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# Microbiological Contamination of Drinking Water in a Commercial Household Water Filter System

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The microbiological quality of filtered water in a commercial water filter system (Brita) was tested in households and in two laboratories. In 24 of 34 filters used in households, bacterial counts increased in the filtered water up to 6,000 cfu/ml. In 4 of 6 filters tested in the laboratory, bacterial counts in the fresh filtrate were higher than in tap water after approximately one week of use both at room temperature and at 4°C, suggesting growth or biofilm formation in the filter material. In some cases colony counts in the filtered water were 10,000 times those in tap water. The filter material of 5 of 13 new commercial filters was contaminated with bacteria or moulds. National or international regulatory agencies should ensure that water filters marketed for domestic use do not allow deterioration in the microbiological quality of drinking water.

Contaminated drinking water is still a cause of major outbreaks of diarrheal diseases not only in developing but also in developed countries (1, 2). In recent years, however, not only microbial contamination but also contamination of drinking water with toxic substances from the environment has become of major concern to the population. A new market has thus been discovered by producers of water filters who claim to improve the taste of water and to decrease environmental pollution of drinking water with heavy metals such as lead or toxic organic substances. Many of these plastic filters, which may be used for up to 60 days, are filled with ion exchanging resins and/or activated charcoal to bind the toxic substances. Some producers add silver to the filter material to prevent bacterial growth or biofilm formation.

As it is well known that water bacteria produce biofilms on plastic materials when they are kept wet for long periods of time, we investigated plastic water filters from one of the world's leading filter companies (Brita, Germany) in households and under laboratory conditions. The main objective was to determine whether these filters change the microbial quality of drinking water.

## Materials and Methods

*Field Study.* Citizens in Freiburg, Germany who used water filters were invited in a newspaper article to participate in the study. Forty-eight households responded and were given written instructions to send tap water and filtered water in sterile flasks (provided by the laboratory) within three hours or, if later, cooled to 4°C to the laboratory with a questionnaire indicating name, address, telephone number, date and time of sampling, kind of filter, duration filter in use, and use of filtered water. The pour plate technique was used to determine total bacterial counts (Trypticase Soy Agar, Difco, USA) with incubation at 20°C and 36°C for up to 5 days. Results were read after 44 ± 4 hours.

*Laboratory Investigation No. 1 (Freiburg).* Six commercial filters (Aquafine, Brita) were used according to the manufacturer's instructions for filtration of water from three different taps in one building. Water from one tap was used for two filters each, one of which was stored at room temperature, the other at 4°C. For 29 days, total bacterial counts were made daily except weekends in tap water immediately prior to filtration, in filtered water immediately after filtration (fresh filtrate) and in filtered water 24 hours after it was collected in a container which is part of the commercial water filtration system (24 h filtrate). The method used for bacterial counts was that described in the "Deutsche Trinkwasserverordnung" (German Drinking Water Regulation) of December 5, 1990 (pour plate technique, 1% meat extract, 1% peptone, incubation at 20°C ± 2°C and 36°C ± 1°C, total bacterial count in 1 ml after 44 ± 4 hours incubation, DEV-Agar, Merck No. 1147).

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**Table 1:** Bacterial contamination of filtered water (fresh filtrate and 24–72 h filtrate) after 8–10 days of use of a commercial filter system according to the manufacturer's instructions. Storage of the filter system was at room temperature or at 4°C.

