Comparative Analysis of the Filtron and Biosand Water Filters

William F. Duke, MD,[1*] Rick Nordin[2] and Asit Mazumder[2]

* Corresponding author;

[1]University of Victoria, Restoration of Natural Systems Program , Victoria, British Columbia, V8W 3N5
[2]University of Victoria, Department of Biology, P.O. Box 3020 STN CSC, Victoria, British Columbia, V8W 3N5

email addresses for authors: BSDuke (bsduke@telus.net), RNordin (nordin@uvic.ca), AMazumder (mazumder@uvic.ca)

Running Title: Comparison of filters

Abstract

For many of the 1.1 billion people who now lack access to safe water, affordable water filters designed for use in individual households provide a practical alternative to municipal water treatment systems. Two of the most commonly promoted filters in developing countries are the Filtron ceramic filter and the BioSand intermittent slow sand filter. To compare the performance of these two filters, pond water was put through each filter for 30 consecutive days. Turbidity, TOC, DOC, E. coli and total coliform counts were recorded daily for the source water and for the filtered water from each filter. Flow rates and frequency of cleaning were also recorded for each filter. Both filters lowered the turbidity, TOC, DOC, and bacterial counts significantly.The Filtron filter was more effective in removing bacteria, but it was limited by flow rates of only 1-2 liters per hour as well as the need for frequent cleaning. The biosand filter produced flow rates of about 20 liters per hour and did not require cleaning during the study period, but it was less effective in removing bacteria.

Introduction

Providing clean, safe water to the 1.1 billion people who now lack access to it (*1*) will prevent many of the 4,400 deaths occurring each day from water-borne diseases (*2*). In many areas of the world, endemic water-borne enteric parasites cause chronic and recurring illnesses affecting the health of large segments of the population (*3*). Most of the people at risk live in developing countries, in rapidly-growing urban fringes, or in poor rural areas and indigenous communities (*1*). Often water scarcity complicates the lack of safety. However, even in areas where source water is abundant, the water must be treated before it can be considered safe to drink (*4*).

The UN has defined the minimum daily requirement for clean water as being 7.5 liters per person per day (*5*). This includes water to drink and water used to prepare food. To include water used for personal hygiene increases this minimum to 15-20 liters per person. The UN has estimated that it would cost about $50 US per person to provide adequate clean water and sanitation in rural areas and about $105 US per person in urban areas (*4*). Traditional western-style municipal water treatment plants are impractical for many of the populations at risk because of the high costs of construction per person served. There are also the difficulties associated with system maintenance and water quality monitoring (*6*). Affordable household treatment systems, constructed from locally available materials, are logical alternatives to municipal systems (*7*). Two water filters which meet those requirements are the Filtron ceramic filter and the BioSand intermittent slow sand filter. Both have been widely distributed in developing countries around the world.

The Filtron was developed in 1981 by the Potters for Peace, a non-profit organization based in the U.S. The final design was worked out by Ron Rivera, a ceramic artist in Nicaragua, during the 1990's. The Filtron has been distributed in many countries in Central America and Southeast Asia. It is illustrated in fig.1.

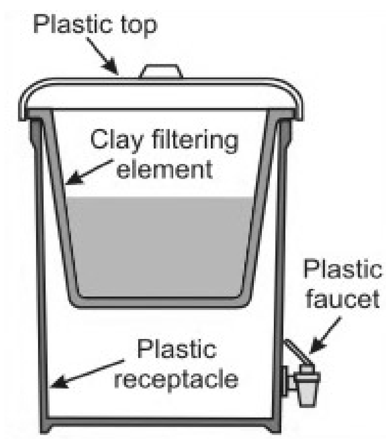

Figure 1: Filtron filter

The inner vessel is a ceramic pot formed in a mold which assures a standard size and shape. The pot is made from a proscribed mix of clay and graded sawdust. During the firing process, the sawdust burns creating a system of pores within the ceramic, allowing water to flow slowly through the vessel wall. After the pot has been fired, its inner and outer walls are painted with a colloidal silver solution. The silver anion in this solution acts as a bacteriostatic agent, enhancing the filter's ability to remove bacteria (*8*). The pot holds seven liters and has a large lip so that it can be suspended within a commonly-available 20 liter plastic bucket as shown in Figure 1. A plastic tap is placed in the bucket near the bottom. The pots can be constructed in small factories, using locally available skills and materials. Quality control is performed by checking flow rates. Pots producing more than two liters per hour or less than one are to be rejected (*8*).

The BioSand filter, illustrated in fig. 2 (*9*), is the design worked out by Dr David Manz at the University of Calgary, also during the 1990's (*10, 11*).

