Recertification Kit - Issue VII
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- Introduction to High Purity Treatment Trains
Introduction

April 2015 will bring exciting changes that will strengthen WQA’s Professional Certification program.

This year, WQA introduced the online Modular Education Program (MEP), which uses a revolutionary training method that helps orient new hires and grow their expertise faster and more efficiently than learning through textbooks or lectures alone. As such, it also provides better preparation for certification exams. The structure of the new program includes a variety of levels, customized to the various job roles within a company, so that everyone can use the education, not just those planning to get certified.

The MEP’s focus on practical application helps better prepare new hires for field work and reduce errors. The built-in mentoring process helps ensure students learn the right way to do a job the first time. It opens up topics of conversation between learner and mentor, and it helps to build managers’ confidence in their employees.

The program provides online documentation of the student’s progress and of the hands-on activities completed in the field. Sales people will have proof of their correctly specified systems; installers will have proof of neat, safe installations done to code; and certified water specialists will have a track record of treatment train design for problem water. Managers can easily monitor their people’s progress. Essentially, the program is a tracked cognitive apprenticeship with proof of expertise.

What’s a cognitive apprenticeship? It’s an efficient merging of two training methods, formal learning through books or lectures and informal learning through shadowing and hands-on practice. Neither method alone produces particularly satisfactory results, but together they yield higher retention of concepts and faster development of expertise.

WQA’s Professional Certification program requirements are being modified to take full advantage of the new training methods and to strengthen the program in the eyes of consumers and regulators.

Tanya Lubner, Ph.D.
Director of Education & Professional Certification
Water Quality Association

* Any questions on the WQA Professional Certification Program may be addressed to the education department at 630-505-0160, or certification@wqa.org.
H2Uh-Oh: Do You Need to Filter Your Water?

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“The quality of drinking water in the United States is among the best in the world,” says University of Arizona water-safety expert Kelly Reynolds. “However, outbreaks of disease from drinking water do still occur and can lead to serious or sometimes fatal health consequences.”

Sometimes bacteria are the culprit. Sometimes it’s viruses. Sometimes it’s parasites. Then there are the thousands of drugs and household and industrial chemicals—most of them unregulated—that wind up in the rivers, streams, reservoirs and underground springs that provide our drinking water. What’s a drinker to do?

“For years, people said that America has the cleanest drinking water in the world,” William K. Reilly, the Environmental Protection Agency’s administrator under President George H. W. Bush, told The New York Times last year.

“That was true 20 years ago. But people don’t realize how many new chemicals have emerged and how much more pollution has occurred. If they did, we would see very different attitudes.”

Part of the problem: “The regulatory system is, frankly, slow to respond to emerging threats to water safety,” says Shane Snyder, a water-contaminant expert and professor of environmental engineering at the University of Arizona.

Here’s some of what may be lurking in your tap water...and why you may not be able to rely on your local water utility to keep you safe.

Germs

“We estimate that 19.5 million illnesses occur each year in the United States that are caused by microorganisms in drinking water,” says University of Arizona microbiologist Kelly Reynolds. Particularly vulnerable are older adults, young children and people with weakened immune systems.

The culprits: viruses (primarily Norovirus), bacteria (like Campylobacter, E. coli, and Shigella) and cysts that are produced by protozoa like Cryptosporidium and Giardia. They can cause diarrhea, headaches, and, in rare cases, chronic conditions like reactive arthritis.

How do germs get into drinking water?

• Contaminated surface water. About two-thirds of Americans get their water from surface water sources like reservoirs, lakes and rivers. “And all surface waters, no matter how pristine, contain waterborne pathogens from birds and animals, such as Campylobacter and Salmonella,” notes Reynolds.

Surface water can also harbor gastrointestinal germs that are flushed down the toilet by humans when they’re sick. How do they get into waterways? Blame it, at least in part, on the weather.

The water systems that serve some 40 million Americans—often older systems in the Northeast, the Great Lakes region and the Pacific Northwest—carry sewage and storm water in the same pipes. When water from heavy or sustained rains overloads a system, the overflow—wastewater along with rainwater—is discharged into rivers and creeks to prevent it from backing up.

At least 40,000 sewage overflows occur each year in the United States. And that wastewater could become your drinking water after it’s been treated by your local water utility. Since treatment plants can’t eliminate 100 percent of the germs, some can get through to your tap.

Climate change will likely add to the stress on water utilities in the Northeast and Midwest if, as predicted, it results in more and heavier precipitation there. Researchers at Johns Hopkins University in Baltimore found that heavy downpours preceded half of the 548 reported waterborne disease outbreaks in the United States from 1948 to 1994.¹

• Contaminated groundwater. “Historically, groundwater supplies were thought to be free of disease-causing microorganisms because the soil naturally filters them out,” says Reynolds. But viruses and other microbes from contaminated septic tanks, landfill leaks, or inadequate disposal of animal waste or wastewater can end up in water beneath the surface.
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The Environmental Protection Agency now requires utilities to disinfect groundwater that has a history of contamination.

Leaks in the distribution pipes.
Disease-causing microorganisms can also get into drinking water after it leaves the treatment plant. About a quarter of the nation’s water distribution pipes are in poor condition, with leaks, cracks and corrosion. On average, a city loses 18 to 44 percent of its water from leaking pipes, notes Yale University microbiologist Stephen Edberg.

Those pipes are often buried in the same trenches as sewer pipes. Changes in water pressure can allow contaminants in the soil to be sucked into the water pipes, fouling the drinking water.

“The proportion of disease outbreaks linked to breaches in the water distribution has increased over the past decade,” says Reynolds, “and it’s going to be a continuing problem.”

• Plumbing. In 2004, University of Arizona researchers measured bacteria in the tap water of seven Tucson homes. The EPA limits the amount of these bacteria—which in most cases are harmless—to no more than 500 per milliliter of drinking water. Tucson’s public water averaged only about 50, so it was relatively clean.

Not so in most of the homes. Water from kitchen and bathroom faucets in the seven houses averaged more than 3,000 bacteria per milliliter. Levels varied among homes (one had virtually none, while another had 13,000 bacteria), and from day to day within the same house. Bathroom tap water in two homes averaged 2,400 bacteria first thing in the morning, then dropped to 140 after running the water for 30 seconds.

Where do the bacteria come from?
“If you have pets that lick the faucet, or children with dirty hands who play with the faucet, or if you handle raw meats and then touch the faucet, bacteria can enter the pipes and grow,” says Reynolds. “They get backwashed into the pipes, where they can form a layer, or biofilm.”

Another potential source of bacteria is stagnant water sitting in pipes. “Maybe you’re on vacation or maybe you have a second home,” says Reynolds. “Bacteria can grow in pipes while you’re gone, and then you can get a big dose when the water is turned back on again.”

The antidote: “Flush out the system by letting the water run until it’s as cold as it gets,” suggests Reynolds. “That will certainly rinse out bacteria that haven’t established a biofilm on the inside of the pipes.”

If a bacteria biofilm has developed, it could loosen over time as the water faucet is used, says Reynolds, “and a chunk can break off and you can suddenly get exposed to a big dose of bacteria. It could be a significant health risk.”

What to Do
Use a filter that has been certified for microbiological purification by the Water Quality Association (WQA), NSF International or Underwriters Laboratories (UL).

Lead
It’s clear that lead can damage the brains and nervous systems of children. But it may also cause high blood pressure, cataracts, decline in mental abilities and kidney problems in adults. (See Nutrition Action, March 2005, cover story.)

“We’re learning that older adults should also be concerned about lead poisoning,” says researcher Marc Edwards, a professor of civil and environmental engineering at Virginia Tech University in Blacksburg.

“Recent studies have shown that low levels of lead in the blood that we once considered safe are causing health problems in adults. No one thinks to ever look for it in older people.” (The most common symptoms are abdominal pain, headache, fatigue, muscular weakness, and pain, numbness or tingling in the extremities.)

The evidence that lead affects the brain is troubling. In one study of nearly 600 women aged 47 to 74, those with higher levels of lead in their bones scored worse on memory and other cognitive tests than those with lower levels. The women with higher lead had scores comparable to women who were three years older.

Where does lead in water come from?
“The lead or brass service lines that connect the community water supply from streets to homes in older cities can leach lead,” says Edwards. So can the lead solder or brass and lead plumbing fixtures inside many buildings.
“Sometimes just one tap in a house might be providing water loaded with lead,” notes Edwards. “It could be because some plumber had a bad day and did some sloppy soldering 40 years ago when your house was being built.”

A Case in Point
The ex-mayor of a North Carolina town had suffered from chronic fatigue for years. “The kitchen tap in her apartment was perfectly clean,” Edwards reports. “It was her bathroom faucet that had just outrageously high amounts of lead.” All it took was an occasional drink of water from the bathroom tap.

Another potential source: hot tap water, which can contain high levels of dissolved lead.

“We’re finding that there’s quite a heavy use of hot tap water by the elderly to make tea, coffee, soup, and other foods,” says Edwards. “And some devices that are used to heat water—like coffeemakers and those electric heating coils that are submerged directly into a cup of water—can dissolve high levels of lead into the water. It’s safer to take cold water and heat it in a teapot on the stove.”

What to Do
“People shouldn’t panic, because the vast majority of taps in this country are safe,” says Edwards. “Maybe only one out of 100 faucets is dispensing hazardous levels of lead into the water.” That may not seem like many, says Edwards, “but if that’s your family and that’s your house, it’s not good.”

For about $20 per sample, you can have your water tested for lead. But testing isn’t 100 percent reliable.

“We’re discovering that little pieces of lead particles or solder, or lead rust that has corroded, can flake off the inside of pipes,” says Edwards. “And that can deliver very, very high doses of lead” that a one-time test can miss.

The solution: a filter that removes lead at the faucet for all the water you use for cooking and drinking. “If there’s a lead problem, it’s probably coming from your plumbing, so you’ve got to treat it right at the end of the system,” says Edwards.

“Chlorine is an extremely good disinfectant for killing disease-causing bacteria and viruses in drinking water,” says Paul Westerhoff, director of Arizona State University’s School of Sustainable Engineering and the Built Environment. “Plus, it’s cheap.”

That’s why more than half the country’s water treatment plants use chlorine. Another 30 percent use chloramine, a combination of chlorine and ammonia. Others use ozone. But there’s a downside to those disinfectants.

“Chlorine combines with organic matter that is naturally found in water to form hundreds of compounds called disinfection byproducts, or DBPs,” says Westerhoff. Chloramine and ozone produce smaller amounts of DBPs.

The EPA regulates the 11 most common and best-studied DBPs. Nine of the 11 cause cancer in laboratory animals. ([4](#))

“This is an absolutely clear-cut case of humans being exposed to chemicals that are known to be toxic in high doses,” says David Savitz of the Mount Sinai School of Medicine in New York. “We all drink this water.” (The EPA estimates that 94 percent of Americans consume foods and beverages that are made with chlorinated water.)

“The question is whether the DBPs are present at high enough levels to have measurable adverse effects on our health,” Savitz explains. Researchers have focused on bladder cancer and pregnancy.

