



A Study of **Water Quality**



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A STUDY OF WATER QUALITY

By Dr. Charles E. Renn

FOREWORD

Even though it is not true that man is losing his race with the growing need for water, it is not debatable that water does hold the key to man's survival. He must have water to drink, to wash, to grow food, to sustain industrial growth, to support transportation and to provide recreation. Without water, life is barren and hopeless.

Men have fought for it, honored it, degraded it and manipulated it. It has always posed problems of too much, too little or too bad. It is a beautiful servant and a tyrannical master. One never misses it until it is not available. In Benjamin Franklin's wise words, "One does not think of water until the well is dry!"

Water is a complex material. After centuries of use, we still do not understand its internal structure. In spite of this ignorance, we can control it for the wise use of man, beast and plant.

This booklet helps to clarify our problems, solutions and methods of testing.

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This text is distributed by LaMotte Company, Chestertown, Maryland 21620. We at LaMotte Company wish to express to Dr. Renn our deep appreciation for this splendid contribution to the study of water quality.

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INTRODUCTION

Water isn't simply water. The water that we know is always water and something else. It's the combination that we have to work with that makes it useful and interesting; that makes it necessary to know about water quality. Most materials take up a little of other materials, but water picks up more of the materials that it contacts than anything else, and it is changed more by what it takes up than most of the materials in our experience. Water is the "universal solvent."



Fig. 1 Water is vaporized into the atmosphere by the rays of the sun. This conversion of water from a liquid to a gas produces the most pure form of water found in nature. Meteorologists have determined that there are continually present in our atmosphere over 3,000 cubic miles of water. This is a gigantic quantity of water, yet is less than 1/100th of one percent of the total water in the Hydrologic Cycle.

For example, when water vapor, high in the atmosphere, condenses to form droplets of liquid water (mist and rain or solid water – snow) it takes in some of the other vapors of the atmosphere too. When water vapor changes to droplets or crystals of water, it is likely to form about fine particles or dust in the atmosphere. These droplets may form about minute crystals of salt that have been carried up into the sky from storms over the oceans, dust from the prairies, smoke particles from forest fires, volcanic dust, or stack dust from the cities. The newly formed fine droplets of water in the clouds won't be pure water. The droplets will contain a little oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2) dissolved from the same atmosphere that contained the water vapor. They may also contain traces of ozone, nitrous oxides, argon and other gases of the atmosphere. These droplets condense to rain that is water and something else.

RAIN WATER & SOMETHING ELSE

Most rain water behaves like a very weak acid because of the carbon dioxide that it dissolves from the atmosphere as it is formed and as it falls. It may pick up other materials, like sulfur dioxide or ammonia, as it falls through the atmosphere that contains these gases, but the carbon dioxide that rain water carries is usually the most important added material.

When the weakly acid rain water falls on the earth's surface, it reacts with materials in soils and rocks, and more things are added to the water. Materials that dissolve in weak acids are taken up—calcium, magnesium, iron, zinc, and other metals, for example. These tend to reduce the acidity of the water, but they increase the concentration of minerals in the water.

A NEVER-ENDING LIFE CYCLE

Over a very long time, weakly acid rains may extract all of the reactive metals from parts of the earth's surface. The most active metals are now in the oceans; they were removed first. The salts of the seas were carried from the earth's surface millions of years ago (Fig. 3). The rivers still carry small residuals to the oceans. This is a long process. Water distills from the oceans to the atmosphere. Water vapor condenses into the skies to clouds and rain. The rain falls through the atmosphere and takes up atmospheric gases, including small amounts of acid producing carbon dioxide. The weakly acid water flows in streams through the soil and rocks to rivers, lakes, and seas. The water continues in cycles, but the salts that it takes from the rocks and soil remain in the seas.

Since the beginning of time, water has been involved in this never-ending series of physical and chemical changes. The cycle of physical changes of evaporation, condensation and precipitation is known as the "hydrologic cycle" (see Fig. 2).

The chemical process in which the water dissolves and carries away the minerals and salts in the soil is called "leaching."

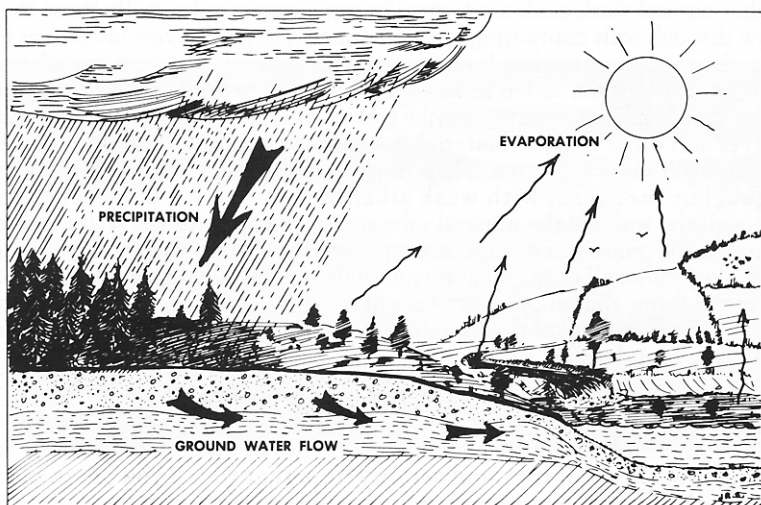


Fig. 2 The Hydrologic Cycle is activated by the thirst of relatively dry air for moisture.

MORE CARBON DIOXIDE IS ADDED

The carbon dioxide that water picks up is the most important non-water material in water. More is taken up after it falls and infiltrates the soil, flows in streams, or during storage in ponds, reservoirs, and lakes. This added carbon dioxide is produced by living and dying processes, by respiration of plants and animals in the water, and by the microbiological decomposition of dead organic materials. No matter what the source of the carbon dioxide, its presence in water makes the water like a weak acid and increases its ability to pick up materials that are slightly alkaline.

One of the most useful measurements of water quality is the determination of the concentration and forms of carbon dioxide in water. This will tell what will happen when the water is used in various ways, how it must be treated to control corrosion, and what must be done to prevent deposits of clogging scale formed by the breakdown of unstable combinations with metals, like calcium bicarbonate, in heated water lines.

Other natural weak acids are formed in some waters, principally those that flow through soils containing large amounts of decaying vegetation—as in the thick, decomposing leaf cover of hardwood forests in northern climates. When the fallen leaves decompose, they produce weak organic acids that behave in many ways like carbon dioxide—the decomposition of leaves and other organic materials in soils also produces carbon dioxide, often much more than that taken from the air. All of these acids are very weak, but they react with weak alkaline minerals as the water flows through the soil and the mineral salts are carried along as the water moves through the ground to springs, streams, rivers and on to the sea. Over long periods of time, all of the alkaline minerals may be taken from the soil and only the forms that are unreactive will remain—usually sand and clays of various types, and all of the limestone containing calcium and magnesium will have been leached away.

CONCERNING TIME AND AMOUNTS

When you think about the chemical properties of water, it is necessary to change your scale of time and activity from that which you use in class laboratory. The processes in water are much slower, the concentrations of reacting materials are much lower—usually only milligrams per liter or parts per million (these are equivalent units of measurement) and the changes are not usually obvious to the eye. But we use such large volumes of water over such long periods of time that changes in water quality are of great practical importance. The costs of water systems—reservoirs, conduits, municipal distribution lines, tanks, pumps and wells, and household and industrial plumbing—are very great, so that we must pay attention to what water does to them to keep them working at the least cost. In special cases like high pressure boilers for power generation, the changes that go on at high temperature and high pressure can be so damaging that water completely free from corrosive impurities must be produced.

Waters that flow through soils, and mineral deposits that contain no reacting materials, will retain their weakly acidic properties; they may pick up more weak organic acids from decaying vegetation in the soil. Such waters are low in mineral content and are “soft” waters.



Fig. 3 97% of the earth's water supply is found in oceans and seas that are too salty for drinking, irrigation and most industrial uses.

Salt Concentration of Various Water Supplies

(Concentrations given in milligrams per liter)

Distilled Water	0
Lake Tahoe	70
Lake Michigan	170
Missouri River	360
Pecos River	2,600
Ocean	35,000
Brine Well	125,000
Dead Sea	250,000
Great Salt Lake, Utah	266,000

They may be colored with natural stains extracted from decaying leaves of the forest floor or swamp pools. These waters are usually highly corrosive and may contain iron or manganese extracted from soils and decaying vegetation or from the walls of iron pipes. To prevent corrosion it is necessary to add alkaline minerals to react with the carbon dioxide and organic acids that are present.

