TIMELY INFORMATION

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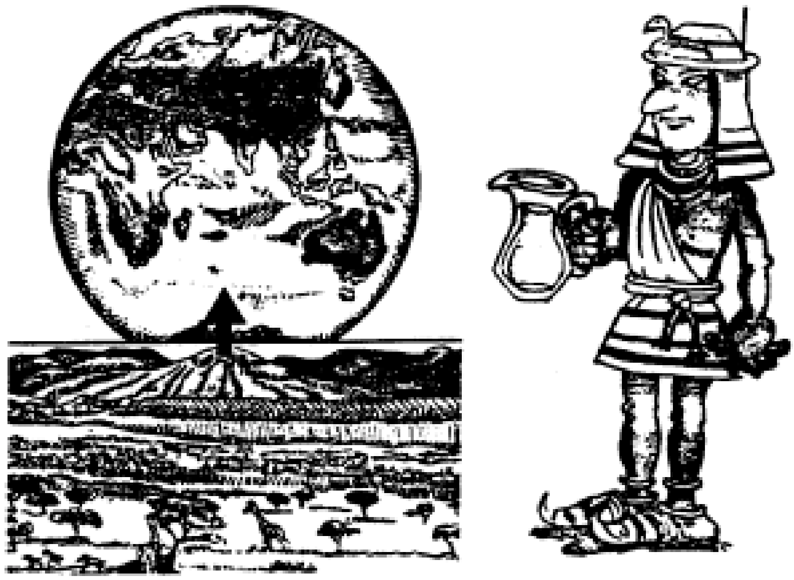

WATER: THE LIFE BLOOD OF PLANET EARTH

James E. Hairston, Extension Water Quality Scientist,
and Professor of Agronomy and Soils
Laura Booth, Extension Associate in Water Quality
and Environmental Education
John M. Beck, Research Associate, Agronomy and Soils

Our intent in this article is to improve your knowledge of and appreciation for water, which truly is the liquid of life. We will refer to the abundance of water on earth, its forms, its sources, its primary uses, its purity and pollution, its movement through the water cycle, and some of the many unusual properties of water that make it a paradox of nature and absolutely essential for life on earth as we know it. We will discuss the importance of water in the development of agriculture and civilization, including modern civilization. We will also include some opinions on how modern technology and accelerated pollution have increased public fear of chemicals, increased the anti-science/ anti-technology sentiment in our society, and how this sentiment coupled with the "information age" in which we now live makes us more susceptible to "infotainment" and "sensationalistic" reporting of what may or may not be facts.

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Earth's Water Resources

What makes our planet so unique is its vast supply of water resources. Water is the life blood of our planet and without it there would be no life on earth as we know it. If we look for life on another planet, the first thing we look for is water. Because water is so common on our planet, we often fail to realize how precious and how unusual it is. In fact, water is the most unusual substance we find anywhere on earth.

Most of earth's water is in the form of salt water in the oceans. The total volume of these oceans is estimated at 317 to 326 million cubic miles and they cover over 70 percent of the earth's surface. If the earth were a perfect sphere, ocean water would be sufficient to submerge the entire globe to a depth of 800 feet.

Water Quality in Nature. Water is the single best solvent we know and seldom if ever found completely pure in nature. Natural purity is directly related to water source and level of contamination. Contaminants that enter water due to the activities of people are called pollutants. Natural purity and the level of contaminants must be considered in determining how water can be used. Sea water, for example, is not suitable for potable or drinking water, but has many other uses. More information will be given on salt water and fresh water as well as water pollution in subsequent paragraphs. The primary point to remember is that much contamination occurs in nature but pollution is caused by people.

In nature you find water in its purest form just after it has evaporated or transpired from land, water or plant surfaces. This water has left most of its contaminants behind. However, when this water vapor condenses to form rain drops it begins to dissolve gases and other materials from the atmosphere before it even reaches the earth's surface. Oxygen, nitrogen and carbon dioxide, the most common gases in the atmosphere, are always found in water. Natural rainfall is somewhat acidic (pH = 5.6), or a weak carbonic acid solution, due to the effects of dissolving CO_2 from the air. This acidic condition makes rainfall an even better solvent for certain salts as it moves over and through the earth's land-based surfaces.

Acid Rain. Rainfall more acidic than normal is called acid rain. Sulfur and nitrogen oxide gases and other soluble gases from a variety of sources, primarily from the burning of fuels, may reduce the pH of rainwater further, making it more acidic. Internal combustion engines and fires that utilize the atmosphere for oxygen release nitrogen oxides into the air. This cannot be prevented since air contains 78 percent nitrogen. Whether sulfur oxides are released or not depends on the particular fuel that is being burned (oxidized).