- Bladder cancer. “Using water with elevated levels of DBPs over years or decades does appear to be associated with a small increased risk of bladder cancer,” says Savitz. A 2004 meta-analysis of studies pooled from the United States, Canada, France, Italy, and Finland found that men—but not women—whose tap water containing an average of more than 1 part per billion of DBPs (the legal limit is 80 ppb) had a 24 percent greater risk of being diagnosed with bladder cancer than men who had no more than 1 ppb in their water. ([5](#))

The EPA estimates that from 2 to 17 percent of the 56,000 new cases of bladder cancer each year in the United States may be caused by DBPs in drinking water. When the agency slightly lowered the maximum levels of some DBPs permitted in water in 2006, it estimated that the move would prevent about 275 cancer cases a year.
New research suggests that breathing in some DBPs and absorbing them through the skin could be more harmful than swallowing DBPs. Roughly half of our exposure to chlorinated water comes from washing with it and being near running water and flushing toilets, notes Savitz.

- Pregnancy. “Tap Water can Increase Risk of Miscarriages During First Trimester,” warned the Associated Press headline in 1998. In a study of roughly 5,000 pregnant women in northern California, those who lived where the tap water contained more than 75 parts per billion of disinfection byproducts were nearly twice as likely to miscarry, but only if they drank at least five glasses of water a day.\(^6\)

But a later study by Savitz found no link between DBPs and miscarriage in 2,400 pregnant women in Texas, Tennessee, and North Carolina.\(^7\) “It was a pretty sophisticated study and it didn’t corroborate the California research,” says Savitz, then at the University of North Carolina in Chapel Hill.

Levels of the 11 regulated DBPs in drinking water have dropped by 60 to 90 percent since the early 1970s. “Their regulation has led to a huge improvement in drinking water quality,” notes Westerhoff.

But there are more than 600 DBPs in water, and “new research over the last decade suggests that some of the unregulated ones that occur at very low concentrations are actually more genotoxic than the 11 regulated ones,” he adds.

Genotoxic compounds damage DNA and can cause cancer. Among the metropolitan areas with the highest levels of the 11 regulated DBPs: Baltimore, Boston, Little Rock, Phoenix and Washington, DC.

**What to Do**

Use a water filter that’s certified to reduce volatile organic compounds (VOCs), which include DBPs.

**Other Chemicals**

“There’s growing evidence that numerous chemicals in water are more dangerous than previously thought, but the EPA still gives them a clean bill of health,” Linda Birnbaum, director of the government’s National Institute of Environmental Health Sciences, told The New York Times in December 2009. “These chemicals accumulate in body tissue. They affect developmental and hormonal systems in ways we don’t understand.”

Some examples:

- Atrazine. It’s the pesticide most often found in drinking water, especially in the Midwest, where it’s applied to cornfields to kill weeds. It’s also widely used on lawns, in parks, and on golf courses.

In some studies, women living in areas with higher levels of atrazine in the drinking water were more likely to have lower-birth-weight babies. And in two studies, women in those areas were at higher risk of having babies with gastroschisis, a birth defect in which the intestines, stomach, or liver push through a hole in the abdominal wall.\(^8\)

The EPA limits atrazine in drinking water to 3 parts per billion when averaged over an entire year. But people in agricultural areas may be exposed to much higher levels when use of the pesticide spikes during the growing season. The EPA says that it is reevaluating the safety of atrazine, and will decide “whether new restrictions are necessary to better protect health and the environment.”

- Perchlorate. It’s an ingredient in solid fuels used for explosives, fireworks, road flares, and rocket motors. It also occurs naturally and is a byproduct that forms in bleach. And it can be detected in drinking water and groundwater in 35 states and in the urine of just about every American.\(^9\)

In large amounts, perchlorate blocks iodine from reaching the thyroid gland, which can make it harder to produce thyroid hormone. Perchlorate may also block the transfer of iodine from mother to fetus, which can hinder normal growth.

California, Massachusetts, and New Jersey limit perchlorate levels in drinking water. In 2008, the EPA concluded that national perchlorate regulations wouldn’t produce a great enough public health benefit. The agency now says that it’s reevaluating its decision.
“It’s extremely difficult for water utilities to remove perchlorate,” says University of Arizona water expert Shane Snyder. “The only technologies available are ion exchange, which is extremely rare in centralized water treatment systems, or a reverse osmosis system that’s also rarely used because it is energy-intensive.”

- Drugs. When you take an aspirin, or birth control pills, or Lipitor, or another drug, tiny amounts end up in the toilet bowl, where they’re flushed into the sewage system and, eventually, into a wastewater treatment plant.

“Conventional wastewater plants typically remove more than 90 percent of these compounds,” explains Snyder. “But even if you have 99.99 percent removal, that still leaves parts per trillion in the water which is subsequently discharged into rivers and streams.” And that water, with its drug residues, can eventually end up coming out of your tap.

While the traces of drugs in drinking water are one-ten-thousandth to one-hundred-thousandth the amount in any therapeutic dose, “I don’t know that we can completely dismiss the impact on human health,” says Snyder, “because we don’t know much about the toxicity of mixtures of drugs. But based on the concentrations of the individual compounds, harm to humans doesn’t appear to be likely.”

What to Do
- Atrazine. Use a filter that’s certified to reduce levels of volatile organic compounds (VOCs), which include atrazine.
- Perchlorate. Only reverse osmosis and ion exchange filters reduce perchlorate.
- Drugs. Claims that filters reduce drug residues are based on the manufacturers’ own tests. Official standards to verify the tests are in the works, though.

Is Bottled Water Better?
Is bottled water safer than tap water?

“There are not a lot of outbreaks associated with bottled water,” notes the University of Arizona’s Kelly Reynolds. But it’s not clear whether that’s because bottled water is less contaminated, or because it’s harder to pin outbreaks on it.

“Bottled water gets distributed all over the country,” says Reynolds. “If it caused an outbreak, that might be hard to identify.”

In theory, purified bottled water should be safer. “Many bottled water companies start with tap water that has met all federal standards,” notes Reynolds. “And the companies often add an additional treatment”—something like ultraviolet light or ozone to further disinfect the water or reverse osmosis to remove chemicals. “So you do sometimes get a higher standard of treatment.”

The two big differences between tap and bottled water:

- The EPA, which regulates tap water, requires utilities to notify consumers when their water fails to meet legal standards. The FDA, which regulates bottled water, doesn’t require bottlers to do the same. (The EPA’s and FDA’s standards are essentially the same.) So bottled-water drinkers are unlikely to know about any violations.
- Tap water doesn’t come in plastic bottles that can end up in landfills.

Bottle Basics
Purified Water: Most likely municipal tap water that has been distilled or treated with a process like deionization or reverse osmosis to remove impurities. The two major bottled drinking waters, Dasani and Aquafina, are purified water.

Spring Water: Comes from an underground formation from which water flows naturally to the surface of the earth. May be collected only at the spring or through a borehole tapping the underground formation that feeds the spring.

Mineral Water: Contains not less than 250 parts per million total dissolved mineral solids when it emerges from its source. No minerals can be added.

Sparkling Bottled Water: Contains the same amount of carbon dioxide that it had as it emerged from its source. (Companies sometimes add CO2 to replace what’s lost during bottling.) Depending on the source, it may be
labeled something like “sparkling drinking water,” “sparkling mineral water,” or “sparkling spring water.”(10)

(10) Adapted from International Bottled Water Association (bottledwater.org/content/labeling-0).

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QUIZ 1: H2Uh-Oh, Do you need to filter your water? (0.2 CPD)

1. What is a convenient way for consumers to reduce microbial levels in tap water?
   a. Disinfect the plumbing
   b. Use a filter for certified for microbial reduction
   c. Spray disinfectant on faucet outlet
   d. Boil water before drinking

2. What would you recommend to consumers to reduce their exposure to lead originating from their home’s distribution system?
   a. Don’t drink from the faucet
   b. Add a certified filter for lead reduction
   c. Drink only from the hot water tap
   d. Drink only from the cold water tap

3. Lead can come from several sources within a home plumbing system, what is not a source?
   a. Lead service line
   b. Solder
   c. Brass fittings
   d. Copper lines

4. Which disinfectant has the highest usage rate for municipal drinking water plants in US?
   a. Ozone
   b. Chloramine
   c. Chlorine
   d. UV

5. Which microorganism is not responsible for causing illness?
   a. Viruses
   b. Heterotrophic Bacteria
   c. Cysts
   d. Campylobacter Bacteria

6. What percentage of waterborne disease outbreaks was due to heavy downpours for a 36 year period?
   a. 25
   b. 50
   c. 75
   d. 100

7. There are several classifications for bottled water quality. Which one is not a bottled water quality classification by the FDA (Standards of Identity)?
   a. Mineral Water
   b. Spring Water
   c. Still Water
   d. Purified Water

8. Why is the EPA reevaluating the safety of Atrazine?
   a. To determine whether a water utility can efficiently remove atrazine
   b. To determine where atrazine is found in the environment
   c. To determine whether new restrictions are necessary to protect health and environment
   d. To determine whether a wastewater treatment plant can remove atrazine to low levels

9. It is extremely difficult to remove perchlorate from water. Which statement best describes treatment technologies available for perchlorate reduction?
   a. The technologies available for perchlorate concentration reduction are ion exchange and RO
   b. Oxidizing media is a promising technology for perchlorate concentration reduction
   c. Lime soda softening and slow sand filtration are effective at reducing perchlorate concentration
   d. The only technology available for reducing perchlorate concentration is ion exchange

10. Prescription drug disposal down toilets to wastewater treatment plants has led to very low levels of drugs being found in home taps. Which statement below best describes the product performance claim testing standards for reduction of drug concentration?
    a. No official standard exists today because the EPA has not found any significant health risk
    b. Official testing standards have been completed using manufacturer’s testing
    c. The USEPA is evaluating a testing standard to verify a manufacturer’s test
    d. All current product performance claims are based on the manufacturer’s own testing

11. Disinfection byproducts (DBP’s) occur when a disinfectant combines with organic matter that is naturally found in water. Why have DBP levels dropped significantly since the 1970s?
    a. DBP levels have dropped due to the wide spread of POU filters
    b. USEPA regulations of DBPs has led to the decrease
    c. Home owners are using more POE filtration
    d. Manufacturer’s filter development has created better DBP reduction capabilities
This article describes the steps required to properly design an effective residential water treatment system. Emphasis will be directed toward collecting and analyzing water supply data and selecting treatment techniques. Acid neutralizing, air induction, carbon filtration, chemical injection, filtration, oxidation-filtration, reverse osmosis, selective ion exchange, ultraviolet and softening will be addressed.

Proper application of treatment also includes installation of the equipment according to local codes and regulations and following the equipment manufacturer’s specifications as well as training the end-user on maintenance procedures and maintenance schedules. Maintenance responsibilities should be discussed with the end-user before the system is actually installed. This will increase the likelihood of continued proper treatment system performance.

**Steps in Designing a Residential Water Treatment System**

The basic steps in designing an effective and properly functioning residential water treatment system are:

1. Identify the contaminants to be treated or conditions to be corrected through consultation with the end-user followed by proper water testing and analysis.
2. Select the treatment technique or techniques to be used by reviewing the best available technology for contaminant reduction, with emphasis on utilizing technologies with the fewest chemical additives and mechanical parts possible.
3. Study the quantitative water supply data for this system. Consult with your end-user to reach a reasonable system design which will meet the flow rate demand and daily volume requirements.
4. Select the equipment based upon the results of the previous three steps and determine how to sequence the treatment devices in the proper order to meet pretreatment requirements and provide maximum capability for reduction of contaminant concentration.

