Reducing Occupational Risks of Microbial Contaminants in Water

By Kelly A. Reynolds, Ph.D.

A variety of human pathogens are known to be present and transmitted via water. The World Health Organization reports that 16.4 million deaths worldwide were due to infectious and parasitic diseases in 1993. Estimates of up to 80 percent of these are thought to be linked to contaminated water, equaling over 35,000 deaths a day.[3]

Throughout the world, one in four hospital beds is occupied by someone that is there because he or she became sick from consuming unsafe water. Public health agencies suspect reported waterborne disease is only the tip of the iceberg relative to the actual number of cases. Many victims of water-borne illness either do not seek medical attention or are not properly diagnosed, resulting in significant underreporting. The economic impact of the "stomach flu" in the United States is estimated up to $20 billion per year, but how much is due to water-borne, food-borne or airborne illness is unknown.[8]

In addition, even when a water-borne outbreak is recorded, in nearly half of the cases, no etiological agent is identified. For microbial waterborne outbreaks in the United States between 1980 and 1990, the causative agent was not identified in 43 percent of all cases.[2] The primary causative agents that were identified were *Cryptosporidium* (20 percent), viruses (15 percent), *Giardia* (11 percent), bacteria (10 percent) and miscellaneous pathogens (1 percent).

In 1992, 40 percent of all lakes and rivers in the United States were deemed unfit for swimming or drinking, with pathogens being the second most common cause for impairment.[16] Enteric pathogens, or harmful organisms of the gastrointestinal tract, are primarily passed via the fecal/oral route. Once a pathogen is ingested, they multiply and are excreted in the feces of infected individuals. Other environmental pathogens are transmitted via

Table 1: Major Water Related Pathogens

Group	Pathogen	Disease or Condition
Viruses	Enteroviruses	meningitis, paralysis, rash, fever, myocarditis, respiratory disease, diarrhea
	Hepatitis A and E	hepatitis
	Norwalk virus	diarrhea, vomiting
	Rotavirus, Astrovirus, Calicivirus	diarrhea
	Adenovirus	diarrhea, eye infections, respiratory disease
	Reovirus	respiratory, enteric
Bacteria	*Salmonella*	typhoid, diarrhea
	Shigella	diarrhea, fever
	Campylobacter Yersinia enterocolitica	diarrhea
	Vibrio cholerae	profuse watery diarrhea, rapid dehydration, vomiting
Protozoa	*Naegleria*	meningoencephalitis
	Entamoeba histolytica	amoebic dysentery
	Cryptosporidium, Giardia	diarrhea
Blue-green algae	*Microcystis, Anabaena, Aphanizomenon*	diarrhea, blisters, pneumonia, possible production of carcinogens
Helminths	*Ascaris lumbricoides*	ascariasis
	Trichuristrichiora	Trichuriasis-whipworm
	Necuteramericanus	hookworm
	Taenia saginata	beef tapeworm
	Schistosoma mansoni	Schistosmiasis (complications of liver, bladder and large intestines)

(Source: modified from C.P. Gerba, "Pathogens in the Environment," *Pollution Science,* Academic Press, San Diego, Calif., 1996.)

Table 2: Characteristics of Water Related Pathogens

Organism	Size (pm)	Shape	Environmentally Resistant Stage
Viruses	0.01-0.1	variable	virion
Bacteria	0.1-10	rod, spherical, spiral, comma	spores ordormant cells
Protozoa	1-100	variable	cysts, oocysts
Helminths	1-10[9]	variable	eggs
Blue-green algae	1-100	coccoid, filamentous	cysts

(Source: modified from C.P. Gerba, "Pathogens in the Environment." Pollution Science. Academic Press. San Diego. Calif.. 1996.;

aerosols, vapors and mists and can enter through mucus membranes of the eves, nose and mouth. In addition, abrasions in the skin may offer a route of pathogen entry and infection.

Table 1 is a limited list of pathogens associated with waterborne illness. These pathogens may be infectious or they may initiate illness by producing harmful toxins. Table 2 shows the relative size, shape and environmental form of each general class of pathogenic microorganisms that may be found in water.

Water-related viral pathogens

Many of the enteric waterborne viruses are known to persist for months in the aquatic environment, much longer than mostenteric bacteria. Their small size also allows for extensive movement through soil and water. While they are also known to cause vomiting and diarrheal disease, the range of illness varies and includes serious or fatal afflictions such as meningitis, hepatitis and paralysis. The incubation period from the time of exposure to the manifestation of illness may be anywhere from l-to-65 days, depending on the nature of the virus, with symptoms generally lastinghours to months. Infections are usually self-limiting with treatment generally confined to supportive therapy.

Enterovirus

Enteroviruses were first isolated from sewage and water. This group comprises 3 strains of poliovirus, 34 strains of echovirus and 30 strains of coxsackievirus and may play a role in insulin dependent diabetes, heart disease and miscarriages.[1,7610]

Hepatitis

Hepatitis E virus has been linked to large outbreaks in developing areas and primarily attacks young adults (15-40 years of age) with a high case fatality rate among pregnant women (30 percent).[1^] An HEV outbreak, linked to surface water in India affected 79,000 people.[10] No outbreaks, however, have been reported in the United States. In contrast, 98 percent of the population has antibodies to hepatitis A virus, a common environmental contaminant in developed countries. The most common agent identified in outbreaks is Norwalk virus, first associated with an outbreak in Norwalk, Ohio, in 1968. This virus cannot be artificially cultured in the laboratory and, thus, data on survival times, infectivity, susceptibility to disinfection and presence in the environment is limited.

Rotavirus, etc.

In addition, rotavirus is a major risk to infants as the leading cause of infant mortality due to pediatric diarrhea . Other potentially important water-related viruses include calici virus, adenovirus and reovirus.