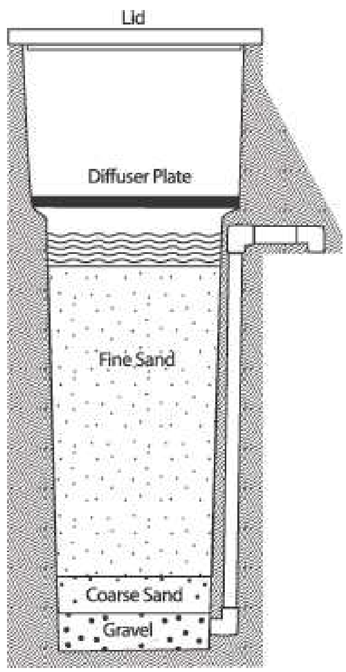

Figure 2: Manz Biosand filter

The container is constructed from concrete formed in a mold. Gravel, followed by coarse sand and then fine graded quartz sand, are layered in the container as shown. Source water is poured through a diffuser plate to prevent flow disruption of the sand. The water level remains at 5 cm above the sand and is determined by the level of the out flow spout. This assures that the sand remains wet, even with intermittent filling of the reservoir. The capacity of the vessel from the baseline water level to the lip of the container in the Manz design is about 20 liters, and the filter produces a flow rate of about 30-40 liters per hour. The biosand filter used in this study was also designed by Dr. Manz, and is commercially available from Davnor. It functions according to the same principles as the concrete design but is made for the commercial market. The model used is the smallest and least expensive of those available from Davnor. The container is made of durable plastic. The PVC plumbing is mounted to the outside of the container. The model used has about 1/3 the capacity of the concrete design of Dr. Manz. Filtration occurs as a result of mechanical trapping in the interstices created by the surface interfaces of the sand granules. Adsorption of suspended substances to the surface of the sand granules also plays a significant role. But the ability of the filter to remove bacteria, protozoa and parasites is enhanced by a biologically active layer which develops in a micro-environment created near the interface of the sand and the standing water (*12*). The standing water obtains oxygen by diffusion from the air at its surface and is rich with nutrients trapped in the upper layers of the sand. This layer, known as the *schmutzdecke,* (German, meaning "dirty blanket") is populated by an array of microbes which apparently act as predators, consuming or inactivating pathogens introduced in the source water. It takes from one to three weeks for the *schmutzdecke* to mature and function properly (*13*).

Both of these filters have been shown in multiple studies to be effective in removing, or significantly lowering, the number of bacteria and parasites (*8, 11, 14*). There is also anecdotal evidence that they have been effective in lowering the incidence of disease in families and in communities where they are used (*14, 15, 16*). This study is designed to compare the overall function of these two filters when exposed to identical source water for thirty consecutive days.

Materials and Methods

The Filtron filter used in the study was made in a factory in Nicaragua, which makes the filters for local use and for export. The ceramic filter pot was shipped along with the outer plastic bucket, tap and lid. The biosand filter used was provided by Prostar Industries in Victoria, B.C. which is the distributor for the commercially available line of plastic biosand filters made by Davnor Water Treatment Technologies Ltd.

The source water samples were collected from seven different ponds in the greater Victoria area. The source water samples were collected daily in 24 liter plastic containers. All water samples were collected and processed by one examiner and handled in a similar manner. Each day a single seven liter aliquot of source water was added to each filter. The total output from each was recorded one hour later. Samples were then collected from the source water and from the filtered water produced by each of the filters. Turbidity readings were obtained daily using a HACH turbidimeter. TOC (total organic carbon) and DOC (dissolved organic carbon) data were obtained using the Shimadzu TOC-V Total Carbon Analyzer at the University of Victoria Fresh Water Research Laboratory. Data quality was checked with regular standard and blank samples. The *E. coli* and total coliform bacterial analyses were performed at the Capitol Region District Water Department laboratory using the membrane filtration method of bacteria counting.

At one week intervals, maximum flow rates were recorded for each filter. This was accomplished by filling the reservoirs of the filters and then adding source water at 5 minute intervals so that the reservoirs remained nearly full during the one hour sampling period. Total output of each filter for that hour was then recorded as the maximum hourly flow rate. The filters were cleaned when the hourly flow rate reached 1/2 of the initial flow rate. The amount of water used to clean the filter was also recorded.

Results

The turbidity and bacterial growth from the source water ponds are summarized in Figure 1. The Filtron data is summarized in Figure 2. The Filtron was effective from the first day, removing 99% or 100% of the bacteria in 73% of the samples, and removing 90% or more of the bacteria in 97% of the samples. The level of contamination in the source water was not reflected in the filtered water. The flow rates for the Filtron decreased rapidly with turbid source water, and the pot required scrubbing more frequently as days passed. By the end of the study, the filter was being scrubbed every other day (see Appendix 3). Each time the filter was cleaned, five liters of filtered water was needed to properly rinse the pot inside and out during the scrubbing process.

The biosand filter removed 90% or more of the bacteria in only 31% of the samples. However, the filter was functioning more consistently near the end of the study, perhaps indicating that the biosand filter's *schmutzdecke* was maturing by that time.

The flow rate of the biosand filter remained about the same, averaging around 18 liters per hour. As a result, it was not cleaned during the study period. It is of note that the biosand samples which were collected immediately following the weekly maximum flow rate process tended to show less improvement than on other days, suggesting that at maximum flow rate, the *schmutzdecke's* capacity to remove bacteria may have been exceeded.

By the second half of the study, both filters were about equally effective in lowering turbidity, TOC, and DOC levels (Fig. 3, 4 & 5).

