faucets (Figure 1) were attached to a laboratory model plumbing system located in the microbiology laboratory at National Kaohsiung Normal University (Figures 2 and 3). Two counter-top goose neck faucets were installed at a sink. A Nephros filter was installed at the test faucet under the counter for treatment of water from the sink. A clear PVC screen was installed to separate the two faucets so there will be no interference between the two faucets. In addition, a baffle was placed under the water stream to prevent the splashes; a potential retrograde contamination. The model plumbing system simulates a real building water system that provides microbiological contaminated tap water to the sink. The water was set to run through the faucets daily from 8am to 6pm at room temperature.

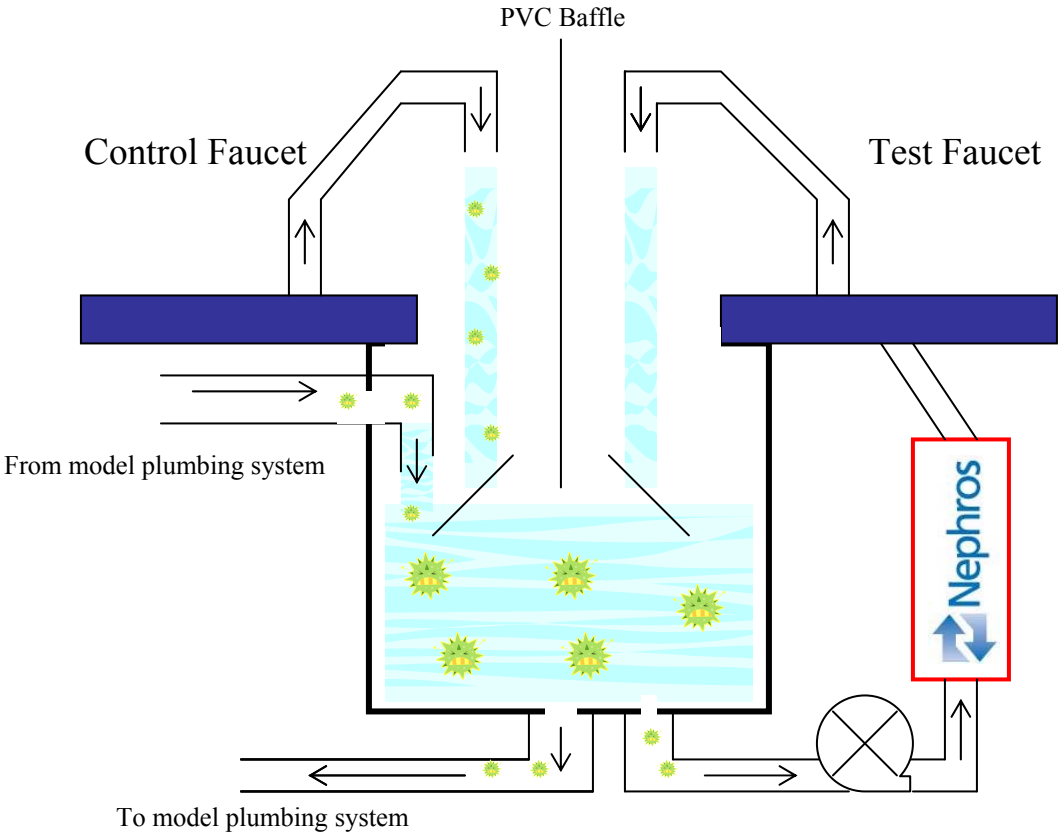

Figure 1. Plumbing Setup with a goose neck faucet and a Nephros filter

Figure 2. A model plumbing system with goose neck faucets and a Nephros filter

Figure 3. Close up of the system - A model plumbing system with two goose neck faucets and a Nephros filter.

B. System Operation:

The experiment was performed for 14 days at total water volume of 30,240 liters (3.6 (L/min) x 60 (min/hr) x 10 (hr/day) x 14 days), which represents more than 7.5 months of filter use @ 4,000 L/month[1].

C. Test Organisms

Environmental isolates of *Legionella* (*L. pneumophila*), *Pseudomonas* (*P. aeruginosa*), *Stenotrophomonas* (*S. maltophilia*), *Acinetobacter* (*A. baumannii*), *Klebsiella* (*K. pneumoniae*), and *Mycobacterium* (*M. abcessens*) species were selected as the test organisms. These bacterial suspensions were prepared and standardized by comparison with a McFarland No.1 standard (approximate density of 3×10^8 cfu/mL). The starting bacterial concentration for each organism in the model plumbing system was approximately $3x10^3$ cfu/mL.

D. Sample Withdrawn and Analysis

Water sample was withdrawn at T = 1, 2, 3, 4, 5, 7 and 14 day from the both test faucet (after Nephros filtration) and control faucet (no filtration). Swab cultures were taken from the inner surface of faucets to determine if the faucet is colonized with waterborne pathogens. The standard microbiological method was followed for sample processing (Manual of Clinical Microbiology, (2003).

E. Study Period:

Experiment I - Oct 6 to Oct 20, 2008.

Experiment II – Oct 20 to Nov 3, 2008

[1] Based on the manufacture's estimation on the filter specification.

IV. Results

Experiment I -

A. Total Bacteria Removal from Filter:

No bacterium was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 2,500,000 cfu/mL of bacteria, in average, were recovered from the control faucet (Figure 4)

a、 *Legionella* Removal: No *Legionella* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 29,000 cfu/mL of *Legionella*, in average, were recovered from the control faucet (Figure 5)

b、 *Stenotrophomonas* Removal: No *Stenotrophomonas* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 54,000 cfu/mL of *Stenotrophomonas*, in average, were recovered from the control faucet (Figure 6)

c、 *Pseudomonas* Removal: No *Pseudomonas* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 239,000 cfu/mL of *Pseudomonas*, in average, were recovered from the control faucet (Figure 7)

d、 *Acinetobacter* Removal: No *Acinetobacter* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 887,000 cfu/mL of *Acinetobacter*, in average, were recovered from the control faucet (Figure 8)

e、 *Klebsiella* Removal: No *Klebsiella* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 1,333,000 cfu/mL of *Klebsiella*, in average, were recovered from the control faucet (Figure 9)

f、 *Mycobacterium* Removal: No *Mycobacterium* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 21,000 cfu/mL of *Mycobacterium*, in average, were recovered from the control faucet (Figure 10)

B. Colonizations of Faucets:

No bacterium colonization was found in the test faucet by swab sampling. However, colonization was observed in the control faucet (Table 1).