Water-related bacterial pathogens

Major bacterial pathogens in water include *Salmonella sp., Shigella sp., Campylobacter sp., Yersiniaenterocolitica, Vibrio cholerae, Escherichia coli* (certain strains) and *Legionella sp.*

Salmonella to E. coli

Salmonella is often associated with typhoid fevers, resulting in weeks to months of malaise, vomiting, cough and abdominal pain. There are 2,000 serotypes, all pathogenic to humans, producing potentially fatal toxins. Concern over these pathogens extends to foods, as they grow in beef and chicken. *Shigella,* on the other hand, is only found in humans and may be transmitted via recreational or drinking water. *Campylobacter* and *Yersinia* are often traced to animal feces and may be transmitted by food or water. *Vibrio* is a native marine organism associated with watery diarrhea. The effect of rapid dehydration has lead to a 60 percent fatality rate with *Vibrio cholerae* infections.[8] *E. coli* is found in the gastrointestinal tract of all warm blooded animals and is usually harmless. However, certain strains, such as the enterotoxigenic and enteropatho-genic *E.coli,* cause profuse watery diarrhea, cramps, vomiting and may be the cause of "travelers diarrhea". In addition, enterohemorrhagic *E.coli,* O157:H7 produces potent toxins causing bloody diarrhea and often leading to fatality in the young and the elderly.

Legionella

Legionella is thought to be common to natural waters and generally harmless unless conditions allow it to proliferate to higher levels of concentration. No outbreaks have been directly linked to natural waters but under conditions of stagnation and warming (optimal is 37°C), the organism enters it's growth phase and, at higher concentrations, may cause Legionnaire's disease or a milder illness known as Pontiac fever. In 1976, 34 members of the American Legion contracted fatal *Legionella* infections after attending a conference in Philadelphia, Pa. This organism tends to persist and grow in faucets, shower heads, cooling towers, dental lines and hot water tanks and are more resistant than indicator bacteria to common methods of disinfection.

Parasites

Giardia lamblia and *Crytosporidium* spare parasites associated with water-borne outbreaks and are known to be highly resistant to conventional methods of disinfection. *Giardia* has been associated with an outbreak as early as 1965. Community outbreaks are often associated with the lack of filtration as a treatment method. A variety of wild animals are known to harbor the organism and it can often be isolated from surface waters and otherwise pristine water sources. *Cryptosporidium* was first associated with human disease in 1976 and first identified with an outbreak in 1984.[6] This organism infects cattle and is estimated to occur in 55-to-87 percent of all U .S. surface waters and as much as 27 percent of the filtered drinking water supply.[15] The largest waterborne outbreak on record was due to *Cryptosporidium,* infecting 400,000 persons in Milwaukee, Wis., and resulting in 104 deaths in 1993.[1] Although bacterial indicator levels were met in the water supply, *Cryptosporidium* was still present, possibly due to recent heavy rains and abnormally high runoff levels just prior to the outbreak. Other parasites associated with or suspected of causing water-borne disease include: *Balantidium coli, Entamoeba histolytica, Naegleria, Cyclospora,* and *Microsporidiwn.*

Helminths and algae

Two more groups of water associated pathogens include helminths and blue-green algae. Examples of helminths are tapeworms, roundworms, ascaris, and nematodes. One female helminth can lay up to 200,000 eggs per day. The eggs persist in the environment and become ingested by a human host, often resulting in illness. Worldwide, numbers of infected individuals are currently estimated at 800,000 to 1 billion, primarily in tropical and subtropical regions.[8] Most U.S. infections occur in the Gulf of Mexico region. Blue-green algae occur naturally in the environment and are an important contribution to the food chain and nutrient cycles. But, under conditions of high nutrient levels in water, these organisms begin to increase in concentration and produce toxins harmful to wildlife, livestock, pets and humans.

Protecting yourself

Knowing that pathogens are present in waters, questions therefore a rise from water treatment service personnel, water store operators and other water industry employees, as to the risk of exposure to these disease-causing organisms.

The potential dose to water industry employees may be much higher than the general public since part of their task may be to handle filters specifically designed for, or incidental to, pathogen removal. Therefore, water treatment personnel are potentially exposed to the equivalent volume of water that previously passed through the filtering device. An entire science of "risk assessment" has evolved with formal approaches to identifying, characterizing and estimating the probability of becoming ill from exposure to environmental pathogens.[4 & 13] Using mathematical models and recently developed software packages,[14] risk assessment can help to evaluate the public health significance of exposure to even low levels of microorganisms in waters, based on data from previous infectivity and epidemiological studies. Predicting risk is invaluable for determining areas in need of attention for pathogen and public health control but water treatment personnel must find ways to minimize their individual exposure risk. This can be accomplished through the use of a few simple barrier approaches.

The first line of defense against pathogen exposure is contact avoidance at the route of transmission. Transmission routes are usually oral, respiratory or subcutaneous. Pathogens may reside on inanimate surfaces, such as filters and housings and be transferred to hands that may easily contact the mouth, eyes and nose. Organisms may also be aerosolized and transmitted in mists, resulting in oral and respiratory ingestion of pathogens. Studies have shown that a simple flush of a toilet produces pathogen-containing aerosols traveling a distance of more than five feet in every direction." Therefore, conditions of backpressure release and aerosol production should be minimized during service operations.

The second line of defense from pathogen exposure is to protect exposed areas of transmission. Macro-and micro-abrasions of the skin may serve as an entry site for pathogens. Wearing designated clothing, gloves, masks and glasses will help to minimize pathogen transmission. Gloves and masks are often disposable and should be changed frequently to prevent cross contamination of other surfaces.

Safety equipment

Protective clothing—Task-specific clothing, such as designated work shirts or lab coats, art[1] desired since pathogens are known to survive on surfaces and be transported to other individuals. Adenovirus type 3, for example, has been shown to survive up to 10 days on paper, under ambient conditions, while type 2 survives from 3-to-8 weeks on environmental surfaces.[11] Clothing should be frequently laundered.

Eye protection—Protective eyewear may be useful to prevent exposure to splashes, splatters or mists. Safety, style and comfort should all be considered when choosing appropriate eye protection. Side shields are useful for preventing aerosols from reaching the eye from the side of the lenses. Goggles are designed to fit over prescription lenses for added safety. Safety goggles or glasses should be washed after each use with an antiviral /bacterial soap and water or ethanol solution.