THE pH FACTOR IS THE FIRST CLUE

There are various ways of determining the “aggressiveness” or corrosiveness of soft waters. It is necessary to know how much of the weak acids—carbon dioxide and organic acids—are present, and how active they are. Very commonly this is approximated by making “pH” measurements. This is a convenient measurement that describes the relative concentration of positive hydrogen ions and negative hydroxyl ions produced in the water by weak acids and other dissolved substances. A water with a pH value of 7.0 contains equal concentrations of hydrogen ions and hydroxyl ions; when the pH is below 7.0, there are more hydrogen ions than hydroxyl ions, and when the pH is about 7.0, there are fewer hydrogen ions than hydroxyl ions. The acidic, freshly-fallen rain water may have a pH value of 5.5 to 6.0. If it reacts with soils and minerals containing weak alkaline materials, the

hydroxyl ions will increase and the hydrogen ions decrease, the water may become slightly alkaline with a pH of 8.0 to 8.5. Most natural waters will have pH values ranging from 5.0 to 8.5 (see Fig. 4).

Because the pH measurement can be made so simply, and because it can tell so much about the past and future reactions of water, it is routinely made in water laboratories. The relative concentrations of hydrogen and hydroxyl ions can be determined with precision and convenience with the “glass electrode” and a very sensitive voltmeter, but very useful field and laboratory measurements can be made with simple portable colorimetric chemical kits that depend upon the changes in tints of various dyes that are sensitive to the relative concentrations of hydrogen and hydroxyl ions. The pH measurement is essentially a measurement of the “activity” of acids and bases in water.

The pH test is made in the following manner: a measured amount of the water sample is collected in a calibrated comparison tube. A measured amount of the indicator solution is added and the contents of the tubes are mixed. The color that results from the mixture of the indicator and water sample is compared with a series of color standards that represent the color developed at various pH levels (see Fig. 5).

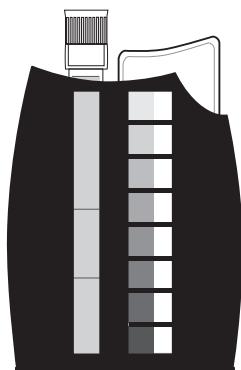


Fig. 5
A comparator provides standards of known value for evaluating the results of colorimetric tests.

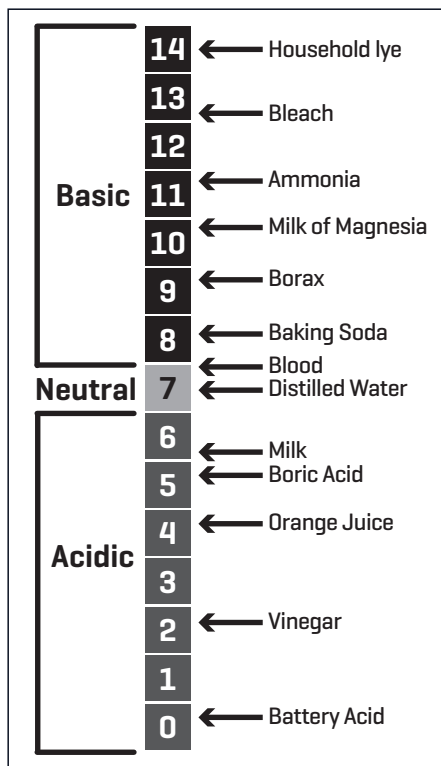


Fig. 4 The approximate pH values of some common substances including the pH range for most natural water supplies.



Fig. 6 A titration procedure requires the accurate measurement of the amount of titration solution needed to bring about a color change in the sample.

To measure the “amount” of acid or alkaline mineral in water, it is most convenient to produce a reaction that will combine with the acidic or alkaline material and measure the amount of an acid or alkali of known strength required to combine with the alkaline or acid material in the water. This technique of chemical testing is called a titration (see Fig. 6).

CARBON DIOXIDE IS ESSENTIAL

Although carbon dioxide in water starts a series of changes that are often troublesome—corrosion, bringing calcium, magnesium, iron, manganese and other minerals into solution—it is important to life. In soils, carbon dioxide and weak organic acids produced by the roots of plants and by microbiological processes in the soil make minerals soluble and available to plants; and because these weak acids hasten chemical “weathering,” they are important in the production of fertile soils.

Aquatic plant life depends upon carbon dioxide and bicarbonates in water for growth. Microscopic plant life suspended in the water, the “phytoplankton,” as well as larger rooted plants (waterweeds), utilize carbon dioxide in the photosynthesis of plant materials. This process requires large amounts of radiant energy from light.

One end product of photosynthesis is oxygen. The others are organic compounds of the growing plants—starches, sugars, oils, proteins, etc. The carbon in all of these materials comes from carbon dioxide in the water.

THE BALANCE OF AQUARIUM WATER

The changes that take place, when growing plants take up carbon dioxide during photosynthesis, are readily observed in simple aquaria containing common aquarium plants, without fish or other animals. If the aquarium is brightly lighted, it will be discovered that the pH of the water will rise as the carbon dioxide is taken up by the plants. The alkalinity of the water will also rise as the pH rises. In some conditions it may be possible to see fine bubbles of oxygen produced by photosynthetic reduction attached to the fronds of the aquarium plants, and if the water contains much calcium, fine films of calcium carbonate may be formed on plant surfaces or the walls of the aquarium (see Fig. 7).

Aquatic animal life in the aquarium will produce opposite effects. Fish, snails, insect larvae, worms and bacteria secure their energy for growth and activity by combining oxygen in the water with carbon and

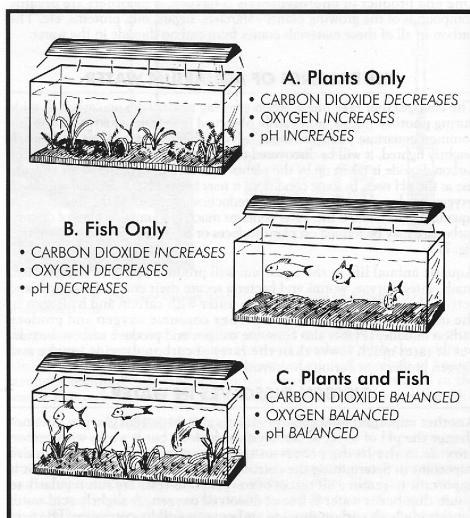


Fig. 7 Aquarium (A) with plants only will show a decrease in carbon dioxide, an increase in oxygen and an increase in pH. Aquarium (B) with fish only will show an increase in carbon dioxide, a decrease in oxygen and a decrease in pH. Aquarium (C) with both fish and plants shows a proper balance of carbon dioxide and oxygen and the pH value will remain steady.

hydrogen in the organic matter that they eat. They consume oxygen and produce carbon dioxide. (Plants also consume oxygen and produce carbon dioxide, but at rates much lower than the rates of carbon dioxide uptake and oxygen production during photosynthesis in light.)

OXYGEN DISSOLVES IN WATER

Another important atmospheric gas in water is oxygen. Oxygen does not change the pH of water as carbon dioxide does, but it works with carbon dioxide in the living processes that go on in water. Oxygen is also important in determining the corrosiveness of water. In boiler waters it is important to remove all traces of oxygen, and tests are run regularly to insure that boiler water is free of dissolved oxygen. A slightly acid water containing both carbon dioxide and oxygen will be corrosive. The acid condition and carbon dioxide initiate corrosion, but oxygen is necessary to make it continue.

The measurement of oxygen in water is important because it is one of the practical indications of purity. Organic polluting materials added to water consume oxygen, and most of the aesthetically objectionable qualities of polluted water that we notice are related to the absence of oxygen.

If there are no oxygen-consuming pollutants in water, the concentration of oxygen present will be determined by the water temperature and its salt content. In fresh waters, the salt content is so low that this has little effect, so that the oxygen present should be that set by the water temperature. If there is more oxygen present, then some oxygen-producing process, usually photosynthesis, is adding it; if less is present, then some oxygen-consuming process, usually plant and animal respiration or decomposition of organic matter, is removing it. One simple, commonly-used method for determining the presence or absence of pollution is to store water in closed bottles for several days and measure the concentration of oxygen that disappears from the water due to the decomposition of organic matter. Clean, natural waters will usually lose less than 0.5 mL oxygen per liter in five days in closed bottles held at 20°C. (A controlled, laboratory modification of this simple test is used for monitoring the performance of waste treatment plants. It is called the Biochemical Oxygen Demand test or BOD test.)

DISSOLVED OXYGEN REQUIRED BY FISH

Oxygen is required by fish and other animal life in water. The concentration varies from species to species, but most fish require at least 4.0 milligrams per liter to survive for long periods, and may require more for activity and rapid growth. Some fish, like trout and salmon, require much higher concentrations.

Several conditions combine together to determine the oxygen requirement. The limitations work against one another in this fashion.