Salt Water. Since the oceans are salt water, they have little value for some uses. However, most plant and animal life on earth is in the oceans. Anything that impacts the oceans will impact the entire earth. Most experts agree that the oceans contain about 97 percent of the earth's total water supply. Other than this tremendous surface supply of salt water there are huge reservoirs of salt water beneath the earth's surface. Most of these are near the coast of land bodies and are associated with ocean water or salt water that was trapped when ocean water was receding from land masses. Fresh water is generally located above these salt water zones along the coast. Excessive pumping of fresh water can cause salt water to rise and move inward, a condition called salt water intrusion. Some coastal cities, Savannah, Georgia, for example, are beginning to see this happen.

In the foreseeable future we may be forced to desalt sea water to meet the fresh water demands of society. Some scientists feel that we will be using wind power, wave power, and solar energy to create electricity across the oceans in the future. Some of this electricity could then be used to electrolyze sea water to produce hydrogen and oxygen, both of which may be used to meet energy needs in the future as fossil fuel deposits are depleted. Some of the hydrogen may even be burned in a way to produce fresh water from ocean water while generating electricity in the reverse process.

Fresh Water. Since 97 percent of the water on earth is salt water, that leaves a maximum of only 3 percent that is fresh water. Of this 3 percent at least 2/3 is frozen in polar and glacial ice. Therefore, only 33 percent of the fresh water on earth or 1 percent of the total water on earth is liquid fresh water. Of the total liquid fresh water 98 percent is ground water and 2 percent is surface water. So all our lakes and flowing streams which account for most of our water uses make up only 0.02 percent of the total water found on earth.

Now we begin to realize the importance of ground water. That's where most fresh water is stored, although some of it is not readily available. We can expect greater and greater demands on ground water in the future.

Hydrologic Cycle. Because of the cyclical nature of water movement through the water cycle, a given water molecule may be used over and over again through the centuries. For example, the bath water used by Cleopatra over 2000 years ago has flowed to the sea and mixed throughout the oceans. Some has evaporated and fallen on the continents as rain, and may have been used over and over again since that time. This water eventually reaches the ocean again. Were the oceans not constantly refilled from runoff and rainfall they would drop almost 40 inches per year from evaporation losses.

This precipitation that replenishes our fresh water supplies is ample to supply any human demands that we can fathom, except for two things. It is extremely variable and the distribution is far from uniform. For example, Northeastern India is saturated with over 400 inches of rain per year, while other areas may wait several years for a modest shower.

Average rainfall of the United States is about 30 inches per year, but distribution, like the rest of the world, is very uneven. This is equivalent to nearly 13 million acre feet of water per day that falls on the U.S., enough water to cover a football field 120 feet deep every second. What happens to all this water depends on the hydrologic cycle.

Agriculture and Civilization Depend of Water

Until people learned to cultivate crops and domesticate animals, what we now call agriculture, there was no such thing as a civilized society. Up until then there was little time to do anything but hunt and gather food. People that traveled in tribes were very nomadic and when a food supply was used up they were forced to move on. However, they also had to follow the water supplies. As people learned to produce from the land they could then settle down and there was more time for other activities and creative thinking.

Archaeological digs indicate evidence of cultivated agriculture around 11,000 to 9,500 B.C. in northern Iraq and 9,500 to 8,800 B.C. in southern Iraq, near the Tigris and Euphrates rivers. Agriculture development in both areas of Mesopotamia was highly dependent on water. Rainfall in northern Iraq averaged around 18 to 20 inches per year, and this was adequate for certain crops under good management. Rainfall in southern Iraq however was much less, probably around 5 inches per year, and irrigation was essential. Irrigation made abundant food production possible and large cities such as Babylon were built.

It is believed that civilization spread from this region east to India and China and west to the land around the Mediterranean Sea. The knowledge of tillage and irrigation that was initiated in Mesopotamia was being carried along trade routes and systems of arable agriculture were being developed. As agriculture developed, so did the early civilizations, with rapid increases in population. The population of Mesopotamia at its peak has been estimated at about 25 million. Today it is less than 10 million. What happened to the productive agriculture and all these people? The land that once contained as many as eleven empires is now a desert of shifting sand.

Some authorities believe that climatic changes reduced productivity of these areas and led to the downfall of these empires. Agricultural scientists, who have studied this matter in detail, believe that accelerated soil erosion and degradation of the water supplies that were vital for irrigation in this dry climate, were the real causes. Lack of knowledge and failure to adequately manage their most valuable natural resources, land and water, resulted in sediment loads filling in not only the river bed but their irrigation canals and ditches. In time, human labor was insufficient to cope with removal, so sections of irrigated land were abandoned. The abandoned land now eroded faster from wind and drifting soil filled in the remaining irrigation structures. The large populations, mostly in large cities, could no longer be supported. Cities were abandoned and the area became a desert of shifting sand.