Experiment II -

A. Total Bacteria Removal from Filter:

No bacterium was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 570,000 cfu/mL of bacteria, in average, were recovered from the control faucet (Figure 11)

a、 *Legionella* Removal: No *Legionella* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 527,000 cfu/mL of *Legionella*, in average, were recovered from the control faucet (Figure 12)

b、 *Stenotrophomonas* Removal: No *Stenotrophomonas* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 4,000 cfu/mL of *Stenotrophomonas*, in average, were recovered from the control faucet (Figure 13)

c、 *Pseudomonas* Removal: No *Pseudomonas* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 7,500 cfu/mL of *Pseudomonas*, in average, were recovered from the control faucet (Figure 14)

d、 *Acinetobacter* Removal: No *Acinetobacter* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 20,100 cfu/mL of *Acinetobacter*, in average, were recovered from the control faucet (Figure 15)

e、 *Klebsiella* Removal: No *Klebsiella* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 3,300 cfu/mL of *Klebsiella*, in average, were recovered from the control faucet (Figure 16)

f、 *Mycobacterium* Removal: No *Mycobacterium* was recovered from the test faucet which the water was filtered by Nephros filter. Approximately 17,700 cfu/mL of *Mycobacterium* in average, were recovered from the control faucet (Figure 9)

B. Colonizations of Faucets:

No bacterium colonization was found in the test faucet by swab sampling. However, colonization was observed in the control faucet (Table 2).

V. Conclusion

Nephros water filter can effective remove waterborne pathogens from a contaminated tap water in a laboratory plumbing system.

Reference

Anonymous Reference

Anonymous (2003). Manual of Clinical Microbiology. Washington, D.C., American Society for Microbiology Press.

Harpel, S., S. Engelhart, et al. (2006). "Performance of a new 14-day water filter during daily use in clinical routine at 2 university medical centers." J Hosp Infect 64(Suppl1): S47.

Lin, Y. S., J. E. Stout, et al. (1998). "Disinfection of water distribution systems for Legionella." Semin Respir Infect 13(2): 147-59.

Sheffer, P. J., J. E. Stout, et al. (2005). "Efficacy of new point-of-use water filter for preventing exposure to Legionella and waterborne bacteria." Am J Infect Control 33(5 Suppl 1): S20-5.

Sidari, F. P., J. E. Stout, et al. (2004). "Keeping Legionella out of water systems." Journal American Water Works Association 96(1): 111-119.

Trautmann, M., S. Halder, et al. (2008). "Point-of-use water filtration reduces endemic Pseudomonas aeruginosa infections on a surgical intensive care unit." Am J Infect Control 36(6): 421-9.

Trautmann, M., H. Royer, et al. (2004). "Pseudomonas aeruginosa: new insights into transmission pathways between hospital water and patients." Filtration 1(1 Suppl): 63-70.

Vianelli, N., M. B. Giannini, et al. (2006). "Resolution of a Pseudomonas aeruginosa outbreak in a hematology unit with the use of disposable sterile water filters." Haematologica 91(7): 983-5.

Vonberg, R. P., T. Eckmanns, et al. (2005). "Use of terminal tap water filter systems for prevention of nosocomial legionellosis." J Hosp Infect 60(2): 159-62.

