Analyzing the Solutions to Drinking Water Contamination

-The Technology of Water Treatment

For Human Consumption

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With water problems throughout our country increasing every day for municipal, rural and private water systems, there is a corresponding demand for reliable water treatment devices.

Furthermore, our tap water tastes (and often smells) too bad to enjoy. So, we have become a nation that has switched to soft drinks and other less healthful beverages. Like pollution itself, it may be decades before we see the real consequences of this widespread habit.

Everyone wants and expects quality water, but there is so much ignorance, confusion and misinformation on the most effective way to obtain it. One thing is for sure; there is no simple gadget filter that can give you and your family the protection it needs to avoid the consequences of modern water pollution.

An equally serious problem is that many people don't believe anything is wrong with their water because it may not have a particularly bad taste, smell, or odd color. The truth being that the most harmful pollutants are tasteless, odorless and colorless.

If we are to avoid the potential hazards of this growing crisis we must all share in the responsibility of becoming educated in what it takes to assure safe, quality drinking water. **Here is one serious problem you can do something about with confidence.**

Municipal Water Treatment - No Longer Enough

The average American hasn't been worried about water pollution until recently. We've always believed that whatever impurities got into the water, the city treatment plant would get out - that by the time it got to our house it was decontaminated and returned to a state of reasonably pure safe water.

Unfortunately, all of the water treatment facilities being built today are geared solely for the prevention of waterborne diseases, so that none offers adequate protection from the increasing levels of toxic chemical contamination - and every year hundreds of new chemicals and pollutants further endanger our sources of water. While the Safe Water Drinking Act of 1974 was a significant step in monitoring and setting limits for harmful pollutants, it regulates only a handful of the known toxic chemicals.

The Ingredients We Want Out

With the wide spectrum of impurities and contaminants that are often in today's water supplies, you are understandably challenged to sort out the best and most effective solution. To help us make the best choice let's summarize what we're faced with.

Biological Impurities:

Bacteria, Virus and Parasites - Years ago, in what are now the developed countries, waterborne disease bacteria accounted for countless millions of deaths. Still, worldwide in underdeveloped nations, waterborne diseases are estimated to kill more than 25,000 people everyday! The effects of such waterborne microorganisms can simply be immediate and devastating. This is therefore the first and most important consideration is making water acceptable for human consumption.

Generally speaking, you can count on modern municipal supplies to be relatively free of **harmful** organisms due to routine disinfection with chlorine and chloramines and frequent sampling. Understand this does **not** mean tap water is free of all bacteria - it is not by any means.

Those on private wells and small rural water systems have reason to be more concerned about the possibility of bacterial contamination from septic tanks, animal wastes, etc., and should have periodic tests done for fecal contamination. The employment of unskilled water system operators in small communities presents further complications and reason for concern.

Authorities say that at least 4000 cases of waterborne disease are reported every year in the U.S. Further, they estimate that much of the temporary ills and everyday gastrointestinal disorders that go routinely unreported can be attributed to organisms found in our water supplies.

No matter what kind of water treatment device is used, an effort should be made to eliminate bacterial contamination at the source with proper disinfection.

Inorganic Impurities:

Dirt and Sediment or Turbidity - Most waters contain some suspended particles which may consist of fine sand, clay, soil and precipitated salts. The degree of cloudiness caused by this turbidity may be such that it is both unpleasant to look at and drink. While turbidity itself unusually presents no great threat, it can be a source of food and lodging for bacteria and interfere with effective disinfection.

Mineral Salts or Total Dissolved Solids - These substances are the amount of dissolved rock and compounds from the earth. The entire list of them could fill this page. The presence and amount of Total Dissolved Solids in water probably present the greatest controversy among those who promote water treatment products. The following guidelines, however, concerning the consequences of higher levels of TDS (or minerals) in water, generally holds true:

- High TDS results in undesirable taste which could be salty, bitter or metallic.
- High TDS water is less thirst quenching.
- Some of the individual mineral salts that make up TDS pose a variety of health hazards. The most problematic are Nitrates, Sodium, Sulfates, Barium, Copper and Fluoride.
- The USEPA Secondary Regulations advise a maximum level of 500 mg/L (500 ppm) for TDS. Numerous water supplies exceed this level. When TDS levels exceed 1000 mg/L it is generally considered unfit for human consumption.
- High TDS interferes with the taste of foods and beverages making them less desirable to consume.
- High TDS make ice cubes cloudy, softer and faster melting.
- Minerals in food are not only in a better form, but they are far more abundant than in water. Typically, an 8-ounce glass of milk contains more calcium and magnesium than 5 gallons of water!
- Minerals in water exist in the so-called *inorganic* form as salts. In contrast, minerals in food are in a much better form by being combined with proteins and sugars. This *organic* form of minerals is much more biologically acceptable to the body.
- Water with higher TDS is considered by health advocates to have a poorer cleansing effect in the body than water with a low level of TDS.