Hand protection—Hands should be well cleansed prior to touching any objects, or eating, using an anti-bacterial/viral soap. A variety of protective gloves are available, each suited to particular situations. Gloves may be constructed of a wide range of materials including natural rubber, leather, neoprene, nitrile or latex. Each offers unique protection for a multitude of applications. Latex gloves, for example, are commonly used, providing inherent elasticity and maximum dexterity. However, they are prone to pinhole punctures and cracks that are invisible to the eye but vast to a microorganism. Therefore, two layers of latex can be worn for added protection against microbes. If a sample is suspected of being highly contaminated, gloves are available which supply the ultimate protection with no measurable permeability to microorganisms. SilverShield gloves (Siebe North, available through Fisher Scientific, Pittsburgh, Pa.) offer a dependable and economic solution by providing disposable, lightweight and flexible gloves that are resistant to tears and highly impermeable. In addition, N-Dex Nitrile gloves (Best Manufacturing, available through Fisher) also are highly resistant to punctures or invisible abrasions. This material tears easily, once violated, so that minute punctures do not go unnoticed.

***Surface disinfection*—Finally, surface** disinfection may help to decrease occupational exposure to pathogens. Surfaces suspected of contamination may be wiped with a 10 percent solution of household bleach, 95 percent ethanol or a variety of microbial disinfectants available on the market to minimize contact exposure. Any filter medium or equipment removed from devices where pathogens may accumulate should be carefully placed in plastic, sealable bags for transport and disposal.

Conclusion

Always keep in mind the variety of pathogens potentially present in water and protect yourself from exposure and risk of illness by taking these few precautionary steps. Also, realize that immunocompromised individuals are at increased risk of becoming infected by pathogenic organisms and have a higher probability of being hospitalized or dying. Conditions resulting in compromised immunity include organ transplant, chemotherapy, pregnancy, current illness, excessive smoking and drinking and age (very young or elderly). Most importantly, be aware of the potential hazards and exposures, determine your acceptable risk and plan accordingly to take safety precautions and utilize the plethora of protective equipment available. □

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Tel: (404) 639-3235
Fax: (404) 639-3236
Website: www.cdc.gov
Chief: Dr. Richard Knudsen

National Institutes of Health

Division of Safety,
Occupational Safety & Health
9000 Rockville Pike
Bethesda, MD 20892
Tel: (301) 496-2346
Fax:(301)402-0313
website: www.nih.gov/od/ors/ds
Chief: Deborah Wilson

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Safety Products Division, Customer Service
1801 Gateway Blvd., Ste. 101
Richardson, TX 75080
Tel: (800) 926-8999
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Website: http://www.fisher1 .com

SWING INTO SPRING

Part 1

Is Show Selling Right For You?

By Lee Edwards

Editor's Note: This is the first of a two-part series to usher in the spring show season for the water treatment professional looking to expand his business options in 1998. The first part focuses on tips for the big shows hosted by convention centers and state fairgrounds, etc., in your state capital or county seat. The second, which will run in May concentrates more on the smaller shows-be they local home shows, business expos, mall shows or county fairs and festivals.

Some water equipment companies we talk with tell us that trade shows and malls are a huge source of business. Others say they never get real business from shows and malls. We have one client who does so well that they have a separate team of people just to work shows. No matter where you live or what you sell, shows should be a good and inexpensive source of leads. Take a look at some of the ways the real showmen make every gathering a success.

What shows work?

Almost any show that draws homeowners can be successful. This includes fairs, home shows, etc., but it also includes craft shows, ski shows, boat shows, wine shows—almost any show that is geared to people with families and disposable income. Also, malls are excellent sources of leads. Almost any gathering will produce results if you approach it correctly.

Drawing a crowd

Many companies spend hours working on signs for their booths, but our research shows that very few companies report people coming up and reading the signs and making a decision. Use signage to identify yourself but that's about all signs will do for you. As you will see, we believe your staff can stop the people as they go by and that signs and attractions are unnecessary.

Many water equipment dealers use the giant suspended running faucet (which was once patented by Culligan but is now available to anyone). It is a good attraction but has the problem of running water, which cannot be left unattended for even a minute or it can get water all over.

Other companies now may use a pump-assisted reverse osmosis (RO) display. They pour food dye and assorted terrible looking substances into water and pass it through the RO. They display the waste tank and the product water and even "amaze" the audience by drinking the product water.

Some dealers make attractive booths by running miniature lights through clear PVC pipe and using it to create a booth that is light, easy to assemble, eye-catching and relatively inexpensive.

Short shifts

We recommend you do not book long shifts. Look at shows and malls and you often see worn-out sales staff sitting in chairs, too tired to be friendly or ambitious. If a mall or other show is open 12 hours, make your shifts short. With a 6-hour shift, time is available for sales people to go out and do demonstrations immediately. For example, a sales person on shift at a show from 9 a.m. to 3 p.m., has time to go out that same day and do demonstrations after 3 p.m. with any people they met at the show.

We also recommend you never have chairs in your booth. Your staff should stand and work their entire shift. If they can't do it, assign shorter shifts. A comfortably seated sales staff ends up talking to each other and is difficult for buyers to interrupt. Less comfort means more sales. Make sure your staff knows that no one, for any reason, cannot attend their show shift. Not appointments, sales or family emergencies can stop the shift. If you allow them to go out and get a sale during a show shift, you run the risk that they all will and your booth will be unattended.

Working the aisles

We recommend that you have at least two sales people on each floor shift. You cannot work shows with one person. One person means one customer ties up the entire staff. One person means any breaks for smoking, eating, phoning, washroom or meals leaves your booth unattended.

It's recommended you have two water coolers right at the edge of your booth, close to the aisle. You can also stock your booth with lots of bottles of water and small paper cups to offer passers-by. Be sure to ask those who

The BASICS of CHEMISTRY

by C.F. "Chubb" Michaud

Summary: *Water chemistry is basic but, nonetheless, it's still chemistry. Some people shy away from trying to understand this subject because they feel it's over their heads. However, understanding the fundamentals of chemistry is necessary in order to grasp the full breadth of how certain aspects of water filtration work—especially ion exchange.*

Part 1 of this article will point out the basic ionization process and the relationships that exist between one species and another. It will also introduce the reader to the wealth of information available on the Periodic Table of Elements, the universal guide to chemical properties. Part2 will examine the guidelines for the proper use of a water analysis and point out some traps to avoid. Part 3 will then describe how to use chemistry and ion exchange selectivity to solve certain treatment problems.

