WHITE PAPER:
Minimizing Health Risks of Waterborne Contaminants in Healthcare Settings

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ABSTRACT

Contamination of water supplies with potentially pathogenic organisms to hospitals and health care environments is very common. However, the extent of the problem is largely unrecognized, and there are no specific guidelines for protecting patients and health care workers from exposure. Point-of-use water (faucets and showers, water fountains, ice machines) may be the source of the transmission of waterborne microorganisms. Patient exposure to waterborne pathogens is derived from such point-of-use sources, as well as to contaminated medical equipment rinsed with tap water, or the hands of medical personnel washed and rinsed in tap water. Systematic water disinfection technologies are not completely and sustainably effective in reducing the bioburden of pathogens in hospital water. Complete eradication of waterborne microorganisms by these technologies is not attainable due to the continual establishment of biofilm communities downstream of the point-of-disinfection. Point-of-use filtration presents a limited option to lessen exposure to waterborne pathogens and the risk of waterborne HAIs. However, point-of-entry water filtration is shown to be 99.9 percent effective in eliminating all waterborne pathogens and contaminants entering the facility through the public water supply.

IDENTIFYING THE PROBLEM

Hospital-acquired (nosocomial) infections are one of the leading causes of death in the United States, typically affecting patients whose immune systems are compromised. Nosocomial infections are normally transmitted through three main environmental routes – air, surface contact, and water [i]. Consequently, a significant concern confronting public and private health care systems, including hospitals and other health-related facilities (primary and surgical clinics, laboratories, veterinary clinics, nursing homes, etc.), is waterborne contamination. Accepted as the most reliable weapon to reduce health care-associated infections, hospital tap water has also been recognized as "the most overlooked, important, and controllable source of health care-associated infections (HAIs)."[ii iii]

Waterborne Contaminants and Pathogens. Contamination of the hospital water supply with potentially pathogenic organisms is very common. Peer-reviewed literature has shown that hospital tap water contains microbial pathogens and that biofilms in water systems resist disinfection, and deliver pathogenic organisms to the health care environment. At-risk patients are susceptible to infection through direct contact, ingestion, and inhalation of waterborne pathogens. A wide range of bacteria, fungi, and protozoa in the water supply may be pathogenic and should be cause for clinical concern. Common bacterial pathogens include *Legionella spp., Pseudomonas aeruginosa,* and some mycobacteria. *Aspergillus* is a particularly disconcerting mold found in hospital water, which may protect bacterial pathogens such as legionella *pneumophila* from destructive chemical disinfectants and environmental forces as they support bacterial growth and replication.[iv]

Anaissie et al.[v] reviewed the potential sources of water and mechanisms through which water could serve as a source of infectious microorganisms. Hospitals and health care facilities generally draw their water from the municipal water supply. Water is treated at the treatment plant, then travels through a system of biofilm-laden pipes before reaching the hospital. Waterborne microorganisms have been found in hospital water tanks, as well as tap water that flows from faucets and showers**.** It is the water's contact with biofilm that is the primary cause of poor tap water quality at the point-of-entry to the hospital. However, other factors such as distribution pipeline and storage tank age and corrosion, poor water system design, and water stagnation are also major contributors. Biofilm can become dislodged from pipe surfaces as the result of increased water demand during the summer months that results in higher water flow rates and increased shearing forces. Periods during which facility construction takes place also result in biofilm disturbance due to direct mechanical contact with pipes, as does the of occasional use of normally stagnant water at less frequently access points-of-use.

Patient exposure to waterborne microorganisms in the hospital occurs while showering, bathing, drinking water, ingesting ice or eating prepared foods. It can also occur through contact with contaminated medical equipment such as tube feed bags, flexible endoscopes, and respiratory equipment that have been rinsed with tap water. The hands of health care personnel washed using tap water can also lead to patient exposure.[vi vii viii]

Providing safe water for hospital use provides the obvious benefit of minimizing at-risk patient exposure to microbial pathogens. However, in order to determine whether or not total and complete microbial eradication from a hospital water supply is feasible, it is necessary to understand the challenges that must be overcome in the attempt to attain that goal.