Toxic Metals or Heavy Metals. Among the greatest threats to health is the presence of high levels of toxic metals in drinking water - Arsenic, Cadmium, Lead, Mercury, and Silver. Maximum limits for each are established by the USEPA Primary Drinking Water Regulations. Other metals such as Chromium and Selenium, while essential trace elements in our diets, have limits imposed upon them when in water because the form in which they exist may pose a health hazard.

Toxic metals are associated with nerve damage, birth defects, mental retardation, certain cancers and increased susceptibility to disease.

Asbestos. Asbestos exists as microscopic suspended mineral fibers in water. Its primary source is asbestos/cement pipe commonly used after World War II for city water supplies. It has been estimated that some 200,000 miles of this pipe is presently in use to transport our drinking water. Because the pipes are wearing away this deadly substance is showing up with increasing frequency. Asbestos has been linked to gastrointestinal cancer.

Radioactivity. Even though trace amounts of radioactive elements can be found in almost all drinking water, levels that pose serious health hazards are fairly rare - for now. Radioactive wastes leach from mining operations into groundwater supplies. The greatest threat is posed by nuclear accidents, nuclear processing plants and radioactive waste disposal sites. As containers containing these wastes deteriorate with time, the risk of contaminating our aquifers grows - a toxic time bomb.

Organic Impurities:

Tastes and odors. If your water has a disagreeable taste or odor, chances are it is due to one or more of many organic substances ranging from decaying vegetation to algae, to hydrocarbons, to phenyls, to a host of others. While not the most health threatening of impurities, they certainly rank high among the reasons to treat water and make it suitable for drinking.

Pesticides and Herbicides. The increasing use of pesticides and herbicides in agriculture shows up in the water we drink. Rain and irrigation carry these deadly chemicals down into the groundwater as well as into surface waters. Our own household use of these substances also contributes to actual contamination. These widely used chemicals are among the most health threatening chemicals in existence and if consumed, even at low levels, can be the cause of circulatory, respiratory and nerve disorders. Only six of the hundreds of pesticides have regulations for maximum contaminant levels set by the EPA.

Toxic Organic Chemicals. The most pressing and widespread water contamination problem is a result of the organic chemicals created by industry. Over 50,000 chemicals have come into use since World War II and the EPA considers seven out of ten of them to be potentially or definitely detrimental to human health.

These chemicals end up in our drinking water from hundreds of sources which include industrial discharge, sewage treatment plants, accidental spills and leaks, waste dumps - even from the millions of tons of household products discarded each year. You can read about them showing up in our water supplies everyday in one publication or another.

The effects of chronic long-term exposure to these toxic organics, even in minute amounts, are extremely difficult to detect. First of all, the contaminated drinking water may look and taste perfectly normal. The user’s symptoms might include recurring headache, rash or fatigue - all of which are hard to diagnose. Other more serious consequences like higher cancer rate, birth defects, growth abnormalities, infertility and nerve damage among the water users may go unnoticed for decades.

Over 700 specific organic chemicals have already been identified in drinking water throughout the country. Many authorities, however, believe that these organic compounds represent just a small fraction of the total chemical content that endangers our well-being. The EPA has set limits for organic contaminants, but only for a small percentage of those known to exist and **then** only for water systems serving 10,000 or more people, and 92% of all our water systems serve fewer than 10,000 or more people. Part of the problem of regulation involves the practical consideration of what can feasibly be achieved, in addition to the incredibly high cost of testing for these contaminants. Just a single test for one toxic organic may cost hundred of dollars!