The designer must not become complacent because the contaminants are the same as found in other cases. Each project is unique, and must be given close study and careful consideration.

The next few pages will describe in greater detail how to effectively implement the steps outlined above.

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**Step One: Identify the Contaminants**
Before beginning water treatment system design, the water specialist must determine the water quality goal of the end-user. The designer should ask the residents if they are targeting any specific contaminants or bothersome water problems. Awareness of the area’s geology and water chemistry can also be an asset in identifying water contaminants or problems at a particular site.

There are two categories of contaminants as categorized by the United States Environmental Protection Agency (USEPA), Secondary (Nuisance) Standards and Primary (Health-related) Standards. Each category will be discussed separately.

**Identifying Secondary Standards or Nuisance Contaminants**
Contaminants on the Secondary Standards list often affect water-using appliances and/or plumbing fixtures. A walk-through household inspection to evaluate the nature and severity of possible plumbing fixture damage or staining of water-using appliances may provide evidence of contaminant residue. Water-using devices and areas where aeration occurs or heated water is used need careful inspection.

**Table One: Common Secondary Standards or Nuisance Contaminants and Treatment Methods**

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Treatment Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>Reverse Osmosis (POU)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Ultraviolet (POE) Chlorination (POE)</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>Neutralizer (POE) Soda Ash Feeding (POE)</td>
</tr>
<tr>
<td>Chloride</td>
<td>Reverse Osmosis (POE or POU)</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Activated Carbon (POE or POE)</td>
</tr>
<tr>
<td>Cyst</td>
<td>Sub-Micron Filtration (POU)</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Reverse Osmosis (POU)</td>
</tr>
<tr>
<td>Hardness</td>
<td>Cation Softener (POE)</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>Aeration (POE) Oxidation-Filtration (POE) Chlorination (POE)</td>
</tr>
</tbody>
</table>

**Identifying Primary Standards or Health-Related Contaminants**
Contaminants on the Primary Standards list are
hazardous to health. These contaminants are difficult to identify simply by visual inspection of the water-using appliances or fixtures because they typically leave no residue. Knowing the local geology and water chemistry will provide a strong basis for contaminant identification.

It is recommended that a state-certified water testing laboratory be used to confirm the presence and concentration of Primary contaminants. The water specialist should be aware of any state regulations which may mandate water testing procedures for specific contaminants.

The following contaminant list addresses only the most common contaminants from the Primary Standards. A complete water analysis for other contaminants listed under the Safe Drinking Water Act may be recommended if the specialist feels it advisable.

### Table Two: Common Primary or Health-Related Contaminants

<table>
<thead>
<tr>
<th>Responsible Contaminant</th>
<th>Most Common Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>Sores on skin</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Gastroenteritis</td>
</tr>
<tr>
<td>Cysts</td>
<td>Diarrhea</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Mottling (staining of teeth)</td>
</tr>
<tr>
<td>Lead</td>
<td>Delays in physical and mental development in children; kidney problems, high blood pressure in adults</td>
</tr>
<tr>
<td>Mercury</td>
<td>Inflammation of the mouth</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Temporary (but dangerous) blood disorder in infants</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Protects organisms from disinfectants (not a health effect but interference with treatment for microbiological contaminants)</td>
</tr>
</tbody>
</table>

**Step Two: Select the Treatment Technique**

Knowing the effects of each contaminant is necessary to determine if the contaminant treatment technique should incorporate POE (Point of Entry) technologies to treat all the water in the house or POU (Point of Use) methods to treat only a portion of the water in the house. For example, POE treatment is mandatory when the health effect is caused by contaminant inhalation. POU can be utilized when the health effect is strictly caused by contaminant ingestion (taking in by drinking or in food). Table Three will assist in treatment selection.

When discussing with the end-user which contaminants are found in the water should be treated, the water specialist must be careful to try to reduce any exaggerated fears of the end-user and must make every effort not to create any unreasonable concerns. The USEPA established the maximum allowable concentrations for the contaminants on the Primary Standards list, which can be used as a starting point for discussing the need for treatment with the end-user.

### Table Three: Common Treatment Techniques

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Treatment Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>Reverse Osmosis (POU) Select Anion Exchange (POE)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Ultraviolet (POE) Chlorination (POE)</td>
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<td>Activated Carbon (POE or POU)</td>
</tr>
<tr>
<td>Cyst</td>
<td>Sub-Micron Filtration (POE or POU) Ultraviolet (POE or POU)</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Reverse Osmosis (POU)</td>
</tr>
<tr>
<td>Hardness</td>
<td>Cation Softener (POE)</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>Aeration (POE) Oxidation-Filtration (POE) Chlorination (POE)</td>
</tr>
<tr>
<td>Iron Algae</td>
<td>Chlorination (POE)</td>
</tr>
<tr>
<td>Iron/Ferous</td>
<td>Cation Softening (POE) Aeration-Filtration (POE) Oxidation-Filtration (POE)</td>
</tr>
<tr>
<td>Iron Sulfide</td>
<td>Aeration-Filtration (POE) Oxidation-Filtration (POE) Chlorination (POE) Reverse Osmosis (POU)</td>
</tr>
<tr>
<td>Lead</td>
<td>Specialty Filtration (POU) Reverse Osmosis (POU)</td>
</tr>
<tr>
<td>Low pH</td>
<td>Neutralizer (POE) Soda Ash Feeding (POE)</td>
</tr>
<tr>
<td>Manganese</td>
<td>Cation Softening (POE) Aeration-Filtration (POE) Oxidation-Filtration (POE) Filtration-Softening (POE)</td>
</tr>
<tr>
<td>Mercury</td>
<td>Reverse Osmosis (POU) Select Ion Exchange (POU) Select Ion Exchange (POE)</td>
</tr>
</tbody>
</table>
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continued from page 11

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Treatment Method</th>
</tr>
</thead>
</table>
| Nitrate     | Reverse Osmosis (POU)  
Selected Anion Exchange (POE) |
| Sulfate     | Reverse Osmosis (POU)  
Select Anion Exchange (POE)  
Select Anion Exchange (POU) |
| Turbidity   | Filtration (POE)  
Filtration (POU) |

Step Three: Study the Quantitative Water Data

Each treatment system must be designed to deliver the amount of water the end-users need each day at the pressure needed to make the plumbing fixtures and cleaning appliances work effectively. Therefore the water specialist must determine the output capabilities (flow rate and daily volume) of the particular water supply as well as analyzing what the family’s daily water needs are. Even the most superior treatment system design is doomed to failure if improper water supply diagnosis is performed. But if this homework is completed intelligently, the total treatment system will perform effectively for many years.

There are two types of residential water supplies: municipal water systems and water wells. The two types of systems require different approaches in evaluating output capabilities in terms of flow rate, daily volume requirement, and pressure.

Evaluating Output Capabilities of System Using a Municipal Water Supply

In analyzing the capabilities of a household water system using water from a municipal water system, the following questions need to be asked:

1. What is the diameter of the water meter outlet pipe?
2. What is the diameter of the main water supply pipe in the building?
3. What is the static water pressure on the piping systems?
4. Where is the end-user located along the municipal piping run? Near the end? Near the beginning?

The water pressure and pipe diameter will provide the water specialist with maximum flow rate, as illustrated in Table Four. To find the maximum possible flow rate, find the intersection of the row of the appropriate static water pressure with the column corresponding to the internal pipe diameter.

Table Four: Maximum Water Flow Rates/Pipe Diameter/Static Pressure

<table>
<thead>
<tr>
<th>Static Water Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.0 psi</td>
</tr>
<tr>
<td>40.0 psi</td>
</tr>
<tr>
<td>60.0 psi</td>
</tr>
<tr>
<td>80.0 psi</td>
</tr>
</tbody>
</table>

Evaluating the Output Capabilities of a Water Well System

In analyzing the capabilities of a household water system which draws its water from a private well, the following questions must be asked:

1. What is the well pump rating (volume per hour or volume per minute)?
2. What is the water pressure setting of the pressure switch?
3. What is the diameter of the main water system in the house?

The well pump rate can be determined by an on-site water flow test: 1) Have on hand a five-gallon bucket or container. 2) Open a water spigot located on or as near as possible to the well tank piping. The increase in pressure on the water pressure gauge on the well tank piping indicates pump operation. 3) When the pump begins to operate, immediately begin the timing process and time how long it takes to fill the five-gallon bucket or container. 4) Use this information to extrapolate the gallon per minute flow of the well pump as indicated below.

Flow rate in gallons/second (gps) = \( \frac{5 \text{ gallons}}{40 \text{ seconds to fill}} \)

Flow rate in gallons/minute (gpm) = flow rate (gps) x 60 min/sec.

For example:

Flow rate in gallons/second (gps) = \( \frac{5 \text{ gallons}}{40 \text{ seconds to fill}} \)
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Flow rate in gallons/second (gps) = 0.125 gps
Flow rate in gallons/minute (gpm) = 0.125 gps x 60 min/sec.
Flow rate in gallons/minute (gpm) = 7.5 gpm

The water pressure setting of the pressure switch is important because of the direct correlation between pressure, maximum flow rate and specific pipe diameters. (See Table Four)

Calculating End-User Flow Rate Needs and Daily Volume Demands
To ensure proper sizing of the equipment, the end-user’s flow rate needs and daily volume demands must be estimated and matched with the equipment manufacturer’s operational specifications and the output capabilities of the water system.

The treatment equipment must not be exposed to an excessive flow rate demand because this could cause contaminant breakthrough in undersized equipment. Improperly-sized equipment may be subject to premature equipment failure due to excessive service or to inadequate flow during regeneration.

The end-user’s specific daily volume and flow rate requirements must be determined through a detailed evaluation of all the household water-using devices. During the walk-through household inspection, the water specialist should watch for plumbing fixtures such as whirlpools, which may create excessive water demand.

Flow rate demands are often most influenced by the number of bathrooms present, since most water usage devices are located there. All residential demand estimates assume intermittent, not continuous, water usage. Local plumbing codes should be referenced and followed for determining water demand sizing procedures. Typically, these are based on a count of plumbing fixtures in the home, which is then converted to a flow rate.

A concern is that the flow rate data used in the conversion calculations does not take into account the effects of water conserving fixtures and the change in habits in water use that result in lower flow rates. A treatment system sized to existing code requirements can be unnecessarily oversized. Research results from a study by Aquacraft in 2002 have shown that actual peak demand flow is significantly lower than what is referenced in the plumbing codes.1 The state of Wisconsin, for example, allows for an alternative sizing method for specific residential applications to avoid oversizing treatment.2 Model code writers are currently reviewing household flow rate research results to determine if changes to the model codes are needed.

Table Five compares flow rate demands between the current Uniform Plumbing Code (UPC) and the alternative sizing method recognized by the state of Wisconsin.