Some scholars now believe that diseases and other problems associated with water may have had a major impact on the downfall of early empires too. Plagues and other diseases transported through contaminated water supplies have been known to kill millions of people throughout the world. Lead poisoning and the chronic effects associated with it may have played a role since some early civilizations used drinking and eating utensils that contained high concentrations of lead. Other sources of water contamination were probable.

Modern Society Still Depends on Water

As with ancient civilizations, we have found that our needs and demands for water increase with time. Our major cities and much of our industry are located adjacent to water supplies. The present economic development of many communities is tied in directly with commerce or industry, most of which is dependent on water supply. Future development and progress, as we think of them, require large volumes of water, and competition for available supplies always increases with time. Only within the last 100 years have we learned to tap the vast underground supplies of fresh water.

Primary Water Uses. Human water use is generally divided into two main categories, consumptive and non-consumptive uses. These are similar but not always the same as withdrawal and non-withdrawal uses. In withdrawal or off-stream uses, water is taken from its natural setting in streams, lakes, or underground aquifers prior to being used. For non-withdrawal or in-stream use, water is not taken from its natural setting.

Six withdrawal uses of water are generally inventoried in the U.S. These include public water systems, industry or commerce, agriculture, domestic uses, mining, and thermonuclear power generation. The first three are the major water consumers. The primary agricultural uses are watering of livestock and irrigation. A consumptive agricultural use that is rapidly increasing in some states is aquaculture.

The major non-withdrawal or in-stream uses of water include navigation, hydroelectric power generation, recreation/ preservation, and sewage treatment. Some industries may return much of their water to the stream and may be labeled as non-consumptive users, although they are generally considered consumptive users.

All water users, especially those that utilize water in handling or treating waste products and then discharging back into a stream system, have the potential to seriously degrade water quality.

Modern Society Driving Ecosystem Changes and Changes in Perception of Science

All living organisms must extract materials and energy from their surroundings in order to live, and in doing so, they modify their environment and impact other organisms within the territorial bounds of the ecosystem. There is no way around this. For humans to survive, just as any other living species, they must extract basic essentials such as food, water, clothing and shelter from their environment. They have been doing this since their arrival on the face of the earth. Therefore, humans have been impacting their environment since this time.

Lets consider the entire planet earth as a single ecosystem, with ecosystem defined as a system formed by the interaction of a community of organisms with their environment. Normally, we consider ecosystems on a much smaller scale, but if we include humans as part of natural systems, then we must think of the earth as a single system because human actions cause global impacts.

The advent of agriculture, more than anything else, is responsible for changing the way humans live and has led to what we now refer to as civilization. Not until people learned to produce from the land, could they settle down and devote time to creative thinking. Only then, did the arts and sciences begin to flourish. <u>Without the developments in agriculture, most other things in life that we appreciate today would never have happened</u>.

However, developments in agriculture, and the subsequent worldwide proliferation of our species and further technological developments, have all led to accelerated, wide-scale pollution. In fact, the more advanced our civilizations the greater their capacity to cause accelerated pollution. Yet, at the same time, civilized peoples are not willing to give up the tools, medicines and modern conveniences that have extended their lives and made living easier and more enjoyable--even though they may frequently refer to "the good old days" of the past.

Good Old Days Not Really so Great. Lets assume that people could go back to the golden days of the mid-1800s for example, when life was without many of its current problems--much less pollution, no overcrowding, no pesticides, no smog. Maybe even the ozone hole would be much smaller and there would be no concern for global warming and the rapid extinction of species. However, if one goes back to such a time they must accept all of the previous era--not only the lack of wide-scale pollution and open spaces, but also the absence of anesthesia, the absence of antibiotic 'wonder drugs', a life expectancy of 44 years instead of 74, one-third of all women dying in childbirth, no television, no computers, no frozen foods, and the absence of many other things taken for granted.

Given the opportunity, most people would not even choose to go back just a few years. They like the portable telephones, jet travel, microsurgery, the use of computers, more efficient cars, or other conveniences brought about through science.

However, at the exact same time that people in modern societies are enjoying all the conveniences of science, we are seeing a growing lack of trust and respect for science. There are real concerns for negative environmental impacts, many of which came about as byproducts or side effects of technological developments, but there are also concerns for the growing misinformation, misinterpretations and use of pseudo-science in our society as the general public becomes more scientifically illiterate. Some of these issues will be discussed in more detail in following paragraphs.

Perception of Science Changing. Public perception of science has changed much within the past 100 years. Early in the twentieth century, the 1920s to 1930s in particular, science was considered to be the final word--a scientific argument was truth. Public perception has now gone from the naive faith that scientific discovery means progress--through the disillusionments that came with Silent Spring, Three Mile Island, Love Canal, and the exploding space shuttle--to a complete lack of trust in science by many. The downside of technology and the changing views of science are part of our history. The one time popular slogan of "better living through chemistry" is not as popular as it once was. Many of our scientific discoveries have led to pollution and the degradation of our planet in ways that we may not yet fully comprehend. There is much argument over whether new and more modern technology can be used to solve problems brought on by scientific exploration and applications of earlier technology. As we close the century we are finding that science may not have the answer to everything.