Factors that contribute to the microbial contamination of water include:

- The temperature of water at various points in the water distribution system.
- The development and persistence of biofilm in the water delivery system, particularly in areas of the water distribution system where water tends to stagnate.
- The inability of systemic disinfection technologies (e.g. chlorine dioxide, hyperchlorination, copper-silver ionization, hot water flushing) to reach all locations within the water delivery system.
- The accumulation of scale in a water delivery system and the role it plays in enhancing the conditions for microbial growth.

SCOPE OF THE PROBLEM

Water as a Reservoir of Hospital Pathogens. While >40 *Legionella spp.* are known, most outbreaks of Legionnaires' disease are caused by *Legionella pneumophila* serotypes 1 and 6; 600 to 1,300 cases are reported each year in the U.S., although these figures may represent underreporting.

Drinking water that is microbiologically contaminated is a cause of community-acquired infection. Microbes in hospital water can also cause nosocomial (e.g., hospital-acquired) infection, yet guidelines for preventing such infections do not exist. Research by Anaissie et al. (2002) assessed the magnitude of the problem caused by waterborne nosocomial infections, and advocated for immediate action for their prevention.[ix]

Further, common to moist surfaces is the development of a conditioning film of chemicals of chemicals that rapidly leads to the development of bacterial biofilms[x], which subsequently support a range of free-living protozoa, metazoan, and other invertebrates in engineered water systems[xi xii xiii].

According to their investigation, an estimated 1,400 deaths are reported each year in the United States as a result of waterborne nosocomial pneumonias caused by *Pseudomonas aeruginosa* alone. At the time of the research, no clear guidelines existed for the prevention of these infections. By contrast, guidelines for the prevention of community-acquired waterborne infections are now routinely used. Hospitals caring for patients at high risk for infection do not enforce the standards of water quality recommended by U.S. public health agencies for patients' community counterparts. Because of the seriousness of these nosocomial waterborne infections and the availability of low cost, sterile water, it is recommended that patients at high risk for infection avoid exposure to hospital water and use sterile water instead, coupled with surveillance to help prevent infections.[xiv xv xvi]

Since 1971, The CDC, the EPA, and the Council of State and Territorial Epidemiologists have collaborated on the Waterborne Disease and Outbreak Surveillance System (WBDOSS) for collecting and reporting data related to occurrences and causes of waterborne disease outbreaks associated with drinking water. This surveillance system is the primary source of data concerning the scope and health effects of waterborne disease outbreaks in the United States.[xvii] Data collected during January 2007 to December 2008 summarized 48 outbreaks and 70 previously unreported outbreaks.

WBDOSS includes data on outbreaks associated with drinking water, recreational water, water not intended for drinking (WNID) (excluding recreational water), and water use of unknown intent (WUI).

<u>Data Outcome:</u> A total of 24 states and Puerto Rico reported 48 outbreaks during this period, 36 (75%) were associated with drinking water, which caused illness among 4,128 persons, and were linked to three deaths. Etiologic agents were identified in 32 (88.9%) of the 36 drinking water-associated outbreaks; 21 (58.3%) outbreaks were associated with bacteria, five (13.9%) with viruses, three (8.3%) with parasites, one (2.8%) with a chemical, one (2.8%) with both bacteria and viruses, and one (2.8%) with both bacteria and parasites. Four outbreaks (11.1%) had unidentified etiologies. Of the 36 drinking water-associated outbreaks, 22 (61.1%) were outbreaks of acute gastrointestinal illness (AGI), 12 (33.3%) were outbreaks of acute respiratory illness (ARI), one (2.8%) was an outbreak associated with skin irritation, and one (2.8%) was an outbreak of hepatitis. All outbreaks of ARI were caused by *Legionella spp.* A total of 37 deficiencies were identified in the 36 outbreaks associated with drinking water. Of the 37 deficiencies, 22 (59.5%) involved contamination at or in the source water, treatment facility, or distribution system; 13 (35.1%) occurred at points not under the jurisdiction of a water utility; and two (5.4%) had unknown/insufficient deficiency information. Among the 21 outbreaks associated with source water, treatment, or distribution system deficiencies, 13 (61.9%) were associated with untreated ground water, six (28.6%) with treatment deficiencies, one (4.8%) with a distribution system deficiency, and one (4.8%) with both a treatment and a distribution system deficiency. No outbreaks were associated with untreated surface water. Of the 21 outbreaks, 16 (76.2%) occurred in public water systems (drinking water systems under the jurisdiction of EPA regulations and water utility management), and five (23.8%) outbreaks occurred in individual systems (all of which were associated with untreated ground water). Among the 13