To comprehend how toxic these chemicals really are one need only look at how little is required to present potential health hazards. TCE, a once widely used solvent and suspected carcinogen, is routinely showing up in water supplies. Just two glassfuls can contaminate 27 million gallons of water! A pesticide, Endrin, has a maximum level of .0002 milligrams per liter of water. Put another way, just one pound of Endrin could contaminate 5 billion gallons of water! Among the most prevalent toxic organic contaminants is the group of chemicals called Trihalomethanes or THM's for short. As mentioned in Water Course #1, THM's are formed when chlorine, used to disinfect water supplies, interacts with natural organic material (e.g., by-products of decayed vegetation, algae) toxic organic chemicals are created. The most common of the THM's found in our drinking water is chloroform. With few exceptions, every chlorinated water supply can be expected to contain detectable levels of THM's.

Sorting Through the Solutions

It should be apparent by now that there are simply too many health endangering contaminants, too many shortcomings in municipal treatment methods and regulations, and too much potential for industrial accidents, for intelligent adults to continue blindly trusting what comes out of their tap.

One's first reaction might be to suggest that we upgrade out nation's water treatment plants. While this is theoretically and technologically possible, it is economically unfeasible except perhaps for a single specific contamination problem. The reason becomes clear if one weighs the cost of the required high tech water treatment and the dilemma of having to treat **all** the city water when **less than 2% is used for human consumption.**

Ask yourself, is it logical to have water used to irrigate the lawn and fight fires undergo the same costly treatment as the water we drink? And even if we did, the results of that expensive treatment might be negated as the water passes through deteriorating and contaminated pipes.

A centralized treatment approach would also exclude those on small rural or private well supplies - which accounts for a large percentage of our population.

What About Bottled Water?

Many people take what they think is the foolproof approach to the problem of water purity and that is to buy bottled water for drinking and cooking. They will put up with the inconvenience, the expense ($.80 - $2.00 per gallon), and unattractiveness of bottled water for the assurance of safety. But is the assumption correct? Some bottled water is of excellent quality, being free of virtually all toxic contaminants. Such bottled water is usually treated with a sophisticated water purification system. On the other hand, many bottled waters are no better than the tap water in the contaminants they contain - even though their taste may have been improved. To date there are no uniform regulations governing the quality of domestic bottled water.

A Better Idea - Point of Use Water Treatment

The idea of treating just the water you will consume for drinking and cooking where you consume it may be the most efficient and cost effective approach to coping with deteriorating tap water quality. Appropriately named, “point of use” water treatment has become a billion dollar a year industry virtually overnight.

Point of use water treatment devices for the home are available in an amazingly wide variety of sizes, designs and claims, in an attempt to meet the need for more extensive removal of impurities.

Point of Use Water Treatment Technology

Now that you understand what you’re confronted with in water contamination, let’s take a close look at the technology available for home point of use treatment.

Mechanical Filtration. One of the most widely used water quality improvement methods is mechanical filtration which acts much like a fine strainer. Particles of suspended dirt, sand, rust and scale (i.e., turbidity) are trapped and retained, greatly improving the clarity and appeal of water.

When enough of this particulate matter has accumulated on or within the filter element, it is usually discarded.

From an appearance standpoint, water filtered of particles as small as 5 microns (.0002 inches) would be considered very clear to the naked eye, though it could still contain many invisible impurities. Special filters are even available which can remove virus. Their expense and frequent replacement makes them impractical for everyday home use, but they are a necessity in labs and hospitals.

Activated Carbon Adsorption. Carbon adsorption is probably the most widely sold method for home water treatment because of its ability to improve water by removing many disagreeable tastes and odors including objectionable chlorine.

Activated carbon is made from a variety of carbon-based materials such as coal, petroleum, nut shells, and fruit pits. These are heated to high temperatures with steam in the absence of oxygen (the activation process) leaving millions of microscopic pores and great surface area. One pound of activated carbon, in fact, provides over 125 acres of surface area! The pores trap microscopic particles and large organic molecules while the activated surface areas cling onto or “adsorb” the smaller organic molecules.

While activated carbon theoretically has the ability to remove or reduce numerous organic chemicals like pesticides, THM’s, TCE, PCB, etc., its actual effectiveness is highly **dependent** on the following factors:

1. The type of carbon used and the amount used.
2. The filter design and how slowly water flows through it (contact time).
3. How long the carbon has been in service and how many gallons it has treated.
4. The kinds of impurities it has removed.
5. The water conditions (e.g., turbidity, temperature, etc.).