<table>
<thead>
<tr>
<th>Homes with kitchen sink, dishwasher, automatic clothes washer, laundry tray, bar sink and…</th>
<th>Current code</th>
<th>Alternative method</th>
</tr>
</thead>
<tbody>
<tr>
<td>One bathroom*</td>
<td>8.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Two bathrooms</td>
<td>0.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Two bathrooms and one exterior hose bib*</td>
<td>12.2</td>
<td>11.0</td>
</tr>
<tr>
<td>Two bathrooms and two exterior hose bibs*</td>
<td>15.8</td>
<td>13.5</td>
</tr>
<tr>
<td>Three bathrooms</td>
<td>13.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Four bathrooms</td>
<td>15.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Four bathrooms, two half-baths, and one whirlpool</td>
<td>22.7</td>
<td>8.3</td>
</tr>
</tbody>
</table>

* Bathrooms are assumed to have a lavatory sink, toilet and bathtub/shower combination
b All exterior hose bibs are ¾” size

The demand calculations in Table Five are based upon on the use of flow-restricted (water-conserving) devices only. Thus a three bathroom house would have a 7.0 gpm demand.

In lieu of local-code approved alternative sizing methods, Table Six demonstrates the sizing method required by most local plumbing codes, which calculates flow rate demand, sometimes referred to as load, by totaling up the fixture units for the household and then comparing that figure to the flow rate table shown in Table Seven. The information presented in Tables Six and Seven is for illustration only. Refer to your local plumbing codes for the appropriate flow rate demand calculation procedures and conversions.
Table Six: Weighted Factors for Non-Flow Restricted Fixtures (Water Supply Fixture Units)

<table>
<thead>
<tr>
<th>Type Fixture</th>
<th>Unit Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathtub</td>
<td>2.0</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>2.0</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>2.0</td>
</tr>
<tr>
<td>Lavatory</td>
<td>1.0</td>
</tr>
<tr>
<td>Kitchen Sink</td>
<td>2.0</td>
</tr>
<tr>
<td>Outside Hose Bib</td>
<td>1.0</td>
</tr>
<tr>
<td>Shower</td>
<td>2.0</td>
</tr>
<tr>
<td>Toilet</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table Seven: Flow Rate Demand per Fixture Unit Total

<table>
<thead>
<tr>
<th>Fixture Unit Total</th>
<th>Flow Rate Demand (in gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>10.0</td>
<td>6.0</td>
</tr>
<tr>
<td>15.0</td>
<td>8.0</td>
</tr>
<tr>
<td>20.0</td>
<td>10.0</td>
</tr>
<tr>
<td>25.0</td>
<td>12.0</td>
</tr>
<tr>
<td>30.0</td>
<td>14.0</td>
</tr>
<tr>
<td>35.0</td>
<td>15.5</td>
</tr>
<tr>
<td>40.0</td>
<td>17.0</td>
</tr>
<tr>
<td>45.0</td>
<td>18.5</td>
</tr>
</tbody>
</table>

Let’s estimate the flow rate demand, in gpm, of a house with:
- 3 showers
- 3 toilets
- 3 lavatories
- 1 clothes washer
- 1 dishwasher
- 1 kitchen sink
- 1 hose bib

The total fixture count would equal 25.0 units (Table Six) which corresponds with a 12.0 gpm flow rate demand (Table Seven). The water specialist must now determine the daily volume water usage requirements of the end-user. Daily volume water usage is a function of the number of people living in the household.

The formula is:

\[
\text{Daily Volume Usage} = \text{Number of people in household} \times \text{estimated daily volume water usage per person}
\]

Let’s estimate the flow rate demand, in gpm, of a house with:
- 3 showers
- 3 toilets
- 3 lavatories
- 1 clothes washer
- 1 dishwasher
- 1 kitchen sink
- 1 hose bib

The total fixture count would equal 25.0 units (Table Six) which corresponds with a 12.0 gpm flow rate demand (Table Seven). The water specialist must now determine the daily volume water usage requirements of the end-user. Daily volume water usage is a function of the number of people living in the household.

The formula is:

\[
\text{Daily Volume Usage} = \text{Number of people in household} \times \text{estimated daily volume water usage per person}
\]

The current estimate for daily volume water usage per person is 75 gallons. So a household of four people would mean that:

\[
\text{Daily Volume Usage} = 4 \text{ People} \times 75 \text{ gallons per person/day}
\]

\[
\text{Daily Volume Usage} = 300 \text{ gallons per day}
\]

Step Four: Select the Specific Equipment

The next step is the actual selection of specific water treatment equipment which will reduce the targeted contaminants, function effectively within the water system’s output capability range, meet the end-user’s water supply flow rate (gpm) and daily volume demands, and operate within the manufacturer’s specifications and performance recommendations.

Decisions about whether POE or POU treatment is needed will influence the choice of treatment and the position or sequence of each particular treatment device in the total treatment system.

The equipment manufacturer’s literature should always be consulted to ensure proper contaminant reduction and consistent equipment and system performance as well as installation instructions and maintenance requirements.

In addition, the water specialist/system designer must always seek to further his knowledge of appropriate treatment techniques and should bring a considerable body of expertise to the process of treatment selection and equipment choice for a particular system.

Table Eight reviews in summary form the most common POE and/or POU treatment alternatives.

A discussion of some of the pretreatment and installation concerns follows the table.

Table Eight: Common Treatment Alternatives

<table>
<thead>
<tr>
<th>Treatment Technique</th>
<th>Contaminant</th>
<th>POE</th>
<th>POU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated Carbon</td>
<td>Chlorine</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aeration-Filtration</td>
<td>Ferrous Ion</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Hydrogen Sulfide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Iron Sulfide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Treatment Technique</th>
<th>Contaminant</th>
<th>POE</th>
<th>POU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidation-Filtration</td>
<td>Ferrous Iron</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Hydrogen Sulfide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Iron Sulfide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cation Softener</td>
<td>Hardness (Ca &amp; Mg)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Ferrous Iron</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Chemical Feed Soda Ash</td>
<td>Carbon Dioxide</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Low pH</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Filtration</td>
<td>Turbidity</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Filtration-Softening</td>
<td>Ferrous Iron</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Ferric Iron</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Neutralizer</td>
<td>Low pH</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Reverse Osmosis</td>
<td>Arsenic</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Chloride</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Nitrate/Nitrite</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Selective Ion Exchange</td>
<td>Mercury</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Sulfate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Nitrate/Nitrite</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sub-Micron Filtration</td>
<td>Cysts</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Turbidity</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ultraviolet Irradiation</td>
<td>Bacteria</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Consider Pretreatment and Water Treatment Equipment Factors

Below are discussions of various factors that should be considered for each technology.

Activated Carbon can be utilized for dechlorination at both the Point-of-Entry or the Point-of-Use. Activated carbon systems are typically installed in municipally-supplied water systems, which should have adequate water quality controls to reduce the need for pretreatment. If the water supply is free of bacteria, iron, manganese and turbidity, the only mandatory pretreatment would be a turbidity reduction cartridge-type filter. This will increase bed life by reducing particulate matter and preventing it from collecting in the pore structure of the Granular Activated Carbon.

Aeration-Filtration is used as a POE technique and is restricted to well water applications due to the water pressure differential requirement of the system’s air inductor. The air inductor is installed in the piping system between the well pump and the well tank due to the differential pressure requirement. The differential pressure and the well pump flow rate have a direct effect on the volume of air induced into the piping system. The inductor will induce air into the pressurized piping system only when the well pump is operating within a given pressure range. Contact the micronizer (air inductor) manufacturer for application data pertaining to water pressure and flow rate.

The aeration system should also include some type of air separation vessel which can be installed either before or after the well tank. This vessel will serve as a device to shear the air from the water and to subsequently vent the excess air from the vessel to the atmosphere. The air venting system utilizes float technology which consists of either an external or internal vessel.

The final piece of the aeration system is some type of depth filtration bed. The filtration bed utilizes standard filtration technology to trap the precipitated hydrogen sulfide, iron, iron sulfide and/or manganese from the aerated water supply. The composite media of this filter can vary from multimedia to pyrolusite.

Media-Based Oxidation-Filtration uses an oxidant such as chlorine, manganese oxides, or potassium permanganate and an oxidation-filtration media to augment the reaction between dissolved oxygen and the contaminant to be removed. This action causes precipitation of the contaminant, which the filter bed then traps by utilizing standard filtration forces. The oxidation capacities of the filter media vary and occasionally require rebidding. Oxidation-filtration can be implemented for the effective reduction of hydrogen sulfide, iron, iron sulfide and manganese.

Cation Water Softening is designed for clear water supplies with very low turbidity levels. POE cation exchange consists of a sulfonated polystyrene-divinylbenzene resin, which is predominantly ion selective for calcium, magnesium, iron and manganese. Cation resin can also be an alternative treatment method for barium, cadmium, lead and radium reduction, if applied correctly. Utilizing cation resin for specific contaminant reduction is job-specific and should not be assumed to be the best technology of choice for all applications. Contact your resin manufacturer for
application details.

Chemical Feed systems as referred to in this paper will be synonymous with chlorine and soda ash. The POE chemical feed pump is normally used on well water treatment systems. In this case, the chemical feed pump is electrically actuated by the well pump electrical switch. An alternative electrical actuation circuit can be provided by a flow switch which operates the chemical feed pump on a preset minimum and maximum flow rate.

For treatment of contaminants such as bacteria, hydrogen sulfide, iron algae or iron sulfide, the chemical feed pump is used to inject a chlorine and water solution into a retention tank. The tank must be sized to provide sufficient contact time between the chlorine and contaminant it is being added to control. The amount of contact time needed will depend on the chlorine dosage used. The chemical feed injection point and retention tank would be located on the outlet side of the well tank. Chlorine has the potential to oxidize high levels of iron and manganese, which could result in the production of a very turbid solution requiring specialty depth filtration media on the outlet of the retention tank.

The chemical feed systems can also be used to control corrosion due to carbon dioxide or low pH. For corrosion applications, the chemical feed pump would inject a soda ash and water solution into a retention tank designed for 10-minute contact time. Thus a 5 gpm well pump would require a 50 gallon retention tank to provide ideal corrosion reduction.

Warning: Always use an activated carbon filter as post treatment to chlorine feed to protect the end-user from chlorine taste and odor and from possible disinfection byproduct contamination, which can result from the chemical reaction of chlorine and natural organics in the water.

Filtration Systems utilize media with irregular surface characteristics which create maximum removal capacities for suspended solids (turbidity). These POE filters utilize standard filtration forces to reduce suspended solids in a water supply. A treatment system could incorporate this type of filtration as post-aeration and/or post-chlorination treatment to trap precipitated contaminants.

Filtration-Softening is a viable POE treatment technique for reducing high levels of iron and manganese. The filtration medium is an oxidation-type medium to assist in iron and manganese oxidation. The cation softener then polishes the water by reducing the dissolved iron and manganese levels. This combination can reduce iron levels from 10.0 mg/L to 0.30 mg/L and manganese levels from 2.0 mg/l to 0.005 mg/l. The cation softener should be regenerated with a strong brine and resin cleaning solution. This regenerant combination provides an optimum resin bed cleaning which allows for years of trouble free service.