Figures and Tables

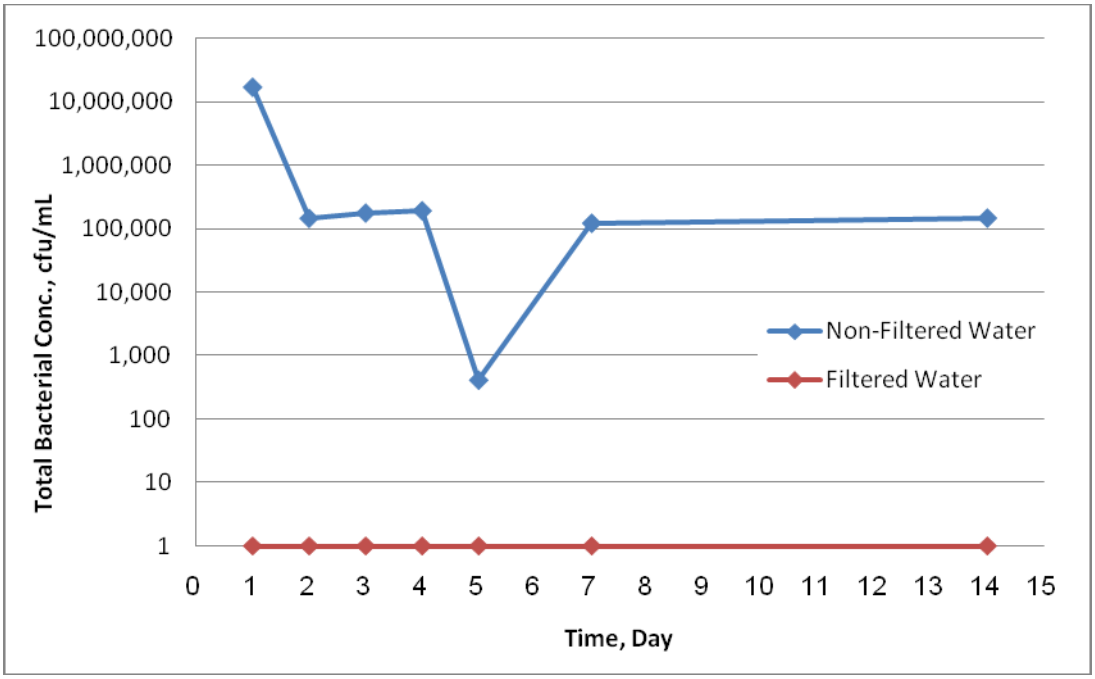

Figure 4. No bacterium was recovered from filtered water

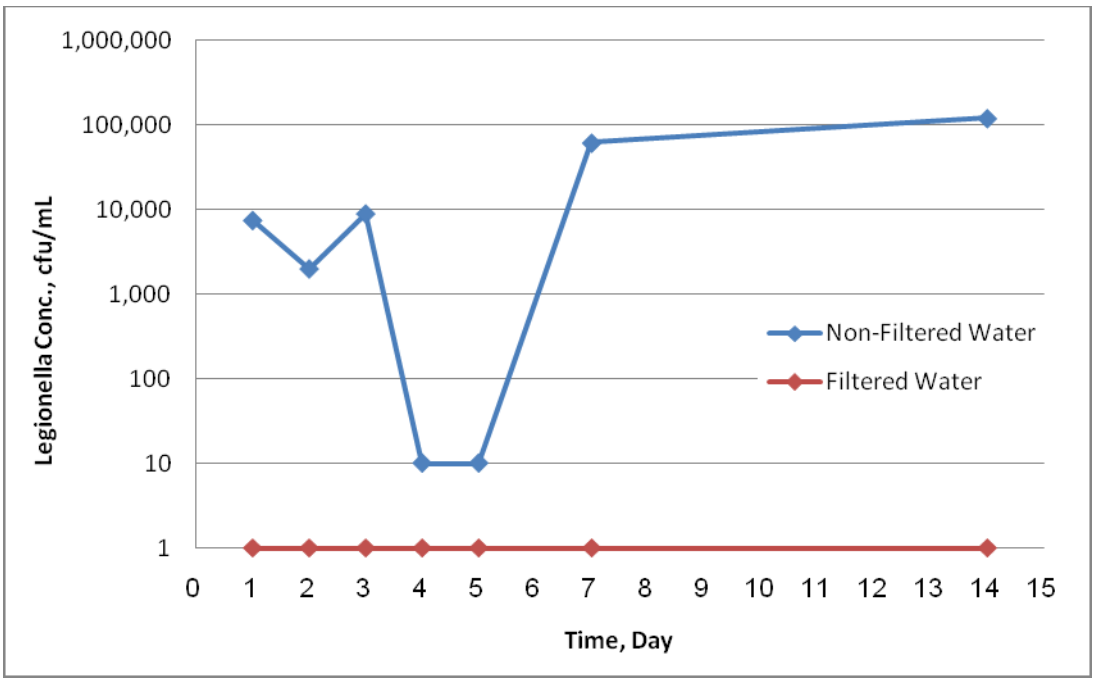

Figure 5. No *Legionella* was recovered from filtered water

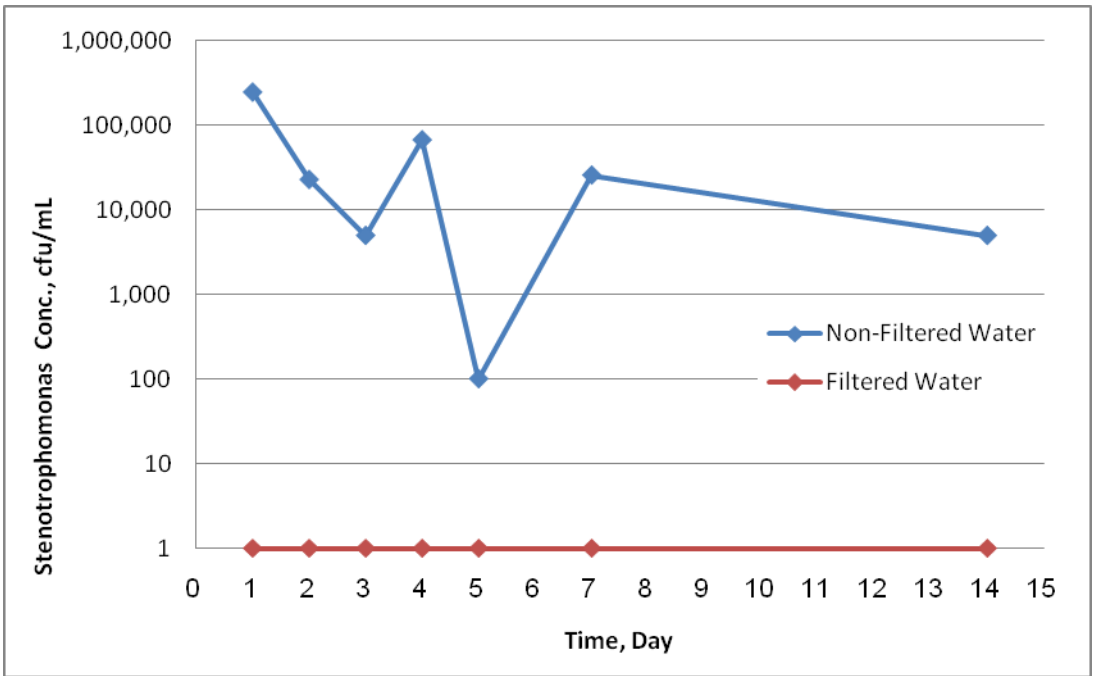

Figure 6. No *Stenotrophomonas* was recovered from filtered water

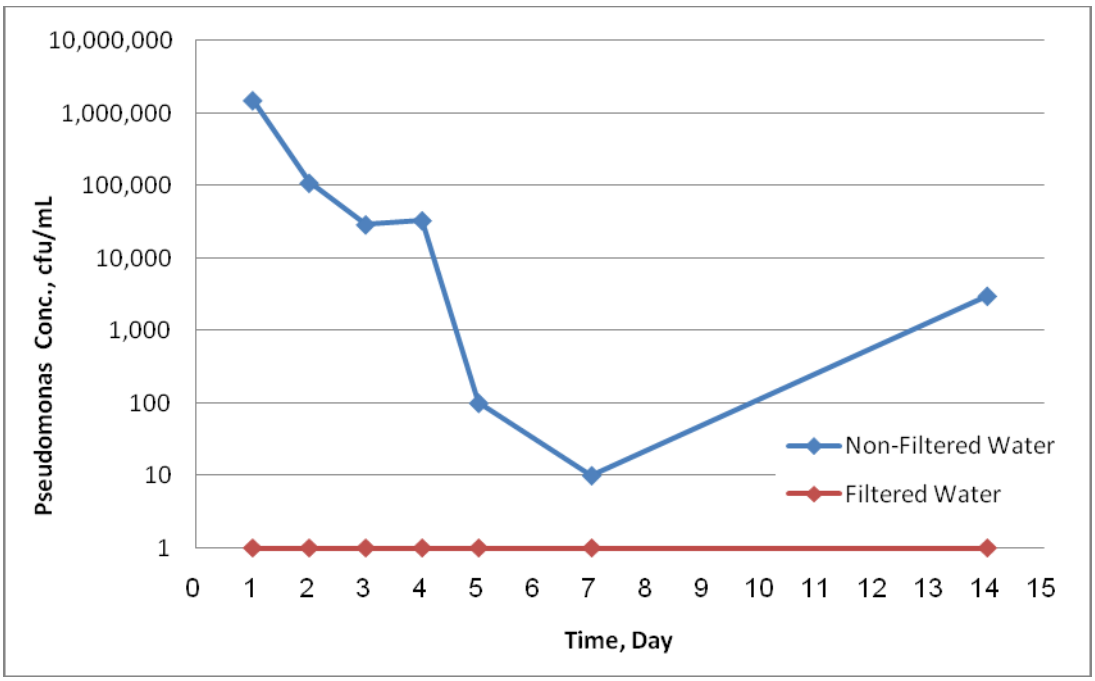

Figure 7. No *Pseudomonas* was recovered from filtered water

