TESTING ANTIMICROBIAL EFFECTIVENESS IN POOL FILTER MEDIA

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Background

Antimicrobial-containing filter media designed for pool and spa applications has been in commercial use for five years. The purpose of treating the filter media with an antimicrobial material is to provide a means of inhibiting bacterial growth on the surface of the filter. By doing this, the service interval between cleanings will be extended. Bacteria multiply by a process known as binary fission, so the increase in a bacterial population is by geometric progression. The rate of growth is determined by the availability of nutrients, temperature, pH and the chemicals present. It is the growth of large colonies that can lead to staining, odor generation, or both. For example, in an aqueous environment, bacteria will affix and protect themselves on surfaces such as filter media by secreting material called biofilm. They can, depending on the microorganism, produce unpleasant odors, make clean-up more time-consuming and shorten the time between needed cleanings. Preventing bacteria from growing on the media will result in elimination of these disadvantages.

Some filter manufacturers have embraced the idea of antimicrobial-containing media, while others have not. A possible reason for this may be the need for more convincing proof of the effectiveness of antimicrobial-containing media. Much of the antimicrobial supplier data consists of studies done with plastic plaques submersed in hot water or with fabric undergoing repeated launderings. Although these studies are useful and interesting, they obviously were not designed with pool and spa applications, where the media is continually exposed to water for many months, in mind.

In the past at Fiberweb, we have studied what happens to media in spas. We exposed material in a spa for months to demonstrate the lasting effectiveness of the antimicrobial content of the media. (See Figs. 1 & 2.) We took samples submersed in a spa and tested them for inhibition to bacterial growth by inoculating the samples with bacteria to see if the bacteria would grow or be inhibited from growing. An analytical procedure was also performed to measure the residual antimicrobial in the samples after exposure. This test evaluated the ability of the antimicrobial to function after continuous exposure to the water and treatment chemicals in a spa environment. However, there have been requests for data showing the effectiveness of the antimicrobial while "in" a pool because pool conditions differ dramatically from those of a spa.

Pool Environment Test Development Overview

Our objective is to develop a test to simulate a pool environment that:
1. could be conveniently carried out in the laboratory using readily available equipment,
2. would show the effectiveness of antimicrobial-treated filter media, and

3. would take a considerably shorter time frame compared to the spa test.

This test is currently ongoing.

Design questions included: what flow rates to maintain through the media test samples; how to grow microorganisms; and what pool conditions to maintain. The key to the test is the ability to grow and sustain microorganisms in the tank. We would focus on maintaining a reasonable chemical treatment regime for a swimming pool and periodically evaluate media for bacterial growth.

Items we had to overcome included: the lack of contaminants such as skin cells, which normally would be collected on the surface of the filter media; and controlling chlorination. (The National Spa & Pool Industry recommended-level-of-treatment for pools is to maintain 1 to 3 ppm or parts per million of free available chlorine.)

To help understand how we set up the experiment, I'll first provide an overview of pool water treatment. The treatments we performed for our test are given in Table 1. There are additional treatments besides these to control things like scale formation, but for our test these were ignored.

Table 1
Suggested NSPI Standards – Swimming Pools

	Minimum	Ideal	Maximum
Free Chlorine, ppm	1.0	1.0-3.0	3.0
Combined chlorine, ppm	None	None	0.2
pH	7.2	7.4-7.6	7.8
Total Alkalinity, ppm	60	80-100	180

Overview of Pool Water Treatment
To imitate a pool environment, we must control chlorine, pH and total alkalinity levels.

Chlorine. In pools, chlorine is the most commonly used sanitizer for treating organic wastes, with the major source of the organic wastes originating from bathers. Perspiration, saliva and urine all produce nitrogen-based waste products. These wastes are ideal food sources for microorganisms, and they must be removed to maintain water quality. To maintain the quality of pool water, an oxidizer, in the form of chlorine, is used to remove these organic waste compounds. Chlorine reacts with these nitrogen-containing organic compounds to form chloramines, measured as combined chlorine, which are stable compounds. Chloramines, however, are undesirable forms of chlorine. They are very pungent and irritating, especially to the eyes, and they produce chlorine odors even when they are at very low concentrations. (Water that is properly chlorinated will have very little odor.) A properly maintained system will further reduce chloramines to simpler materials such as CO_2, N_2 and salts. Once combined, chlorine is no longer available in its free state and therefore not available to further sanitize. Chlorine that is not combined remains available to sanitize and is referred to as free chlorine.