Neutralizers incorporate a limestone-based medium which sacrificially increases the alkalinity and subsequently the pH of the water supply. The rate of the limestone medium depletion is determined by the concentrations of carbon dioxide, hardness, pH and total dissolved solids (TDS) in the water supply. Limestone media is very effective in pH correction within the range of 6.0 to 6.9 and CO₂ concentration is below 200 ppm. When the pH is lower than 6.0, the water specialist should consider mixing magnesium oxide with limestone to widen the unit’s pH correction range to 5.7 to 6.9. It is recommended that a chemical feed system be used to inject a soda ash and water solution into a retention tank when the pH is below 5.7. Remember, limestone-based media increase the water hardness at least two-fold. A neutralizer should be followed by a cation water softener to reduce the hardness to less than one grain per gallon (gpg).

Reverse Osmosis technology is typically classified as a POU technology. However, it can be an effective POE system. The expense of POE reverse osmosis reduces the number of systems installed at that treatment level. The majority of reverse osmosis systems are installed as POU devices designed to reduce specific contaminants from drinking water.

Reverse osmosis as POU technology is a safe technology for the reduction of many known health-related contaminants that are ingested, but it would not be very useful for contaminants absorbed through the skin or nasal passages since not all of the water in the household would be treated using the POU approach. A reverse osmosis system should be used as contaminant polishing system and should be preceded by proper pretreatment for contaminants such as bacteria, hardness, hydrogen sulfide, iron, iron algae, manganese and turbidity. The reverse osmosis membrane has different rejection percentages for each contaminant, so make a thorough study of the manufacturer’s literature for proper contaminant application.

A reverse osmosis system generally incorporates the
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following features: 5-micron and/or carbon prefilter, CTA or Thinfilm membrane, acid-washed bituminous carbon postfilter, air gap faucet, 2-gallon permeate storage tank, membrane drain flow control, permeate check valve and a shut-off.

The RO system’s filter maintenance schedule is dependent on contaminant concentrations, water pressure and temperature, pretreatment quality and usage patterns. An annual water analysis to confirm membrane performance is recommended.

Warning: Don’t utilize reverse osmosis technology to reduce a health-effect contaminant which is inhaled or absorbed.

Selective Ion Exchange Technology can be employed for both POE and POU applications. There are many ion exchange resins available for specific contaminant reduction. However, not all of them are manufactured to FDA protocol. Only resins made to these standards should be used when treating residential water supplies. Ion-selective resins are manufactured in either the hydrogen or sodium chloride regenerant form. Since these resins utilize ion exchange, the regenerant form of the resin determines the potential change in either the treated water’s sodium chloride content or its pH. These resins can be on-site regenerated when appropriate.

Contact your resin supplier for regeneration details. Due to the regenerant required and local sewage regulations, the resin is sometime discarded in lieu of on-site regeneration. Be sure to research the feasibility of proper disposal of the exhausted resin, because it could contain a regulated contaminant which requires special waste disposal procedures.

Sub-micron Filtration is designed as a POU device to reduce very small particulate matter or cyst-type microorganisms. The filters have absolute ratings from 0.40 to 1.0 gpm. The flow rate is restricted to 1.0 gpm or less, and pretreatment is mandatory to achieve acceptable cartridge life. It is recommended that water to be treated with a sub-micron filter be pretreated with a 5-micron cartridge filter.

Some sub-micron filters are constructed of extruded carbon or polypropylene. The extruded carbon filter provides chlorine reduction as well as sub-micron filtration; the polypropylene filter provides only sub-micron filtration.

Ultraviolet Systems are normally used for POE treatment because bacteria can affect the end-user in the shower as well as contaminating the drinking water from a kitchen faucet. An ultraviolet system utilizes a ballast which energizes a lamp that produces light at a 254-nanometer wavelength. Coliform bacteria are destroyed when bombarded by intense light at this wavelength.

Proper pretreatment for ultraviolet systems is mandatory to assure maximum effectiveness of the ultraviolet system. Contaminants such as hydrogen sulfide, iron, iron algae, manganese and turbidity can decrease the effectiveness of the UV system by preventing the prescribed amount of UV light from getting to the bacteria. The bacteria will be shielded by, or will hide inside of, some of these contaminants and are therefore not exposed to the necessary amount of ultraviolet energy.

The germicidal lamp is protected from the water supply by a quartz sleeve. Some of these contaminants tend to precipitate on the hot quartz sleeve, reducing the amount of light transmitted and lowering the bacterial kill rate. The germicidal lamp must be replaced at least once a year, typically every 9000 hours of operation. The ultraviolet system is usually energized 24 hours per day to guarantee bacteria kill. Since this wavelength of light is invisible to the naked eye, it is recommended that the UV system include a lamp failure indicator or alarm to notify the end-user of the need for lamp maintenance.

Reviewing Manufacturer Specifications

For all treatment options, the designer must consider product limitations and pretreatment requirements which will affect longevity of performance and frequency of product maintenance. Close attention should be paid to manufacturer’s installation and performance specifications to assure proper product sizing and performance.

Following is a list of common manufacturer’s specifications that should be reviewed as part of the equipment selection process:

- Backwash Flow Rate
- Disinfection Procedures
- Drain Pipe Size
- Electrical Voltage Requirements
- Electrical Ground Fault Interrupter (GFI) Requirement
- Inlet and Outlet Pipe Size
- Maximum Drain Flow Height (lift)
- Maximum Influent Contaminant Concentration
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- Minimum Water Pressure
- Maximum Water Pressure
- Minimum Water Temperature (especially for RO)
- Maximum Water temperature (especially for RO)
- Rinse Flow Rate
- Service Flow Rate
- Total Regeneration Flow Rate
- Total Regeneration Volume Discharged

Reviewing Backwash Requirements
It is important that the water systems supply pressures and flow rate output (Table Four) meet the equipment manufacturer’s specifications for backwash and service operations. If these pressures and flow rates do not meet specifications, the treatment equipment may not reach its optimum chemical treatment capability. POU technology typically requires minimum, if any, regeneration flow, whereas POE systems can require substantial regeneration flow rates due to the specific weight of the media.

Table Nine below identifies backwash flow rate specifications for the most commonly used residential equipment. Backwash and service flow rates are similar with some media.

If the treatment system receives excessive service flow rates or inadequate backwash flow rates, the media will foul prematurely, resulting in system failure. Contact your equipment manufacturer for detailed regeneration and service flow rate specifications.

Table Nine: Backwash Flow Rate Requirements per Medium and Tank Diameter

<table>
<thead>
<tr>
<th>Medium</th>
<th>Flow Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8” Diameter Tank</td>
</tr>
<tr>
<td>Birm®</td>
<td>2.8</td>
</tr>
<tr>
<td>Cation Resin</td>
<td>1.58</td>
</tr>
<tr>
<td>Calcite</td>
<td>3.50</td>
</tr>
<tr>
<td>Greensand</td>
<td>3.15</td>
</tr>
<tr>
<td>Magnesium Oxide</td>
<td>3.50</td>
</tr>
<tr>
<td>Pumice</td>
<td>2.45</td>
</tr>
<tr>
<td>Pyrolucite</td>
<td>7.00</td>
</tr>
</tbody>
</table>

Step Six: Discuss Proper Maintenance with the End-User
The equipment maintenance responsibilities should be discussed with the end-user prior to the installation of the equipment, and preferably during the equipment selection process. Provide a clear and readable maintenance schedule for the household and take the time to be sure the end-user understands what is required and when.

This communication link will allow for proper treatment system performance for years to come and will help to assure that the household has quality water and that you will have a satisfied customer in the community.

Step Five: Install According to Manufacturer’s Specifications
Installation considerations will not be addressed in this excerpt. For more information, please refer to the full WQA QuickCourse, How to Design a Residential Water Treatment System, or consider the Installer training through WQA’s Modular Education Program.

Note that equipment which is not properly installed will not give proper service. Installation procedures should follow equipment manufacturer’s specifications and local codes. Installers must also be aware of industry-based recommendations which may go beyond codes to assure proper service.

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1. According to the paper, what is the first step to take, before beginning the design process?
   a. Determine which equipment you are going to run a sale on this month and sell the customer on the “special of the month.”
   b. Determine by asking what the water quality goal of the end-user is.
   c. Determine where in the basement or kitchen the equipment will need to be installed.
   d. Determine what contaminants are in the water.

2. Which of the following should always be treated by POE treatment?
   a. Contaminants which are known to be health-related, such as arsenic.
   b. Contaminants which are not primarily health-related, such as metallic taste.
   c. Primary contaminants which are ingested (eaten or drunk).
   d. Primary contaminants which are inhaled.

3. Why are residential RO systems generally installed as POU systems?
   a. RO systems work so slowly that they absolutely cannot be used as a POE device.
   b. RO systems for POE would usually be too expensive, compared to other POE treatment options.
   c. RO systems are not capable of removing the types of contaminants the POE customers need removed.
   d. RO systems cannot be used on residential well systems.

4. When working to identify contaminants on the Secondary Standards list in a particular residential water supply, what is one important early step to take?
   a. Inspect plumbing fixtures and other water-using appliances in the house to look for clues.
   b. Install a trial filter for 30 days and look for improvements in the water.
   c. Find out what kind of water treatment system the neighbors bought.
   d. Ask the homeowner what kind of system he/she is looking for.

5. What flow rate (in gpm) is needed to effectively backwash a 10-inch diameter tank of greensand media?
   a. 1.10 gpm
   b. 3.15 gpm
   c. 4.90 gpm
   d. 7.06 gpm

6. Which of the following contaminants is generally removed by POU methods?
   a. Manganese
   b. Carbon Dioxide
   c. Hardness
   d. Arsenic

7. Which is the definition for contaminants found on the Primary Standards list?
   a. Contaminants which cause distress, but not necessarily health problems.
   b. Contaminants which can cause health-related problems.
   c. Contaminants which may make the property appear less desirable to a buyer; such as musty or rotten egg smells.
   d. Contaminants which come from natural sources, such as minerals in groundwater.

8. Which of the following would you probably need to know to calculate maximum possible flow rates for a house on a municipal water system?
   a. The diameter of the drain piping.
   b. Material from which the main water delivery pipe to the house is made.
   c. Height (in feet above the ground) of the water-using fixture that is highest in the house.
   d. Static pressure of the piping system in the house.

9. Which of the following contaminants is generally removed by POE methods?
   a. Iron
   b. Nitrate
   c. Fluoride
   d. Lead
<table>
<thead>
<tr>
<th>Quiz Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 10. If the static water pressure in a house is 30 psi and the OD of the water supply pipe is 3/4", what would be the maximum flow rate available? | a. 5.0 gpm  
 b. 10.0 gpm  
 c. 16.0 gpm  
 d. 18.0 gpm |
| 11. What is the flow rate on a well if 50 seconds are required to fill a 5 gallon bucket? | a. 6.0 gps  
 b. 10.0 gps  
 c. 6.0 gpm  
 d. 10.0 gpm |
| 12. Your customer has an older house without the flow-restricted plumbing fixtures. The house has a washer and a dryer in the basement, an older sink without a dishwasher in the kitchen, and one bathroom with a toilet, tub and lavatory. Using the information in tables six and seven, calculate the flow rate required for this house. | a. 10.0 gpm  
 b. 8.0 gpm  
 c. 6.0 gpm  
 d. 4.0 gpm |
| 13. If your customer’s household consists of two parents, two children and one grandparent all living full-time in the house, what would be the family’s total daily water demand? | a. 375 gpd  
 b. 300 gpd  
 c. 250 gpd  
 d. 200 gpd |
| 14. How large should a retention tank, which provides soda ash/water contact be when a chemical feed system is used to provide pH adjustment as protection against corrosion? | a. 100 times the gpm rating of the pump  
 b. 50 times the gpm rating of the pump  
 c. 20 times the gpm rating of the pump  
 d. 10 times the gpm rating of the pump |
| 15. What are the ratings for sub-micron filters? | a. Absolute ratings of 1.0 to 4.0 µm  
 b. Nominal ratings from 0.4 to 0.1 µm  
 c. Nominal ratings of 5.0 to 1.0 µm  
 d. Absolute ratings of 0.4 to 1.0 µm |
Making Sense of an Incomplete Water Analysis

by Frank DeSilva

The water treatment professional is often required to recommend a treatment scheme to rectify problem water. More often than not, the initial water analysis data that the end user provides is not sufficient to make a valid recommendation. This article provides the items you need to get from your customers in order to make a valid recommendation for resin selection and throughput predictions: the influent conditions and also the effluent requirements.