One major problem with carbon filters is the growth of bacteria. At first, when the carbon is fresh, practically all organic impurities and even some bacteria are removed.

Once organic impurities accumulate they can become food for the growth of more bacteria which can then multiply within the filter to great numbers. While this bacteria may not be disease causing, their high concentration is considered by some to present a health hazard. It is often advised, therefore, that after periods of non-use (such as overnight) a substantial quantity of water be flushed through the carbon filter to minimize the accumulation of bacteria.

Another problem with carbon filters is chemical recontamination which can occur when the carbon surface has become saturated with the sum total of impurities such as by-products of decayed vegetable matter and microorganisms. These impurities prematurely use up the carbon's capacity, preventing it from doing what it does best - adsorbing lightweight toxic organic impurities like THM and TCE and undesirable gases like chlorine.

Recent design innovations in carbon filter have attempted to address some of the problems and limitations of this treatment method and they are worth mentioning so you can become as informed as possible.

Oligodynamic, Silver Impregnated or Bacteriostatic Carbon. Some manufacturers impregnate the surface of carbon granules with silver compounds which are supposed to inhibit the growth of bacteria within the carbon bed. However, EPA sponsored testing of such filters has shown that they are "neither effective nor dependable in meeting their claims." Some manufacturers have also made misleading claims that their silver impregnated filters will eliminate bacterial contamination from virtually any water source. The low concentration of silver found in these filters is not capable of destroying normal flow conditions. Because silver is also toxic to human, such filters are regulated by the EPA under the Insecticide, Fungicide and Rodentaide Act and must be registered the unit or its effectiveness, though it does certify that the carbon will not release more that 50 part per billion of silver - the maximum safe level.

Compressed Carbon or Block Carbon Filters. This fairly new configuration of basic carbon filters has some advantages over conventional loose granular types. Very fine pulverized carbon is compressed and fused together with a binding media (such as a polyethylene plastic) into a solid block. The intricate maze developed within the block insures contact with organic impurities and therefore more effective removal. The phenomenon of channeling where the buildup of impurities creates open paths through a loose bed of carbon granules is eliminated by block type filters.

Carbon block filter can also be fabricated to have such a fine porous structure that they are capable of mechanically filtering out coliform and other associated disease bacteria. This in not to say all bacteria or any virus are filtered out. This feature, however, will require that filters of this type be replace much more frequently.

Among the disadvantages of compressed carbon filters is their reduced capacity due to the inert binding agent and their tendency to ply up quickly with particulate matter. It has also been discovered that the binding agents in some carbon block filter give off toxic chemicals of their own. They are also substantially more expensive than conventional carbon filters.

The Limitations of Carbon Filters. Nothing is more effective than a properly designed carbon filter for removing many of the toxic organic contaminants. But they fall far short of being an overall water treatment system for providing protection from the wide spectrum of impurities outlined previously in this course.

1. They are not capable of removing any of the desirable excess mineral salts or Total Dissolved Solids.
2. They have no effect on harmful nitrates, or high sodium and fluoride levels.
3. They have only a limited and unreliable effect on toxic metals like lead, cadmium, mercury, and arsenic.*
4. For any carbon filter to be effective, even for organic removal, water must pass through the carbon, whether it be granular or compressed, slowly enough to insure that complete contact is made between the carbon and the impurities. This all important factor is referred to in the industry as "contact time". Generally, the longer the contact time the more effective the carbon filter. At useful flow rates of 0.5 - 1 gallon per minute the contact time is basically determined by the amount of carbon, and few manufacturers use an acceptable amount of carbon.

It should be clear why the small faucet mount filters are ineffective at removing organic contaminants with the exception of some tastes and odors. EPA tests of available home carbon treatment systems revealed that contact times varied from less than 1 second to as long as 185 seconds. **Only** those filters that had at least a 35 second contact time were capable of removing over 90% of THM's. Most filters do not meet this requirement.

***Note:** In the testing of one particular block carbon filter for which toxic metal removal claims are made, the testing laboratory insisted that the following discussion be included with their results. "A note of caution must be emphasized in that many conditions and variables may affect the efficiency of removal of metal ions from water. Not much study has been made on removal of metals by activated carbon so not much is known about the mechanism of removal. The nature of the influent water needs to be taken into account as well as amounts of organic compounds, ionic concentration and pH will affect removal efficiencies. I suggest that each installation be treated as an individual example and the parameters of removal efficiency and capability be determined on each application."