The most common method of introducing chlorine into the water is through the use of hypochlorite salt. The one most commonly used for pools is sodium hypochlorite. Once introduced into water, equilibrium is established between the strong oxidant hypochlorous acid [HClO], which is the major disinfectant in chlorine, and the weaker hypochlorite ion, [ClO-].

H2O + HClO   H 30+ + ClO-

Equilibrium is pH dependent and is very sensitive in the range of 7 to 8.

Hypochlorite is not effective in inhibiting bacteria. The negative charge on the hypochlorite ion hinders its passage through the bacterial membrane (cell wall) and therefore its ability to oxidize it. HClO is the preferred species to oxidize the bacterial cell contents.

Free chlorine (in the form of HOCI) can be consumed in other ways besides oxidizing organic wastes, which was mentioned earlier. The action of the ultraviolet energy of sunlight converts free available chlorine to the inactive chloride ion, and it is also consumed in destroying bacteria and algae introduced by swimmers and the environment.

The amount of chlorine consumed in the process of treating organic wastes is referred to as the chlorine demand of the water. Chlorine consumption depends on the amount of contamination that is present. Enough sanitizer must be added to meet the chlorine demand of the water before a measurable residual can be maintained. Once the chlorine demand is satisfied, any additional or residual chlorine is referred to as free chlorine.

It's essential to maintain a free chlorine residual at all times to have clear, sanitary pool water. This is the chlorine that is available to disinfect pool water and oxidize organic substances as they enter the water. The recommended level, as mentioned previously, is 1 to 3 ppm of free or available chlorine.

Chlorine levels need to be measured to ensure the water is being properly maintained. One method for measuring chlorine is DPD (diethyl-p-phenylene diamine) tablets, which distinguish free from combined chlorine. Using them is simple and rapid to do, and it is the method we used for our test.

- A DPD NO. 1 tablet is dissolved in a measured amount of pool water to produce a colored solution.

- Color standards can then be used to determine the amount of free available chlorine present in the water. However, photometers are available that are specifically pre-calibrated for this application and interpret the color directly into a numerical value (ppm of free chlorine). We used the photometer.
- The amount of chloramine or combined chlorine present is indirectly determined by adding a DPD NO. 3 tablet to the same test sample and measuring any color change. This value is the measure of *total* chlorine in the water.
- The difference between the total chlorine measurement and the free available chlorine test result equals the chloramine or combined chlorine content of the water.

Total Chlorine - Free Chlorine = Chloramines (combined chlorine)

The NSPI recommends that the level of chloramines not exceed 0.2 ppm.

pH. The pH of the water must be maintained in the range of 7.2 - 7.8 because of its impact on chlorine efficiency and bather comfort, as well as corrosion and scaling. Things such as rain, dust and bather wastes can all raise or lower pH. Table 6 lists things that will affect pH as well as control it. In pools, a slightly alkaline pH of 7.4 - 7.6 is best because this range is most comfortable to the human eye and provides for optimum use of free chlorine, while maintaining water that is not corrosive or scale-forming. Table 2 lists some negative effects of pH change.

Table 2

When pH is too low (below 7) some effects are:

- Water becomes acidic
- Chlorine residuals dissipate rapidly
- Eye irritation occurs

When pH is too high (above 8)

- Chlorine activity is slowed and inefficient
- Water becomes cloudy
- Eye irritation may occur

Alkalinity. Total alkalinity is a measure of the buffering capacity of pool water and is expressed in ppm. Control of pH is simplified by maintaining total alkalinity in the range of 80 - 100. Total alkalinity is closely associated with pH but rather than a measure of hydrogen ion concentration, it is a measure of the ability of a solution to neutralize hydrogen ions. This acid-neutralizing (buffering) capacity of water is desirable because it helps prevent wide variations in pH whenever small amounts of acid or alkali are added to the water. If total alkalinity is too high, it is difficult to adjust pH. When total alkalinity is too low, pH bounce will occur.