1. Oxygen is more soluble in cold water than in warm water; fish are more active in warm water than in cold water and they require higher concentrations in warm water.
2. Organic matter consumes oxygen less rapidly in cold water than in warm water, so that warm waters are likely to contain less oxygen
 - A. Because warm water cannot dissolve as much.
 - B. Because decomposing organic matter consumes it more rapidly.

3. Decomposition of organic matter in water increases the carbon dioxide content and reduces the pH of water.
4. Fish cannot take up oxygen as rapidly in low pH waters containing carbon dioxide as in high pH waters with low carbon dioxide.

The fish that are most sensitive to decreases in dissolved oxygen in water will disappear first when waters become polluted with organic wastes. Those that are less sensitive and can tolerate the extremes produced by pollution are likely to increase, because polluted waters are commonly more fertile and contain a larger supply of food materials. It is characteristic of streams that become progressively polluted that the number of kinds of organisms decreases while the number of a few kinds of organisms increase.

NATURE'S TEAMWORK COMBATS POLLUTION

It would seem that everything would run downhill with the development of cities and industries on lakes, rivers, and streams and with the increased discharge of organic materials in wastes to these waters. There are some natural correcting processes, however, and these have been exploited by engineers in the development of waste treatment processes to reduce the adverse effects of wastes going to clean waters.

The plants and animals that live in water work together to reduce the organic content of water. One way of thinking about this is to regard them as energy-losing machines. To live, they must extract energy from the food supply of the water—that is, from the organic carbon, hydrogen, nitrogen, sulfur, and other energy-containing elements in the organics in the water. They perform a wasteful conversion of these materials to their own cell stuffs—only a few percent of what is eaten or taken in is converted to living new materials. The rest is lost as “ashes”—that is, carbon dioxide, and very slowly, decomposable dead cell material. Much of the carbon dioxide may be exchanged back to the atmosphere, and the dead cells fall and are trapped in the mud or are carried downstream, ultimately to estuaries and the sea. It takes many pounds of microscopic organisms to make a pound of fish, and the sequence of food organisms in the chain may involve dozens of different kinds of plants and animals ranging from minute diatoms, through insect larvae, minnows, and small fish. The important thing is to keep water quality in a range that will allow the development of many kinds of organisms that feed on each other. The dissolved oxygen content of water is one of the most useful measurements for determining this.

MOVEMENT OF SURFACE WATER

Water, in its liquid state, is restless. Yielding to the law of gravity, it must travel. Much of this water travels across the earth's surface in the form of streams and rivers.

The mineral quality of water in streams and rivers changes with the seasons. Both the flow and water quality of rivers is affected by the seasonal growth of grass and trees on the watershed. In a sense, the river competes with grass and trees for water. When the winter snows melt and the spring rains follow, our rivers in the temperate zone commonly flood and send heavy flows to the sea. The thawing soils release minerals in the first early flows, so that this pulse is commonly rich in minerals released during decomposition of the previous autumn's crop of plants. This is quickly diluted by the heavy spring flows. As summer progresses and the lands and slopes are covered with fresh plant growth, the flow of the rivers drops

sharply because grass and trees take up water from the soil as it flows through the ground toward the river bed. The flow in the river diminishes and minerals concentrate due to increased evaporational losses during the long, hot summer days. The quality of water in the river may now be determined by deeper ground waters and springs that are not tapped by the trees and grass. In the middle Atlantic states, flows from limestone caverns make the water very hard—high in calcium—during the summer and early autumn.

The flows of rivers usually increase shortly after the first frosts of autumn kill the leaves and stop transpirational movement of water from the soil to the air. The frost kill commonly begins at higher altitudes and moves down into the plains, and it is sometimes possible to trace changes in water quality in springs and tributary streams along the way of this progression.

MOVEMENT OF GROUND WATER

Not all of the restless water that reaches the earth's surface travels in streams and rivers, however. Some of the surface water seeps down into subterranean layers of the earth called "Aquifers" (see Fig. 8). This ground water travels slowly through the fine spaces of deep soil and fine crevices in rock until it is tapped by wells drilled into the aquifer or until it encounters a natural fault in the earth's structure. Ground water is generally clear and colorless; however, it usually contains high concentrations of dissolved minerals and salts because of its long contact time under pressure with the soil particles.

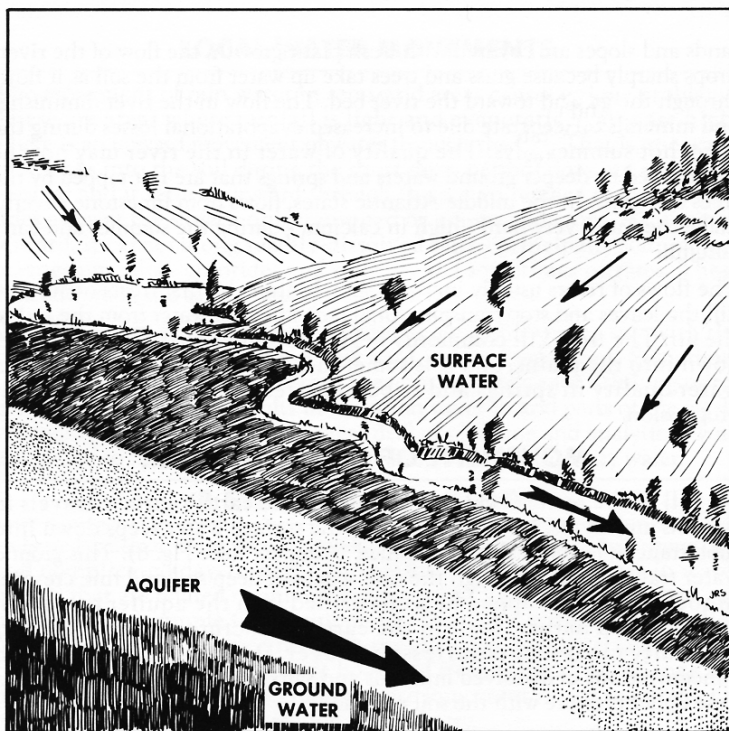


Fig. 8 Water moves rapidly along the surface of the earth; it moves much more slowly through subterranean layers of porous soil.

Generally, well waters require little treatment because the soil processes do this naturally. But some well waters have special problems. In residence supplies, there is little choice in the location of the well. Some wells draw from underground sources that are highly mineralized and saline. Wells may go down into buried swamps and yield water containing organic stains, iron, manganese, hydrogen sulfide, even methane. Such difficult waters can be treated to make them taste and odor free, noncorrosive, and non-staining. The first step is testing to see what is in them; tests can be used to determine the most efficient treatment and relatively simple tests can be used to see that the treatment is working right. The unit of measurement of flow for surface water and for ground water illustrates why variations in chemical composition are to be expected. The flow of surface water is measured in feet per second and the movement of ground water is usually measured in feet per year.

LOCAL WATER MOVEMENTS

The movement of rain water in semi-arid areas causes unique problems. These are areas where rainfall is light and evaporation rates are high. There is an upward movement of water through the soil. That is, the water that soaks into the soil during the short rainy periods does not penetrate very far and it returns upward through the soil to replace the water that dries away at the surface or is transpired by grasses and crops. As it moves upward, it carries along readily-dissolved salts—principally sodium and magnesium salts—chlorides and sulfates, and sometimes nitrates. These concentrate in the surface soil as the water evaporates.

When rain comes in such areas, it washes away the surface salt with the storm runoff. The streams carry very hard, mineralized waters. Sometimes these are so loaded with salts that they are unsuitable for drinking or for irrigation. The control of salts in irrigation water in arid parts of the world is a highly specialized science; a great deal of planning and analytical work is required to make the most of a limited supply of poor quality water.

A STUDY OF LIMNOLOGY

In large bodies of water, like deep lakes and reservoirs, there are interesting and complicated day-to-night and season-to-season changes in water quality that are related to animal and plant life. These can be studied and measured with simple field equipment. There is a water science called “limnology” which is concerned with the chemical, biological and physical changes that take place in large bodies of fresh water. This science has many practical uses; it is becoming more important as our requirements grow for better water for recreation and industry.

There are some striking examples of the way in which carbon dioxide, oxygen, plant and animal life, and the chemical qualities of water are related. During the summer in the temperate zone, most bodies of water more than five feet deep, in locations where they are protected from strong winds, will become “thermally stratified.”

During the sunny warm day, the water at the surface becomes warmer than the deeper water; it expands slightly and becomes less dense. Because it is lighter than the water below, it stays on top as a separate layer, separated from the deeper water. It forms a sort of lake on top of a lake (see Fig. 9).