outbreaks with deficiencies not under the jurisdiction of a water system, 12 (92.3%) were associated with the growth of Legionella spp. in the drinking water system, and one (7.7%) was associated with a plumbing deficiency. In the two outbreaks with unknown deficiencies, one was associated with a public water supply, and the other was associated with commercially bottled water. The 70 previously unreported outbreaks included 69 Legionella outbreaks during 1973--2000 that were not reportable previously to WBDOSS and one previously unreported outbreak from 2002.[xviii]

In summary, more than half of the drinking water-associated outbreaks reported during this period were associated with untreated or inadequately treated ground water, indicating that contamination of ground water remains a public health problem. *Legionella* was the most frequently reported etiology among the drinking water-associated outbreaks. One-third of these outbreaks occurred in building premise plumbing systems outside the jurisdiction of water utility management and EPA regulations; *Legionella spp.* accounted for >90 percent of these outbreaks, indicating that greater attention is needed to reduce the risk for *legionellosis* in building plumbing systems.

Pathogens Are Not the Only Problem. Much attention recently has been drawn to the problem of unhealthy levels of lead and other chemical and biological contaminants in the public water systems which supply tap water to residential and nonresidential facilities such as hospitals and other health care facilities.[xix]

According to EPA estimates, only 91 contaminants are regulated by the Safe Water Drinking Act (SDWA), yet more than 60,000 chemicals are used within the United States. Government and independent scientists have scrutinized thousands of those chemicals in recent decades, and identified hundreds associated with a risk of cancer and other diseases at small concentrations in drinking water, according to an analysis of government records by The New York Times. More than 62 million Americans have been exposed since 2004 to drinking water that did not meet at least one commonly-used government health guideline intended to help protect people from cancer or serious disease. This is according to an analysis by the Times of more than 19 million drinking-water test results from the District of Columbia and the 45 states that made data available. But because such guidelines were never incorporated into the Safe Water Drinking Act, the vast majority of that water never violated the law.[xx]

<u>Lead.</u> While lead paint and dust are the primary source of lead exposure, especially in older homes, drinking water is also a source of exposure to lead. The harsh chlorinated water flowing out of urban water treatment facilities will often cause lead to leach into the pipe water. While measures have been taken during the last two decades to reduce exposure to lead in tap water, lead can still be found in some metal water taps, interior water pipes, or pipes connecting a house to the main water pipe in the street. Lead found in tap water usually comes from the corrosion of older fixtures, or from the solder that connects pipes. When water sits in leaded pipes for several hours, lead can leach into the water supply.