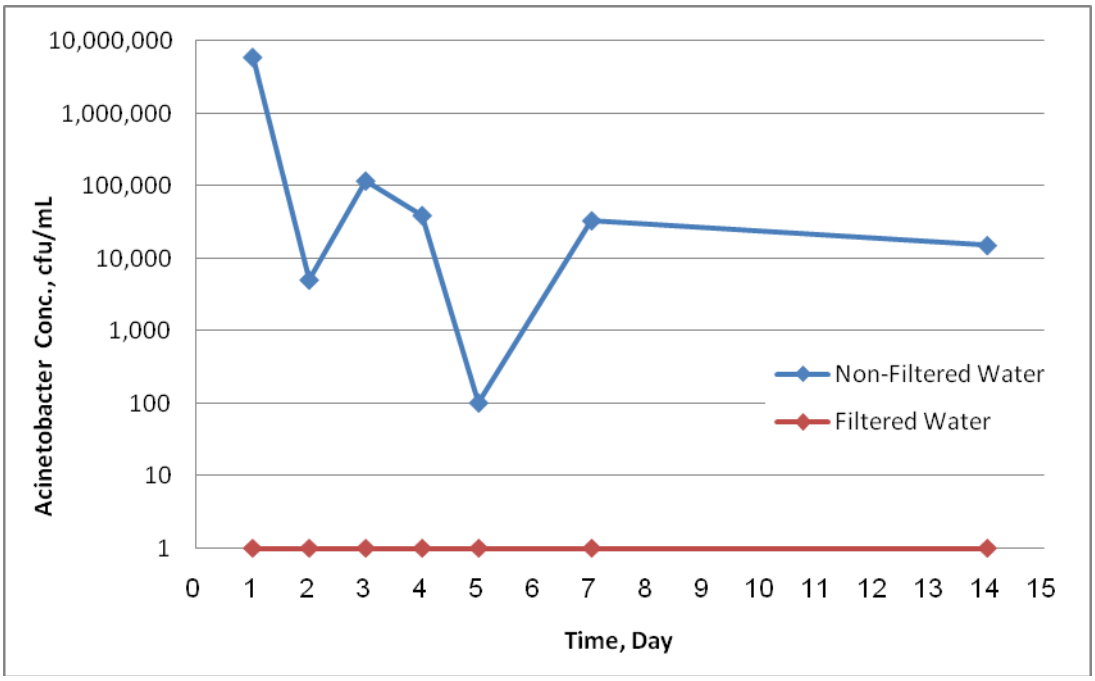

Figure 8. No *Acinetobacter* was recovered from filtered water

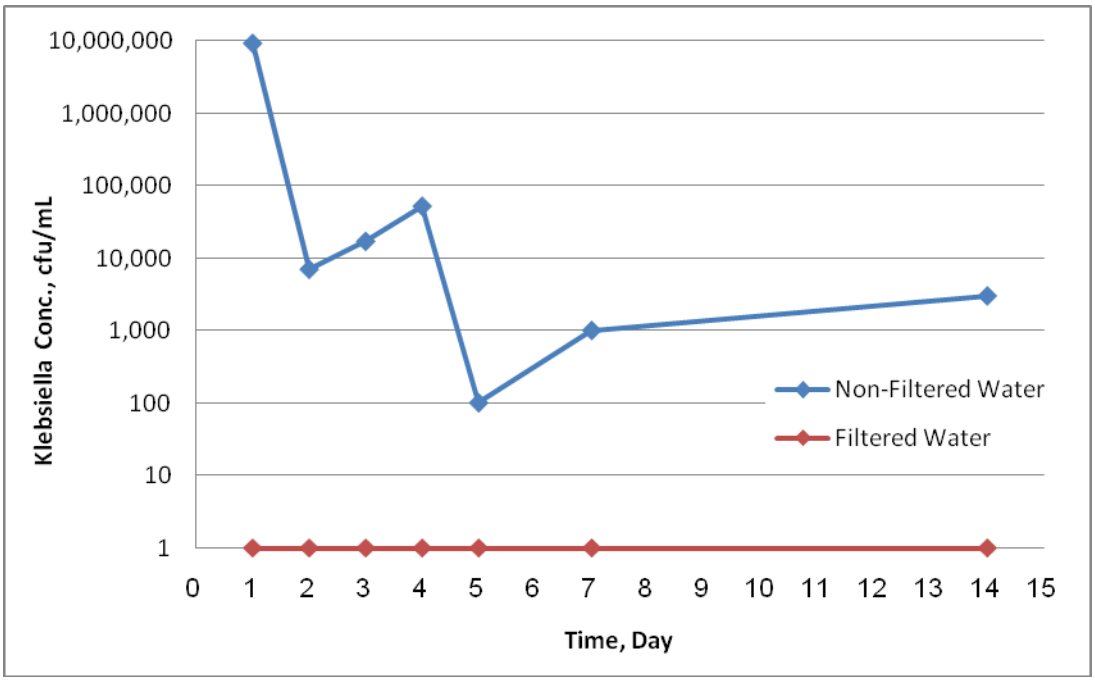

Figure 9. No *Klebsiella* was recovered from filtered water

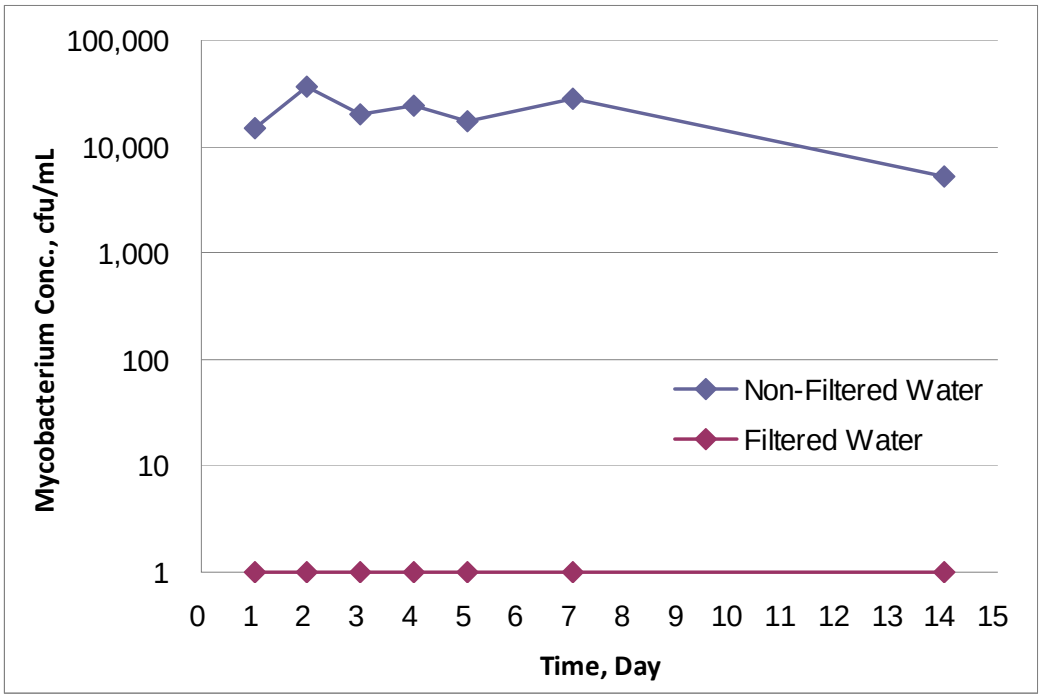

Figure 10. No *Mycobacterium* was recovered from filtered water

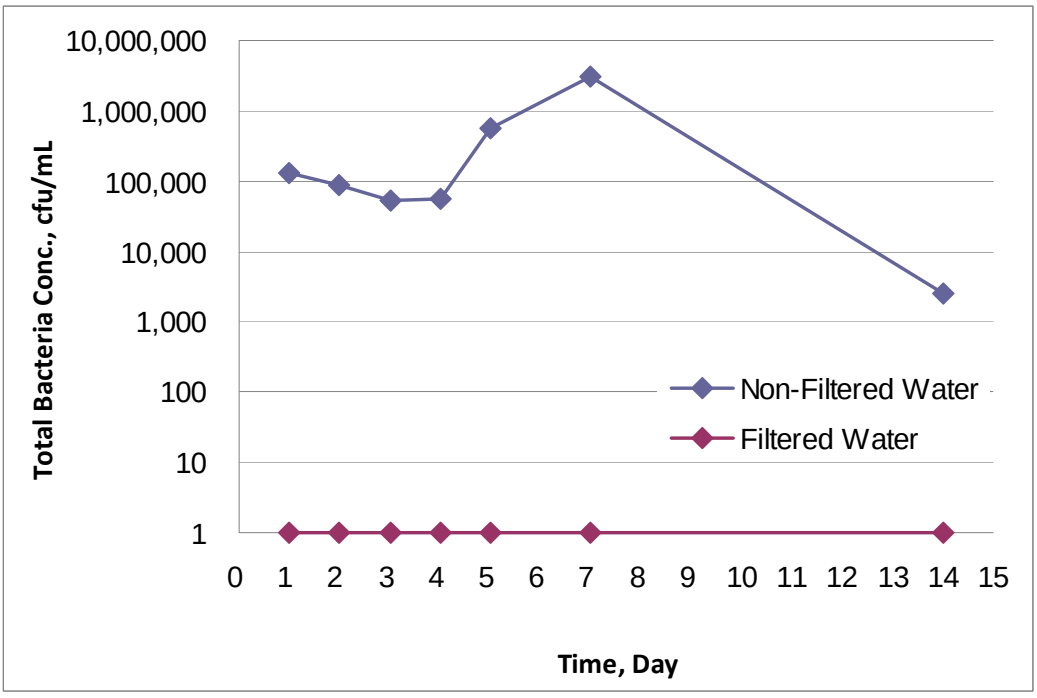

Figure 11. No bacterium was recovered from filtered water