Author's note: I have gotten into the habit of listing ions in mg/L if they are reported as the ion and in ppm if they are reported as CaCO$_3$. This is a convention used by Bill Bornak in his book, Ion Exchange Deionization.

Information Needs by Application

Cationic applications
(hardness removal, metals removal, radium removal)
- pH
- TDS or conductivity
- hardness (or separate calcium and magnesium numbers)
- iron
- manganese
- all metals of concern if metals removal is the application (copper, lead, cadmium, etc.)
- other cations as needed (radium, for example)

Anionic applications
(sulfate removal, nitrate removal, chromate removal, uranium removal, organics removal, perchlorate removal, fluoride removal, dealkalizers, boron removal)

Technically, the same type of resin will remove all of the constituents listed; however, the determination of which anion resin will actually be the best choice is dependent upon the water analysis parameters that are requested. For instance, a type II strong base anion resin will work well for arsenic removal on high pH/low TDS water, while a hybrid strong base anion resin would work well on a low pH/high sulfate water.
- pH
- TDS or conductivity
- sulfate
- nitrate
- chloride
- alkalinity (or HCO$_3$-)
- silica (for arsenic applications)

Of course, for the contaminant of concern (arsenic, chromate, uranium, etc.) you’ll need to know the influent concentration and also the effluent requirement. It is also useful to know if the iron and manganese concentrations are above 0.5 ppm and 0.25 ppm respectively. If so, the client needs to lower the iron and/or manganese level before introducing water to the anion unit.

Deionizer applications
- pH
- TDS or conductivity
- calcium
- magnesium
- sodium
- potassium (if any)
- sulfate
- chloride
- alkalinity
- silica
- CO$_2$

Deionizer applications will specify effluent quality in terms of conductivity, resistivity, silica or sodium.

Customer provided information
It's not often that the customer will have all the items you are asking for. TDS or conductivity is easy to test for and you'll usually be able to obtain those numbers. Here's an example of roughing up a water analysis from partial information.

The customer provides us with a water analysis that shows the following:
- Conductivity 550 microsiemens
- hardness 150 ppm
- alkalinity 125 ppm
- chloride 30 mg/L
- silica 15 mg/L
- pH 7

What’s missing? The breakdown of the hardness into calcium and magnesium, the sodium, the sulfate and CO$_2$.

First the cations. If you’re trying to get a cationic water analysis together and the customer only has the inlet conductivity of 550 and the hardness of 150 ppm as
CaCO₃ here are the assumptions you can make.

Take the inlet conductivity and convert it to TDS ppm as CaCO₃ (550/2.53 = 217.4 ppm as CaCO₃). By subtracting the hardness of 150 ppm as CaCO₃, you find the sodium level as CaCO₃ (217.4 - 150 = 67.4 ppm as CaCO₃).

Since we don’t have separate numbers for calcium or magnesium, you can use an old rule of thumb that says that calcium is usually two thirds of the total hardness number and magnesium the remaining third. So, the calcium is 100 ppm as CaCO₃ and magnesium is 50 ppm as CaCO₃.

Cation summary, all as ppm CaCO₃:
- calcium 100 ppm
- magnesium 50 ppm
- sodium 67.4 ppm

Now let’s take a look at the anions.

Assume that all the customer had for us is the alkalinity (again a simple test for the customer to do), chloride and silica.
- alkalinity 125 ppm as CaCO₃ (If the water analysis states alkalinity, it is reported as CaCO₃. Sometimes the alkalinity is reported as HCO₃⁻, and so you must convert that to ppm as CaCO₃)
- chloride 30 mg/L
- silica 15 mg/L

The first thing to do is convert the chloride to ppm as CaCO₃ (30 x 1.41 = 42.3 ppm as CaCO₃). Now find out what the sulfate level is by subtracting the chloride as CaCO₃ plus the alkalinity as CaCO₃ from the total cation (217.4 - (125 + 42.3) = 50.1). So the sulfate is 50.1 ppm as CaCO₃.

The silica is not incorporated into the ionic balance since it is weakly ionized and does not contribute to the conductivity or TDS.

Table 1 is a summary of what we have calculated, now shown as ppm as CaCO₃:

<table>
<thead>
<tr>
<th>Cations</th>
<th>Anions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>100</td>
</tr>
<tr>
<td>Magnesium</td>
<td>50</td>
</tr>
<tr>
<td>Sodium</td>
<td>67.4</td>
</tr>
<tr>
<td>Total</td>
<td>217.4</td>
</tr>
</tbody>
</table>

The total cations and anions should be equal at this point since they all contribute to the electroneutrality of the solution. There may be some potassium present in the cations. However, for our calculations, it is lumped in with the sodium since it is also monovalent. On the other hand, there may be low levels of nitrate present; it is lumped in with the chlorides as a monovalent. (This is for DI calculations only. If we are dealing with a nitrate removal job, we need to know precisely how much nitrate is present.)

This is not all of the exchangeable anions, however, since we still have the silica and carbon dioxide to contend with. The silica is reported at 15 mg/L as silica. The conversion to CaCO₃ is 0.83 (15 x 0.83 = 12.5 ppm as CaCO₃). Adding that to the total anions, 12.5 + 217.4 = 229.9 ppm as CaCO₃ as total exchangeable anions (TEA). To be completely thorough, you would want to calculate the CO₂ level to see what its contribution would be to the anion loading.

When discussing the alkalinity measurement of natural waters, the assumption is made that the carbonate/bicarbonate concentration far exceeds the hydroxide concentration and that all of the alkalinity is estimated as due to a combination of carbonate and bicarbonate. The alkalinity concentration reported on the water analysis also does not take into account the dissolved carbon dioxide gas (H₂CO₃). The graphed summary of the carbonate system in Figure 1 can be used to estimate what fraction of the three forms of CO₂ (H₂CO₃, HCO₃⁻, CO₃²⁻) exist at a given pH.
Making Sense of an Incomplete Water Analysis

continued from page 22

At a pH of 7, the ratio of CO₂ to M alkalinity (total alkalinity) is 0.16 (0.16 x 125 = 20 ppm CO₂ as CaCO₃). That means that our total exchangeable anions are now 229.9 + 20 = 249.9. To calculate the load in grains per gallon, divide the ppm as CaCO₃ by 17.1. Total cation load therefore equals 217.4/17.1 = 12.7 grains per gallon (gpg). Total anion load equals 249.9/17.1 = 14.6 gpg.

Here’s our water summary once again. Provided by customer: conductivity 550 microsiemens; hardness 150 ppm; alkalinity 125 ppm; chloride 30 mg/L as Cl; silica 15 mg/L as SiO₂; pH 7. Table 2 is the calculated analysis (all shown as ppm as CaCO₃).

<table>
<thead>
<tr>
<th>Cations</th>
<th>Anions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>100</td>
</tr>
<tr>
<td>Magnesium</td>
<td>50</td>
</tr>
<tr>
<td>Sodium</td>
<td>67.4</td>
</tr>
<tr>
<td></td>
<td>Alkalinity 125</td>
</tr>
<tr>
<td></td>
<td>Silica 12.5</td>
</tr>
<tr>
<td></td>
<td>CO₂ 20</td>
</tr>
<tr>
<td>Total</td>
<td>217.4</td>
</tr>
<tr>
<td></td>
<td>249.9</td>
</tr>
</tbody>
</table>

Of course, any predictive information provided to the customer at this point must clearly show the calculations and assumptions that have been made. The less complete the original water analysis is, the higher the safety factor or engineering factor should be. A typical engineering factor that is used for DI calculations is 0.9 or a 10-percent downgrade for cation or 15 percent for anion, which is applied to the throughput calculations. If we run a projection on the water analysis that we just calculated, you might want to use 0.8 or 0.75 as the safety factor.

About the author
Francis J. ‘Frank’ DeSilva is National Sales Manager for ResinTech Inc. of Cherry Hill, N.J. ResinTech is a manufacturer and supplier of ion exchange resin, activated carbon products and the Aries line of laboratory demineralizers and cartridges.

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QUIZ 3: Making Sense of an Incomplete Water Analysis (0.2 CPD)

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
</table>
| 1. Which of the following is NOT a necessary parameter to for cation-removal applications? | a. Concentration of iron  
b. Concentration of arsenic  
c. Concentration of manganese  
d. Hardness concentration |
| 2. Why is the sulfate concentration an important consideration when using anion exchange to remove arsenic? | a. High sulfate concentration will irreversibly foul anion resin  
b. Sulfate concentration will affect the choice of anion resin  
c. Sulfates interfere with pH correction chemicals  
d. Sulfates will oxidize arsenic III to arsenic V |
| 3. If a TDS measurement is not taken, which parameter can be used to calculate TDS? | a. Hardness concentration  
b. Iron concentration  
c. Silica concentration  
d. Conductivity |
| 4. What is the rule of thumb for estimating calcium and magnesium concentration from hardness concentration? | a. Calcium concentration is \( \frac{2}{3} \) of the hardness concentration, and the remainder is magnesium, all in ppm CaCO\(_3\).  
b. Magnesium concentration is \( \frac{1}{3} \) of the hardness concentration, and the remainder is calcium, all in ppm CaCO\(_3\).  
c. Calcium concentration is \( \frac{1}{5} \) of the hardness concentration, and the remainder is sodium, all in ppm CaCO\(_3\).  
d. Magnesium concentration is \( \frac{2}{5} \) of the hardness concentration, and the remainder is sodium, all in ppm CaCO\(_3\). |
| 5. If the inlet conductivity is 600 microsiemens, what is the TDS (in ppm CaCO\(_3\))? | a. 2.80  
b. 217.4  
c. 237.2  
d. 600.5 |
| 6. If the sodium concentration is not provided as part of the water analysis, how should it be calculated? | a. The sodium concentration will be \( \frac{1}{5} \) of the hardness concentration.  
b. The sodium concentration will be \( \frac{1}{3} \) of the TDS.  
c. The sodium concentration will be the difference between the conductivity (in \( \mu \)S) and TDS in ppm CaCO\(_3\).  
d. The sodium concentration will be the difference between TDS and the hardness concentration, both in ppm CaCO\(_3\). |
| 7. What information is needed to convert alkalinity as HCO\(_3\)- to CaCO\(_3\)? | a. The equivalent weight of free CO\(_2\).  
b. The equivalent weight of HCO\(_3\)-  
c. The concentration of CaCO\(_3\)  
d. The concentration of HCO\(_3\)- |
| 8. Consider the initial anion water analysis given in the article. How can the sulfate concentration be calculated, if it is not measured as part of the water analysis? | a. Sulfate concentration will be equal to the difference between the TDS concentration and the sum of alkalinity and chloride concentrations, all as ppm CaCO\(_3\).  
b. Sulfate concentration will be \( \frac{2}{3} \) of the TDS, as ppm CaCO\(_3\).  
c. Sulfate concentration can be calculated from the pH and alkalinity, as ppm CaCO\(_3\).  
d. Sulfate concentration will be the difference between the TDS concentration and chloride concentration, all as ppm CaCO\(_3\). |
QUIZ 3: Making Sense of an Incomplete Water Analysis (0.2 CPD)

9. In incomplete water analyses, the calculated sodium concentration may actually be due to a combination of sodium and potassium and the chloride concentration may be a combination of chlorides and nitrates. Why might the nitrate concentration need to be measured separately from the chlorides, while the potassium concentration does not need to be separated from the sodium?

a. In potable water applications, nitrates are a potential health hazard and require individual monitoring to insure consumer safety.

b. The ratio of potassium to sodium concentrations is extremely small, while the ratio of nitrate to chloride concentration can be significantly larger.

c. Sodium and potassium take up the same amount of space on cation resin, while nitrates require significantly more space than chlorides.

d. Nitrates compete more strongly with chlorides for anion resin sites, causing chloride breakthrough, than potassium competes with sodium for cation resin sites.