Lead is associated with a wide range of toxicity, extending from acute, clinically obvious, symptomatic poisoning at high levels of exposure down to subclinical (but still very damaging) effects at lower levels. Lead poisoning can affect virtually every organ system in the body. Further, the neurobehavioral changes associated with early exposure to lead appear to be persistent and irreversible.[xxi]

<u>Chlorine and Fluoride.</u> Moreover, chlorine and fluoride, introduced into drinking water, are increasingly shown to involve hidden and often long-term dangers. Once thought to be safe, research has shown that "Chlorine is the greatest crippler and killer of modern times. It is an insidious poison."[xxii] According to the EPA, repeated exposure to trace amounts of chlorine in water is linked to bladder, colon, breast, and rectal cancers; heart trouble; premature senility; asthma; eczema; and higher rates of miscarriage and birth defects.[xxiii]

Fluoride has been added to the public water supply since the early 1940s as a result of studies suggesting that ingesting small amounts of fluoride could prevent tooth decay. As well as being linked to a wide number of health problems, mass medication of the U.S. population with fluoridated drinking water is shown to reduce IQ levels in children in 36 of 43 studies.[xxiv]

Hexavalent Chromium (Chromium-6). Drinking water supplies for two-thirds of Americans are contaminated with the carcinogenic chemical made notorious by the film, *Erin Brockovich*, which was based on the real-life poisoning of tap water in a California desert town. There are no national regulations for the compound.[xxv] While long known to cause lung cancer when airborne particles are inhaled, recent science has also shown that, when ingested, it can cause stomach cancer.

Chloramine. More than one in five Americans are drinking tap water that has been treated with a derivative of chlorine known as chloramine. This disinfectant is formed by mixing chlorine with ammonia.[xxvi] The result is a toxic disinfection byproduct (DBP) which reacts with natural organic matter like decaying vegetation in the source water. DBPs are over 1,000 times more toxic than chlorine, and out of all the other toxins and contaminants present in municipal water, DPTs are the worst. One of the most common DBPs, trihalomethanes (THMs) have been shown to cause cancer in laboratory animals, and are also linked to reproductive problems in both animals and humans, such as spontaneous abortion, stillbirths, and congenital malformations, even at lower levels. These types of DBPs can also weaken the immune system, disrupt the central nervous system, damage the cardiovascular system, disrupt the renal system, and cause respiratory problems. A more thorough analysis of the dangers of chloramine in the water supply is presented by Johnson-Kula and Lieberman (2006).[xxvii]

ADDRESSING SOLUTIONS

Major waterborne (enteric) pathogens are relatively well-understood, and treatment controls are effective when well-managed. However, water-based saprozoic pathogens that grow within engineered water systems (primarily within biofilms/sediments) cannot be controlled by water treatment alone prior to entry into water distribution and other engineered water systems.[xxviii]

Systemic Water Disinfection. Systemic water disinfection technologies vary in efficacy and cost. Superheated water can be used to flush the water delivery system, but this method is expensive (e.g., labor to perform the operation), potentially dangerous (e.g. risk of scalding), and can damage water systems that may not be designed for repeated high temperature operations. Periodic chemical disinfection with agents such as chlorine, chlorine dioxide, ozone, and hydrogen peroxide can also be used to reduce the level of microbial contamination. However, if used regularly at the concentrations recommended, these compounds can be corrosive to piping materials. Although chlorine is routinely added to drinking water, many organisms are resistant (e.g. *Cryptosporidium sp*.). Also, since organic material absorbs chlorine, biocidal activity will be negatively impacted as organic material concentrations increase. Finally, when amoeba-resistant bacteria take up residence inside an amoeba host that is in turn resistant to a particular chemical disinfectant, they can escape destruction by that disinfectant.

Point-of-Use (POU) Filtration. Cervia at al. site numerous studies substantiating that the transfer of waterborne bacteria from unfiltered tap water sources in the health care environment to at-risk patients via inhalation of water vapor, ingestion (e.g., drinking and ingestion of ice), and direct contact (e.g., showering, bathing, wet hands of a health care provider, and contact with medical devices rinsed with tap water) is a genuine source of concern. And while POU filtration shows effectiveness in water contamination at the faucet, there are limitations to this method. Waterborne pathogens, such as *P. aeruginosa*, may enter the health care environment internally/endogenously via patient colonization, and through other contaminated fluids and instruments, such as endoscopes, bronchoscopes, artificial saliva, and even mouth swabs. For this, adequate staff and patient training with respect to the appropriate use, maintenance, and replacement of POU filters is important to reduce the risk of possible retrograde contamination of incoming tap water.