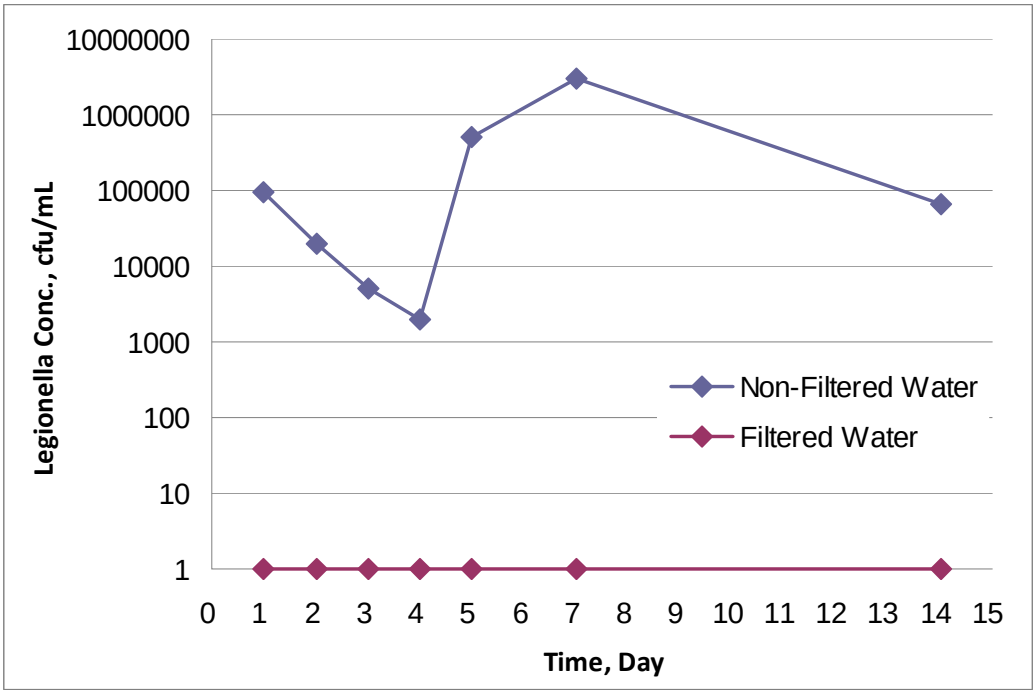

Figure 12. No *Legionella* was recovered from filtered water

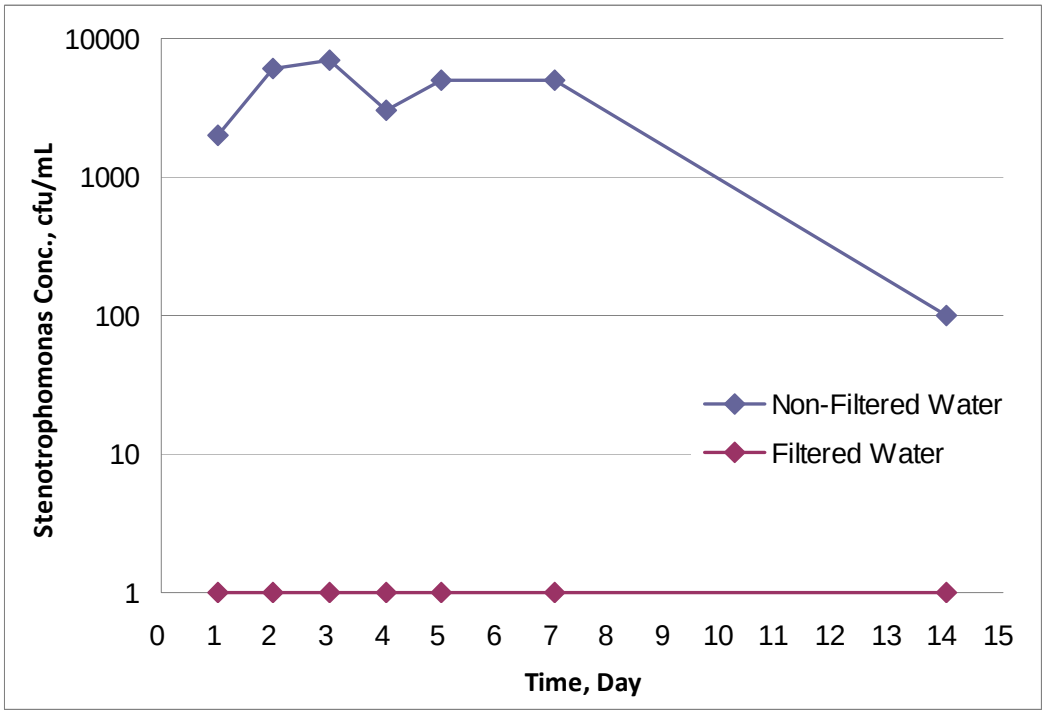

Figure 13. No *Stenotrophomonas* was recovered from filtered water

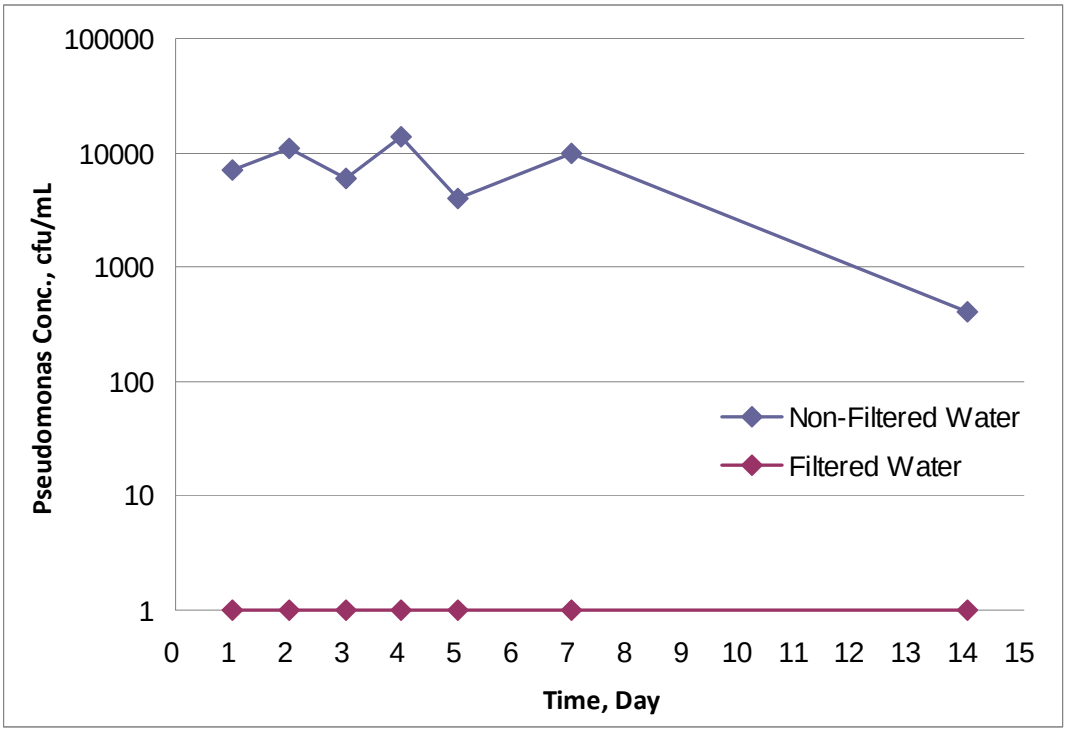

Figure 14. No *Pseudomonas* was recovered from filtered water

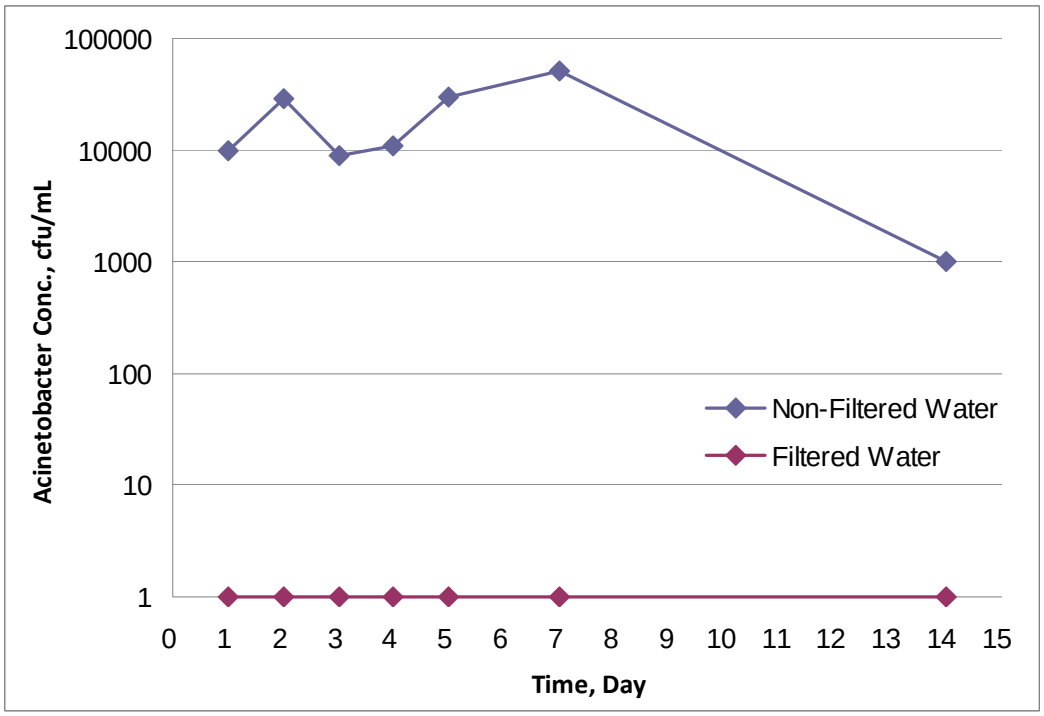

Figure 15. No *Acinetobacter* was recovered from filtered water