| | No. of colonies (median) on incubation at 20°C (cfu/ml) | No. of colonies (median) on incubation at 36°C (cfu/ml) |
|---|---|---|
| Tap water | 2–300 (38) | 1–600 (15) |
| Filtered water (fresh filtrate) | | |
| Storage of filter system at 22°C | | |
| Filter no. 1 | 1– >10,000 (>10,000) | 0– >10,000 (>10,000) |
| Filter no. 2 | 3– >10,000 (449) | 2– >10,000 (230) |
| Storage of filter system at 4°C | | |
| Filter no. 3 | 3–9,000 (83) | 0–700 (8) |
| Filter no. 4 | 4–75 (17) | 2–33 (3) |
| Filtered water (24–72 h filtrate) | | |
| Storage of filter system and filtrated water at 22°C | | |
| Filter no. 1 | 0– >10,000 (>10,000) | 1– >10,000 (>10,000) |
| Filter no. 2 | 4– >10,000 (84) | 6– >10,000 (98) |
| Storage of filter system and filtrated water at 4°C | | |
| Filter no. 3 | 0–183 (11) | 1–666 (7) |
| Filter no. 4 | 0–158 (2) | 0–24 (1) |

*Laboratory Investigation No. 2 (Berlin).* Tap water from only one tap was used for filtration in four commercial filters according to the method described above with the difference that filters 2 and 4 were used only Monday, Thursday, and Friday, filters 1 and 2 were kept at room temperature, filters 3 and 4 at 4°C, and all filters were used for only 28 days.

*Laboratory Investigation No. 3 (Freiburg, Berlin).* Thirteen commercial water filters were purchased in four pharmacies (3 in Berlin, 1 in Freiburg) and opened under sterile conditions in a laminar air flow cabinet. The bottom of the filter was checked for microbial contamination using Rodac plates, and the filter material inside the filters was suspended in sterile broth and investigated quantitatively for bacterial contamination.

*Identification of Organisms.* The organisms isolated in the field study and the laboratory investigations were identified using standard techniques.

## Results

Most households used filtered water for preparing tea or coffee, for flowers or for ironing, but also as drinking water and for preparing infant formulas. In 64% of the households total bacterial counts in filtered water were higher than in tap water of the same household, most of which used the commercial filter tested (n = 34). The bacterial counts of filtered water compared to tap water are given for the commercial filter system tested in Figure 1. Fourteen households used nine other filter systems, most of which also led to increased bacterial counts in filtered water.

Figure 2 shows an example of the increased bacterial counts in the fresh filtrate from one tap in laboratory study No. 1. After approximately one week bacterial counts in filtered water were usually higher than in tap water. Bacterial counts in the fresh filtrate were higher than in tap water in four of six commercial filters tested, suggesting bacterial growth or biofilm formation in the filter material at room temperature or even at 4°C. In general, colony counts in the 24-hour filtrate were lower than in the fresh filtrate indicating that the silver ions, which are released from the filter material into the water, exert their antibacterial effect only after a certain period of time. Figure 3 shows that even if a filter is kept in the refrigerator fresh filtrate contains significantly more bacteria than tap water.

The results of the study in Berlin are summarized in Table 1.

In most samples of filtered water colony counts were higher on the 4th day of use at room temperature and on the 15th day of use at 4°C. In some cases the colony count in the filtered water was 10,000 times that of tap water.

The most significant isolates from the filtered water were *Aeromonas hydrophila*, *Pseudomonas cepacia*, *Pseudomonas fluorescens*, *Pseudomonas putida*, *Sphingomonas paucimobilis*, *Acinetobacter lwoffii*, and coagulase-negative staphylococci.

**Table 2:** Microbial contamination of 13 new commercial filters purchased in pharmacies.

| Filter no. | Bottom of the filter (cfu/16 $cm^2$) | Filter material (cfu/g) |
|---|---|---|
| 1 | 68 | 99 |
| 2 | 2 | 24 |
| 3 | 300 | 11 |
| 4 | NG | 4 |
| 5 | 11 | NG |
| 6 | NG | NG |
| 7 | NG | NG |
| 8 | 61 | 40 |
| 9 | 2 | NG |
| 10 | 7 | NG |
| 11 | 120 | NG |
| 12 | 300 | NG |
| 13 | 82 | NG |

NG = no growth.

The results of culture of samples from new commercial filters are given in Table 2. Many of them were contaminated with bacteria, fungi and moulds which could grow in water, and in 5 of 13, filter materials were contaminated as well, one with 2,000 mould colonies (40/g filter material, mostly *Aspergillus* species).