However, while POU filtration technologies (e.g., faucets, showerheads) may help to interrupt clinical outbreaks, especially for patients at high-risk for infection,[xxix] they vary in initial and long-term maintenance costs, efficacy against specific organisms, and compatibility with facility plumbing system materials. In addition, POU filtration cannot eradicate biofilms within health care facility plumbing, and they do not address the larger problem of prevention of waterborne pathogens from entering the hospital or clinical environment itself. Further, in a large hospital environment, POU filtration devices would need to be available for all water outlets, to include not only faucets and showers for patient staff use, but also drinking fountains, ice machines, hot water heaters, nozzles, storage tanks, water systems in kitchens, labs, surgical units, sterilization of equipment (such as autoclaves), and other distribution outlets where potential contamination from contact or ingestion directly or indirectly can occur.

Point-of-Entry Water Filtration and Purification System. It is shown that the best water filtration technology involves point-of-entry (POE) filtration and purification. A proven safe and effective method of eliminating the problems of contaminants in both residential and non-residential water is to install an energy-efficient POE water filtering and purification system. Because it provides filtration and purification at the juncture where the public water enters the building (sometimes referred to as a "whole house"), this water filtration system will do the best job of removing waterborne pathogens, other contaminants, and the harsh chemical byproducts from the building environment.

There are several health- and cost-related reasons that show POE systems are the best alternative to systemic water disinfection, point-of-use, and other filtration methods. Because point-of-entry systems block contaminants before they are released into the hospital or facility plumbing, they allow water to emerge from every water source in the building. Not only does a POE system remove pathogens and contaminants as soon as they enter the plumbing system (eliminating the need for multiple point-of-use filters), but prevent these contaminants from being released into the air and inhaled through steam and vapors.

<u>Filtration</u>. Filters are designed to trap various kinds of debris, dirt, and organic particles that will otherwise enter the equipment and/or plumbing system, restrict water flow, and create breeding ground for bacteria. Filtration is the first line of defense for residential, commercial, and industrial facilities, where the source of water may be ponds, wells, or streams that have high exposure to contamination from airborne pollutants, surface run-off, agricultural or industrial waste, or similar dangers. The first step in achieving clean water is to install a filtration device that effectively removes particulate matter and similar debris. Filtration is an important step in water treatment, especially for water intended for human consumption. Filtration systems provide a bacteriostatic environment, and are designed to remove volatile organic chemicals, hydrogen sulfide and sulfur, herbicides, pesticides, chemical fertilizer residues, trihalomethanes, and many other pollutants.

Recommended filtration units are comprised of several filter types and media that remove harmful chemicals, metals, and toxins from the water as it passes through these layers. Filters used in staged filter housings are configured as shown in Attachment I. Other filter mediums and system filters can be determined by a water quality analysis. If fluid conditions require additional micronic particle trapping for enhanced results, filters are available in various micronic sizes providing flexibility and adaptability to meet the needs of all fluid conditions and applications. Attachments II and III reveal test results utilizing recommended filtration.

<u>Ultra-Violent Disinfection/Purification</u>. The best POE systems utilize an ultraviolet (UV) technology, which has proven documented effectiveness both scientifically and commercially for over 50 years. It is nature's own disinfection/purification method, and the preferred solution for both small flow residential applications as well as large flow commercial projects. The UV disinfection technology used in a POE system provides safe process and potable water, free of disease-causing pathogens. As water passes through the UV chamber, UV light will attack and render harmless any bacterial, viral, or spore contamination present in the treated water. High intensity UV light destroys contaminants with a 99.9 percent or greater kill rate based on the multi-process technology provided in the system. The output water is thus disinfected and offers exceptionally high quality for human consumption and use. Once installed, these systems require little or no maintenance, and use only a minimal amount of power.