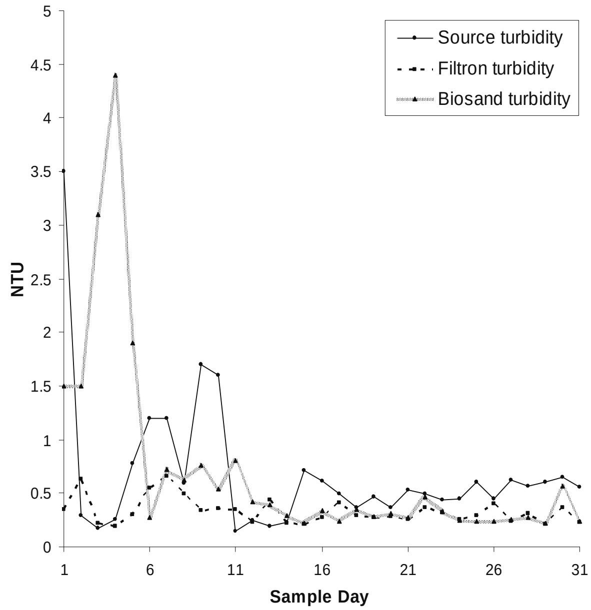

Figure 3: Turbidity Comparison

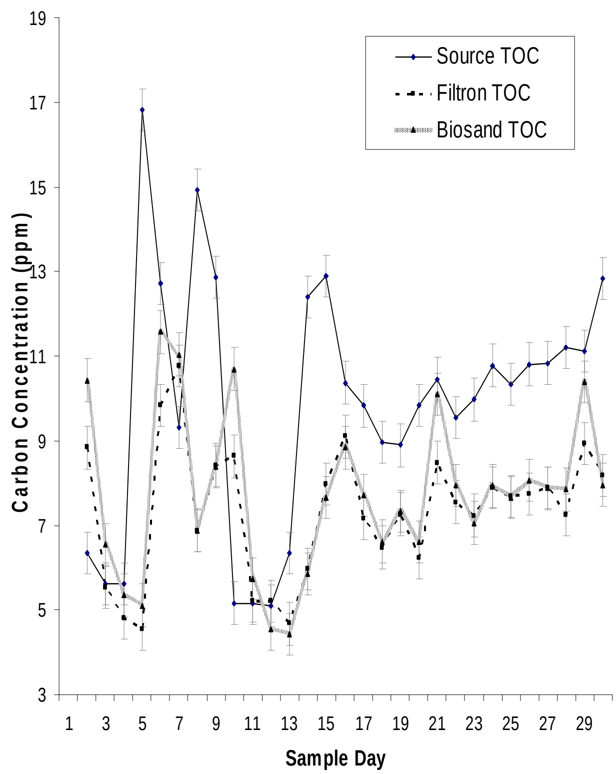

Figure 4: TOC Comparison

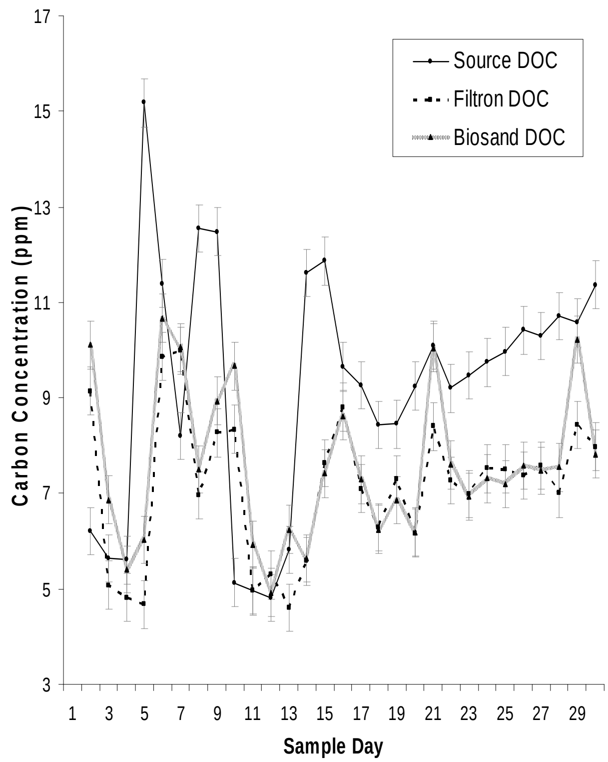

Figure 5: DOC Comparison

The percent removal of bacteria from the source water by each filter is summarized in Figs. 6 & 7 below. Subjectively, the quality of water produced by each of the filters was high and indistinguishable one from the other.