There are probably several reasons for the growing lack of trust in science. First of all, many citizens are scientifically illiterate and have a terrible fear of chemicals (chemophobia) simply because they do not understand the dose-response relationship between living organisms and chemicals. Secondly, people do not understand risks nor how they respond differently to voluntary vs. non-voluntary risks. They tend to forget that there is a certain amount of risk associated with everything we do and every time we change directions or alternatives we change the circumstances associated with risk. This means that nothing is perfectly safe, but too frequently those scientists viewed by the public as so-called experts have sought to assure consumers that a new drug, pesticide, food additive, or other chemical product is "perfectly safe," only to find later evidence that the product is not as safe as originally believed.

Value of Science Often Misunderstood. The role, processes, and products of science are grossly misunderstood or misrepresented. As the world struggles with problems resulting from an increasing human population, unsustainable use of resources, and increasing poverty and disease, scientific knowledge is urgently needed to help guide current solutions and chart a more sustainable course for the future. Science is needed to help provide guidance to the nation's policies, to strengthen our technological capabilities, to manage our activities, resources, and wastes in a sustainable fashion, and help improve the quality of life for all.

Addressing our present and looming environmental, social, and economic problems adequately requires (1) a stronger knowledge base, (2) enhanced communication and understanding of that knowledge by the public, and (3) better and faster incorporation of the information into policies and practices.

Improving scientific literacy and enhancing the communication of scientific knowledge to the public entail (a) improving science education, (b) developing effective mechanisms for countering misinformation or the misuse of scientific understanding, (c) formulating vehicles for the development of consensus statements from knowledgeable scientists, (d) facilitating the training of science journalists, and (e) improving scientists' skills in communicating science.

In spite of all the advantages brought about by scientific advances, we are still seeing a growing lack of trust in science among our citizens. Keep in mind that some have had a negative view of scientific discovery from the time that humans first moved out of caves and initiated the process. But growth of this anti-science sentiment during recent years appears to be closely associated with the view that modern technology can so easily kill us, and may be doing just that by slowly degrading our environment.

There is much concern over which way we will go. There is much argument over whether new and more modern technology can be used to solve problems brought on by scientific exploration and applications of earlier technology. One thing is certain about all living things, they either change or they die. The same thing is probably true for our living planet, the earth.

Misinformation Becoming More Common. Our society is in the middle of an information revolution. You might even say that we have information overload. In the United States, for example, we are inundated with reminders and symbols of this information revolution, including personal computers, cellular phones, interactive television, voice activated video recorders, fax machines and electronic and voice mail. Huge amounts of data can be transferred over vast distances in an instant, and the much-vaunted fiber optics based information superhighway is now a reality. Thus, we are fast approaching a point at which our ability to compute, measure, monitor, and transfer information will far exceed our ability to understand and interpret the data we obtain. Plus, total information discovery is doubling about every six years. Many of us feel like we are drowning in information but starving for knowledge. This makes us much more susceptible to misinformation from others that comes through sensationalistic and "infotainment" type reporting.

Because we have a basic freedom of speech in our society, anyone can make their opinions known to the press or media. Well known individuals with sincere but sometimes reckless accusations can tremendously impact public opinion in our society, depending on media response and reporting. Many issues may be exaggerated or over-dramatized to get extra attention. This is sometimes the case with certain environmental issues. Sensational stories may result because of human nature and a free press, but with all its faults and failings, a free press is still better than its alternative. We have to keep in mind that because we hear something on TV or read something in a news report does not necessarily mean that it is absolutely reliable, authoritative, accurate, unbiased, or even credible.

Some media groups will continue to focus on the anti-chemical, anti-technology, anti-business stories and sensationalize beyond the facts? There are five basic reasons for this.

1. The truth is boring.
2. Emotion makes for good ratings.
3. Networks are facing tough competition.
4. It is fashionable to be anti-chemical.
5. Journalism tends to attract liberal crusaders.

Some journalists really think that by being anti-chemical, anti-technology, anti-business, and pro-environment, they are serving the best interests of their audience. Others sincerely believe they know "the truth" and no matter how much scientific evidence is on the other side, they will still question it. This is unfair to people who look to media sources for objective information.

Science cannot be treated like any other political debate, in which you talk to one side and then the other side, and formulate an opinion. This would be like generating pseudo-science at best. Some pseudo-science may be harmless as one of the opiates of the masses, but when it is incorporated into political movements, as it sometimes is, it has the potential to completely undermine the public's confidence in real science. A coordinated effort by scholars will be needed to combat the politicization of science that even appears to be growing in academic arenas.

