# *HUMAN ENTERIC VIRUS REMOVAL IN POINT-OF-USE HOUSEHOLD FILTERS*

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**ABSTRACT**

Household drinking-water treatment of non-reticulated water supplies relies largely on point-of-use (PoU) filters. Source waters of non-reticulated water supplies are often microbially contaminated but little is known about human enteric virus reductions in these filters. We evaluated reductions of human rotavirus, adenovirus and norovirus in 10 commonly used activated carbon, polypropylene and polyester microfilters (cartridge 25.4 cm long, 7 cm in diameter) with pore sizes of 0.2–5 μm. Replicate virus challenge tests were conducted on each filter using chlorine-free tap water under a constant flow rate of 1 L/min.

Virus reductions, expressed as $\log_{10}$ reduction values (LRVs), in the carbon filters (LRVs=1.17–6.0) were significantly greater than those in the polypropylene (LRVs=0.02–0.54) and polyester (LRVs=0.00–0.73) filters ($P \leq 0.0001$). Virus reductions in the polypropylene and polyester filters did not differ significantly ($P > 0.24$). In most of the filters investigated, the norovirus and adenovirus reductions were similar ($P > 0.49$). Compared with the norovirus and adenovirus reductions, the rotavirus reductions were significantly lower in the carbon filters ($P \leq 0.009$).

All the filters tested failed to meet the "protective" rotavirus reduction level (LRVs ≥3 $\log_{10}$) required for household drinking-water treatment (WHO, 2011). Our findings highlight a critical need for additional water treatment when using PoU microfilters, for example, water boiling or ultraviolet radiation, or the use of effective surface-modified filter media to prevent drinking-waterborne infections from enteric viruses.

**KEYWORDS:**

Enteric viruses, household filters, drinking water, $\log_{10}$ reduction value; filtration

**PRESENTER PROFILE**

Liping Pang is a science leader at ESR with a PhD in civil engineering. Her expertise is in the experimental investigations and modelling of contaminant transport in porous media, in particular subsurface microbial transport. Her recent research

involves developing synthetic pathogen surrogates and DNA tracers for water applications.

# INTRODUCTION

It is estimated that each year tens of thousands of people in New Zealand contract gastroenteritis from pathogen-contaminated drinking-water supplies, resulting in substantial societal and economic impacts (Moore et al., 2010). The risk of drinking-waterborne infection is particularly high for communities that are on non-reticulated water supplies. Source waters of non-networked supplies are often contaminated with microbial pathogens, including human enteric viruses, which are derived from human faeces via land disposal of municipal and septic tank effluent and sludge, leaking sewers, and latrines.

Virus infection risk via drinking-water is evidenced in the findings of two surveys in New Zealand. In a 15-month fortnightly survey of 25 freshwater sites, pathogenic human viruses were detected in 21–44% of the samples (Till et al., 2008). Likewise, in a 2-year fortnightly survey of a North Island river and a South Island river, pathogenic viruses were detected in 97% of the samples (Williamson et al., 2011).

Viral pathogens are especially problematic. Compared to enteric bacteria, enteric viruses can survive much longer, and are more difficult to filter out due to their much smaller sizes. Some waterborne diseases have been caused by enteric viruses in the absence of faecal bacteria, such as in the 2012 norovirus outbreak in a South Island resort township (Jack et al., 2013).

Communities that are on non-reticulated water supplies mostly rely on the use of point-of-use household filters for drinking water treatment. Most household drinking water treatment uses microfilters made of polypropylene, polyester, or activated carbon because they are easy to use, relatively inexpensive and readily available. However information is lacking on the efficiencies of these filters on virus removal.

We have recently examined 10 different household microfilters that are commonly used in New Zealand (Pang et al., 2022) for their efficiencies in removal of human adenovirus, rotavirus, norovirus GII. These viruses were detected the most frequently in New Zealand's surface water and were positive in 65%, 64% and 61% of the samples, respectively (Williamson et al., 2011).

# METHODS

Ten different commonly used imported PoU filter cartridges were purchased from local filter retailers. The cartridges were 25.4 cm long and 7 cm in diameter. These included 0.2 µm, 0.45 µm (absolute) and 1 µm polypropylene cartridges, 1 µm (nominal and absolute) and 5 µm polyester cartridges, 0.5 µm, 1 µm and 2 µm activated carbon cartridges. Clean cartridges were fitted into housing units.

The filtration experiments were carried out on these filters to simulate instantaneous contamination events. Experiments were conducted within a class 2 biosafety cabinet in a PC2 microbiology laboratory. Chlorine-free tap water (pH=8, ionic strength 1.22 mM), which was sourced from deep alluvial gravel

groundwater, was applied at a constant flow rate of ~1 L/min in all experiments. This flow rate was within the cartridges' operational flow rate ranges specified by the manufacturers. For each filter, 3–5 virus challenge runs were conducted and 30 samples were taken during each experiment. Virus concentrations of the filter effluent samples were analysed using the quantitative polymerase chain reaction (qPCR).