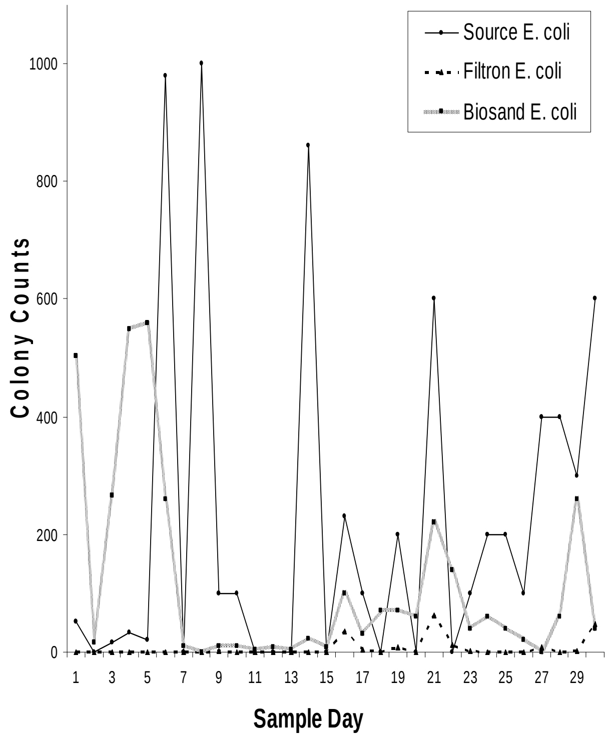

Figure 6: E. coli counts

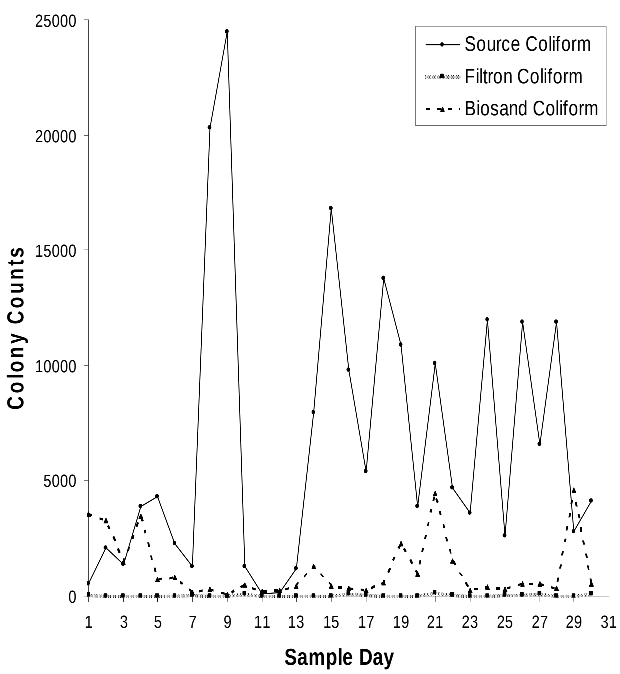

Figure 7: Total coliform counts

Discussion

The Filtron ceramic filter and the biosand intermittent slow sand filter are both low cost solutions for household water treatment. Each has its advantages and limitations. Performing a comparative study of this kind focuses attention on the differences between the filters. Consequently, it is important to point out the similarities. Both filters clearly improved the quality of the source water in terms of clarity, amount of organic carbon it contains, and number of bacteria. Both can be built with locally available materials and skills for less than $15 US. They both rely on another factor besides mechanical trapping to remove bacteria and other pathogens. In the Filtron it is the colloidal silver, and in the biosand it is the *schmutzdecke*. Neither should be thought of as portable. Studies have shown that they both tend to occupy a single area in the home and remain there (14). Another similarity is that they both are supported primarily by non-profit organizations, not by public funds or private industry alone. In addition, the economic sustainability of local factories and small-scale sales programs, independent of outside funding, has not yet been demonstrated for either filter.

Each filter has specific liabilities. The Filtron, for example, is somewhat fragile because it is made with a low fire ceramic and susceptible to breakage. In fact, the first Filtron sent for this study was broken during shipping, despite meticulous packing. This delayed the study nearly a month until a replacement arrived. The Filtron also must be removed from the outer container for cleaning, and frequent handling increases the possibility of breakage or contamination. Frequency of cleaning increases with the turbidity of the source water, so pre-filtering or settling of source water would decrease the frequency of cleaning. The most significant limitation of the Filtron is the filtration rate. One to two liters per hour, even under optimal circumstances, will not provide the basic needs for a family of four. The biosand filter has its own limitations. It is much heavier, so transport is more complicated and expensive. The biosand is more expensive to build, about twice as much as the Filtron ($15 vs. $8). The biosand also relies on a biological layer that can take weeks to mature, and there is no easy field test to determine when the *schmutzdecke* is functioning properly.

Each filter also has specific attributes. The Filtron demonstrated a better capacity to remove bacteria than the biosand in this study. In 50% of the samples, the E. coli count was reduced to 0 per 100cc. In another 36%, the counts were reduced to less than 10 per 100cc. The biosand filter reduced the E. coli counts to 0 per 100 cc in only two of 31 samples, and to less than 10 per 100cc in only six. However, both filters had overall bacterial removal efficiencies above 90% during the last week of the study, possibly indicating that the *schmutzdecke* was maturing and thus enhancing the filter's performance.

Water quantity is also important, and the flow rate produced by the biosand filter exceeds the minimum needs of most families. The Davnor model used in the study had a flow rate of about 18 liters per hour. The concrete version commonly distributed in developing countries reportedly has a flow rate approximately twice that rate (30-40 liters per hour).

Conclusion

The Filtron is more effective in removing E. coli and total coliformes than the biosand filter, but a flow rate of only 1-2 liters per hour and the frequent need for cleaning limit its ability to meet UN minimum requirements. The biosand filter's flow rate is adequate to meet this standard for quantity, but not consistently for quality, as defined by the WHO (*2*). It is, therefore recommended that the filtered water from the biosand filter be disinfected in some manner, such as UV radiation or chlorination, before being consumed (*7*).