The upper warm layer of water is in contact with the atmosphere so that it can exchange oxygen and carbon dioxide with the atmosphere. But the deeper water cannot exchange oxygen and carbon dioxide with the atmosphere; it must get along

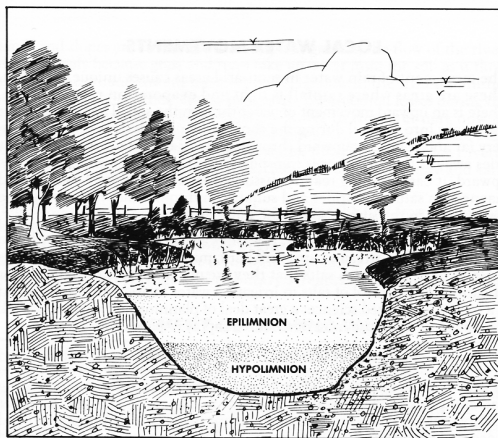


Fig. 9 Thermal stratification can produce the formation of two distinctly different layers of water. The longer the stratified layers remain undisturbed, the greater the difference in the chemical composition of the water of these layers.

on the oxygen that it had in it before the top layer warmed and isolated itself.

The warm surface layer, the upper lake or “epilimnion” is also more brightly illuminated than the deeper layer—the “hypolimnion.” This means that photosynthesis and growth of microscopic plants—principally algae—will be much more rapid in the upper warm water. As a consequence, carbon dioxide will be taken up and oxygen will be produced. The pH of the surface water will rise as the carbon dioxide is removed by the growing plants. All other minerals that are used by growing plants will also be taken up from the water—potassium, calcium,

magnesium, iron, manganese, phosphorus, ammonia and nitrate nitrogen, sulfate, and other inorganic materials.

The microscopic animal population will feed upon the microscopic plant crop. There will be many generations of plants and animals in the summer season, since these small organisms grow rapidly and have short life spans. Dead organisms rain down from the upper warm water layer into the deeper, cooler waters; this rain of plant and animal debris carries with it the organic carbon of the materials’ built-in photosynthesis and the inorganic mineral nutrients that went into the microorganisms as well. Since the light surface water and heavier deep water cannot mix, all of this material makes a one way trip downward.

OXYGEN SHORTAGE CAUSES CHEMICAL CHANGES

In the lower layers of water the dead materials decompose. Bacteria and fungi break them down, and small bottom animals that can tolerate low oxygen feed on them. This breakdown of debris from the upper layer produces carbon dioxide and consumes oxygen. It also releases the mineral materials of the fallen organisms. Sometimes these differences are made striking by the complete exhaustion of oxygen in the lower stratum. If the surface water was rich and contributed much organic debris to the deeper waters, all of the oxygen that the lower layers held when they were shut off from the atmosphere by thermal stratification will be used up. Organisms that require oxygen will die and their decomposition will call for more oxygen. If the oxygen depleted condition lasts for a few days, the bacteria that decompose organic residues will start to use oxygen from other compounds that may be present. They may pull oxygen out of nitrates to form nitrogen gas. When this is used up they will take oxygen from sulfate and hydrogen sulfide will be formed. If the condition goes on for a long period, special methane-forming bacteria may pull oxygen out of carbon dioxide and water to produce hydrogen and methane in the organic rich muds. These “reducing” conditions also free iron and manganese and make them soluble as ferrous and manganous compounds.

PERIODIC CHANGES IN WATER QUALITY

In addition to the changes in water quality due to thermal layering, waters that contain living things will show day-to-night changes in quality. When the light falls off in the evening and night comes in the water, photosynthetic processes stop. Carbon dioxide uptake and oxygen production stops, and oxygen uptake and carbon dioxide production slows. The pH of the water drops.

Oxygen uptake and carbon dioxide production continue till the morning light is intense enough to bring photosynthetic processes into dominance again. In waters where there is much life, the oxygen may drop to disastrously low levels if there is heavy overcast and insufficient morning light. Polluted or enriched waters are most likely to show great changes in dissolved oxygen, carbon dioxide, and pH with day to night light changes.

Thermally stratified bodies of water, like large lakes and reservoirs, commonly show big differences in water quality when the stratification breaks down in the autumn. When the surface water cools as the days get shorter and the sunlight hours shorten, it becomes possible for winds to mix the now heavier surface water with the deep layers and to stir the whole mixture. This brings materials that were in the deep water into the mixture and exposes them to light. In many reservoirs and lakes there are autumn “blooms” of algae—the sudden increase in nutrients raised from the bottom to the light starts a short period of rapid algal growth.

During this period of autumn mixture many reservoirs show sudden increases in iron and manganese and treatment for removal must be started. But this is only one of the more obvious changes in water quality that take place in reservoirs and lakes. Water changes in quality from day-to-day, from season-to-season, and from year-to-year.

WHEN WATER IS IMPOUNDED

When a reservoir is built, that is, when a dam is constructed and water impounded, there are many striking changes in the first years. The decomposition of the flooded soils and uncleared forest brush yields organic matter in solution, higher carbon dioxide concentrations, low oxygen, iron, manganese, and sometimes hydrogen sulfide. When possible, the area to be flooded is cleared to reduce these effects.

Some changes are inevitable in lakes and impoundments. A lake or reservoir is a trap for catching things that come in with the water. Most of all, they trap fine silts that settle to the bottom and fill the quieter reaches. So a lake becomes a pond, and a pond becomes a swamp, as the basin fills with settled soil and developing rooted plants and trees. The change may take a long time, and engineers work hard to extend the life of impounded waters, but the change is always in this direction.

IMPROVING WATER QUALITY

Drinking water comes from many sources (Fig. 10). Fortunately, waters of widely varying qualities may be treated to make satisfactory potable water. What is most desired is water that is cool, clear, and as nearly odorless and tasteless as possible, and completely free of disease-causing microorganisms. Very soft waters are treated to make them less corrosive by adding lime or mild caustics to react with the acid carbon dioxide and other weak acids that they may contain. This method of water treatment is known as neutralization. Extremely hard waters (Fig. 11), waters

THE QUALITY OF GROUND WATER DEPENDS ON THE COMPOSITION OF THE EARTH STRATA FROM WHICH IT IS TAKEN.

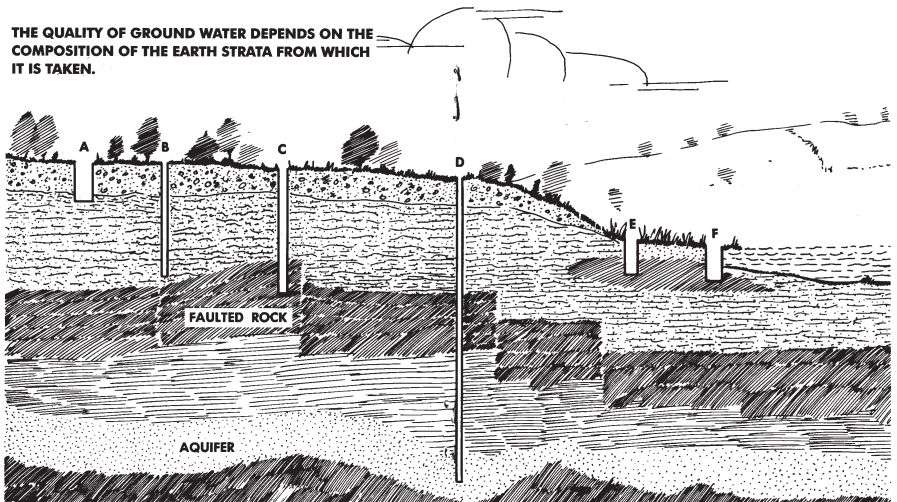


Fig. 10 Wells in the same locality may yield different kinds of water. This is especially true along the coastal areas near the fall line. The shallow well at the left (A) dips into the surface of the aquifer of water stored in the soil above base rock. It receives water that has recently infiltrated into the ground and its quality will vary with the season and rainfall. The deep drilled well (B) takes water that is older and of less variable quality because of the larger storage that it taps. The rock well (C) receives water that runs off the surface of the base rock into the well in the rock. These wells are common where the soils are shallow. The artesian well (D) extends deep into the base rock to reach fissures or sand layers that extend great distances into the highlands. Wells near the coast (E) that penetrate into old buried forests or swamps receive high iron and stained waters. Other wells (F) may receive salty water from the sea mixed with the fresh water moving from the land. Wells are "cased" to insure that the water they take comes from the desired aquifer.