10. Why does the silica contribute to the anion load but its counter ion does not contribute to the cation load?

a. Silica’s counter ion is hydrogen, which is not removed by cation exchange.

b. Anion exchange resins are more sensitive to weekly ionized substances than cation resins.

c. Silica could foul anion resin and needs to be carefully monitored.

d. In water, cations and anions are not always in balance.

11. At a pH of 6.5, what would be the CO₂ concentration as ppm CaCO₃ if the alkalinity is reported as 125 ppm CaCO₃?

a. 35  
b. 44  
c. 60  
d. 75
Introduction to High Purity Treatment Trains

A treatment train is a sequence of water treatment stages where each stage is a specific treatment technology. The output of one treatment stage becomes the input for the next treatment stage. Treatment trains can be subdivided into three components:

1. Primary treatment, where water is brought to the final quality needed at the point of use.
2. Pre-treatment, which protects the primary treatment technology and equipment.
3. Post-treatment, which removes any impurities picked up in storage or the distribution system and acts as a barrier for any debris that the upstream treatment equipment any unexpectedly shed.

Treatment train design requires a consideration of both the water quality and the flow rate that needs to be produced. Once the required water quality has been determined, the starting point of any treatment system design is a thorough analysis of the raw water. This analysis is critical in order to properly identify the contaminants and remove them with the most expedient technology.

Contaminants can be divided into four categories:

1. Microorganisms
2. Particulates (typically indicated as Total Suspended Solids, TSS, although they may also appear on a water analysis as turbidity)
3. Dissolved and Ionized (Total Dissolved Solids, TDS)
4. Organic (Total Organic Carbon, TOC). TOC primarily is a measurement of the concentration of dissolved organic molecules, but in reality it also includes the microbiological contaminants.

Table 1 is an example of a complete water analysis that may be obtained for a high purity water application. All the contaminant classes are represented with the exception of TOC, although color can be an indicator of the presence of organic substances. The place count indicates the bacterial concentration. The dissolved solids are listed alphabetically. Conductivity is also an indication of total dissolved solids content, often measured in micromhos per centimeter. pH is the indication of acidity or basicity of water. Turbidity, indicating suspended solids content, is measured as NTU, nephelometric turbidity units. The TDS and TSS values are also given.

Silica is another contaminant that is important in high purity water, because of the problems it can cause and because of its removal difficulty. TOC is also a parameter that may be of significant concern.

Seasonal variances in raw water quality and parameters such as temperature can impact treatment processes. Some municipal water suppliers may alternate between surface water and ground water, or may blend the two. Often, the municipality will treat the water before it is released into the distribution system. The water may be treated with alum (aluminum sulfate), a common flocculent, to lower the suspended solids concentration. Although the treated water is then allowed to sit in a settling tank, some residual alum may still be present in water supplied to the customer’s facility.

Virtually all municipal water supplies in the US are treated with some sort of chemical disinfectant, such as chlorine (or chloramines), which leaves a residual concentration. Some municipalities will also adjust the pH of the water by injecting a base such as sodium hydroxide, add orthophosphates to inhibit corrosion, or polyphosphate to control the effects of dissolved iron or hardness minerals. All of these additions can affect the operation of water treatment equipment at the customer’s site.
Table 1: Sample Water Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
<th>MDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0.51 mg/L</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>Arsenic</td>
<td>ND</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>6.71 mg/L</td>
<td>0.008 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>33.18 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Chlorine</td>
<td>ND</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>0.17 mg/L</td>
<td>0.006 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>0.10 mg/L</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Lead</td>
<td>ND</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.59 mg/L</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.02 mg/L</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>TNTC</td>
<td>0 cfu/mL</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.31 mg/L</td>
<td>0.1 mg/L</td>
</tr>
<tr>
<td>Nitrite</td>
<td>ND mg/L</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.30 mg/L</td>
<td>0.02 mg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>37.12 mg/L</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>18.40 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Hardness</td>
<td>23.29 mg/L as CaCO₃</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Color</td>
<td>0 color units</td>
<td>1 color unit</td>
</tr>
<tr>
<td>Conductivity</td>
<td>172 micromho/cm</td>
<td>1 micromho/cm</td>
</tr>
<tr>
<td>pH</td>
<td>8.02 units</td>
<td>0.1 units</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.75 NTU</td>
<td>0.3 NTU</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>55 mg/L as CaCO₃</td>
<td>2.5 mg/L as CaCO₃</td>
</tr>
<tr>
<td>Sediment</td>
<td>Absent</td>
<td>Present/Absent</td>
</tr>
<tr>
<td>Silica</td>
<td>3 mg/L</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>TDS</td>
<td>103.20 mg/L</td>
<td>5 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>5 mg/L</td>
<td>1 mg/L</td>
</tr>
</tbody>
</table>

ND = Not Detected
TNTC = Too numerous to count > 200 cfu/mL
MDL = Minimum detection level
cfu/mL = colony forming units per milliliter
TDS = Total Dissolved Solids
TSS = Total Suspended Solids

Once the raw water has been analyzed and the customer’s water quality parameters have been determined, the treatment technologies for the primary, pre-, and post-treatment components of the treatment train can be selected.

Pre-Treatment
Because pre-treatment prepares the raw water for the primary treatment operation, the goal is to remove those contaminants that could affect the performance of the primary treatment technologies and equipment. The pre-treatment technologies will depend on which primary technology is chosen, but typically, they remove suspended solids or slightly soluble dissolved solids which can turn into suspended solids downstream. Pretreatment may also include chemicals that can improve performance of downstream equipment and processes.

Several technologies can be used as pre-treatment. The first of these is often media filtration to remove suspended solids. It could be a cartridge filter or media housed in a pressurized tank. The media itself could be sand, anthracite, etc, or some combination.

The second often-used pre-treatment technology is softening to remove calcium carbonate, magnesium carbonate, and possibly slightly soluble salt compounds such as iron and manganese. Finally, many pre-treatment systems will use granular activated carbon (GAC) filters to remove residual disinfectant. Virtually all disinfectants are oxidizing agents and will attack reverse osmosis membranes, softener resin, and possibly plastic or synthetic rubber components. GAC may also be used to lower TOC concentration.

The placement of the GAC filter in the treatment train depends on what the GAC is being used to address. If TOC is present in significant concentrations, it should be removed prior to the ion exchange softener to avoid fouling the resin. On the other hand, if GAC is used to remove chlorine, it will often be placed after the softener so that the disinfectant can be used to suppress bacterial growth in the softener. While resin will degrade after sufficient exposure to oxidizers like chlorine, bacterial growth in the softener is often considered as a more immediate threat.

In addition to treating what is normally in the raw water, the pre-treatment provides protection against unexpected events, such as municipal maintenance procedures on the distribution lines, which could release suspended solids, an accidentally high concentration of disinfectant added at the treatment plant, or other.

Municipal water supplies are guaranteed to have biofilm. When the municipality performs its scheduled hydrant flushing, much of the biofilm can be released.
Introduction to High Purity Treatment Trains

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into the distribution piping, becoming a contaminant.

Let’s look at how a particular application can dictate which treatment technologies would be used.

The customer manufactures integrated circuits and requires very high quality water for the rinsing process. Because integrated circuits have very tiny line widths, even bacteria in the water will affect the device. Table 2 lists the treated water quality requirements.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
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<tbody>
<tr>
<td>Resistivity (MΩ-cm)</td>
<td>18 MΩ-cm</td>
</tr>
<tr>
<td>Silica (mg/L)</td>
<td>5 µg/L</td>
</tr>
<tr>
<td>Particulates</td>
<td>2 µm/mL</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>1 cfu/mL</td>
</tr>
<tr>
<td>TOC</td>
<td>50 µg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>50 µg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>2 µg/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>2 µg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>1 µg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>5 µg/L</td>
</tr>
<tr>
<td>Residual Solids</td>
<td>10 µg/L</td>
</tr>
</tbody>
</table>

Notice that resistivity is 18 MΩ-cm and the allowed silica concentration is less than 5 micrograms per liter, or ppb. All of the requirements listed in Table 2 are voluntary industry standards, unlike some of the Food & Drug Administration-mandated parameters in pharmaceutical manufacturing, but they’re used routinely throughout the electronics manufacturing industry.

Figure 1 is an example of a treatment system created to produce this quality of water. In this case, the raw water analysis (Table 1) indicated dissolved iron, hardness and chlorine in sufficient concentrations to necessitate treatment. The iron and hardness may form solids under the right conditions downstream, such as during the reverse osmosis (RO) treatment process. An oxidizing filtration medium (Manganese Greensand) is used to treat the iron in the feed water and allow the softener technology to be directed toward hardness removal. Carbon filters are used to remove any chlorine to also protect the downstream RO. The water softener is used as pretreatment for the RO stage, which removes the bulk of the hardness to produce a reasonable quality water.

Electrodeionization (EDI) follows the RO to bring the water up to final 18 MΩ-cm quality. The treated water is directed to a storage tank to help meet peak demand. A pump delivers the water through an ultraviolet treatment unit to further reduce organics, including the bacteria.

Figure 1: Treatment System for Rinse Water in Electronics Manufacturing

Figure 2 is an example of an application that prepares water for boiler feed. After steam generation, impurities in the water will be left behind inside the boiler. The result may be scaling, reduced energy efficiency, potential corrosion, and water inefficiency due to the need for more frequent boiler blowdown operations to reduce contaminants. The higher the boiler’s operating pressure, the more rigorous the water quality requirements. In this example, the primary treatment is RO, which is a commonly applied technology for boiler water treatment. The raw water analysis did not show a significant iron concentration, but did indicate hardness and chlorine. As a result, the pretreatment is a water softener to ensure a reduction in slightly soluble salts that could foul the RO membrane, and a carbon filter to remove chlorine.