"Infotainment" has become the hallmark of some journalism in the United States as well as other countries. There is real concern in our society that "infotainment" seems to be taking over from information. The public seems to be entranced with "infotainment" --a type of pseudo-news infused with entertainment values.

Public obsession with "infotainment," gives media organizations, especially tabloid newspapers and magazines, a special kind of power. Where do we draw the line? Is the media beyond restraint? Will we someday have to put legislative restraints on the media? Some media organizations have anointed themselves guardians of the environment and pubic morality and they now feel that it is their duty to expose and discredit anyone of authority, including politicians and scientists who have different views from theirs.

False Image of Agriculture

Agriculture is our single most important industry because our very livelihood depends on it. However, most citizens do not fully comprehend the importance of this industry to our very survival, and their attitudes toward agriculture are affected by all the negative publicity that comes through many media outlets and from many environmental organizations.

The potential and opportunities for high-yield, intensive agriculture are tremendous even though many environmental groups and media organizations refer to modern high-yield farming as a leading cause of worldwide environmental degradation.

What many people fail to realize, is that high-yield agriculture may actually protect the environment more than it leads to degradation. In fact, high-yield farming has made larger contributions to human health and environmental sustainability than the Audubon Society, the Sierra Club, Natural Resources Defense Council (NRDC), and all the other environmental activist groups put together. High-yield farming has been a triumph over hunger and has many environmental benefits.

High-Yield Farming Saves Wildlife. If we had not tripled the world's crop yield potential by combining high-powered seeds, irrigation, fertilizer, pesticides and mechanization, the world's expanding population would long since have destroyed much of the wildlife which still exists on the earth. Without high-yield farming, we would not be cultivating 5.8 million square miles of land (about the land area of South America); we would be plowing 15 million square miles--an area equivalent to the whole Western hemisphere.

High-yield farming is not the threat to plant and animal diversity that some people assume. The key issue is not the plant and animal diversity in an acre of mono-cultured corn; there is never much plant and wildlife diversity in a crop field, organic or not. The key is the billions of wild organisms that thrive in the two acres that can be left unplowed because we tripled the yield on the best and safest acre.

High-Yield Farming Is More Sustainable. High-yield farming today may be more sustainable than any farming system used in over 10,000 years. History tells us that many civilizations thrived for periods of time and then perished as their agricultural soils degraded. Nothing degrades soils more rapidly than the processes of soil erosion. Modern, high-yield farmers are using herbicides more and more for weed control instead of plows, thus reducing the amount of bare earth exposed to the forces that cause erosion. The world's most severe soil erosion today is in primitive countries trying to support rising populations by extending low-yield farming onto fragile lands.

With the exception of salt build-up under certain irrigation schemes, high-yield farming has not poisoned soils and water supplies with toxic levels of chemicals as some people assume. Current technology allows high-yield farmers to manage their farms on a field by field basis, and even this is about to change because of environmental concerns. Soon, high-yield farmers will be able to make use of global positioning satellites, other satellite data, and equipment outfitted with micro-processors to vary application rates of chemicals, seeds or other inputs on a second by second basis within inches of their desired positions across a field. This will allow farmers to manage yard by yard, not field by field--according to soil type, hydrology, slope, plant population and nearness to waterways or special hazards.

Not Possible to Prevent All Pollution

Contrary to what some would like to believe, we cannot prevent all pollution, especially all water pollution, unless we wipe out our own species. We have had water pollution for as long as we have had people on the face of the earth.

Water pollution can include any human activity that causes physical, chemical, biological, or radiological agents to enter a water supply, thereby, changing its quality. It also includes any action that causes thermal changes in water. Human waste removal which is facilitated by water, has been one of the primary sources of water pollution and major causes of disease transport through water to other humans since the beginning of time.

We know that without water there would be no plant or animal life on earth, and without humans developing agriculture (which is itself very dependent on water), there would be no civilization. Therefore, for civilization as we know it to exist, agriculture must be considered our most essential industry. Along with water it provides all the basic essentials of life; food, clothing, shelter, and now, even some of our energy needs. Although agriculture is absolutely essential, it is also a major contributor to water pollution.

Water and Life

Now we will go back and talk about water because all the other things we have discussed would never have happened without water. There would be no life, no humans, no agriculture, no civilizations, no scientific and technological developments, and no economic, social or environmental concerns. Earth would simply be a dead planet. So, in a way, we can blame everything that happens on earth that we are aware of, on the presence of water. Now lets look at water in detail.

Water may be considered the single most valuable resource on earth because without it life on earth as we know it could not exist. All living things, including plants, animals and people require much water. Even photosynthesis, that most essential of life supporting processes where green plants convert solar energy to chemical energy, requires water. Without photosynthesis most plant and animal life would come to a sudden halt. All animals either eat plants or other animals that have eaten plants. So without water there would be no plants and without plants there would be no animals, and earth would be a dead planet. Therefore, water is considered the key ingredient for life, and solar systems or planets without water are considered to be without life as we know it.