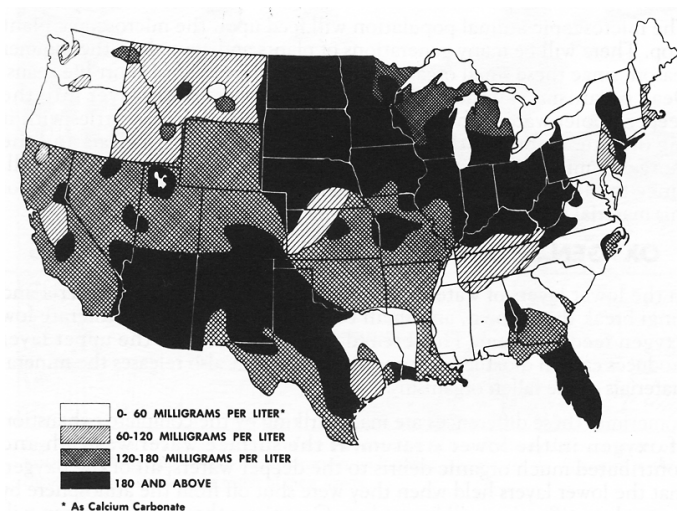


Fig. 11 How hard is the water in your area? This map gives the general locations of the principal hard water areas in our country. Chemical tests can accurately tell the hardness level of any local water supply.

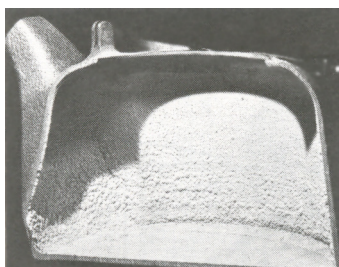
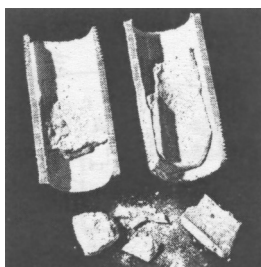


Fig. 12 Hard water deposits are rock-like scale of calcium and magnesium and may be found in pipes, boilers and cooking utensils.

containing so much calcium that they form scale in warm water lines (Fig. 12), are softened by adding weak alkaline agents to raise the pH to the point that calcium and magnesium scale are formed before they enter the pipes, letting the scale particles settle out, and then adding weak acid to bring the water back to the slightly alkaline pH range. The method of water treatment is known as the “lime-soda softening treatment.” It is generally used when large volumes of water are to be reduced to relatively soft water levels.

Calcium and magnesium, as well as other metals in excess may be removed by reacting them with zeolites or ion exchange media. These are usually beds of specially prepared plastic beads or coated sand that behave like very large water insoluble molecules with which the metal ions combine loosely. This method of water treatment in water softening is called “ion exchange” and it is extremely effective in producing water of zero hardness. Another advantage of the special zeolite bed materials is that they may be used over and over—the excessive minerals removed from the water may be washed off the ion exchange beds by flushing them with strong salt solutions or strong acids. Then, the beds are ready for use again.

There are also ion exchange beds that combine with negative ions for removing excessive amounts of chloride and sulfate from water. If the two types of ion exchange beds are combined, or if the materials are mixed together, it is possible to take out both positive and negative ions, and under controlled conditions to produce waters that are of high purity, containing only trace concentrations of minerals. The treatment of water by ion exchange resin beds that remove both positive and negative ions is known as “demineralization.”

REMOVING THE STAIN PRODUCERS

Iron and manganese may be removed in a number of ways, depending upon the special conditions under which they exist in the water. Some of the various methods for iron and manganese removal are:

Ion Exchange

It is possible to remove relatively small amounts of iron from water by means of ion exchange resins. The principle here is the same as that used in the ion exchange softening operation. In this case, the iron ions are exchanged for sodium ions.

Aeration

Aeration is a process whereby water is treated by spraying or splashing the water so that maximum contact between the water and air can be achieved. The purpose of this contact is the oxidation of iron particles that are present in the water supply. Iron and manganese are oxidized in this process causing them to form insoluble compounds that can be readily removed by mechanical filters.

Chemical Oxidation

Strong oxidizing agents are added to problem waters to convert the iron and manganese present into insoluble forms that can be removed by mechanical filtration. This method is effective against high concentrations and offers complete removal. Chlorine and Potassium Permanganate are two oxidizing agents widely used in this method of water treatment. The oxidizing material is added to the water by means of a chemical feed pump. A mixing tank is employed to insure thorough contact of oxidizing material and the water to be treated. The water then passes through a mechanical filter which removes the insoluble particles (see Fig. 13).

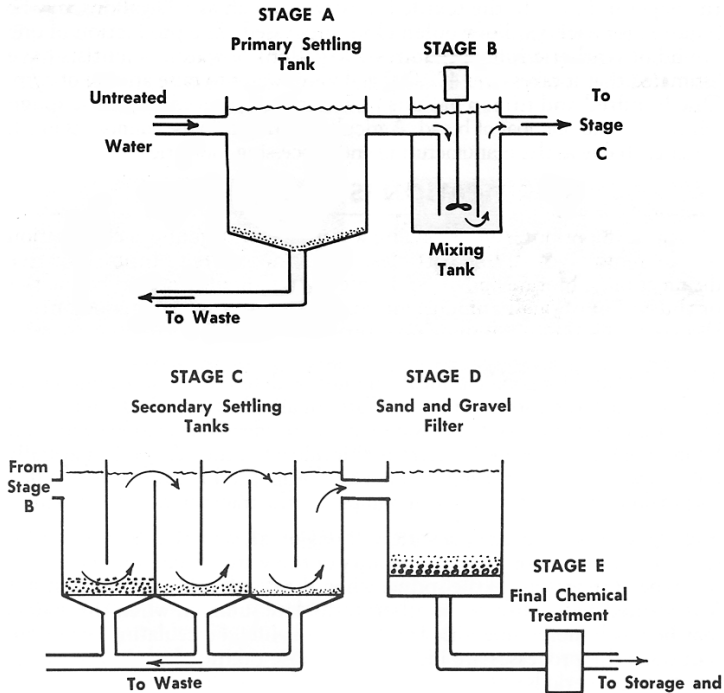


Fig. 13 Five of the basic stages in municipal water treatment are diagrammed above. The stages are (A) primary settling, (B) mixing of the basic chemical treatment materials, (C) secondary settling and clarification conducted in a series of baffled chambers, (D) filtration through a sand and gravel filter and (E) chlorination and final chemical adjustment. Materials added at stage (E) are carried throughout the water distribution system.

Sequestration

This method does not actually remove iron from the water being treated, but it does chemically “tie up” or “fence off” the iron so that it cannot react with other materials. Polyphosphates are the most widely used sequestering agents in the water treatment field.

INDUSTRIAL & AGRICULTURAL REQUIREMENTS

High purity waters are required for boilers of power plants and for many industrial processes, but this requirement is small compared to the general use of a city. So it is usually most economical to treat all of the water to levels that make it satisfactory for drinking and general purpose use, and then to give the required additional treatment in the factory or power plant that requires it.

To appreciate the importance of a satisfactory water supply in industry, it is interesting to note that as much as 40,000 gallons of treated water are required in the production of a single ton of rolled steel. In the production of gasoline, 500 gallons of water are required for the production of a single gallon of gasoline. Ninety thousand gallons are required for the production required for the production of each ton of paper board manufactured by the paper industry. In the textile industry, as much as 500 gallons may be required for each yard of woolen cloth processed. The production of one pound of synthetic rubber requires 300 gallons of water. Scientists have estimated that it takes over 400,000 gallons of water to raise an acre of corn. One hundred and fifteen gallons of water are required to grow enough wheat to make one loaf of bread. Agricultural irrigation uses almost as much water each day as the manufacturing and processing industries (Fig. 14).

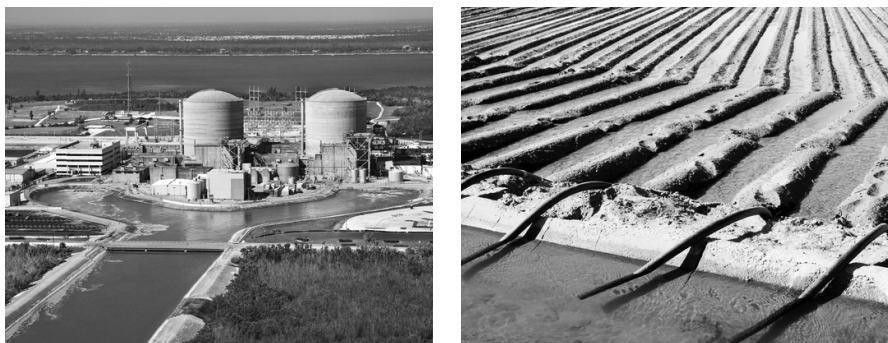


Fig. 14 The amount of water used by industry and agriculture represents 94% of the total water usage in the United States. More water is used by industry for cooling purposes than in any other application. Irrigation is the principal agricultural use of water.

CLARIFICATION IS THE FIRST STEP

The most important step in making water safe for drinking is clarification—the removal of all fine particles (Fig. 14). This is necessary to insure effective disinfection. Chlorine and other disinfectants cannot penetrate silt masses or the bodies of small animals, microscopic worms, and other organisms that feed on and accumulate bacteria in their bodies. They must be removed physically. This is usually done by allowing the water to settle, and then adding very low concentrations of alum with vigorous stirring. Fine, watery clumps of aluminum hydroxide are formed; these usually grow around the particles in water and they carry down the particles as they settle. The settling “floc” sweeps the water clear of even very fine materials. Even muddy waters may be made crystal clear.