Total alkalinity is raised by the addition of bicarbonate of soda (baking soda) or soda ash. Sodium bisulfate or muriatic acid is used to lower it.

Test Procedure Design

Our test apparatus is set up using a 20-gallon tank. The size is convenient since it is 1/1,000th of a typical in-ground pool. The size of the test specimen and the flow rate pumped through it were chosen to simulate what a pool this size would typically use. Using the generally design-accepted criteria given in Table 3, the amount of filter media and the flow rate through the media for the test tank were determined. In our case, we turn the volume over every 5 hours using a flow rate based on residential pools since this is where most of our product is used.

Table 3

Industry Accepted Standards & Practices

- Filter media requirements
  - Spas – 1 ft^2 of media per 10 gallons of water
  - Pools – 1 ft^2 of media per 200 gallons of water
- Cartridge filter flow rates
  - Public pools – 0.375 gpm/ ft^2 of media
  - Residential pools – 1 gpm/ ft^2 of media
- Volume turnover should occur every 3 to 6 hours

With the filter media area and flow rate through the media scaled proportionally, we selected the rate of chlorination and amount of simulated bather waste to be used.

Test tanks were set up as follows.

1. A tank, where the water is continually maintained at 3 ppm free chlorine, and

2. A second tank that is never treated with chlorine.

The 3 ppm level in the treated tank is at the high end of what is recommended and was chosen for that reason. The untreated tank is used as a control to show that microbial growth will occur given the chance under the conditions of the test. The temperature of both tanks is maintained at 29°C (84°F). Each tank is given a daily dose of an artificial perspiration solution as the source of organic waste. Table 4 gives the composition of the mixture, and Table 5 provides a typical swimmer load. To help accelerate the test, we used a bather load that is four times higher than the normal bather load. Table 7 summarizes the test parameters used.

Table 5

Simulated Swimmer Load

Active swimmer generates 2 pints (or ~ 950 ml) of perspiration/hour.

Simulated Pool ~ 1 ml per swimmer/hour.

Early on, we learned that, if we chlorinated only once a day, free chlorine could at times be totally consumed in less than 24 hours. To avoid losing control of the free chlorine level requires smaller, more frequent dosages of sanitizer [Fig. 3]. Using a microprocessor-controlled timer, it is easy to automatically feed a controlled amount of chlorine solution on a fixed schedule. We chose to feed hourly using a chlorine-based sanitizer purchased locally from a pool supply house. We found this method easily kept the free chlorine level within an acceptable range [Fig. 4].

We have since started a third tank with a level of chlorine treatment that is considered unsatisfactory. The target level of free chlorine is 0.5 ppm and was chosen to see how an antimicrobial-treated media would function in this environment. When we measured the bacteria level of the three tanks, we see a correlation of bacteria to the amount of chlorine treatment used, which validated the environment we are trying to achieve [Fig. 5].

Bacteria are counted as CFU or colony-forming-units per 50 ml of water and are done for us by outside test houses.

Findings and Conclusions

Our original premise in developing an antimicrobial-treated media for pools and spas was to inhibit bacterial growth to reduce fouling and extend the time between cleanings due to it. We knew antimicrobial-treated media would do this. Although testing is continuing we feel the experiment has borne this out and we can report the following findings and conclusions:

- Microbes can be easily grown and maintained using a food supply based on artificial body perspiration.