Perhaps the best solution is to combine the two filters, first pouring the source water through the biosand filter, then running a portion of that water through the Filtron prior to drinking. "Improved water" from the biosand filter could be used for bathing and food preparation, and another 4-8 liters of "improved water" filtered with the Filtron to be used for drinking.

Acknowledgements

This study was made possible by the assistance of Shapna Mazumder, Rob Newell, Yuri Yoon, and others at the Water and Watershed Research Program at the University of Victoria; and by the generosity of Wilf and Adam Scheuer at Prostar Industries in Victoria, B.C., who provided the Davnor filter used in this study. The authors are also especially grateful for the editorial assistance of Yvonne Sharpe.

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Figure 3 - Turbidity Comparison

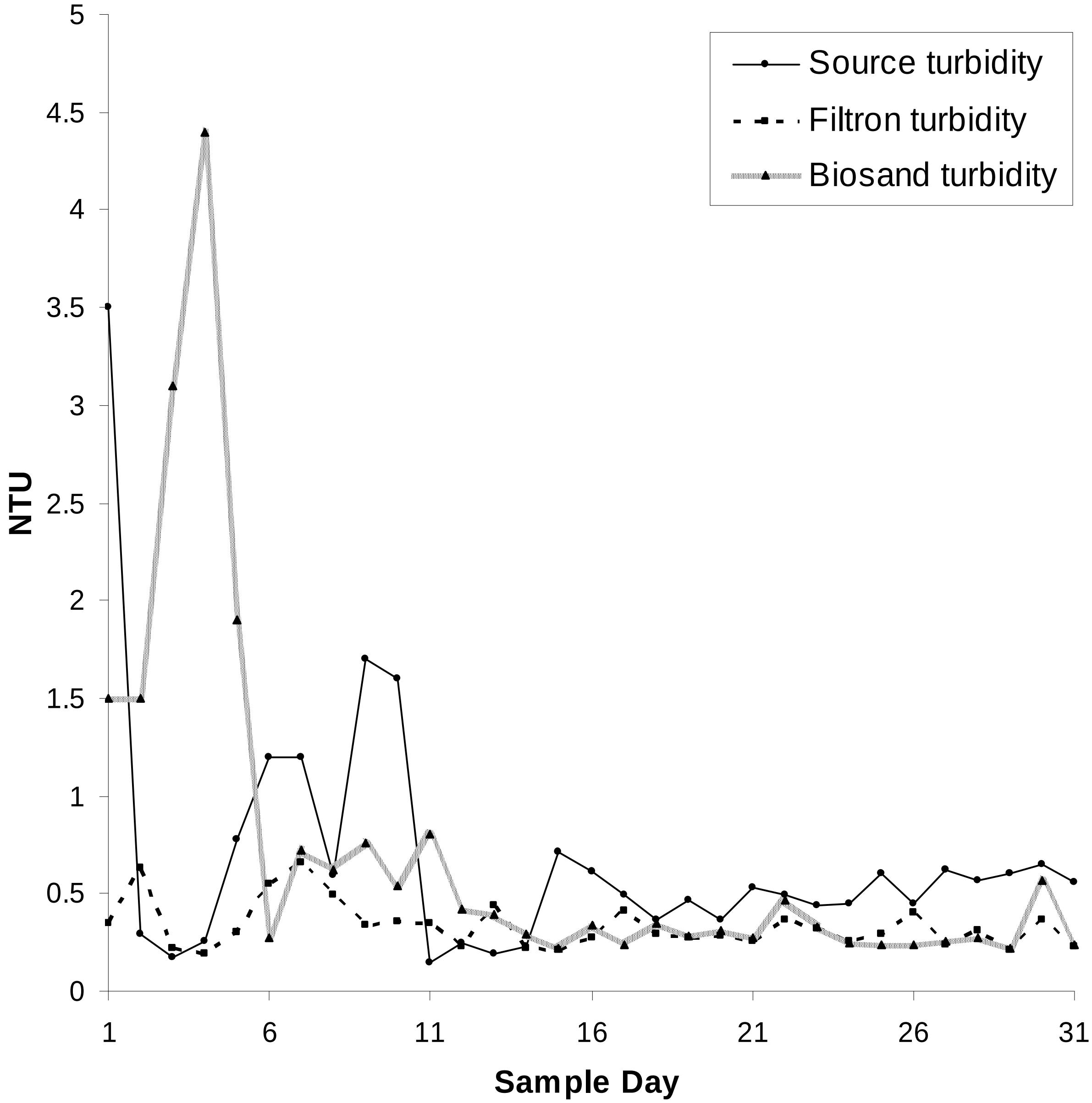


Figure 4 - TOC Comparison

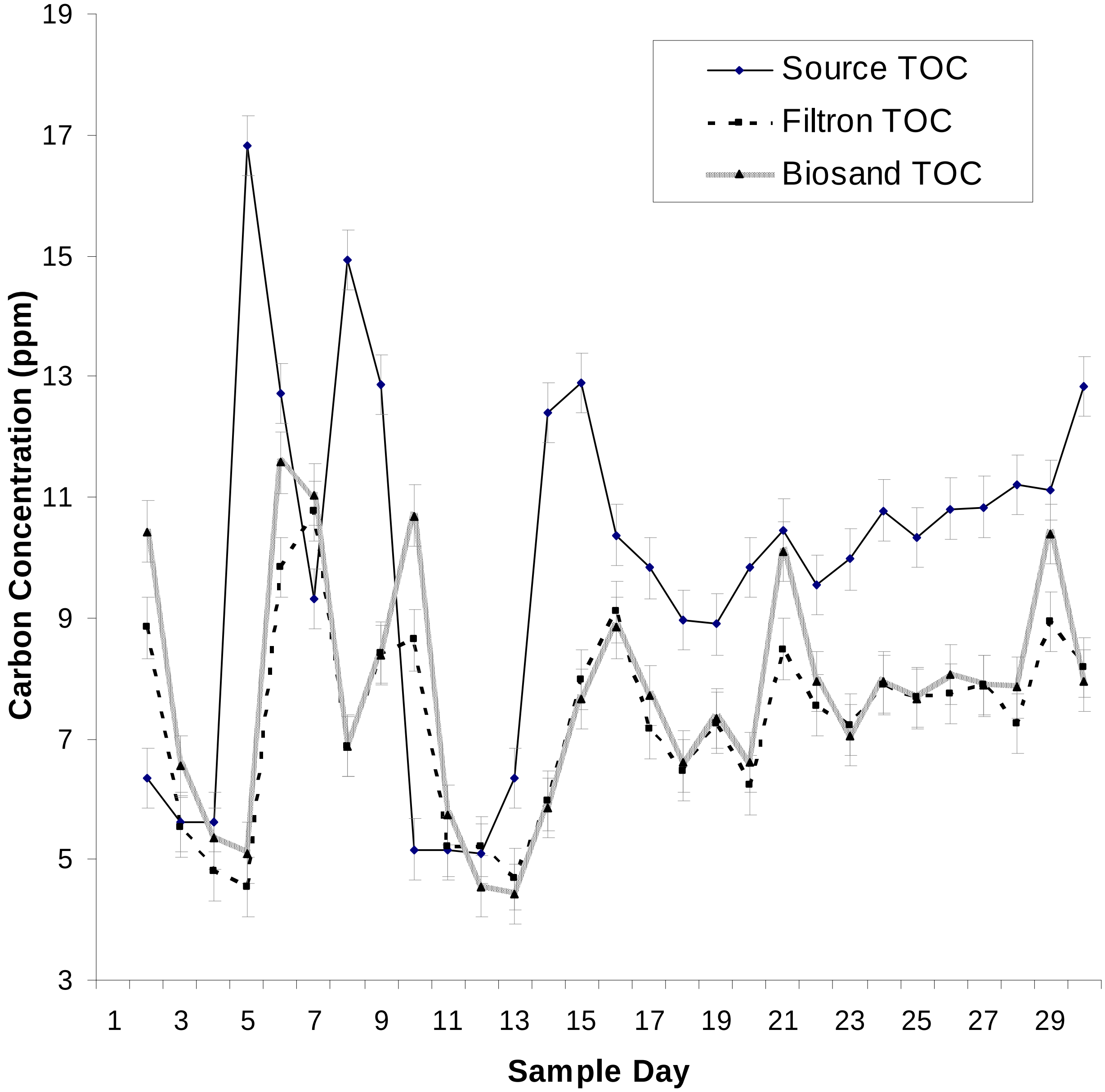


Figure 5 - DOC Comparison

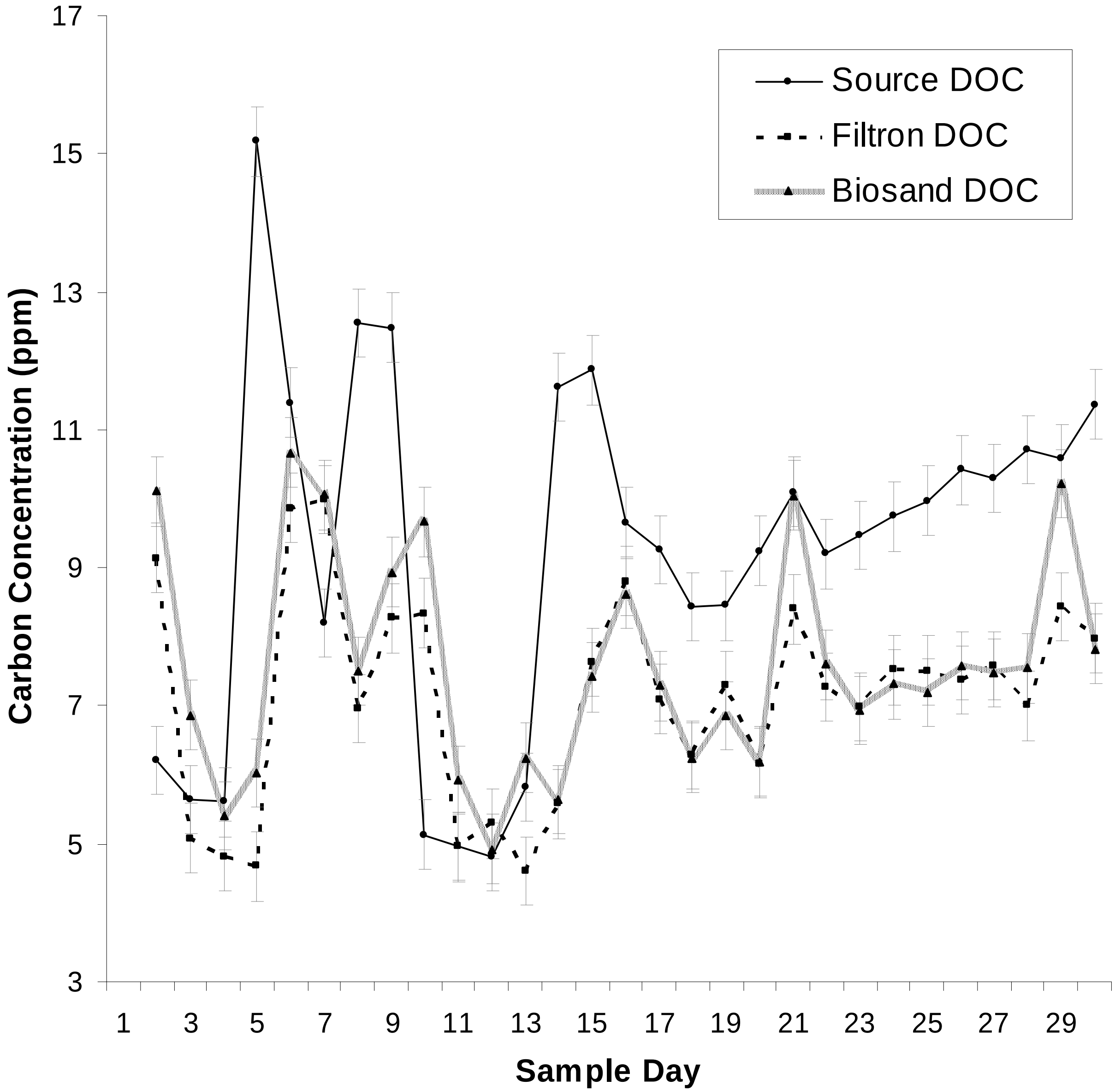


Figure 6 - E. coli Count Comparison