The conditions for good clarification must be determined, and a number of tests are used at treatment plants. Water quality has a marked effect upon the clarification

process. Some waters are more effectively clarified with iron hydroxide formed by adding ferrous chloride and lime. Very soft, naturally colored waters are sometimes treated by this method because the iron floc carries down much of the color and improves the transparency of the water.

Soluble silica materials and a variety of organic flocculation agents are also used, depending upon the local quality of the water. Some waters require one type of treatment in the spring, when the floods bring down much soft leaf-stained water, and yet another in the late summer, when the waters may be much more mineralized and more alkaline. Flocculating agents are harmless; the processes are identical to those taking place in lakes over much longer periods of time.

A great advantage of flocculation and clarification as a first step in water treatment is that it makes filtration much more efficient and economical. If most of the fine solid materials are removed by flocculation and settling, the clarified overflow water contains less that must be removed by mechanical filtration, the filters will work faster and for longer periods of time, and less water will be wasted in washing clogged filters.

LIME-SODA SOFTENING PROCESS

Very hard waters containing high concentrations of calcium bicarbonate may be softened by making the water more alkaline with calcium hydroxide and sodium carbonate (added at Stage B). The reaction with additional calcium ion in an alkaline water produces calcium carbonate, which is insoluble in an alkaline system. The calcium carbonate settles out (Stage C) to leave a clear, alkaline water containing some calcium carbonate and low concentrations of sodium hydroxide. It is usually necessary to reduce the pH of the finished water, and carbon dioxide is commonly added to make this adjustment (Stage E).

TASTE-ODOR-COLOR-TURBIDITY REMOVAL

Odor and turbidity removal may be combined by adding activated carbon (Stage B) in concentrations of one or two parts per million to absorb the odor-producing organics, and then adding alum (also Stage B) in twenty to fifty parts per million to produce a floc that removes both the activated carbon and the turbidity particles. Alum (aluminum sulfate) changes in water to aluminum hydroxide. This is insoluble, and when it is formed it builds little clumps of aluminum hydroxide about particles of silt and activated carbon and carries them to the bottom of the flocculation tank (Stage C). The clarified water is passed through a filter (Stage D) to remove any bits of alum floc and trapped silt of carbon that might not settle.

IRON AND MANGANESE REMOVAL BY OXIDATION

STAGE A. Primary settling tank. Generally, primary settling and storage are combined to insure adequate water quantities for varying demands. The settling-storage system may be a pond, a shallow concrete tank, or a more complicated system with automatic settled solids removal.

STAGE B. Chlorine is the most commonly used oxidizing agent. The pH of the water must be adjusted to control the rate of reaction and the size of precipitated iron flocs produced.

STAGE C. After the floc is formed, it must be removed. Settling is the most commonly used device, as it clarifies the water and greatly simplifies the final filtration step. Many conditions determine natural and pollutional organics, and mineral salts.

Adjustments must be made by the operator to secure the clearest effluent possible.

ADJUSTING THE pH OF RAW WATER SUPPLY

STAGE A. Settling is a common treatment step in large water supplies since it can be combined with storage to advantage and because it simplifies all following steps.

STAGE B. and STAGE E. In most systems the pH of water is raised to control corrosion from soft, naturally acid waters. Occasionally, in some industrial process waters, it is necessary to reduce the pH of alkaline waters. Sulfuric acid, hydrochloric acid, or carbon dioxide may be used, according to process requirements. pH adjustment is often required for industrial waste waters before they are discharged to rivers, lakes, and streams. Most industrial waste waters are acid and require addition of alkaline agents like lime, soda, ash, or ammonia; alkaline waste waters are commonly brought to acceptable pH with sulfuric acid.

CHLORINE IS USED FOR DISINFECTION

Water for cities and communities is usually disinfected. Even waters that come from clean sources, protected watersheds, reservoirs, and deep wells are commonly disinfected to assure safety. Chlorine is most commonly used because it is effective against a wide range of microorganisms, its cost is low, and the methods of applying it have been well-developed. If chlorine is present in the water for a few minutes, disease-producing bacteria will be destroyed. A number of conditions affect the disinfecting action of chlorine. In municipal systems these can be controlled so that if chlorine is detectable, it can be assumed that bacteria will have been killed. The factors that influence the rate of disinfection are (a) temperature; (b) pH; (c) presence of other materials that react with chlorine; (d) time; and (e) the concentrations of the various chlorine combinations that are formed in the water with ammonia and other substances that react with chlorine.

The fact that chlorine can be easily detected and measured makes chlorine a favorite water disinfectant with health agents and others concerned with the public safety of supplies. Chlorine concentrations in the range of 0.1 to 0.4 milligrams per liter are usually maintained in municipal supplies.

SENSIBLE FACTORS OF WATER QUALITY

The water qualities that we can sense by sight, smell or taste are limited, but they are important. A slight cloudiness or milkiness in water, which we call "turbidity," tells us that fine particulate materials are present. Generally, we prefer clean water that is free of turbidity. We prefer clear water instinctively. Clear water has good properties, it can be disinfected more reliably for drinking and it will not support fouling organisms in water lines. But water may be clear and yet unfit to drink because of invisible pathogens; you cannot see viruses and bacteria in water, although high concentrations of bacteria will produce turbid water and turbid waters usually give higher bacterial counts.

Colorless waters are usually more attractive. The natural yellow-brown tint of waters that flow through decomposing leaf deposits in marshes and swamps or heavy forest deposits is harmless; these waters are usually corrosive but they are useful. We simply do not like brown tinted water as well as clear, blue-green water, and we are willing to make the effort to remove the stain. In the same way we are willing to remove harmless traces of odor and taste-producing organics from water.

DRINKING WATER MUST BE ODOR FREE

Some waters must be treated to remove odors. Waters taken from heavily-populated and industrialized rivers contain organics that react with chlorine to produce medicinal or chemical odors. If these organics are removed before the water is chlorinated, the objectionable odors can be eliminated or reduced. Odor-producing substances in water are usually soluble organic materials that appear in trace quantities; these can be detected in concentration ranges in the tenth of parts per billion after they react with chlorine. A high level of removal must be secured. Activated carbon is most commonly used because it adsorbs such organics very efficiently. Special kinds of activated carbon, low in cost, and designed for odor removal are introduced as a preliminary treatment when odors appear; only a few milligrams per liter are required.

The activated carbon does not get into the water system, it is removed during alum flocculation, or on the filters. For small community or household supplies that require odor removal, compact beds of granular activated carbon are used both as filters and odor removal devices.

We can smell some of the materials that affect the quality of water. Hydrogen sulfide, which appears in some well and spring waters is notable. Such waters are corrosive to iron and the vapors blacken silver and damage electrical control equipment.

The growth of phytoplankton in water often produces noticeable odors, sometimes fishy, woody, grassy, fruity, oily, or melony. It is difficult to describe odors, and people vary widely in the description that they use. Some reservoirs repeat regular patterns of phytoplankton growth year after year, and treatment is readied by the calendar.

DOES IT PASS THE TASTE TEST?

Odors can be detected at very low concentrations in water—in the milligram per liter range. But tastes require higher concentrations. We can taste saltiness, bitterness, sodaness, oiliness, astringency, sulfur roughness and similar sensations, but these may not coincide with the odor sense of the same water at all. We cannot taste hardness in water because there is already so much calcium in saliva that the calcium in the water does not add enough to stimulate a sensation.

The sense qualities of water are very important but they are difficult to measure. The only way that we can do this is to compare samples of water with artificial standards. For example, we can make up artificially turbid water standards containing varying amounts of fine clay—ranging from a few milligrams per liter to a few hundred—and compare bottles of the same size and shape until we get a satisfactory match. In the same way, we can compare the “stain” or color of water with the yellow-green-brown of artificial cobalt platinate solutions or dye mixtures.

But we do not have such a range of methods in measuring taste and odor. In the end we have to use people and people are highly variable. An experienced water plant operator can tell a great deal about water from tasting it. It is always necessary to compare taste with a taste-free sample—produced by filtering distilled water through activated carbon, and tests have to be set up to exclude the suggestive effects of odor. Taste tests are extremely important in food and beverage industries to be sure that process water does not introduce unwanted flavors. Beverage vending machines in areas where waters may carry taste or odor commonly contain activated carbon filters ahead of the dispensing equipment.