## Discussion

Bacterial regrowth is a major problem in water distribution systems as well as in domestic water filtration units using activated charcoal (2, 3). The Environmental Protection Agency in the USA has suggested that the bacterial counts in drinking wa-

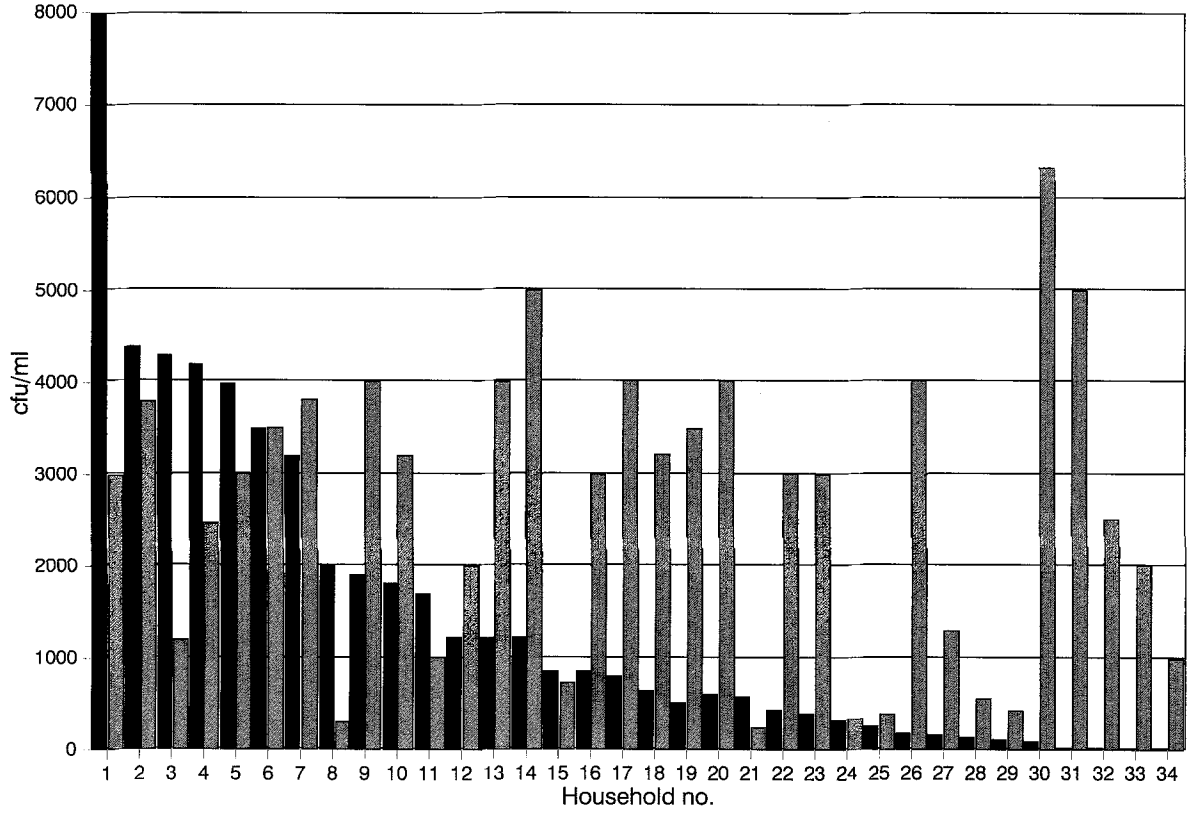


**Figure 1:** Bacterial contamination of tap water (black columns) and filtered water (grey columns) in 34 German households.