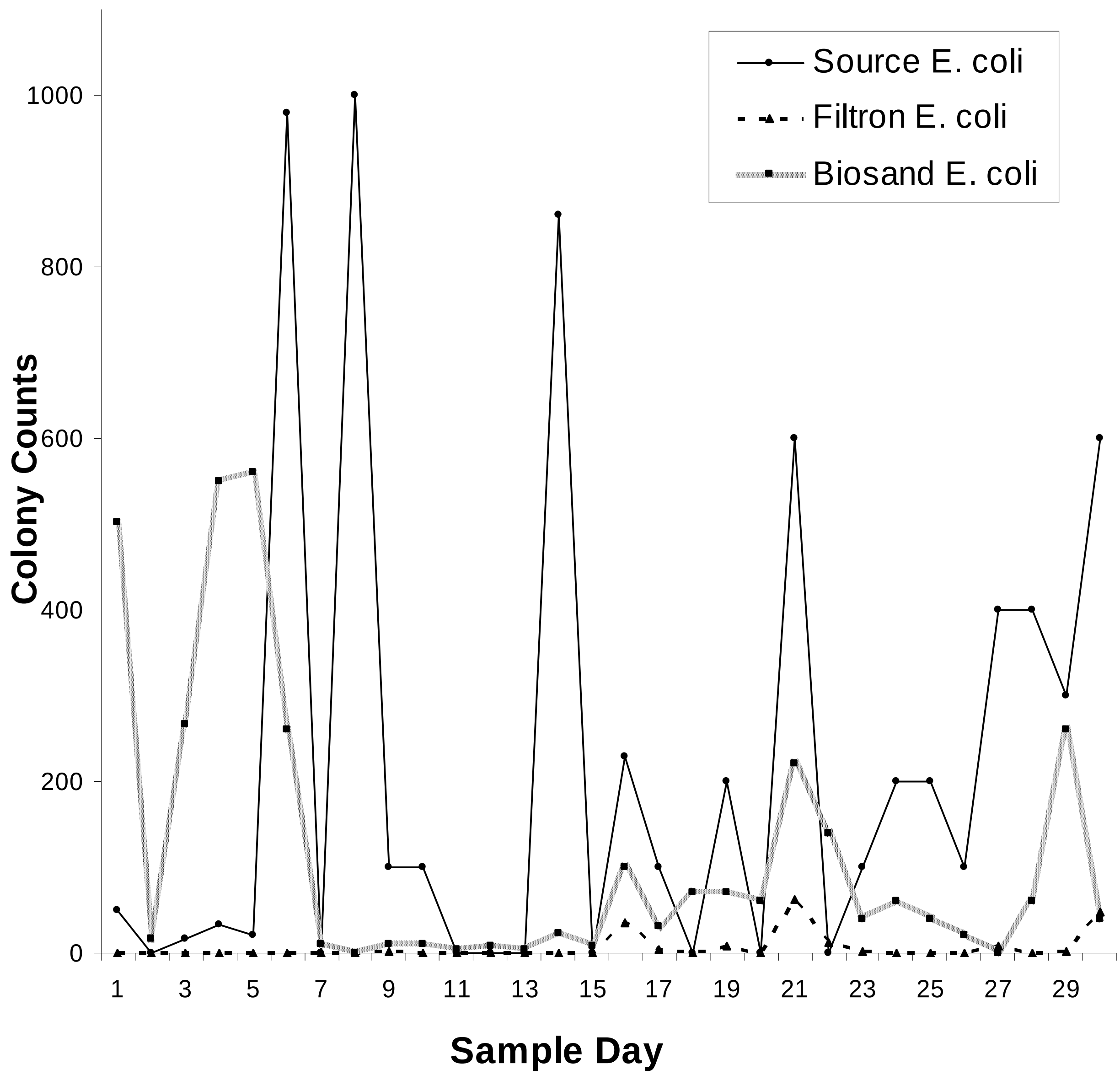
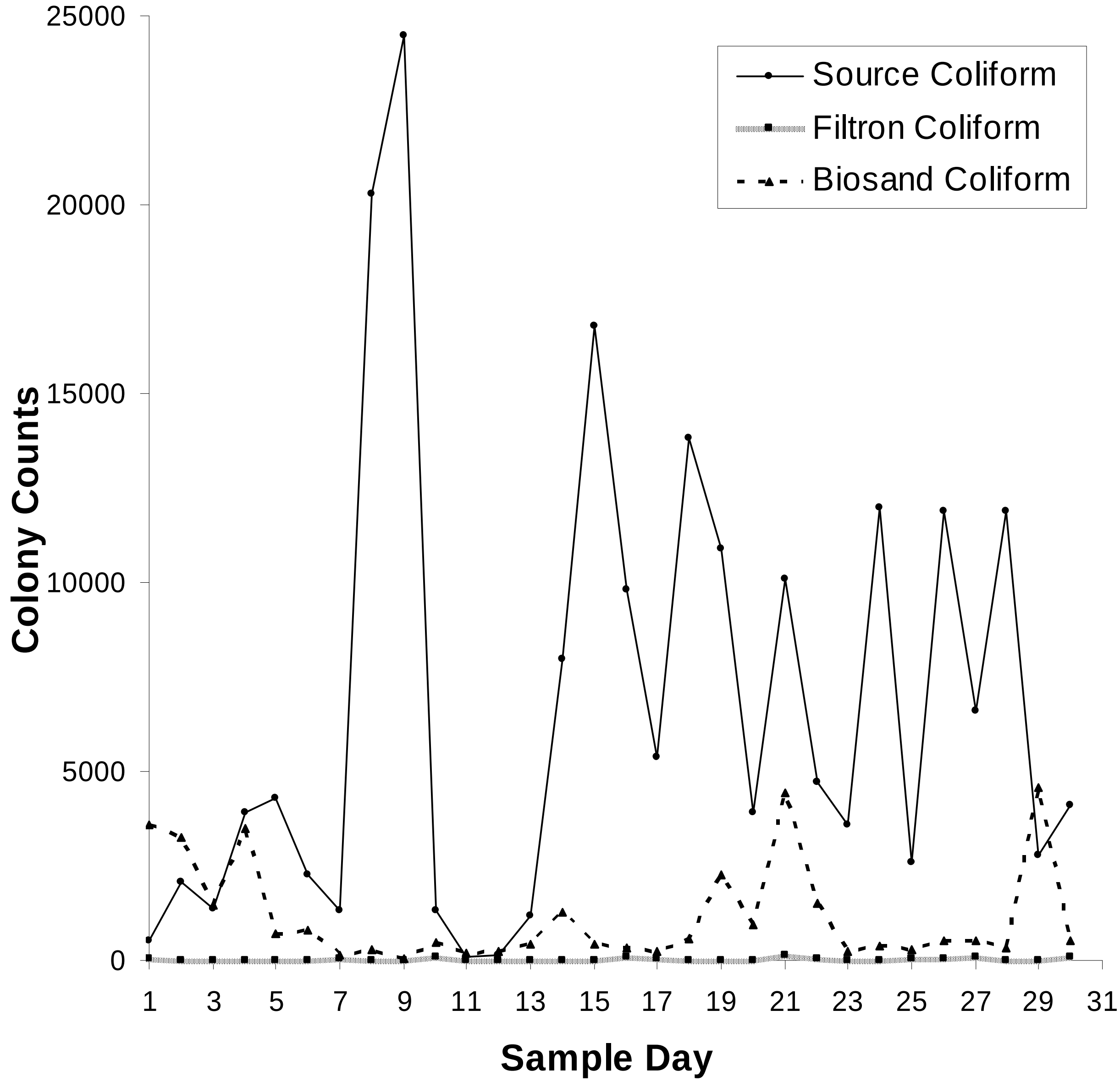


Figure 7 - Total Coliform Count Comparison


Source Coliform
Filtron Coliform
Biosand Coliform
Colony Counts
25000
20000
15000
10000
5000
0
1
3
5
7
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11
13
15
17
19
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23
25
27
29
31
Sample Day