Odor is the most difficult quality to measure. The most practical method is to dilute the sample with odor-free water to the point that a number of people in a testing panel cannot reliably distinguish the sample from odor-free water itself. As soon as people are asked to describe the odor, the results become confused. There is better agreement when the question is whether or not the test sample smells different from the odor-free sample. Odor tests are usually rated by the amount of dilution required to produce an odor-free water and practical values are usually based on doubling the dilution through a long series (2x, 4x, 8x, 16x, 32x, etc.). Again, experienced operators give more consistent results. The sense of smell fatigues very rapidly, so that tests based on changes in concentration are more reliable. This is why test dilutions are based upon doubling or halving rather than smaller changes.

Secondary drinking water quality standards, as established by the Environmental Protection Agency

Fluoride	2.0 ppm
Iron	0.3 ppm
Manganese	0.05 ppm
Chloride	250.0 ppm
Sulfate	250.0 ppm
Foaming Agents	0.5 ppm
Total of all Dissolved Solids	500.0 ppm
pH	6.5 - 8.5

WILL WE RUN OUT OF GOOD WATER?

As our population grows, as more people live in new suburban communities, and as more independent military and industrial communities are established, well waters have become more important. Generally, wells are the first water supplies of small communities. These are replaced in time with larger community supplies and with community sewage systems because it is more economical to treat water in large quantities, and a more uniform water quality can be secured with better laboratory control than is possible in small systems. In the interval, however, many house owners will have to become water experts in the treatment of their well supplies.

Cities and industries on large rivers and lakes must reuse more water—flows of rivers and volumes of lakes are likely to change little, but cities and industries require more water and discharge more used water. As a practical matter, all water has been used over and over. Natural processes have purified it and made it useful again. Now we have to do this more quickly to make it available in a shorter time.

POLLUTION PROBLEMS INCREASE

It is possible to treat heavily polluted water to produce good quality drinking water, but the care required and costs are much higher than the more limited treatment required for good quality sources.

Further, it is important that the rivers and lakes that receive waste waters be kept fit for other uses: recreation, fisheries, and other interests. Most important, they must not be so overloaded that the biological processes that carry out natural purification of waters are impaired.

Biological treatment of waste waters in sewage and industrial waste treatment plants involves natural processes like those that go on in soils, streams and lakes. The same organisms are involved, but the balance of population is shifted to favor a few very active forms. The principal functions of waste treatment are to remove organic materials that consume oxygen in the receiving waters, and to reduce the concentration of suspended materials to a point that chemical disinfection, usually with chlorine, can be applied (see Fig. 15). Even the best biological treatment will not yield water comparable to that which went into the city or industry, because many of the mineral materials cannot be removed by this method of treatment. Treated waste waters will add ammonia, chlorides, calcium, iron, and phosphate to receiving waters.

Ammonia and chloride tests are frequently used in the field for quick estimates of the waste content of the streams, rivers, or lakes being studied. Before modern bacteriological tests were developed, ammonia concentrations in waters were generally used to check for domestic wastes. Most clean, natural surface waters are very low in ammonia; they rarely contain more than 0.15 milligrams of ammonia per liter. Small additions of ammonia from domestic wastes, treated or untreated, appear as marked increases in most streams. The Nessler test for ammonia is extremely sensitive, and a change of 0.1 mg ammonia per liter can be detected easily by direct addition of the reagents to water samples in the field. All domestic waste contains ammonia, and the quantities found are closely related to the population. This makes the test useful for engineering studies of waste treatment requirements.

AMMONIA BREAKS DOWN

Bacteria in water slowly change ammonia to nitrite and ultimately to nitrate. A complete nitrogen test of waste would include (a) organic nitrogen; (b) ammonia; (c) nitrite; and (d) nitrate. The organic nitrogen and nitrate tests require laboratory facilities for precise results, but approximations may be made by field tests.

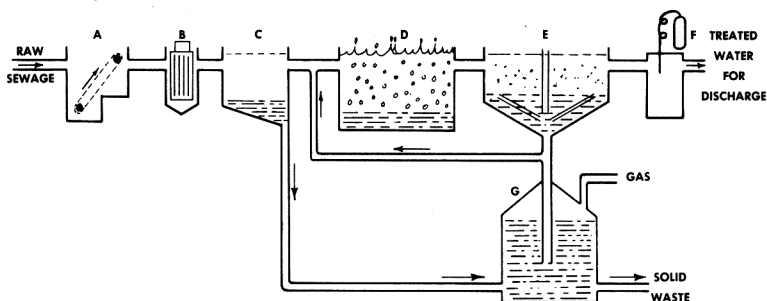
There are sensitive field tests for ammonia and nitrite. This is convenient because the relative concentrations of nitrite and ammonia give information on the nearness of waste discharge or recency of waste addition. If ammonia is present, but not nitrite, it can be assumed that the samples were taken in a zone of recent pollution; if traces of ammonia exist and nitrite tests are high, the waste has been in the water for several days and the stream is undergoing self-purification. If nitrate only is present, then there have been no recent additions of waste and the stream has recovered from the effects of oxygen-consuming wastes.

Ammonia may be added to water from sources other than domestic wastes, so it is important to make field observations of all possible nitrogen contributors. Drainage from barnyards, from fertilized fields, and wastes from some industrial processes may be principal contributors.

CHLORIDES AND PHOSPHATES

On waste surveys chloride analyses are usually included with ammonia tests. All domestic wastes include chlorides and treatment does not change chloride concentration of the waste discharge. Again, there is a good relationship between chloride discharge and population, but many processes within a community may also add chloride—salt from de-icing of streets, for example.

Phosphates may also be used to measure the changes due to waste addition. All domestic wastes contain phosphates; the concentrations are not greatly changed by

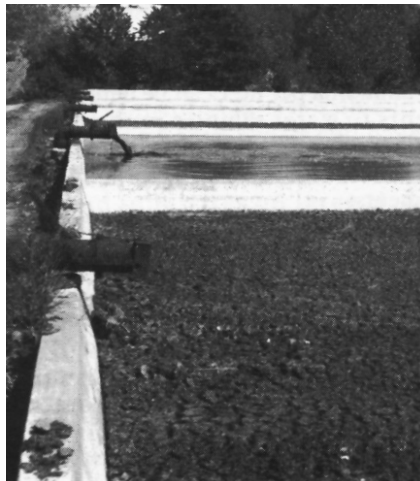


MUNICIPAL WASTE WATER TREATMENT BY THE ACTIVATED SLUDGE PROCESS

Fig. 15 Wastes flow to the treatment plant by gravity. Heavy solids, grit, sand, cinders, etc., settle out in the grit removal chamber (A) and are lifted by belt or spiral to land disposal. The remaining large pieces of materials in wastepaper, fiber, leaves, etc., are ground up in a special grinder (B), and the mixture is passed along to the primary settling chamber (C). Here bits of organic materials settle out, and are pumped to the digester (G). The lighter waste waters flow to an aeration basin (D) where they are violently stirred with air. This stirring hastens biological decomposition and produces fine flocs of active bacteria. The mixture of waste and fine bacterial flocs flows to a final settling chamber (E) where the bacterial floc falls to the bottom and the clear treated waste passes out to chlorination (F) and final discharge. An important feature of activated sludge is the return of part of the settled bacterial floc to the head of the aeration chamber to reinoculate the aeration system. This makes it possible to maintain a high concentration of active bacteria in the aeration chamber and to achieve a high degree of biological oxidation during the two to six hours that the waste is in the chamber. The remaining bacterial floc settled in final settling and the sludge removed in primary settling are pumped to an anaerobic digester where they undergo biological changes over several weeks to a month to produce fuel gas and biological solids that are stable enough to be disposed on soil, or dried and burned.



Solids suspended in water are pumped into a sludge field.



The water evaporates, leaving a layer of organically-rich solid material.

treatment. Some phosphates are added to wastes from washing powders in general use, so phosphates can also be a good indicator of community wastes.

Since ammonia, nitrate, and phosphate are used by aquatic plants—by microscopic phytoplankton and rooted stream plants—it may be possible to detect ammonia, nitrate or phosphate additions only near the source of waste. Plants consume and grow so rapidly that the added nitrogen and phosphorus are taken up by new plant growth and the addition of these nutrients cannot be detected in the water. When algae or other plants die, the nitrogen and phosphorus that they release is quickly taken up by new growing plants, so that waters are likely to test low in these elements during bright, warm weather.

FERTILE WATER SUPPORTS ALGAE

The “biological” quality of water is important in many ways, although the methods for measuring the makeup and behavior of such waters are somewhat more specialized than the methods for testing chemical properties of the water. It is important to know if a water is fertile, for example. Waters that contain phosphate, ammonia, and other nutrients in high concentrations may support heavy blooms of algae that produce odors and tastes in water and clog filters. Generally, efforts are made to keep waters designed for city supplies from becoming enriched; the watersheds of reservoirs are kept free of farming activities, industries, and community developments. They are forested to reduce silt transport into the reservoirs. By creating large protected reservoirs, many of our older cities have been able to keep chemical and physical treatment to a minimum because waters stored for long terms, in some cases for years, become less fertile as living processes remove nutrients and transport them to the bottom. As the population has increased, the areas that may be used for such reservoirs have declined, and more rigorous methods for purifying water must be used to take advantage of waters of large rivers and other sources where the benefits of storage cannot be employed.