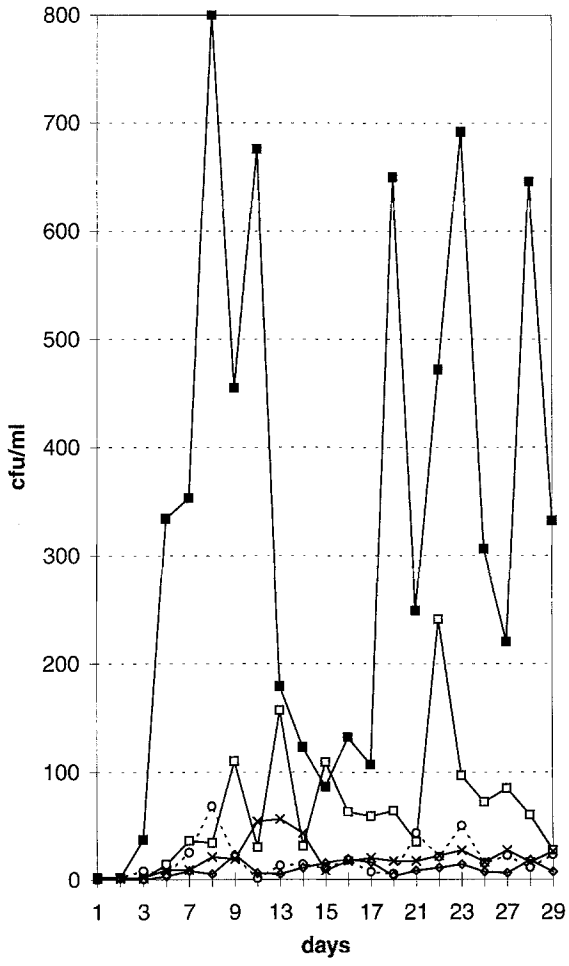


**Figure 2:** Bacterial counts (incubation at 36°C) in water from two commercial filter units as an example. Water originated from 1 of 3 taps. One filter unit was kept at room temperature (RT), a second filter unit at 4°C. Immediately prior to filtration a sample of the tap water was taken as control. Symbols: ○ tap water (control), ■ RT-fresh filtrate, □ RT-24h-filtrate, × 4°C-fresh filtrate, ◇ 4°C-24h-filtrate.

ter should not exceed 500 cfu/ml, whereas in Germany 100 cfu/ml is the upper limit for bacterial contamination of drinking water (4). Domestic water filters, however, are not regulated in terms of the microbiological quality of the water produced, but some manufacturers at least make sure that no known pathogen is present in the system before it is marketed.

Domestic water filters using the principle of reverse osmosis have been evaluated in respect to the risk of gastrointestinal disease due to consumption of drinking water meeting current microbiological standards. In the study of Payment et al. (5) 307 households used their usual tap water without a filter whereas 299 households were supplied with a domestic water filter system applying the principle of reverse osmosis. The estimated annual incidence of gastrointestinal illness was 0.76 among drinkers of tap water compared with 0.50 among drinkers of filtered water. However, the tap water in the study was prepared from sewage-contaminated surface water.

In another study on health hazards associated with drinking water 300 reverse-osmosis water filtration units were installed which produced about two liters of water per hour; the water was then stored in a 10-liter pressurized bladder reservoir (1). Bacterial counts ranging from 0 to $10^7$ cfu/ml were found in the drinking water. Most reservoirs contained water with bacterial counts between $10^4$ and $10^5$ cfu/ml. Bacteria identified were *Pseudomonas*, *Alcaligenes*, *Moraxella*, *Acinetobacter*, *Flavobacterium*, and *Chromobacterium* species.

One of the major sources of regrowth of bacteria in drinking water is biofilm in water reservoirs, water pipes and filters. The multiplication of *Aeromonas* in drinking water during distribution has been attributed to their growth on the biomass component in the biofilm and in sediments in the pipes (6). Coliform organisms (*Klebsiella pneumoniae*, *Escherichia coli*, *Enterobacter aerogenes*, and *Enterobacter cloacae*) isolated from an operating drinking water system were shown to grow better than clinical isolates in unsupplemented distribution water (7). Growth of the *Klebsiella pneumoniae* water isolate was stimulated by the addition of autoclaved biofilm.