<u>POE/POU.</u> One caution to the standard point-of-entry systems is that, once the purified water is passed from the main line into the house or business, the risk of contamination from leeched chemicals and contaminants within the building remains. Water standing in internal pipes for more than a few hours poses a risk of creating biofilms

or leaching from any lead pipes. Most POE systems, therefore, recommend additional point-of-use (POU) systems, such as filters which are attached to a faucet. This can drive up the cost of a system, and still only ensure that the water will be 99.9 percent pure only where there are additional faucet filters. There is one system, however, which has resolved that problem through a process called *deposit control*.

Patented Deposit Control System. The basic component in one of the finest point-of-entry systems is the deposit controller. It is comprised of a microprocessor, solenoid coil wrap, and/or a reaction chamber, through which water flows. Water is thus exposed to a triangular wave signal that lies at the heart of the deposit control technology. As the fluid passes through, it is treated and then carries the treatment downstream to condition the rest of the plumbing system, non-chemically and reliably. The signal constantly changes the polarity, frequency, and amplitude of the current entering the water.

There are several benefits to this method. It increases the capability of the water to hydrate scale ions and other colloidal particles. The hydrogen molecules are enhanced, and the water is made, in effect, "wetter". This "hydrated" water can dissolve unwanted particles, suspect them in a solution, and allow them to be easily filtered out and flushed from the system. Accordingly, the mineral and biological particles that cause scale, deposits, and corrosion are dissolved and washed away. The breeding environments for bacteria, such as biofilm and corrosion, are eliminated.

Testing for this process has been completed in Japan by Makoto Nagashima, PhD. The test results of a particular system using this technology are included in the Attachments to this paper, and are available for more thorough review through Threestrand Quality Health Solutions at www.threestrandstl.com.

CONCLUSION

Water is used in enormous quantities in healthcare facilities. Many aquatic microorganisms can survive and flourish in water with minimal nutrients, and can be transferred to vulnerable hospital patients in direct (e.g., inhalation, ingestion, surface absorption) and indirect ways (e.g., instruments and utensils). Many outbreaks of infection or pseudo-infection occur through lack of prevention measures and ignorance of the source and transmission of opportunistic pathogens.[xxx]

Unfortunately, contamination of hospital water supplies with potentially pathogenic organisms and other waterborne chemicals and volatile organic compounds is very common. Patient exposure to waterborne contaminants and pathogens is derived from a number of sources that include showering, bathing, drinking water, ingestion of ice, exposure to contaminated medical equipment that has been rinsed with tap water, or the hands of medical personnel washed and rinsed in tap water. Equally important, staff and visitors are exposed to these contaminants as well, increasing the risk and instances of nosocomial infection and illness within the hospital or health care facility environment.

Systematic water disinfection technologies have not been completely and sustainably effective in reducing the bioburden of pathogens in water used in hospitals and in residential and non-residential facilities. Complete eradication of waterborne microorganisms by these technologies has not previously been successful due to the continual establishment of biofilm communities downstream of the point-of-disinfection. Point-of-use water (faucets and showers, water fountains, ice machines) may be the source of the transmission of waterborne microorganisms and contaminants.

Newer technology offers far more effective point-of-entry filtration and purification of public water coming into the facility from public water lines by using a process called deposit control. Before contaminated water can enter the facility's water system, thus increasing risk of leaching in pipes and reaching the point-of-use, it is filtered and purified, thus eliminating internal breeding grounds for bacteria, viruses, and other microorganisms. This system is recommended for all public and private health care facilities where purity and safety of tap water is of critical concern.