Mother Nature keeps an orderly house. There are less than 100 elements "in nature" and, by definition, they're all separate and distinct from one another. Copper, nickel, tin, zinc, sodium and oxygen are all elements.

Elements are made up of a balanced number of positive and negatively charged particles called protons (+) and electrons (-), which, along with neutrons (which are neutral), form an atom of that element. The atom is the smallest particle still identifiable as having the properties of the element. All elements are, being balanced with the same number of electrons and protons, neutral in charge.

All elements can—and do—have different numbers of protons with a matching number of electrons. Hydrogen (H) has only one whereas Helium (He) has two. Lithium (Li) has three and so on all the way up to Uranium (U), which has 92. Plutonium (Pu), a manmade element that doesn't exist in nature, has 94 electrons and protons. The heaviest element known, Unihexium (Unh), also manmade, has 106. So, all numbers from 1 to 106 are accounted for. Each differs by only one proton and each is a totally separate substance with its own unique properties.

We use the term Atomic Number (AN) to identify each of the elements and this number corresponds to the number of electrons of the element. These various elements are conveniently arranged on a chart we refer to as the Periodic Table of Elements (see *Figure 1*). The periodic table contains a wealth of information such as density, melting point, boiling point as well as valence, atomic weight and atomic number. Elements are grouped in "families" which have similarities and predictability of reaction.

Atomic weight (AW) represents the mass of an element and is the total of its protons and neutrons. It is possible to have elements of differing atomic weight, but with the same atomic number because the number of neutrons can vary. We refer to these variations as isotopes. For example, chlorine, which is element 17, can have 18 or 19 neutrons. Therefore, it has an atomic weight of 35 or 36. Since these two common isotopes exist in nearly the same percentage, we assign chlorine an atomic weight of 35.5.

The jagged line drawn through the chart in Figure 1 separates the metals from the non-metals (on the right). This helps you to determine how that substance will react with oxygen and subsequently, how that compound will react with water. You might have noticed that boron (B), carbon (C), nitrogen (N), fluorine (F), silica (Si), phosphorous (P), sulfur (S), chlorine (Cl), arsenic (As), etc., on the non-metal side all seem to end up on the same side of the salt molecule. In other words, they are the acid formers whereas hydrogen, sodium, calcium, etc., are the base formers.

When subjected to heat in the presence of oxygen, most metals will form a metal oxide. The most common observation of this is rust, which is iron oxide. Lime is calcium oxide (CaO) and caustic (Na_20) is sodium oxide. If we subscribe to the theory of a fiery creation, we can readily see where the heat came from. When a metal oxide is dissolved into water, a basic, or alkaline, solution is created, as can be seen in Reaction 1 in Figure 3. Non-metals, such as sulfur (S) and nitrogen (N) also form oxides, but when dissolved into water, they form acids. (See Reaction 2 in *Figure 3.)*

When elements combine to form compounds, nature preserves the laws of neutrality. Ammonia (NH_3) is a gaseous compound made up of one atom of nitrogen and three atoms of hydrogen.

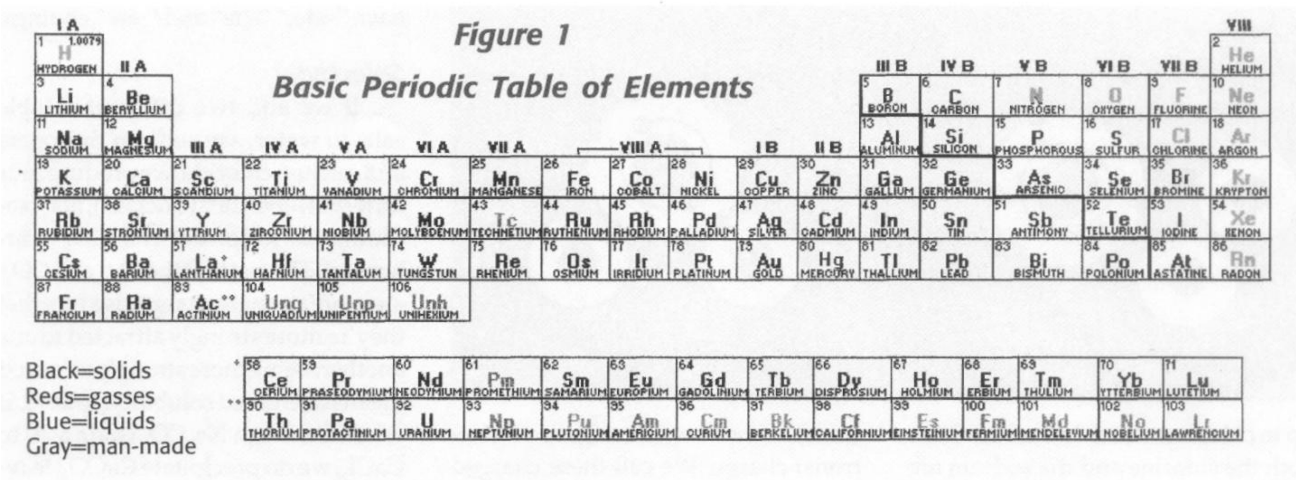

Figure 1

Basic Periodic Table of Elements

Sodium chloride (NaCl) is a compound that's a salt. What determines how many of this will react with how many of that to form so many of those also is fixed by the nature of the element.