- The level of microorganisms is consistent with the level of treatment. The right amount of chlorine means fewer microorganisms present in the water.
- As long as a pool is treated and maintained at the maximum recommended level of free chlorine, there will be little bacteria growing in the water, so under the conditions of our experiment, neither the treated nor untreated media in the properly chlorinated tank will show any bacteria growing on them.
- However, even in pools where the free chlorine level is carefully controlled, upsets occur. We see that in Figure 7, which compares antimicrobial-treated media to untreated media in the tank maintained at 3 ppm free chlorine. On the scheduled day for sample removal, the free chlorine level had dropped. As the graph shows, antimicrobial-treated media will provide backup protection for the filter media should the free chlorine level be lost.
- Even when bacterial growth is rampant, the antimicrobial treatment provides a degree of protection to the filter media by inhibiting or slowing its growth. The untreated and treated tanks in our experiment had an identical set of media samples. We knew that, after a period of time, even the treated samples would be overwhelmed with bacteria in this environment. Initially, bacteria would be inhibited from growing, but over time as the layers built up "new" bacteria would no longer be in contact with the surface of the media and therefore the antimicrobial material. Measured CFUs in the untreated tank water typically far exceeded 200. (At 200 CFUs a public pool would be shut down.) As expected, both the treated and untreated media samples had similar CFU counts on their surfaces. What is significant, however, is the much lower pressure drop, by a factor of nearly 2, as shown in Fig. 6 that was observed for the treated media. We repeated the experiment to be sure.
- Additional work needs to be done and is in progress to study what happens when the free chlorine levels are on the low side.

As a leader in the filtration business, Fiberweb wants to be viewed as a technical leader too. Pool and spa media is a very important product line at Fiberweb that is continually evolving. Information derived from studies like these are used to improve our products. This study is continuing and others are in the implementation stage to further serve our customers.

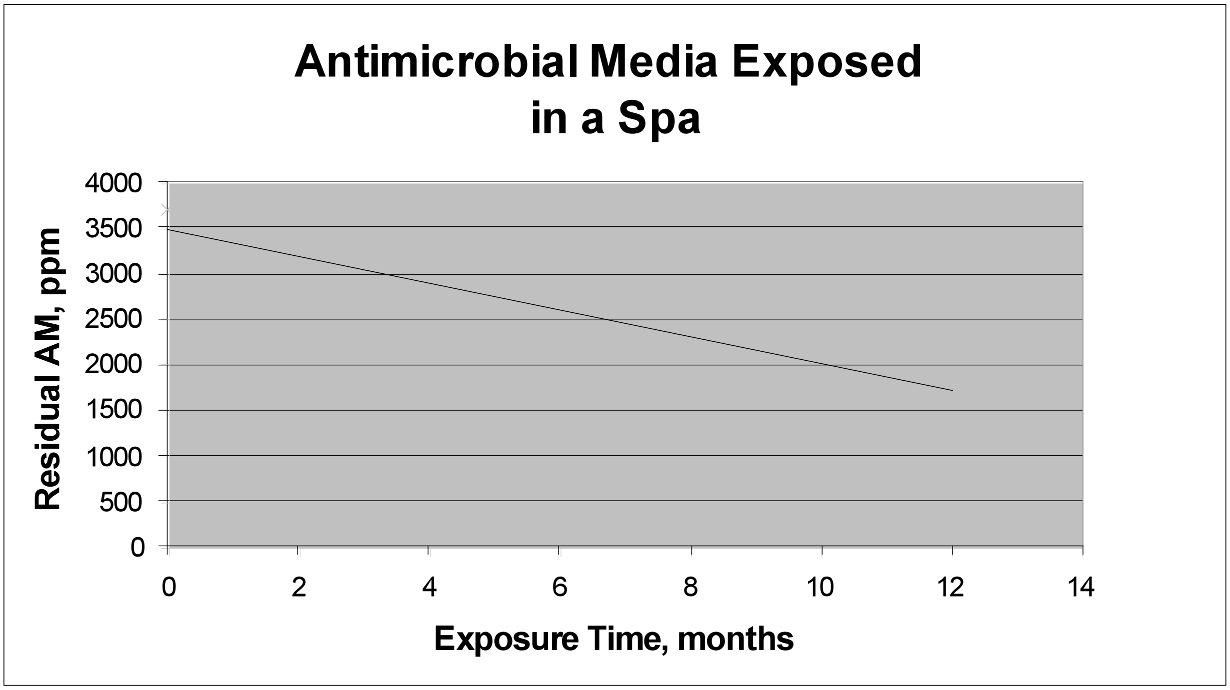
Antimicrobial Media Exposed
in a Spa
Residual AM, ppm
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
Exposure Time, months