Trapping Energy From the Sun.

Photosynthesis:
(in presence of light and chlorophyll)

Carbon dioxide + Water --> Oxygen + Carbon-rich foods
CO_2 H_2O O_2 $C_6H_{12}O_6$

Respiration:
(in light or dark)

Carbon-rich foods + Oxygen --> Carbon dioxide + Water

Not only does water sustain both plant and animal life, it is absolutely essential for humans. It provides for our very creation, our nourishment, and the stability of our environment. Water typically makes up 65 to 70 percent of human body weight. Someone once stated that "the average adult male contains about 12 pounds of ashes and 8 buckets of water". This is true. No food can be used in the body unless it is dissolved in water during digestion. Undissolved material passes through with no food value. The bloodstream which is mostly water transports water to all parts of the body. Some of this water is then used to get rid of waste products. The average adult excretes from 2 to 3 quarts of water per day. Warm-blooded animals also use water to maintain their body temperature. This process alone consumes a tremendous amount of energy.

Thus, not only does water make up two-thirds of your body weight, it has delivered the remainder via breakdown of minerals, transport of nutrients, and carbon capture from the atmosphere. It is the basis of our creation and recreation (e.g., swimming, boating, skiing, fishing, beverage-drinking, etc.), and in every sense, it is *aqua vitae*, "the liquid of life".

Properties of Water

No definition of water is complete without a discussion of its nature and its unusual properties.

Chemical Properties. Although we think of water as one of the most common substances on earth, it is a chemical with very unique properties. The chemical name for water is dihydrogen monoxide, H_2O. What gives water its exceptional properties is the strong polarity of its molecule. The two hydrogen atoms are strongly bound with oxygen in the water molecule, making it electrically neutral. However, because of oxygen's electron-loving nature, it pulls those electrons which it shares with hydrogens closer to itself. This causes the oxygen atom in water molecules to have a weak negative charge and hydrogens to have a weak positive charge. This polarity causes an attraction of oxygen atoms to hydrogen atoms of adjacent molecules and vice versa--creating what is referred to as **hydrogen bonding**. Thus, water molecules tend to cluster and tend to adhere to other polar substances. Without this cohesion of water molecules to each other and strong adhesion of water molecules to other substances, life on earth as we know it could not exist.

With the exception of mercury, water is the only inorganic liquid found on earth. But thanks to the earth's special mix of temperature (influenced to a large degree by water) and air pressure, water is the only substance found in all three phases (solid, liquid and gas) in earth's biosphere. Its importance however, extends far beyond the bio-world into the physical world: it weathers rocks into soils (the substrate of land life), and then transports nutrients into plants and hence animals. As a solvent for carbon dioxide (CO_2), water captures carbon into nature's basic food stocks, that is, land plants and the ocean or lake algae.

Special Features of Water. Water does not behave like any other substance on earth. Many of its physical and chemical properties are unique and extreme exceptions to general rules when compared to chemicals of similar make-up and molecular weight. For example, H_2O has a molecular weight of 18 but exists primarily in liquid form under standard conditions on the earth. Other compounds of similar molecular weight such as methane (CH_4) and ammonia (NH_3), or even heavier compounds such as hydrogen sulfide (H_2S), carbon dioxide (CO_2), and sulfur dioxide (SO_2) commonly exist as gases. If water behaved similar to most substances of similar molecular weight, life on earth as we know it could not exist.

Expansion on Freezing. Unlike most substances, water is more dense as a liquid than a solid. For that reason, ice floats instead of sinking to the bottom. Freshwater is most dense at 4°C and is taken as the universal standard of one gram per cubic centimeter ($1g/cm^3$) or $62.4\ lb/ft^3$ at this temperature. Things less dense will float on water and things more dense will sink to the bottom. Oil and gasoline spills on water make a terrible mess, look unsightly and cause environmental hazards--but just think of what would happen if these sank to the bottom. It may upset us when freezing water cracks our water pipes, but if water did not expand on freezing, the world as we know it could not exist. For example, in a freezing pond or lake, the warmer and more dense water settles to the bottom to provide a sanctuary for life. If cold, near-freezing water and ice went to the bottom, aquatic life as we know it would not exist.

Surface Tension. This arises from the attractive tugging forces between molecules at the liquid surface, and is exceptionally high for water. Hence, water is absorbed strongly by capillary attraction into porous materials, making soils excellent water reservoirs. Water's polarity also ensures strong adsorption onto surfaces of clay particle and organic matter within the soil. If soil could not hold water in this manner against the force of gravity, soils would rapidly drain to much lower moisture contents immediately after rainfall, and much life as we know it could not exist.