Figure 2: Treatment System for Boiler Feed Water

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Another high purity water application is kidney dialysis. Hemodialysis is the activity that replaces kidney functions in people whose kidneys are no longer working correctly, or in people who have undergone trauma and are in need of it temporarily. Hemodialysis is a large consumer of high purity water treatment technologies because of the water quality requirements. The treated water is fed into an artificial kidney, which is also running the patient’s blood through it. The two streams are separated by a diffusion dialysis membrane. Various components are put into the water, such as heparin, that diffuse across into the blood stream. At the same time, the waste products that are in the blood stream diffuse into the water stream and are discharged.

In hemodialysis, two of the most important treated water quality parameters are bacteria and endotoxins, which are pieces of microorganisms. Both can cross the dialysis membrane and cause serious illness or possible death of the patient. Chlorine and chloramines can also be of significant concern as they too can diffuse through the dialysis membrane and result in hemolysis (destruction of red blood cells) and death.

Table 3 is a raw water analysis for this example application. Table 4 lists product water quality standards from the American Association of Medical Instrumentation (AAMI), which are mandatory and enforced. A comparison of the two reveals that the raw water analysis is incomplete and missing the endotoxin and bacteria counts as well as disinfectant residual concentration; however, the illustrated technologies will easily produce the desired treated water quality from normal water supplies.

### Table 3: Raw water analysis - hemodialysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.29 units</td>
</tr>
<tr>
<td>Hardness</td>
<td>8 gpg</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>7 gpg</td>
</tr>
<tr>
<td>Sulfates</td>
<td>14.0 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>0.7 mg/L</td>
</tr>
<tr>
<td>TDS</td>
<td>265 mg/L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>1.6 NTU</td>
</tr>
</tbody>
</table>

### Table 4: Product Water Standards (AAMI), as of 2012

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Max Allowable Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.01 ppm</td>
</tr>
<tr>
<td>Calcium</td>
<td>2 ppm</td>
</tr>
<tr>
<td>Chloramines</td>
<td>0.1 ppm</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.4 ppm</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.2 ppm</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4 ppm</td>
</tr>
<tr>
<td>Nitrate</td>
<td>2 ppm</td>
</tr>
<tr>
<td>Potassium</td>
<td>8 ppm</td>
</tr>
<tr>
<td>Sodium</td>
<td>70 ppm</td>
</tr>
<tr>
<td>Sulfate</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Bacteria</td>
<td>50 cfu/mL (action)</td>
</tr>
<tr>
<td>Endotoxins</td>
<td>0.125 eu/ml* (action)</td>
</tr>
</tbody>
</table>

*eu=endotoxin unit

Turbidity in the raw water, as well as iron and hardness, are addressed in the pre-treatment component of the hemodialysis treatment train (illustrated in Figure 3) by the sediment filter and the water softener. Notice that two activated carbon filters follow the softener. The removal of chlorine and chloramines is critical and the health of the patient is at stake. The second filter provides a back up to the first in case of failure and it provides the additional contact time needed to remove chloramines.
goes to the level achieved in primary treatment.

Water quality deteriorates when the water is sitting in the storage tank and piping, although pumps can also impart contamination. The storage tank feeds the distribution system, the treated water goes out to some point of use, but part of it is recirculated to the storage tank.

Some examples of treatment technologies used in post-treatment are disposable submicron cartridge filters to remove particulates and ultraviolet irradiation to inactivate microorganisms or break down organic substances that may have gotten into the system. Bacteria is of particular concern in the storage and distribution system as they can grow under virtually any condition, and any residual disinfectant was removed upstream. Theoretically, bacteria-free water can be made, but it won’t stay that way.

Typically, submicron filter cartridges (less than 0.2 micron rating) are pretty effective at removing bacteria. If the system is not going to be used for any period of time, then it is wise to put a disinfectant in the storage and distribution loop just to keep this bacterial concentration at a relatively low level. Spray balls can be used with the recirculation process to help uniformly distribute the recirculated water throughout the storage tank. A nitrogen blanket is used in the storage tank to keep oxygen and carbon dioxide out of the treated water in applications requiring very high quality water, such as electronics rinsing. In this application, gasses can affect the product quality.

In the sample treatment systems for electronics rinsing (Figure 1), the treated water from the storage tank goes through ultraviolet irradiation, mixed bed deionization, and a 5 micron guard filter. A “guard” filter is meant to block potential contaminants coming from the treatment process, such as particles of resin beads. The final filter in this case is a 0.1 micron cartridge filter. The water then travels through the distribution loop, and back into the storage tank.

In the boiler feed water treatment and the hemodialysis applications (Figures 2 and 3, respectively), reverse osmosis alone is sufficient to achieve the required water quality.

Post Treatment
Finally, let’s look at the post treatment. Most high purity water applications have varying water usage rates and require storage of treated water for times of peak usage demand. The higher the purity of the treated water, the greater its ability to dissolve anything it contacts, such as the materials used to store the water, convey it or pump it. The role of post-treatment is to remove contaminants the treated water may have picked up from the storage and distribution system and bring the water quality back to the level achieved in primary treatment.

Primary Treatment
Primary treatment is the stage where the concentration of remaining dissolved solids (TDS), large molecular weight organics (TOC), dissolved gasses, and microorganisms are reduced to the levels acceptable for the application. For example, in the electronics rinsing application (Figure 1), both reverse osmosis and electrodeionization are utilized. Reverse osmosis alone will not produce water with 18 MΩ-cm resistivity. It can remove up to 99.8% of the dissolved salts concentration, but in most cases, that’s not sufficient. A “polishing” technology is needed, and one of the more commonly used is electrodeionization.
Introduction to High Purity Treatment Trains

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In the boiler feed water application (Figure 2), the 1 micron filter following the storage tank serves as the post-treatment. In the dialysis application (Figure 3), the post-treatment technologies are easily identified once you find the storage tank and determine the direction of water flow.

In the diagram in Figure 3, the mixed bed deionization system and the submicron filter are typical of what’s used in the hemodialysis industry. The submicron filter in this case, is not only to remove any resin fines, but also to remove any bacteria that may have grown in the mixed bed polishing tanks. The designation, “POUs” indicates the individual dialysis stations.

In addition to making sure the treatment system is providing water that meets the quality requirement, it is also essential to make sure the quantity requirement for the water is being met. Not only does sufficient water flow rate have to be available at the point of use, but enough flow needs to be available for the various cleaning processes required by the treatment equipment.

Media filters, for example, require regular backwashing. It’s not a good idea to use the raw water for backwashing because it could contain suspended solids. To provide the treated water for cleaning, the media filter is sized to provide an excess of treated water. Some of that filtered water is collected and used for backwash.

Water softeners also require some water for backwashing, but even more importantly, for regeneration. Treated water is also needed to carry away the little bit of concentrate formed in the EDI system. Likewise, some portion of the RO feedwater is needed to carry the rejected salts away from the surface of the RO membrane. Typically, large reverse osmosis systems may only require 15% or so of the feedwater volume to be used to carry away the salts that have been rejected. Smaller ones can require as much as 40%. This, too, needs to be taken into consideration when sizing the RO system.

The primary treatment of the treatment system is normally sized to meet the total daily requirements, and the pre-treatment equipment size is based on the primary treatment plus the needed backwashing and regeneration volume. The instantaneous flow rate requirements at the point of use are used to size the storage tank and distribution system.

About the author
In 1980, Peter Cartwright started his own consulting engineering company and has performed consulting services for more than 250 clients in virtually all aspects of water and wastewater treatment. He has authored over 150 articles, several book chapters, and is currently writing a book on membrane technologies.
## QUIZ 4: Introduction to High Purity Treatment Trains (0.25 CPD)

1. Which of the following is not a category of water contaminants?
   - a. TCE
   - b. TDS
   - c. TOC
   - d. TSS

2. Municipal water is sometimes used as a feedwater source in a high purity water treatment system. Which of the following treatment methods often used in municipal water must be taken into consideration for its effects on high purity treatment technologies?
   - a. Reverse osmosis
   - b. Ultraviolet radiation
   - c. Activated carbon filtration
   - d. Chlorination

3. The three components of treatment in a high purity water treatment train are:
   - a. Filtration, Deionization, UV
   - b. Deionization, Reverse Osmosis, Ozonation
   - c. Pretreatment, Primary Treatment, Post Treatment
   - d. Physical Treatment, Chemical Treatment, Ionic Treatment

4. Why are two activated carbon filters in series used in a treatment system for hemodialysis?
   - a. The second filter provides an added layer of protection against endotoxins
   - b. The second filter provides an added layer of protection against sediment
   - c. The second filter provides an added layer of protection against chlorine
   - d. The second filter provides an added layer of protection against TOC

5. Which analyte is not covered by the AAMI standard in the raw water for the dialysis system?
   - a. Bacterial counts
   - b. Chlorine residual
   - c. Calcium concentration
   - d. TOC

6. A typical goal of primary treatment in a high purity water treatment train is to:
   - a. Soften the water
   - b. Remove suspended solids (TSS)
   - c. Adjust pH
   - d. Remove dissolved solids (TDS)

7. Pretreatment in a high purity water treatment train typically includes:
   - a. Reverse Osmosis
   - b. Ozonation
   - c. Softening
   - d. Distillation

8. What is accomplished by placing the activated carbon filter downstream of the softener in the pre-treatment stage of an application using chlorinated municipal water as the influent?
   - a. Controls bacteria levels in the softener
   - b. Reduces TOC concentration
   - c. Catches particulates the softener may shed
   - d. Further reduces TDS concentration

9. When is post-treatment used?
   - a. When water is used for secondary applications
   - b. Following the treated water storage tank
   - c. To bring RO water to 18 megaohm-cm quality
   - d. To remove chlorine after the softening stage

10. What is the purpose of a “guard” filter?
    - a. To “guard” against dissolved solids contacting 18 megaohm-cm water
    - b. To protect treated water against sediment from treatment equipment
    - c. To prevent chlorine breakthrough in hemodialysis treatment systems
    - d. To protect an RO from chlorine or other oxidants

11. Why is the pre-treatment equipment sized for somewhat larger flow rates than the primary treatment requires?
    - a. To provide treated water that can be used to clean pre-treatment equipment
    - b. To insure a sufficient flow rate at the primary equipment in case of reduced production at the source
    - c. To insure a sufficient flow rate and volume is available at the point of use
    - d. To provide additional turbulence for mixing in the storage tank
Instructions
Please use the answer sheet below to record the correct answers. When you have completed the quizzes you would like graded, detach the answer sheet from the booklet and mail to the address below or fax. The answers must be 70% correct to earn credit.

WQA Recertification Newsletter - Issue VII Quiz
Answer Form

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<th>LAST NAME</th>
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Please record your answers below.
Quizzes may also be completed online. Go to www.wqa.org/Recert-Kits and follow the link for the WQA Education Kit, volume 7.

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<th>Quiz 1</th>
<th>Quiz 2</th>
<th>Quiz 3</th>
<th>Quiz 4</th>
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<td>Residential Water Treatment Design</td>
<td>Making Sense of an Incomplete Water Analysis</td>
<td>Introduction to High Purity Treatment Trains</td>
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When you have completed the quizzes, detach the answer sheet from the booklet and mail, email or fax it to:

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