Fig 1

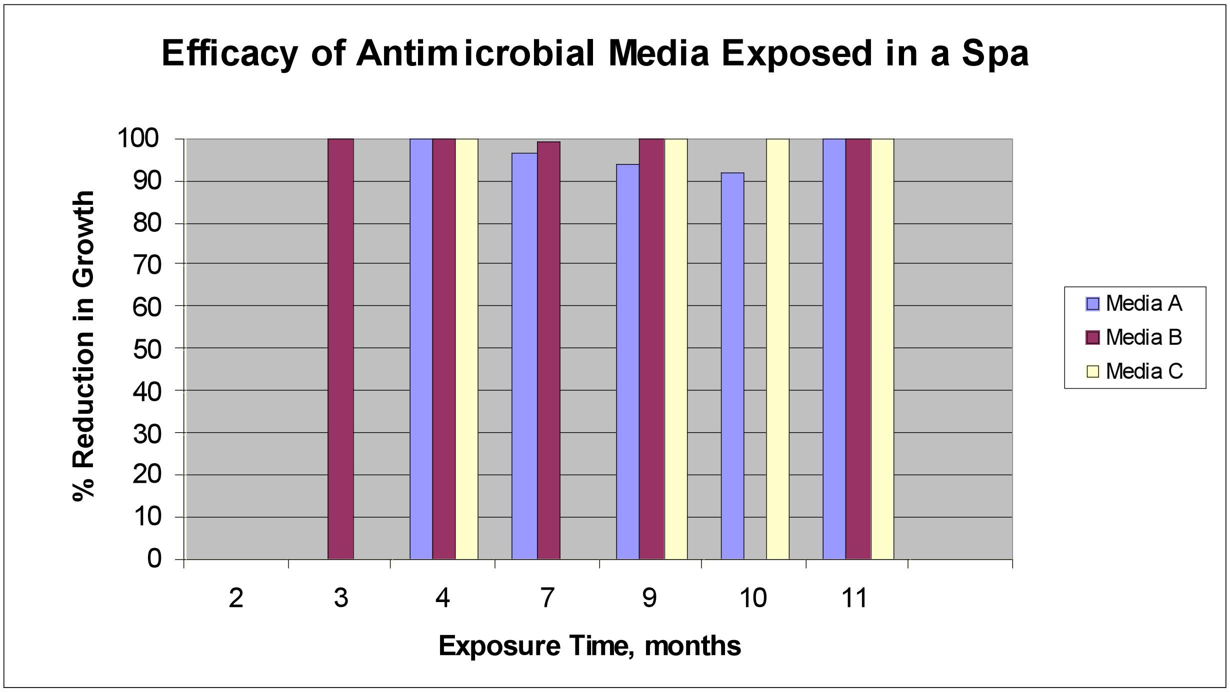
Efficacy of Antimicrobial Media Exposed in a Spa
% Reduction in Growth
100
90
80
70
60
50
40
30
20
10
0
2
3
4
7
9
10
11
Exposure Time, months
Media A
Media B
Media C