Because of high surface tension, water can be maintained in a stream against wind resistance. This may seem unimportant, but because of this characteristic along with water's high heat capacity and high latent heat of vaporization water is very effective in fighting fire, one of the most destructive forces in nature. By comparison, water can be sprayed great distances under pressure while gasoline, which has low surface tension, can not even be poured from one container to another without great spillage under windy conditions.

Thermal Properties. Water is one of the most stable substances on earth. It can be heated to 1000^{o}C without decomposing and has extreme values for certain thermal properties. For example, water has the ability to absorb a tremendous amount of heat, more than almost any other substance. This is called *heat capacity*. Water is taken as the standard in comparing heat capacity and specific heats of other substances. It takes a large amount of heat (80 calories per gram) to melt ice to liquid water at 0^{o}C. It then takes 1 calorie per gram per degree to raise water to the boiling point of 100^{o}C at standard atmospheric pressure. An additional 540 calories per gram is then needed at 100^{o}C to change this heated water to steam. This is called *latent heat of vaporization.* This steam can now be super-heated to very high temperatures without decomposition under closed conditions.

Because of its high heat capacity, water is an excellent thermostat, slowing temperature changes in oceans, water bodies, biological cells, and tissues. Ocean currents become vast and powerful heat carriers, redistributing heat and moderating climate all over the earth's surface. Water's remarkable latent heat makes vapor a very efficient energy carrier also. Earth's hydrologic cycle pumps water vapor from lower to higher latitudes. The heat released on condensation helps redistribute the sun's energy throughout the lower atmosphere, thus moderating climatic extremes. Deserts, where little water is present, may suffer rapid temperature extremes that exceed 120^{o}F during the day and fall below freezing at night.

In comparison to other liquids, water has high *thermal conductivity*. This speeds up heat redistribution in living tissues which experience uneven metabolic and external heating or cooling. Fortunately, compared to solids, water has low conductivity. This slows heat exchanges, reinforcing the thermoregulation effect of water's exceptional heat capacity. By contrast, a metal robot would suffer much greater thermal shocks.

Other Climatic Effects. The cyclic pattern of water coupled with the spinning nature of the earth and the thermal properties of water plays a major role in controlling global and local climates. Without the large mass of water on earth, temperature would change very rapidly from daylight to dark just as it does on the moon. Water absorbs a tremendous amount of energy that is released to the atmosphere at night to moderate temperature fluctuations. Temperatures are also moderated by evaporation to prevent extremely high temperatures just as we perspire to keep cool. Transpiration from plants has a similar affect. The effects of water vapor and the impacts of this vapor on absorption on infrared radiation in the earth's atmosphere are not fully understood even today.

There are special interactions between vegetation, the hydrologic cycle and local climate of an area. If the landscape is completely denuded of plants over a large area, rainfall in this area will probably decrease, day temperatures will generally increase and night temperatures will generally decrease. This pattern is difficult to reverse. Some scientists believe that desertification has been enhanced in some areas, especially areas where rainfall just barely supported the vegetation in the beginning. This could be what happened in the cradle of civilization thousands of years ago.

Dielectric Properties. The dielectric properties of a substance relates to its ability to neutralize the attraction between electric charges. Water has one of the highest dielectric constants for common liquids. Thus, water 'buffers' or weakens the forces between dissolved ions and molecules, making it a powerful solvent and medium for biochemical reactions. This buffering also operates between charged colloid particles, including clay and organic matter in the soil. This gives water remarkable 'softening' powers, which is visible in the drastic reduction of hardness in soils and other materials when wetting occurs. It controls soil cohesion, dispersion, and strength. Without this softening action, plant roots would fail to penetrate soil. Soaking of dirty surfaces (dishes, clothes, etc.) also exploits the softening powers of water.

Acid-base Neutrality. Although water is very stable it reacts chemically with many elements and compounds. But at the same time, it sits benignly at neutral pH, midway between the hazardous acid and alkali extremes, because of the nature of its ionic dissociation. In an acid, some water molecules gain a proton ($H+$) to form the hydronium ion H_3O+ (usually simplified to $H+$). Conversely, in an alkali some molecules give up a proton to yield the hydroxyl ion, OH-. Thus, pure water is a combination of two components, whose chemical potencies cancel. This allows water to play many roles, including two roles in biochemical reactions: passively, as a solvent for minerals, organic solutes, and gases; and actively as a reactant in vital processes such as photosynthesis and respiration.

Just What is Water Anyway?

There is no simple answer to this question, for water means different things to different people. The same thing applies to water quality, because water quality is a relative term. Water that is of ideal quality for one use may be totally unsuitable for another. To most of us, water is what flows from a faucet, or what fills a pond or stream; it is the rain that makes the garden grow, or spoils a picnic. To a sportsman, water is a lake filled with fish, or a surface on which to sail, ski, or surf.