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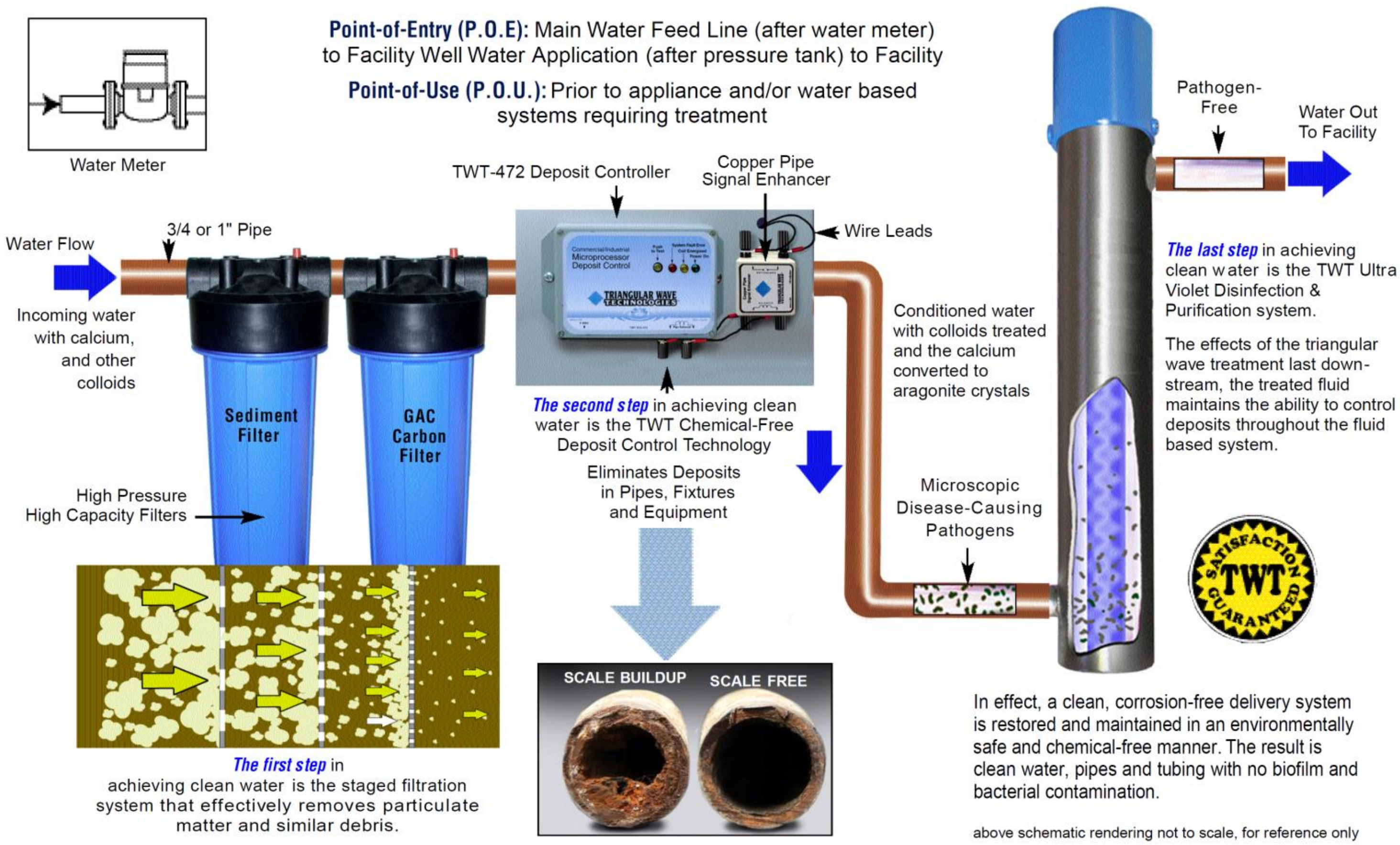
ATTACHMENTS

I. Point-of-Entry Technology with Deposit Control System

The recommended system maintains a corrosion-free delivery system that is maintained in an environmentally-safe and chemically-free manner. The result is clean water, no biofilm in pipes or tubing, and no bacterial contamination. These systems are ideally suited for wells, homes, offices, factories, farms, medical/dental and laboratory environments, hospitals, restaurants, schools, and anywhere the need for cleaner water is required.