Fig 2

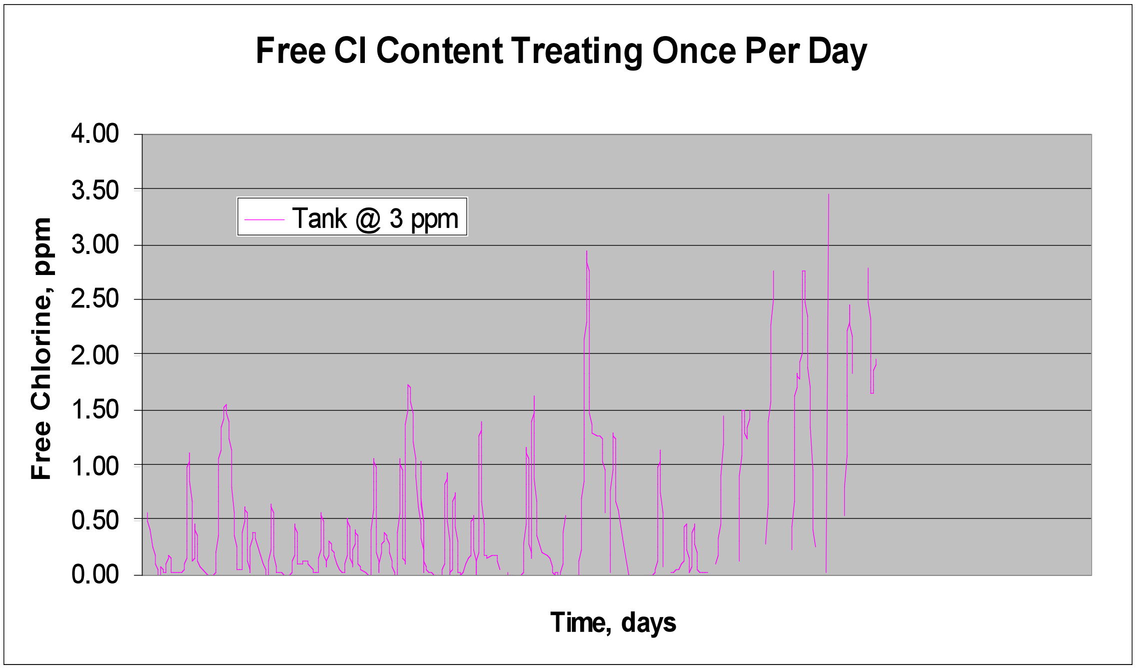
Free Cl Content Treating Once Per Day
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Free Chlorine, ppm
Tank @ 3 ppm
Time, days

Fig 3

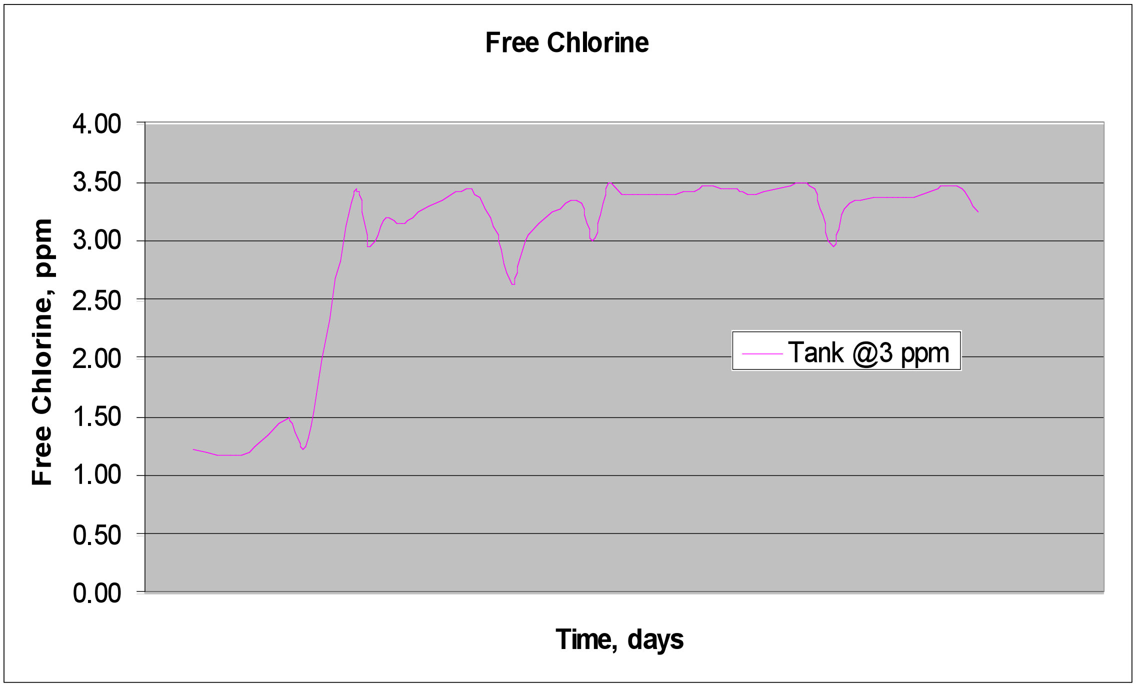
Free Chlorine
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Free Chlorine, ppm
Tank @3 ppm
Time, days