The virus zeta potentials were determined using a Zetasizer Nano ZS. The mean zeta potentials determined from triplicate measurements were -15.40 (±1.25) mV, -17.27 (±0.06) mV and -29.77 (±0.86) mV for norovirus, adenovirus and rotavirus, respectively. We previously determined the sizes of these viruses: norovirus 33–34 nm, adenovirus 68 nm and rotavirus 70–75 nm.

# RESULTS AND DISCUSSIONS

Our experimental results (Table 1) demonstrated that virus reduction efficiencies of polypropylene and polyester microfilters were very low, with LRVs=0.02–0.54 and 0.00–0.73, respectively, which were not significantly different ($P>0.24$). This may be attributed to the uniform and smooth surfaces of the synthetic fibres, and their low isoelectric points, which are pH <2.5 for polyester (Grancaric et al., 2005) and pH=4 for polypropylene (Stakne et al., 2003). The poor performances of these polymeric microfilters suggest that without appropriate modifications of the media, polypropylene and polyester microfilters are extremely vulnerable to virus breakthroughs.

Comparatively virus reduction efficiencies in the activated carbon filters (LRVs=1.17–6.0, Table 1) were significantly greater than those in the polymeric microfilters ($P\leq0.0001$). This may be attributed to the extraordinarily high surface area, great surface roughness, and high volume of micropores of activated carbon.

Compared with norovirus and adenovirus, rotavirus showed lower reductions in the experiments using the activated carbon filters, 1 μm (absolute) and 5 μm polyester filters. In most experiments norovirus behaved similarly to adenovirus and their LRVs were not significantly different ($P>0.49$). These observations may be explained by the measured zeta potentials; which were similar between adenovirus (-17 mV) and norovirus (-15 mV), and rotavirus was more negatively charged (-30 mV). Thus, rotavirus would be subject to greater electrostatic repulsion from the negatively charged surfaces of the filter media, and thus more readily breakthrough.

Rotavirus LRVs ranged 1.2–1.9, 0.04–0.36 and 0–0.73 for the carbon, polypropylene and polyester filters, respectively. These low levels of rotavirus reduction in the PoU filters investigated is a concern. Rotavirus is among the most infectious enteric viruses, thus is used as a reference virus to assess the performance of household drinking-water treatment. For household drinking-water treatment, the World Health Organization (WHO, 2011) specifies "protective" and "highly protective" rotavirus reduction levels of $\geq3$ $\log_{10}$ (99.9%) and $\geq5$ $\log_{10}$ (99.999%), respectively. The Australian/New Zealand Standard 4348:1995 (AS/NZS, 4348:1995) requires a 4 $\log_{10}$ rotavirus removal. All filters tested in this study failed to satisfy these performance targets.

Our experimental results indicate that the virus reduction efficiencies in the microfilters examined were determined by the filter media type and did not directly relate to the microfilters' pore sizes. This suggests that virus removal in the microfilters involved attachment processes predominantly rather than size exclusion.

# CONCLUSIONS

Our study's findings suggest that polypropylene and polyester microfilters were extremely vulnerable to virus breakthroughs. Although activated carbon microfilters were relatively more effective, all filters tested in this study failed to meet household drinking-water treatment performance targets for rotavirus removal. To reduce the risks of drinking-waterborne virus infections, microfilters must be used in conjunction with additional treatment, such as water boiling and ultraviolet disinfection.

Our study's findings also highlight a compelling need for the use of more effective surface-modified filter media to enhance virus removal capacities.

***Table 1**. Log$_{10}$ removal values of adenovirus, rotavirus and norovirus in polypropylene, polyester and activated carbon household filters.*

| Filter type | No. of tests | Adenovirus | Std | Rotavirus | Std | Norovirus | Std |
|---|---|---|---|---|---|---|---|
| 0.2 µm polypropylene | 3 | 0.54 | 0.11 | 0.52 | 0.20 | 0.21 | 0.08 |
| 0.45 µm absolute polypropylene | 5 | 0.02 | 0.03 | 0.04 | 0.05 | 0.13 | 0.07 |
| 1 µm polypropylene | 3 | 0.09 | 0.05 | 0.36 | 0.25 | 0.10 | 0.02 |
| 1 µm absolute polyester | 3 | 0.05 | 0.01 | 0.00 | 0.00 | 0.03 | 0.04 |
| 1 µm pleated polyester | 3 | 0.05 | 0.01 | 0.73 | 0.24 | 0.15 | 0.08 |
| 5 µm polyester | 5 | 0.15 | 0.13 | 0.02 | 0.04 | 0.08 | 0.08 |
| 0.5 µm PAC | 3 | 1.94 | 0.15 | 1.17 | 0.09 | 1.88 | 0.38 |
| 0.5 µm GAC | 3 | 2.36 | 0.19 | 1.40 | 0.08 | 2.00 | 0.12 |
| 1 µm PAC | 3 | 3.26 | 0.13 | 1.89 | 0.11 | 6.00 | 0.00 |
| 2 µm silver-impregnated PAC | 3 | 3.61 | 0.14 | 1.88 | 0.16 | 2.85 | 0.13 |

PAC: powdered activated carbon; GAC: granulated activated carbon.


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