It is also interesting to note that in a model system which used filter-sterilized tap water as the sole source of nutritient to culture a naturally occurring mixed population of microorganisms including virulent *Legionella pneumophila*, legionella grew abundantly on biofilms on plastics at 40°C, accounting for up to 50% of the total biofilm flora. *Legionella pneumophila* was even able to survive in biofilms on the surface of the plastic materials at 50°C (8). Only copper surfaces were inhibitory to total biofouling, having only low *Legionella pneumophila* counts. The commercial filter tested in our study is made from plastic material filled with activated charcoal incorporating silver ions to prevent bacterial growth. However, *Pseudomonas aeruginosa* strains with higher resistance to silver nitrate have been described (9–11).

To the best of our knowledge only one previous study has addressed the issue of bacterial contamination of water filters during long-term use, some of which were produced by the manufactur-

er of the filters tested in this study. Bacterial contamination was found in the Brita filtered water with colony counts of up to 1.6 x $10^4$ cfu/ml (12).

We found that most commercial filters tested produced water with higher bacterial counts than in water prior to filtration, suggesting biofilm formation and bacterial growth in the filters especially after one week of use. Most species isolated from filtered water can cause life-threatening infections in severely immunocompromised patients, especially after colonizing the gastrointestinal tract.

Mothers of newborn babies and other susceptible persons, particularly immunocompromised patients, should be warned against using filtered water unless it is subsequently boiled. Companies producing water filters for domestic use should be required by national or international regulatory agencies to market only filters which do not result in deterioration of the microbiological quality of drinking water.

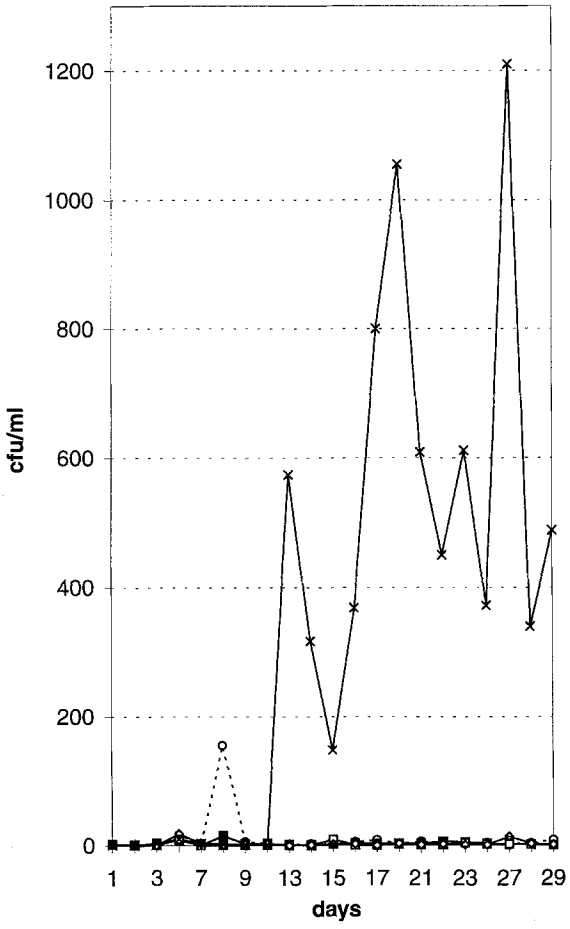


**Figure 3:** Bacterial counts (incubation at 20°C) in water from two commercial filter units as an example. Water originated from 1 of 3 taps. One filter unit was kept at room temperature (RT), a second filter unit at 4°C. Immediately prior to filtration, a sample of the tap water was taken as control. Symbols: ○ tap water (control), ■ RT-fresh filtrate, □ RT-24h-filtrate, × 4°C-fresh filtrate, ◇ 4°C-24h-filtrate.

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