* A third Filter Pod can be added for separate KDF & GAC filtration

II. Test Results

Method:

Reagent grade lead chloride was spiked into drinking water and run through the filter per manufacture and NSF specifications. The influent and effluent water were tested per *EPA Methods for Chemical Analysis of Water and Waste* (EPA-600/4-79-020).

Sample Date: 3-23-90 **Report Date**: 5-04-90

Sample ID: 9003-1233B Di-Tech KDC+1.5

Subject: One KDF was received for testing to determine its ability to handle heavy metal removal from water.

Respectfully Submitted, Pat Brueckner, Chemist

Total Flow	Influent Water	Effluent Water	% Removal
1 Gallon	0.17 mg/L	< 0.01 mg/L	99.99%
5 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
10 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
50 Gallon	0.17 mg/L	< 0.01 mg/L	99.99%
100 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
250 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
500 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
600 Gallon	0.17 mg/L	< 0.01 mg/L	99.99%
750 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
1000 Gallon	0.16 mg/L	< 0.01 mg/L	99.99%
1250 Gallon	0.17 mg/L	< 0.01 mg/L	99.99%
1350 Gallon	0.16 mg/L	0.03 mg/L	81.25%
1425 Gallon	0.16 mg/L	0.08 mg/L	50.00%

Initial flow:	0.4 gallon/minute at 60 psi.
Cycle:	10% on and 90% off for a maximum of 16 hours/day.
Comments:	The KDF filter reduced the level of lead pumped through the unit to a non-detectable level (<0.01mg/L) to 1250 gallons.

III. KDF/GAK Test

The laboratories conducting the testing of this technology were commissioned by various companies involved in the original formulation and manufacture of the Copper-Zinc filter media known as KDF. The following results were produced by the Biological Research Solutions, Inc., Detroit, Michigan Laboratory Report:

NSF Standard 53 Test Protocol Performed by Independent Laboratory

20,000 gallons of city water, spiked with high levels of specific contaminants, was run through a KDF/GAC cartridge. The efficiency shown below was measured *after* 20,000 gallons has passed through the cartridge (when new, removal is 99.+ percent) Most other non-standard tests show results after only one pass of contaminated water, which does not indicate how the filter will perform towards the end of its life. To pass the NSF-53 protocol, the effluent must be under the EPA Maximum Contaminant Level (MCL) throughout the test.

All concentrations are measured in milligrams per liter (mg/l). Test Results at 20,000 Gallons

Chemical	Influent	Effluent	Efficiency	EPA MCL
THM (chloroform)	0.57	0.029	95%	0.1
Lead	0.19	0.006	97%	0.025
Fluoride (1)	8.26	0.78	91%	1.4
Nitrate (1)	30.7	8.03	74%	10.0
Barium	10.4	0.56	95%	1.0
Arsenic	0.37	0.007	98%	0.05
Cadmium	0.03	0.004	87%	0.01
Chromium VI	0.15	0.011	93%	0.05
Chromium III	0.163	0.003	98%	0.05
Selenium	0.1	0.006	94%	0.01
Mercury	0.006	0.000*	99+%	0.002
Endrin	0.0008	0.000*	99%+	0.0002
Lindane	0.011	0.0012	89%	0.004
Methoxychlor	0.32	0.0059	98%	0.1
Toxaphene	0.013	0.000*	99%+	0.005
2,4-D	0.3	0.02	93%	0.1
Silvex (2,4,5-TP)	0.029	0.004	86%	0.01

-- Below detectable limit. *

(1) While this test shows a reduction in these contaminants, KDF is inconsistent in their removal of certain water conditions. Special nitrate and fluoride filters, or reverse osmosis, is offered if removal is needed.

A separate test was run on another KDF/GAC cartridge to determine chlorine removal capacity. The challenge solution contained 3 mg/l chlorine (most cities use less than 1 mg/l). 2 mg/l lead was also added. At 20,000 gallons, both were being removed 99.9 percent. The test was terminated at 28,400 gallons when the chlorine removal rate hit 90 percent. The lead removal rate was still 97.6 percent.