The importance of orbits

The electrons contained in each of the elements are arranged in electron orbits around the shell of the atom's nucleus (center). There is more than one orbit—in fact, there are many. However, each orbit is filled with only a certain number of electrons and that number is more or less the same for all of the elements. Since the number of electrons differs by only one from one element to the next on the periodic chart, only the outermost orbit will contain a different number of electrons. This tiny difference determines many of the properties of that element and the family to which it belongs. For instance, hydrogen, lithium, sodium and potassium all have only one electron in their outermost orbit. Magnesium, calcium and strontium each have two. Fluorine, chlorine, bromine and iodine—the halogen family—each have seven. On the far right of the Periodic Table, helium, neon, argon, krypton, xenon and radon form the inert gasses (non-reactive). Are we starting to get the picture of just how valuable the periodic table might be?

When electrons react to form compounds, they tend to go to a less reactive state. In other words, they try to imitate the "relaxed" state of the inert gases by filling their outer orbits to completion. The innermost orbit needs only two electrons (or zero). The outermost generally wants eight. We can see from the periodic table that hydrogen, AN-1, has only one electron in its outer orbit. Oxygen with an AN=8 has two in its inner and six in the outer. To be "satisfied," hydrogen will give up its electron and oxygen will pick it up. However, to satisfy the full demand of the oxygen, it will require two hydrogens to make the supreme sacrifice— thus, forming the basis of water. This is shown in Reaction 4 in Figure 3 as well as graphically with a depiction of the electron exchanged in Figure 2.

Other than the inert gases, all elements will have from one to seven electrons in their outer orbits. They can either give them up or pick up additional ones to satisfy a full orbit. Sodium, which has one, will give that

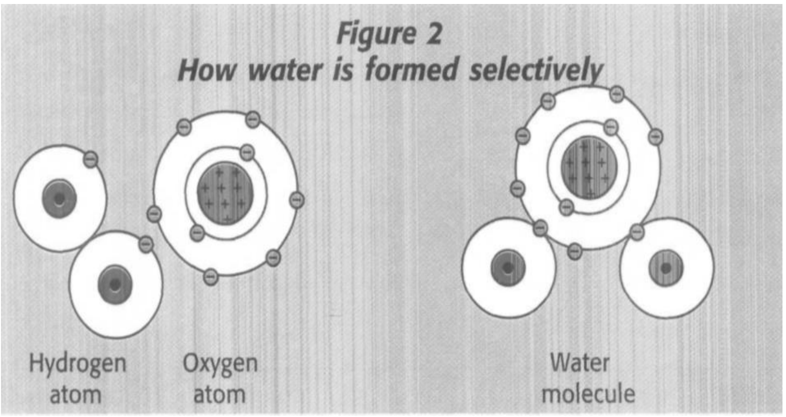

Figure 2
How water is formed selectively

up to chlorine, which has seven. Thus both the chlorine and the sodium are satisfied and the resulting compound, NaCl, is neutral. Potassium has one and oxygen has six. Therefore, oxygen needs two and the resulting compound of potassium oxide is balanced as K_2O.

The role of salt and water in ion exchange

When salt is dissolved in water, the two components of the salt separate. However, they don't regain their original electron counts and therefore are no longer neutral. Since they now have either gained or lost electrons (which have a negative charge), they'll have either a net positive (loss of electrons) or net negative (gain of electrons) charge. We call these charged particles ions. The positive ion is called a cation and a negative ion is called an anion. The number of electrons gained or lost by the element determines the strength of the charge. We call this charge its valence and we denote this by writing the symbol for the element or compound with a corresponding number to signify its ionic charge. Thus, sodium is Na and its ion is Na^+. Chlorine is Cl and its ion is Cl^-.

Table 1 lists some of the more common elements found in tap water, the compound form most likely and its valence.

In general, all metals—even gold—will form oxides and, therefore, bases; Most non-metals will form acids. Acids neutralize bases to form salt and water. This is the most fundamental reaction in chemistry and perhaps, the most important one for ion exchange function. This reaction is shown in Reaction 3 in Figure 3.

Water, H_2O, does not ionize as H^+ and $O^=$. Instead, it becomes H^+ and OH^-. We call the OH ion a hydroxyl ion and denote it with a negative one charge. These two ions are the backbone of the ion exchange demineralizer reaction, which is very simply a commercial application of the most basic law of chemistry shown, again, in Reaction 3 in Figure 3.

Table 1
Common Elements Found in Tap Water

Element	Ionic Form	Valence
Calcium	Ca^{++}	+2
Magnesium	Mg^{++}	+2
Sodium	Na^+	+1
Potassium	K^+	+1
Aluminum	Al^{+++}	+3
Iron	Fe^{++}	+2 (ferrous)
	Fe_2O_3	0 (ferric, rust)
Manganese	Mn^{++}	+2(manganous)
Fluoride	F	-1
Chloride	Cl^-	-1
	OCl^-	-1 (free chlorine)
Oxygen	OH^-	-1 (hydroxy!)
Nitrogen	NO_3^-	-1 (nitrate)
	NO_2^-	-1 (nitrite)
	NH_4	+1 (ammonia)
Sulfur	SO_4	-2 (sulfate)
	SO_3	-2 (sulfite)
	S=	-2 (sulfide)
Carbon	HCO_3-	-1 (bicarbonate)
	CO_3=	-2 (carbonate)
Silica	SiO_2	0 (colloidal)
	H_2SiO_3	<-1 (weakly charged acid)

Although we commonly refer to sodium chloride (NaCl) as "salt"— which it is—it's not the only salt. Any product of neutralization between an acid and a base will form a salt. Magnesium sulfate is a salt; potassium citrate is a salt. The names of salts usually have "-ide," "-ite" and "-ate" endings.

Selectivity

If we add two different soluble salts to water, say sodium carbonate and calcium chloride, we produce four different ions: Ca^{++} (calcium), Na^+ (sodium), Cl^- (chloride) and $CO_3^=$ (carbonate). The fact that the Ca^{++} and $CO_3^=$ are more strongly charged is a hint that they're more strongly attracted to one another. Being more strongly attracted means decreased solubility. Indeed, if we add enough Na_2CO_3 (soda ash) to $CaCl_2$ we do precipitate $CaCO_3$ leaving a solution of salt (NaCl) and perhaps some excess Na_2CO_3 and a slight amount of soluble $CaCO_3$

This process has been used for effectively softening water (removing excess hardness). We see in this example that the ions exchange partners (hence the name, ion exchange) in order of attraction and ionic strength. This is known as ion selectivity and is the backbone of the ion exchange process.