***Note**: Another supplier of block carbon filters restricts their claims of toxic metal removal to the precipitated or undissolved form. Since toxic metals occur in many dissolved forms also, adequate protection from this type of contamination cannot be furnished by block carbon filters.

Distillation. It might be said that distillation is nature's method of purification because the sun continually evaporates water from the world's oceans, and as it comes over land, precipitates as rain or snow to provide us with a new supply of fresh water.

Man has duplicated this process to make one of the more effective water purification methods presently available. A reservoir of water is heated until it turns to steam. This is then cooled so that it condenses back into water. The theory is that impurities such as sediment, Total Dissolved Solids, nitrates, sodium, toxic metals, and microorganisms are left behind as the water turns to steam. The condensed steam should therefore be very pure water. That was, in fact, quite true until our water supplies started to show the presence of so many toxic organics. Many of the toxic organics such as THM's and TCE have a lower boiling point than water and can evaporate with the water, recondense and remain in the collected distilled water.

Some of the more advanced distillers may either incorporate a carbon filter in the main water line to the unit in order to remove organic contaminants; others utilize a fractional distillation technique in which much of the toxic chemical vapors are release through a volatile gas vent before they condense. Though this can pollute the air - there may also be some carry-over of contaminants whose boiling point is close to that of water.

Despite its apparent simplicity, distillation is not without its disadvantages:

1. Distillers are traditionally very hard to maintain and clean. The impurities and mineral salts left behind in the boiling chamber, and especially the heating element, build up a hard scale that is not only difficult to remove, but can significantly impair both the energy efficiency and distilled water quality. This build up must laboriously be removed with strong cleaning solutions, wire brushes and the like.
2. Distilled water should be cooled quickly, preferably in the refrigerator, because its elevated temperature encourages the regrowth of airborne bacteria. That makes its use somewhat less convenient.
3. Many feel that distilled water tastes flat. The primary reason is that the dissolved oxygen, which gives mountain spring water its refreshing taste, is driven off during the distillation process. This can be corrected by aerating the water agitation - another inconvenience.
4. Distilled water can cost a lot to make and may be too expensive for the average family. As the cost of energy increases, the distillation process will become less attractive.

Deionization. The process of deionization (DI) is worth discussing even though it is not a practical water treatment method for household use. It has however, appeared in several home water treatment devices.

Very simply, deionization is a chemical process that utilizes special minute plastic beads (called resins) that, as untreated water passes over them, chemically attract only ions of the Total Dissolved Solids and give up in the water in the process. When the resins become saturated they must be removed and regenerated with acid and caustic chemicals using an involved procedure.

Deionization is not capable of removing a wide range of impurity types. For instance, dirt, rust, sediment, pesticides, organics, asbestos, and microorganisms are **not** removed by the process. It is, therefore, often used in conjunction with other methods. Furthermore, the resins provide an environment that encourages bacteria growth. Deionization is, however, unmatched for its ability to remove one particular impurity - the Total Dissolved Solids or mineral salts. **This** is how many bottles water companies produce their “demineralized” water. The most prevalent use of deionized water is in laboratories and industry where it is indispensable for chemical analysis and industrial manufacturers.

Ultrafiltration / Reverse Osmosis. If a choice had to be made, the Ultrafiltration/Reverse Osmosis process would be elected as **the** state-of-the-art in water treatment technology today. Reverse Osmosis (RO for short) was developed in the late 1950’s under US government funding, as an economical method of desalinating seawater - a dream long sought after by mankind.

Ultra filtration/Reverse Osmosis is revolutionary because it uses a completely new mechanism for processing water - the semipermeable membrane. Surprisingly enough, it looks a lot like common household sandwich wrap and is composed of very similar polymer (plastics). That’s where the similarity ends because this near miracle material is now considered one of the greatest technological achievements of our century.

It’s best to look at the semipermeable RO membrane as providing **two** distinct water treatment processes.

First, it is the ultimate mechanical filter, or ultra filter, straining out virtually all particulate matter, turbidity, bacteria, microorganism, asbestos - even single molecules of the heavier organics. To appreciate the fineness of this ultra filter, as it is referred to in industry, its pores are on the order of .0005 microns or .0000002, (ten millionths) of an inch! That’s smaller than can be seen by the best optical microscopes!