Water is a Chemical. The simple fact is that water is a chemical and a paradox of nature. Water is not just a typical chemical, but an extraordinary chemical that exhibits very unusual properties. Without these remarkable properties, life on earth as we know it could not exist.

Dangers of Dihydrogen Monoxide. Now lets test your level of "chemophobia". Assume you have just been asked to respond to a petition as to what type of restrictions should be placed on a particular chemical named "dihydrogen monoxide". Your choices are; no restrictions, strict control, or total elimination of the chemical. You have been provided with the following information about this chemical:

1. It can cause excessive sweating and vomiting,
2. It is a major component of acid rain,
3. It can cause severe burns in its gaseous state,
4. If accidentally inhaled, it can kill you,
5. It contributes to the destructive process of erosion,
6. It decreases effectiveness of automobile brakes, and
7. It has been found in tumors of terminal cancer patients.

Based on this information, would you support a ban on the chemical dihydrogen monoxide? I think you know how many people would respond, especially if some well-known individual was using the national media and much melodrama to encourage the ban.

In a real world situation, a junior high school student in Idaho posed this information and question to 50 people. Forty-three said they would ban the chemical, six were undecided, and only one knew that the chemical was...WATER.

Special Things About Water

* A typical adult daily diet requires 2 to 2.5 pounds of food dry matter, but 5 to 6 pounds of water.
* Under ideal conditions, an adult can live for over a month without food, but for only 10 days without water.
* Water consumption in the United States is about 370 gallons per person per day, more than 500 times dietary need (U.S. Geological Survey, 1993). Only 80 gallons is indoor use, the remainder being used for irrigation, agriculture and industry.
* Water is an excellent medicine. Daily, we submit ourselves to water's healing and cleansing powers, both internally consumed and externally applied. At times, nothing feels better than a hot shower or bath to restore one's spirits. A pint in the evening prior to bedtime works wonders, especially after excessive food consumption.
* Paradoxically, too much water intake can cause intoxication and kill you. Drinking large quantities of water, in excess of the excretory capacity of the kidneys, can dilute the body's electrolytes and cause water intoxication. Symptoms include nausea, weakness, headache, and in severe cases, seizures and coma (Rubenstein and Federman, 1996). Water intoxication is most likely to occur in bottle-fed babies of low income parents who substitute water for milk or formula to keep infants from crying.
* Surfactants are chemicals that can be added to water to reduce surface tension. They are added to pesticide spray solutions to increase leaf wetting and stomatal entry. Detergents have this type effect and allow water to form smaller droplets and better wet other surfaces.
* Water's polarity is exploited in microwave ovens, where the rotations induced in the H_2O dipole absorb energy from the electric field, oscillating at around

2.45 GHz. Microwave ovens are not very effective in melting ice though because water molecules are frozen into a relatively unresponsive structure.

* The strong polarity of the H_2O molecule makes water vapor a very strong absorber and emitter of infrared radiation, and hence earth's leading greenhouse gas. Without atmospheric vapor, earth's surface would be more than 20°C colder: a frozen planet.

* The large quantities of latent heat released as water vapor condenses to form clouds creates the strong atmospheric winds we refer to as the Chinook and jet stream.

* Plant evaporation occurs on a massive scale, and is also a major leaf cooling mechanism. Without it leaves of plants would overheat and die during hot summer months.

* Plants are very leaky. In their attempt to dissolve and capture meager atmospheric CO_2, their moist tissues transpire vast amounts of water into the air. For example, a typical temperate crop like wheat evaporates over 100 pounds of water to produce just 1 pound of useful dry matter. Thus, the water in a 25 m swimming pool would suffice to product only 15 sacks of grain. This is why irrigation consumes over two-thirds of our global freshwater use.

Conclusions

Nature is full of paradoxes and water is one of them. It is at the same time a very simple yet wonderfully complex substance. It has more exceptional properties than any other substance, properties crucial for life and climate processes. It has extreme (or close to extreme) values among liquids for heat capacity; latent heat of vaporization; dielectric constant; surface tension; tensile strength, thermal conductivity; chemical dissociation (into hydrogen and hydroxyl ions); compressibility; thermal expansion properties; volume change on freezing; and friction of its solid phase (ice). While a few freak substances have more extreme single properties (e.g., hydrocyanic acid has a dielectric constant almost twice that of water), they are life unfriendly.

Earth is special--our sun's only watery planet. Water in turn is special: it is the basis of life, and the main controller of climate. Nature, via distillation in the hydrologic cycle, has supplied the land with large volumes of freshwater, both surface waters and lenses of ground water; and flushed 90 percent of earth's soils free of excess or imbalanced salts. Humans are rapidly spoiling much of this. We need to value and conserve our water resources--without them life is impossible.

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