Fig 4

Table 4 Artificial Perspiration Mixture
• 161 mg/l $(NH_4)_2SO_4$
• 277 mg/l Urea
• 36 mg/l Uric Acid
• 23.2 mg/l Creatinine
• 1 mg/l Creatine
• 57 mg/l Glycine

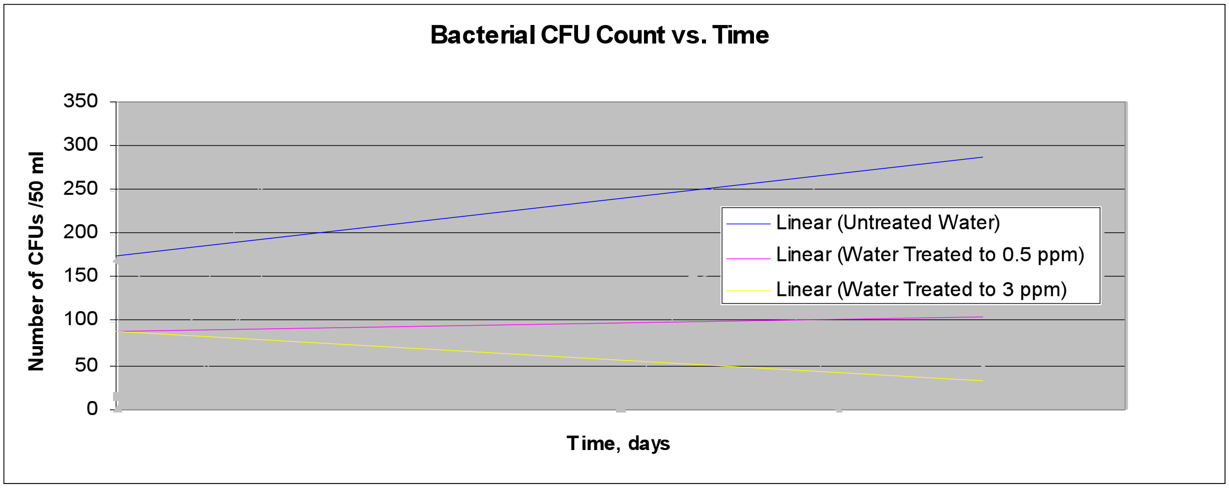

Fig 5

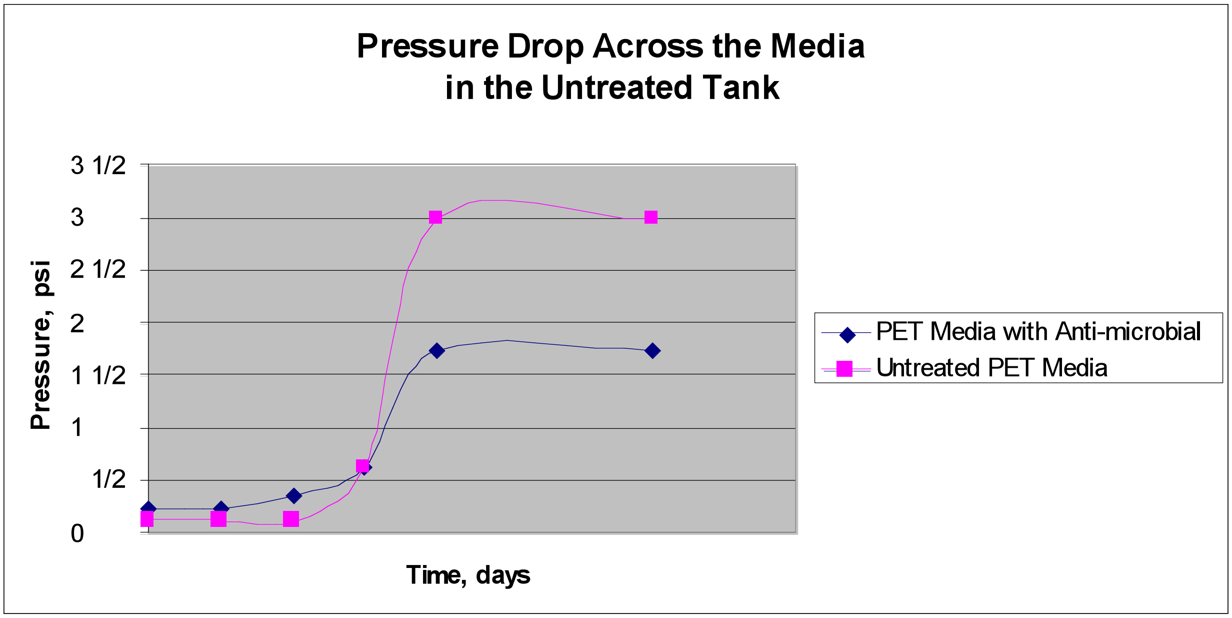

Fig 6

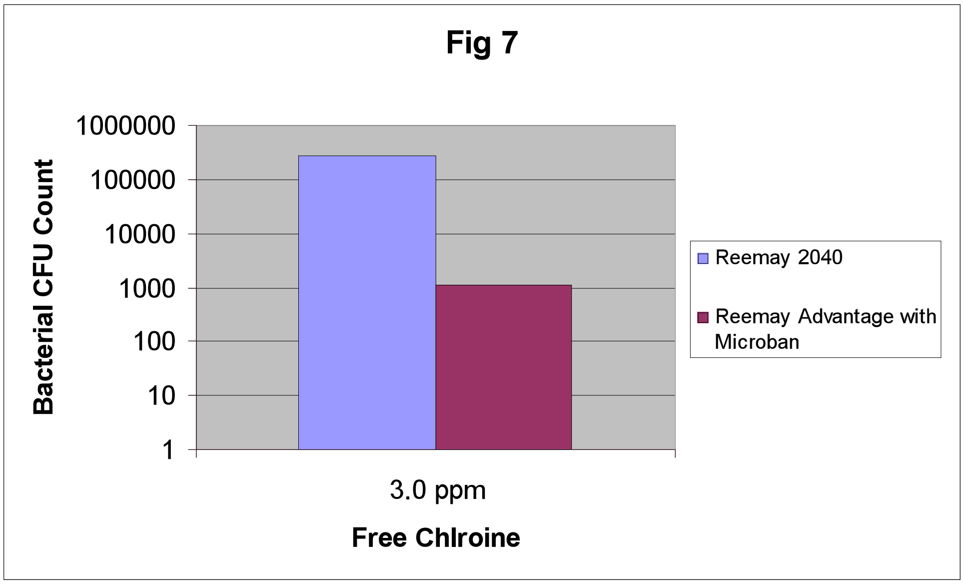

Table 6 Factors That Affect pH

Lowers pH	**Raises pH**
Acid	Soda Ash
Gas Chlorine	Sodium Hypochlorite
Trichlor Chlorine	Calcium Hypochlorite
Dichlor Chorine	Caustic Soda
Rain Water	Bicarbonate of Soda
Alum	Swimmer Wastes
Organic Litter	Algae Growth

Table 7 Effectiveness Test Parameters	
Flow Rate	1 gpm/ft2
Temperature	29oC
pH Range	7.4 to 7.6
Alkalinity Range	80 to 100 ppm
Tank Volume Turnover	Every 5 hours
Filter Media Area/Tank	0.75 ft2
Artificial Waste	60 ml/day

Bibliography:
> A Guide to Pool & Spa Cartridge Filters – Reemay Inc. © 1993
> Hayward technical manual ISC1750-98
> Pentair technical manual 178556
> Swimming Pool Chemistry by Doug De La Matter
> Water Chemistry for Swimming Pools NC State
> Handbook of Chlorination by Clifford White © 1986
> CFU procedure is NAMSA Test Method MG005-112