As shown by Reaction 5 in Figure 3, certain elements or compounds in water can be made to undergo specific selective reactions and these reactions are predictable to some degree according to the element's family association in the periodic table. Divalent ions (those with a double positive charge) such as calcium and magnesium, will react with soap and cause "bathtub ring." They also will react with the carbonate ion to form scale in pipes and heaters. Although we could precipitate these salts with the addition of carbonate ions (see Reaction 5 in *Figure* 3), we have no easy way to remove the resulting solid. Likewise, we can neutralize an acid with a base (see Reaction 3 in *Figure* 3), but we end up with a soluble salt in our water.

With ion exchange resins, only the exchangeable ion is soluble. The counter ion, which is the resin bead itself, is not. This makes the separation after the exchange very easy. In the case of a softener, the resin has an exchangeable Na^+. The hardness (Ca^{++} and Mg^{++}) combined with the resin forms a very strong bond. The water,

Figure 3

Reactions

When a metal is dissolved in water, a basic, or alkaline solutions is created:

Reaction (1)

$FeO + H_2O \rightarrow Fe(OH)_2$

iron oxide, water, iron hydroxide

$Na_2O + H_2O \rightarrow 2\,NaOH$

sodium oxide, water, sodium hydroxide

Non-metals like sulfur and nitrogren also form oxides, but when dissolved into water, they form acids:

Reaction (2)

$SO_3 + H_2O \rightarrow H_2SO_4$

sulfur trioxide, water, sulfuric acid

Acids neutralize bases to form salt and water:

Reaction (3)

$2NaOH + H_2SO4 \rightarrow Na_2SO_4\ 2HOH$

caustic, acid, salt, water

$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2HOH$

lime, acid, salt, water

The formation of water is expressed as:

Reaction (4)

$2H + O \rightarrow H_2O$

hydrogen, oxygen, water

Reaction (5)

$CaCl_2 + Na_2CO_3 \rightarrow 2NaCl + CaCO_3$

Calcium chloride, Sodium carbonate, Sodium chloride, Calcium carbonate (precipitate)

Ion exchange with cation exchanger:

Reaction (6)

$NaCl + {+H^+} \quad {+Na^+} + HCl$

salt, cation exchanger, exhausted exchanger, acid

Ion exchange with anion exchanger:

Reaction (7)

$HCl + OH^- \rightarrow Cl^- + HOH$

acid, anion exchanger, exhausted exchanger, water

minus the hardness, passes on through because the resin is retained in the exchange column. Sodium (or potassium) replaces the hardness on an equivalent basis. This means that it will take two sodium ions from the exchange bead to replace a single calcium or magnesium ion.

In the case of demineralization, both the cations and the anions must be exchanged. This is done by using two different resins regenerated with acid and caustic respectively. The water passes through the cation exchanger first where the positive ions (cations) are exchanged for hydrogen ions (H+). (See Reaction 6 in *Figure* 3.) The acid solution is then passed through an anion exchanger where the acid is neutralized by the exchange of the acid ion (C1-) for the hydroxyl (OH) ion. (See Reaction 7 in *Figure* 3.)

Conclusion

The periodic table of the elements places all elements into families that help us predict properties and determine similarities. We have shown that there is a preferred coupling of certain elements to form reactions (such as $CaCO_3$ precipitation) that lead us to methods of removing those elements from water. This can be done either selectively (such as in softening) or completely (as in demineralization).□

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SAUDI ARABIA

The heart of the Arab World struggles through dry times

By Henry R.Hidell, III

The Kingdom of Saudi Arabia is situated in one of the most strategic regions in the world. The Kingdom has long been one of the major trade routes between East and West—situated as it is between Asia, Europe and Africa. Today, the Kingdom reflects its history of tremendous wealth from the exploitation and development of its oil reserves. Its culture is dominated by the Islamic faith. However, it is a country in transition.

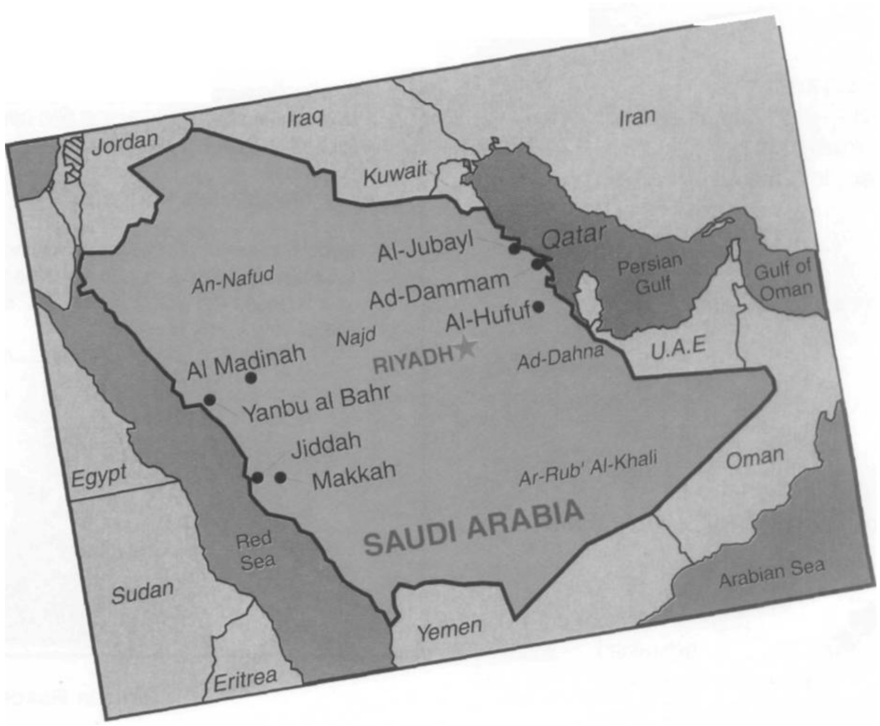
The Saudi Arabian peninsula is about the size of Europe—1,960,582 square kilometers—and contains a variety of landscapes. Some are rich and fertile with high agricultural output while others consist of high dunes and desert conditions. The Rub al Khali or the "Empty Quarter" is a sand desert in the southern area of the peninsula containing 250,000 square miles, the largest sand desert in the world.