All waters contain low concentrations of harmless natural organic materials absorbed from the air, from soils, or generated by the growth and death of microscopic plants. Sometimes additional organics enter in the wastes of communities and industries. When water containing organic matter in low concentrations flows over surfaces, a relatively large proportion of the organic materials absorb and concentrate on the surfaces. Harmless bacteria grow on these organic coated surfaces and produce light slime films; all pipes and tanks that carry moving water bear such light bacterial films. These films are harmless, but if they become thick they change the flow pattern of water near the walls of pipes and increase resistance. In heat exchange systems the films reduce efficiency of cooling. This can be very important in large power plants, where great volumes of water must be moved through the plant to keep the condensers at proper temperature, or in large air conditioning systems. For this reason it is common practice to periodically chlorinate the water to reduce bacterial growth.

HOUSEHOLDS NEED HIGH QUALITY WATER

One very important feature that determines how water is used is its cost. In most parts of this country, water costs so little that we use large quantities without thinking about it (Fig. 16). There are great economic advantages to having all the water that you want without thinking about its quality or cost. Imagine what life

would be like if you had to carry all of the water that you use every day from a well in a jar or bucket. This happens in someplaces. For your simplest needs, you would have to carry your own weight in water every day. So it isn't surprising that our cities developed near rivers, lakes and other waters that could be used for many purposes. Over a long period of time, engineers have developed the methods for collecting, treating and distributing water so that most people don't even think about it, not even its cost. Do you know what water cost your family last year?

One way of visualizing the work that has gone into getting good water to you is to think of your city with everything dissolved away but the water pipes and drains. Would you be able to recognize the downtown section with stores and tall office buildings, the part of town that you live in, and this school area? Normally the pipes through which water is supplied are hidden in the walls and underground, but now you have a chance to see them as part of your community. You can follow the mains back to the water treatment plant, and you can trace the sewers under the street down to the sewage treatment plant.

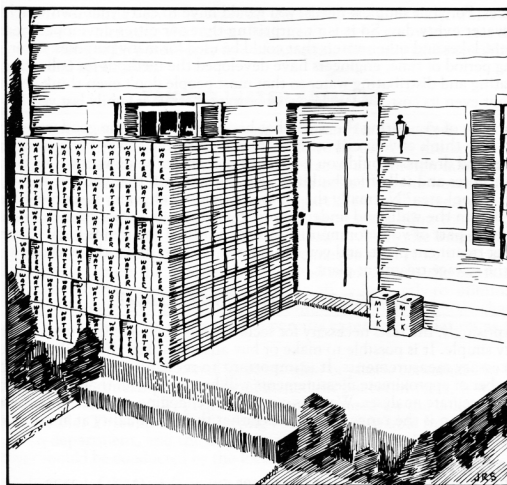


Fig. 16 The daily requirement of milk for a family of four is two half gallon containers. Imagine the daily water requirements of a family of four—600 half gallon containers.

WATER TESTS ARE IMPORTANT

Surprisingly, the tests necessary for securing this objective information are very simple. It is possible to make or buy analytical kits that will give the necessary measurements. It is important to recognize, however, that a number of approximate measurements will be more useful than one or two more accurate analyses. Water is continually changing, and the important information is the range of qualities rather than the quality at any single moment.

WATER FACTS

- Exists as a liquid between 0° and 100° Centigrade (32° and 212° Fahrenheit)
- Exists as a solid at or below 0° Centigrade (32° Fahrenheit)
- Exists as a gas at or above 100° Centigrade (212° Fahrenheit)
- One gallon weighs 8.33 pounds (3.778 kilograms)
- One gallon equals 3.785 liters
- One cubic foot equals 7.50 gallons (28.35 liters)
- One ton equals 240 gallons

- One acre foot 43,560 cubic feet (325,900 gallons)
- Earth's rate of rainfall 340 cubic miles per day (16 million tons per second)

There is very little very pure water on the Earth, and pure water won't stay pure. We are fortunate that most of our needs can be met with water that doesn't need to be pure—only free of materials that may cause trouble in our special application.

TAKING WATER SAMPLES

Great care must be exercised in taking water samples for analysis purposes. It is of great importance that the sample to be used in the analysis is representative of the water source and is free of any foreign matter that may be introduced. The container used for collecting the water sample must be clean and free from any foreign particles. In the event that the water sample is to be taken from a tap, it is important to allow the water to run for several minutes before the sample is taken. Allow the water sample to fill the collecting container several times so that it will be rinsed adequately. Unless the sample is to be tested immediately, the container should be filled to overflowing and the cap affixed securely to eliminate the possibility of an air bubble in the container. A sample bottle that is only half full with the water sample permits extensive oxidation as the sample is agitated in transit.

Water samples can be obtained in either glass or plastic containers. In the event the water sample is being obtained for bacterial tests, it will be necessary that a specially prepared container be used for the collection of this sample. These special collecting bottles are available from the local health department, and the determination of the bacterial count in the water should be conducted by the local public health agency.

At the time of the sampling, it is important to observe if the water supply has any characteristic odor or taste, and also to note if any color or hazy turbidity is present.

In removing a small portion of the water sample from the sample bottle, it is important that the original container be shaken to ensure that any suspended or precipitated materials are properly represented in the small sample being tested. The sample should not be filtered prior to the chemical analysis of the water.

Analytical results are often expressed in milliequivalents per liter. The term milliequivalent (meq) represents 0.001 of an equivalent weight. The equivalent weight is defined as the weight of the ion divided by the number of charges normally associated with the particular ion.

OTHER LaMOTTE HANDBOOKS

OUR ENVIRONMENT BATTLES WATER POLLUTION

Dr. Charles E. Renn
Professor of Environment Engineering Science,
Johns Hopkins University

Order Code 1592

The author identifies flowing water as a living, changing environment and explains the changes that take place and why these changes come about. The text traces a theoretical river from its origin as a mountain brook, detailing the biological and chemical changes that take place as the stream grows in volume and gains a more complex composition, until it finally discharges into a marine estuary. Some of the subjects covered are natural mechanisms that purify water, the reaction of fish to various conditions, the differences between water in motion and water impounded, the relationship between air pollution and water pollution, and the detection and reporting of water pollution factors.

LIMNOLOGY: AN INTRODUCTION TO THE FRESH WATER ENVIRONMENT

William H. Amos
Chairman, Science Department,
St. Andrew's School

Order Code 1593

This text is an authoritative booklet written expressly for instructors and students interested in studying fresh water supplies. The information is presented in a straightforward manner and there is an abundance of photographs and diagrams that illustrate the essential areas of investigation. The text discusses the basic chemical and physical characteristics of water, stream dynamics, plant zonation, the succession of ponds, the energy cycle of ponds and the adaptation of plants and animals to various aquatic conditions. The biological environments of ponds, lakes, swamps, streams and rivers are discussed.

A STUDY OF SOIL SCIENCE

Dr. Henry D. Foth
Professor of Soil Science,
Michigan State University

Order Code 1530

This illustrated booklet deals with the subjects of soil formation, variations in soil composition, the plant cycle, soil reaction (pH), and the major, minor and trace elements. It also includes information on soil as a water reservoir, movement of water in soil, and soil as a filter media for ground water. A glossary of soil science terms is included.

pH, BUFFERS AND ACID-BASE TITRATIONS

Staff, LaMotte Chemical Products Company

Order Code 1595

This booklet deals with the practical applications of pH control by employing pH indicators with color standards or buffer reagents as reference points. Considerable emphasis is put upon both the theoretical as well as the practical applications of acids and bases in chemical testing. Among the tables given is a graph of a typical acid-base titration.

PHOTO CREDITS

H. Armstrong Roberts, Fig. 10; Water Conditioning Association International, Fig. 12; H. Armstrong Roberts, Fig. 16; U.S. Department of Agriculture, Fig. 17. Drawings by J. R. Schroeder.

A STUDY OF WATER QUALITY

By Dr. Charles E. Renn

Water isn't simply water. The water that we know is always water and something else. It is this combination of water with something else that makes it useful or interesting or troublesome. It is this combination that makes it important to know about water quality.

This study follows the life cycle of water, beginning with water in its purest form found in nature, observing as it is altered by its contact with the atmosphere and with the earth. The text includes a study of the biological and chemical processes that take place in natural water supplies and continues the study through the basic treatments involved in the production of high quality water suitable for use in industry and the home.



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