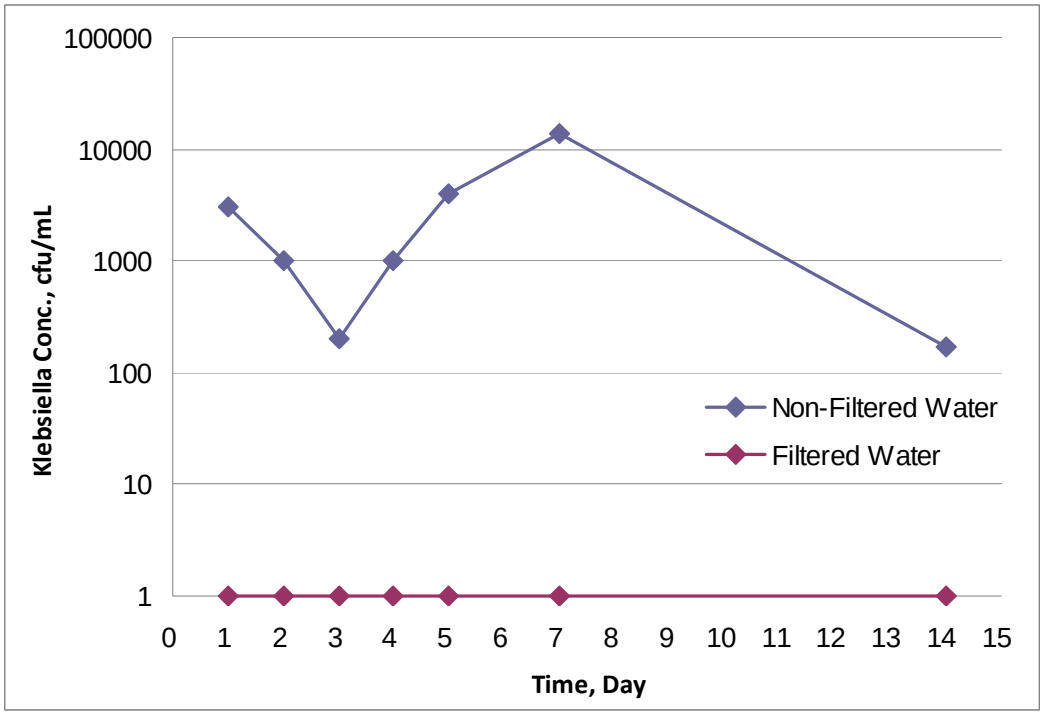

Figure 16. No *Klebsiella* was recovered from filtered water

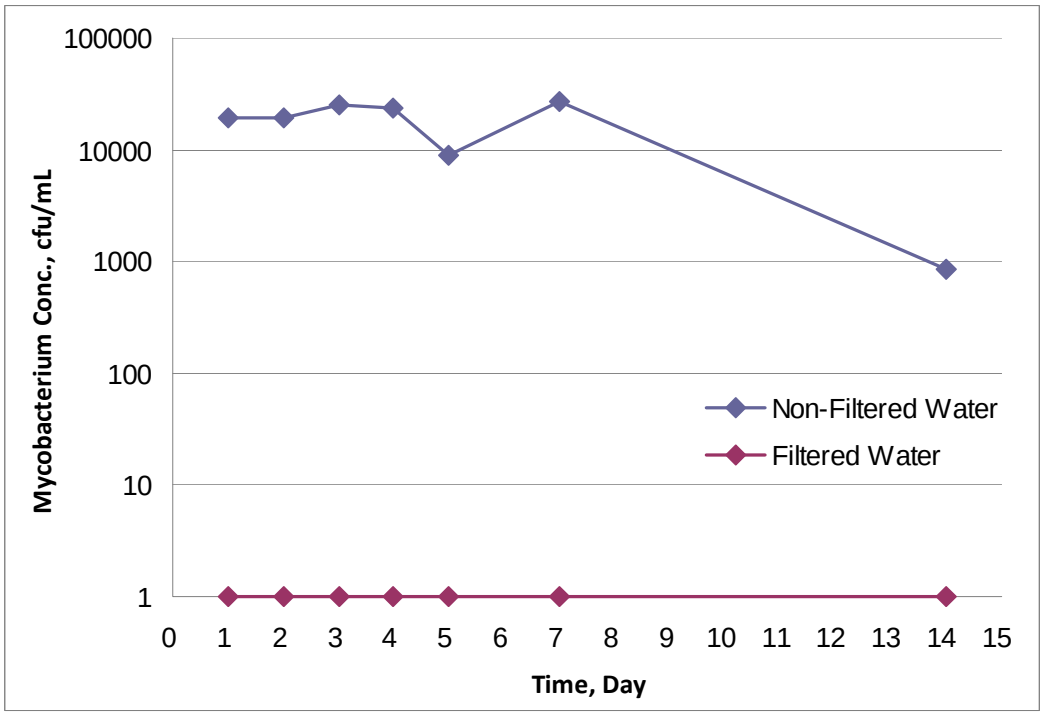

Figure 17. No *Mycobacterium* was recovered from filtered water

Table 1. Concentration of Pathogens in Swab Samples from Test (Filtered Water) and Control (Non-Filtered Water) Faucets (Unit: cfu/swab)

Experiment I

	Legionella		*Stenotrophomonas*		*Pseudomonas*		*Acinetobacter*		*Klebsiella*		*Mycobacterium*	
Day	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
1	0	10	0	10	0	50	0	50	0	10	0	0
2	0	0	0	50	0	200	0	80	0	0	0	0
3	0	10	0	30	0	10	0	90	0	0	0	10
4	0	10	0	360	0	50	0	20	0	10	0	0
5	0	0	0	30	0	10	0	130	0	10	0	20
7	0	270	0	60	0	0	0	20	0	0	0	40
14	0	170	0	0	0	0	0	0	0	0	0	10

Table 2. Concentration of Pathogens in Swab Samples from Test (Filtered Water) and Control (Non-Filtered Water) Faucets (Unit: cfu/swab)

Experiment II

	Legionella		*Stenotrophomonas*		*Pseudomonas*		*Acinetobacter*		*Klebsiella*		*Mycobacterium*	
Day	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
1	0	160	0	0	0	30	0	20	0	0	0	20
2	0	130	0	0	0	30	0	30	0	10	0	20
3	0	70	0	10	0	10	0	10	0	0	0	0
4	0	40	0	2340	0	0	0	0	0	0	0	370
5	0	90	0	0	0	0	0	10	0	0	0	0
7	0	110	0	0	0	10	0	10	0	10	0	10
14	0	40	0	10	0	20	0	40	0	10	0	0