The history of modern Saudi Arabia starts at the turn of the last century when Abdul Azizibn Abdul Rahman al Saud consolidated his power by assembling the major tribes of the peninsula through a 30-year conquest. He proclaimed himself King of Saudi Arabia in 1932. In 1953 when he died, he had some 40 sons, assuring the family Al Saud would forever remain the most influential in the country. The Kingdom is located in a region of the world facing continuous political and religious disputes between moderate and "hardline" religious factions and between those factions and the region's political elements. This condition has influenced Saudi Arabia's business climate significantly.

Population and imported labor

The population of Saudi Arabia is estimated to be about 18-plus million. It's expected to rise to more than 20 million by the year 2000. The population of the rest of the Saudi Arabian peninsula is expected to increase to 10 million people, for a total population on the peninsula of more than 30 million by the year 2000. Growth is expected to be particularly strong in the United Arab Emirates, where people (including many expatriates or foreign workers) have been drawn to service the large financial center emerging in Dubai and industrial development in Abu Dhabi. All of this growth will place a strain on resources of the region, particularly water.

In large part, Saudi Arabia has generally been required to rely on expatriate labor such as Europeans, Indians, Pakistanis, Egyptians and Filipinos. The Saudi national labor force has not been well developed since there is little financial incentive to work because of



send everything all to them, ready to assemble."

Though this portion of the business is only a year old, several customers, including one in Tokyo, are already in the pipeline and Barry hopes that number will grow.

Higher learning

To foster continued success in his business, Barry places a strong emphasis on education—for both his employees and customers. He believes this commitment to knowledge and customer service is what differentiates his business.

To that end, he has an area in his water stores that lists questions along with answers for the most common water problems. "We have a wall that says, 'Everything you wanted to know about water, but didn't know who to ask.' We answer questions such as, what is a micron, how big is a micron? You're selling a 5-micron filter; they don't know what that is," he says. All told, about 30 different topics are covered. He even has a filter cut in half so people can see how everything fits together and works.

In addition to this kind of education, Barry stresses professional certifications for his employees. He and his two store managers just passed the Water Quality Association's (WQA) first level of certified water specialist exams (CWS-I) and they each have plans to continue on through to the strenuous CWS-V. In fact, they are the only three water quality professiona 1 s to have achieved any sort of WQA certification in Hawaii.

"We encourage all our employees to do this," Barry says. "We pay for their study materials. We pay for testing and we send them to the mainland to take the test. We also give them a $1,000 bonus at each stage."

Generally, three of the nine staff members attend the WQA show each and Barry tries to rotate attendance so that everyone has a chance to attend. Also, he and members of his staff attend the International Bottled Water Association's annual meeting.

The importance of service

Barry feels this investment in his staff only leads to improved customer service—and happier customers.

"We have really good employees, really intelligent people," he says, "They're highly paid for this industry and they all manage their own areas and they do a very good job."

In addition to a commitment to knowing as much as they can about their customer's water problems, Barry consults his customers daily to see where they might improve.

"We put out a lot of surveys to our customers and that's where we've learned a lot. They ask us things like, 'Could you put another light on the porch? Could you light the parking lot up a little better? Could you put another machine that changes $5 bills?' These types of things we've learned from our customers," he says.

Looking ahead

As for what the future holds, Barry sees a continuing big need for water treatment systems in his area.

"We have a lot of notices here. Things like, 'Sorry, your water had coliform bacteria in it.'" And, given Hawaii's agricultural focus on crops like sugar cane and pineapple, a lot of pesticides and herbicides are sprayed, which can eventually find their way into the water supply.

With this in mind, Barry sees people becoming more and more aware of the water they drink. "They realize the water coming through their pipes and into their homes may be good for some applications, but not for drinking," he says.

As a result, he sees a lot more companies entering the field, promising cure-all products. But, on the upside, he also sees customer's placing a higher value on the dealer's knowledge and expertise.

To demonstrate this point, Barry points to the phone calls he received recently when the local newspaper ran a release stating that Barry and his two store managers had achieved the CWS-1 level.

"We had a hundred people calling us, congratulating us," he says, "They know we've been here for six years and they appreciate the fact that we're staying on top of this type of thing."

And it's just that type of commit-ment for which Barry McPhee wants to be known—not just today, but 10 years from today.□

Lahaina Pure Water Co.	717 Luakini St. (headquarters) Lahaina, HI 96761 (808)661-6246; (808) 661-6629 (fax) website: www.water-store.com
Owners:	Barry and Irene McPhee
Education:	Barry McPhee. studied marine biology at the University of Hawaii and Long Beach City College, Calif., CWS-I Irene McPhee, bachelor's degree in computer programming from University of Manitoba, Canada
Employees:	9
Annual revenue:	$800,000
Breakdown:	Water stores—30 percent Bottled water delivery—60 percent Commercial/industrial—5 percent Internet services-5 percent
Quotables:	"We listen to our customers. Each year, we have customer appreciation day a couple of days before Christmas. We open up the store and offer food and drinks—and the water is free all day long. The fact is, we do a lot for our customers and the community and they appreciate that. That's the way we advertise."

The Cholera Epidemic

Kelly A. Reynolds, Ph.D.

The word "cholera" brings to mind horrible images of illness and death, but cholera isn't always fatal. In fact, the general public knows little of the disease or its prevention.

What is cholera?

Onset of illness is generally sudden—as soon as six hours after ingestion. With symptoms of abdominal cramps, nausea and vomiting, it's easy to think it could be just another case of the flu instead of something more serious? If left untreated, *Vibrio cholerae* infections can lead to dehydration, shock and even death. *Vibrio cholerae serogroup 01* is the bacterium responsible for recent outbreaks of cholera spread ing rapidly throughout Central and South American countries, although there have been no major outbreaks of this form of the disease in the United States since 1911.