Second, it removes dissolved impurities (e.g. mineral salts, toxic metals) - those even smaller than the water molecules themselves - by a remarkable phenomenon known as Reverse Osmosis. With Reverse Osmosis, the membrane is said to reject these impurities by repelling them from its surface. It is, however, permeable to the water molecules so that they diffuse through in a pure state and collect on the opposite side to make the product water.

RO’s Claim to Fame. The real claim to fame for Ultra filtration/Reverse Osmosis membranes is their ability to remove and reject such a wide spectrum of impurities from water and they do it with very minimal energy usage. In fact, it just requires water pressure. With the exception of distillation, Reverse Osmosis is the only known process which can effectively remove the following types of impurities:

1. Particulate matter, turbidity, sediment, etc.
2. Colloidal matter
3. Total Dissolved Solids
4. Toxic Metals
5. Radioactive elements
6. Microorganisms
7. Asbestos
8. Pesticides and Herbicides
9. Heavier organic molecules (MW>300)

How RO Works - In Practice. Long sheets of semipermeable membrane are ingeniously sandwiched together and rolled up around a hollow central tube in a spiral fashion. This rolled-up configuration is commonly referred to as spiral wound membrane or module. They are available in a large selection of sizes for processing different quantities of water. Typically, a module for home water treatment is as small as 2” diameter and 10” long, while one for industrial use may be 8” diameter and 48” long.

Now that the membrane is in a usable form it must be put in some type of container (called a pressure vessel) so pressure can be maintained on its surface. It is this pressure that supplies the energy to force the water through the membrane, separating it from the impurities. The most amazing aspect of RO is that the contaminants left behind are automatically diverted to a waste drain so they don’t build up in the system as with conventional filter, and purification devices. This is accomplished by using a part of the unprocessed water (feed water) to carry away the rejected impurities to the drain, thus keeping the membrane clean. The flow of impurities to the drain is often referred to as reject water. This is the secret to why RO membranes can last so long and perform like new with minimum maintenance even after years of operation. It is also the reason behind the low cost of producing RO water.

Variety Of Membranes. Membranes are available in a variety of materials. The most common are the so-called cellulosic type. Within this group are cellulose acetate (CA) and cellulose triacetate (CTA).

While CTA is a marked improvement over the original membrane formulation, CA, all cellulosic membranes share one shortcoming. They are susceptible to eventual deterioration from bacterial growth on the membrane surface. While this is rare in regularly disinfected or chlorinated municipal water supplies it can be a real problem when these membranes are used on non-chlorinated or private well supplies. CTA membranes do offer much better resistance to bacterial and chemical attack than CA membranes and have excellent performance on most municipal water supplies.

The latest advances in membrane technology are the new polyamide thin film composite (TFC) types. Based on an entirely new formation, the TFC membranes not only are completely impervious to bacterial attack, but they also have superior rejection of impurities, higher water production and increased resistance to adverse water conditions such as pH. They do have one disadvantage at this time and that is being susceptible to chemical deterioration from chlorine and other oxidizers.

Even Ultra filtration/RO Is Not Without Its Shortcomings. The Ultra filtration/Reverse Osmosis process alone is not without its shortcomings. It is simply ineffective in removing the lighter, low molecular weight volatile organics such as THM's, TCE, vinyl chloride, carbon tetrachloride, etc. They are too small to be removed by the straining action of the ultra filtration ability of the membrane and their chemical structure is such that they are not repelled by the membrane surface. Since these are some of the most toxic of the chemical contaminants found in tap water, it is important they be removed by a carbon filter added to the reverse osmosis system. In fact, nothing could be better for effective carbon filter adsorption than having a Reverse Osmosis membrane prior to it to remove practically all of the contaminants which would gradually impair the carbon's performance.

The RO process also has one other practical limitation. The effectiveness and performance of an RO membrane is greatly determined by the system design into which it is incorporated. While the RO process is theoretically such a complete water treatment method, RO systems, in practice, are often not designed well enough to make full use of the membrane's potential. It requires substantial engineering and experience to produce an effective design. This accomplishment is reserved for just a few technologically advanced companies of which **Water Techniques** is the recognized leader.