Symptoms of cholera infections vary from asymptomatic, or mild, to severe watery diarrhea. All persons are believed to be susceptible to *V. cholerae* infections, however, immunocompromised individuals may experience more severe symptoms and prolonged infection. Researchers estimate that approximately one million organisms must be ingested to initiate disease. Once ingested, the bacterium is thought to attach to the lining of the small intestine and produce a harmful toxin.

Other *Vibrio* species have also been indicated as human pathogens but are associated with much milder forms of disease. For example, *Vibrio cholerae serogroup non-01* causes bloody diarrhea in addition to cramps, nausea, vomiting and fever, with some cases lasting as long as seven days. This organism may also become disseminated in the blood stream, causing further complications, especially in immunocompromised individuals. Sporadic cases occur throughout the year in the United States, especially in warmer months, and isolation from U.S. coastal waters is frequent. However, no outbreaks have been documented. Conversely, major outbreaks have occurred in the U.S. due to *Vibrio parahaemolyticus,* another related bacterium generally associated with mild diarrheal illness. This organism is common in Japan where large outbreaks occur with regularity.

Factors contributing to outbreaks

Vibrio species are naturally present in estuarine (rivers and lakes) and marine environments of both developing and developed countries. Shared habitats with bathers and shellfish offer routes of transmission via recreational activities and consumption of raw or improperly cooked seafood. Consumption of contaminated food and water are the most common routes of *Vibrio* infection. In addition to immunocompromised individuals, persons with reduced gastric acids (including those who consume antacids) and persons suffering from malnutrition tend to be susceptible to a lower infectious dose and contract more severe forms of the illness. Infected individuals shed *Vibrio* pathogens in their feces, contributing to the spread of the organism to areas other than marine and estuarine environments, such as municipal waste that may ultimately compromise drinking and surface waters. Cholera is generally a disease spread by poor sanitation and propagated by conditions of compromised water quality.

In 1991, outbreaks of cholera in Peru quickly grew to epidemic proportions following a reduction in water disinfection practices. The disease spread throughout the Western Hemisphere, resulting in over 340,000 cases and 3,600 deaths since January of that year. As the world's population continues to increase, officials question whether municipal infrastructures are capable of supporting this growth. This is particularly acute in aging systems where cracked pipes allow for infiltration of pathogenic organisms in the water supply. In addition, overcrowding leads to increased water use and depletion of water resources, which leads to conditions of poor sanitation and hygiene and facilitates the spread of a variety of waterborne pathogens.

Treatment options

Vibrio infections are often self-limiting and are highly treatable, provided a clean water source is accessible. Patients must be rehydrated, not just with water, but with a solution of sodium chloride, sodium bicarbonate, potassium chloride and glucose to replace valuable electrolytes lost through rapid dehydration. If treatment is delivered immediately after the first signs of illness, less than 1 percent of cholera patients die. Unfortunately, in developing countries, a clean water source is often not available and adequate treatment, therefore, is not possible. Antibiotics, such as tetracycline, have been shown to shorten the duration of the illnessbutthe most important treatment is to prevent dehydration by electrolyte replacement.

Outbreak prevention

The Centers for Disease Control in Atlanta recommends drinking only bottled or boiled water in areas where cholera outbreaks are prevalent. Carbonated beverages are also safe due to their high acid content but should be consumed without ice. All consumed foods should be thoroughly cooked, including vegetables, fish and shellfish and fruit should be peeled to eliminate surface contamination. Any raw food items that may have been in contact with contaminated water should be rinsed in chlorinated water, peeled or avoided altogether—such as salads. Antibiotics have not proven successful for limiting the spread of cholera. This is in part due to the large number of asymptomatic individuals—who don't readily show symptoms (as many as 90 percent of those infected)—capable of unknowingly spreading the disease. Vaccines are available but do not offer long-term immunity and have not been highly effective in clinical trials.

Environmental factors play an important role in *Vibrio* distribution. High nutrient loads (i.e. from agricultural run-off) and warm temperatures often lead to algal blooms in coastal regions that may harbor, amplify and transmit *Vibrio* pathogens.[3] Disaster conditions of hurricanes, typhoons, monsoons, earthquakes, etc., also play a role in pathogen transmission by contributing to compromised infrastructures and degradation of drinking water supplies through breaching of barriers between sewage and water systems. By recognizing the role climatological factors play in water quality, we may better prepare for future water-borne outbreaks.

With drinking water being a major medium for the transport of pathogenic *Vibrio* organisms, it is an obvious target for outbreakcontrol. The limited number of cholera cases noted in the United States has been attributed to the widespread use of chlorine disinfection and point-of-use trea tmen t devices, in addition to increased sanitation practices and designated waste treatment and disposal. Further evidence for this is the decline of urban infrastructure in the former Soviet Union and resultingrecurrenceof cholera in many cities.[4] For cholera, supplying populations with safe water and sanitation has worked to reduce the incidence where trade barriers, quarantine, antibiotic prophylaxis and ineffective vaccines have failed.[1]

Conclusion

In order to address some of these important water quality issues, the American Academy of Microbiology convened a colloquium of experts in microbiology, engineering, epidemiology and risk assessment in Guayaquil, Ecuador, in April 1995.

The colloquium titled, "Global Issues in Microbiological Water Quality for the Next Century," focused on the needs—from policy and scientific viewpoints—concerning microbial risks in drinking water. Recognizing that the world's population continues to lack access to microbiologicaily safe drinking water, the colloquium concluded:

• The list of waterborne pathogens is increasing;

• Development, implementation, and maintenance of low-cost, low-technology water treatment systems are critical for reduction of global disease;

• Waterborne disease must be made reportable with active surveillance systems implemented;

• Improved risk assessment methodology and database development are needed;

• Individuals and officials must be educated about the social and economic burden of waterborne diseases; and

• Policies related to waterborne disease must be initiated to enable implementation of water treatment.

Inherent in these conclusions are multiple opportunities for the water treatment industry to take part in the reduction of widespread morbidity and mortality due to infectious diseases. Through product development and induced awareness, we may play an important role in focusing on the need to offer the world access to safe drinking water. G

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