Investigating Water Problems

Water Analysis Manual

ABOUT THE AUTHOR

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Dr. Renn was at the forefront of investigating various biological problems of water supply and wastewater engineering, and worked with most of the larger chemical industries. Of special interest to Dr. Renn, were the changes in water quality due to biological processes. He was a member of a number of professional societies including the American Water Works Association, The American Geophysical Union, and the Society of Limnology and Oceanography. He was also active in the teaching of elementary science and the development of equipment for teaching about water.

ABOUT THIS HANDBOOK

This booklet has been prepared expressly for teachers and students who are interested in investigating the quality of water supplies. The intent of this publication is to provide technical support and background information concerning the water quality factors and to give basic information on field and laboratory water testing techniques. It is assumed that the reader is not an experienced chemist, but is an inquirer seeking the essential information that is needed for meaningful interpretation of the results of field studies of aquatic environments.

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Introduction

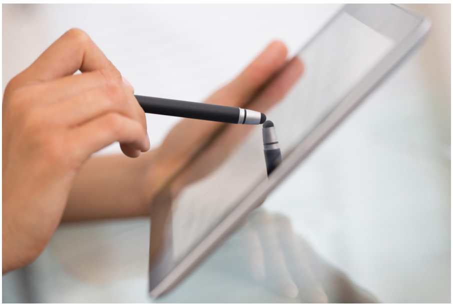
The first step in solving a problem is knowing that you have one. After that comes the details of knowing what the problem is, or isn't, and whether or not the steps that you have taken are in the right direction. In order to successfully find, move, store and purify water, in large quantities and at a low cost, we need to understand it. At the start we have to know what the water is like; then we have to decide what needs to be done to make it usable; and finally, we have to know if we've done it.

You can't always trust your senses and instincts, though they are usually in the right direction. But when we get away from waters with which we have been familiar for a long time, we need something better than first impressions. Usually, it is difficult to get a really useful accounting of these waters. Only extremes are noticeable. An unfamiliar water may be described as outstandingly good or bad; it will be terrible tasting, just wonderful, clear and cool and sparkling, or full of rust, great for the hair or skin, medicinal, and so on. But these are not scientific or engineering descriptions that tell you what you may have to do to produce a useful water supply for your special application.

The Science of Water

There is a science of water, and engineers have worked with water through recorded history. But there are always new problems, new things that we have to learn, and new ways of working with water to meet new uses. This is what makes simple water so interesting.

Of course, water isn't simple. We think that it is because we rarely have to think about it. It's there, and usually there's enough, and it's usually satisfactory because someone else has worried about it. But now and then you have to do the worrying, or you should, and it becomes necessary to develop an efficient system for getting the information that you need.



The most important items of equipment for developing information on water quality are right at hand. You need a notebook and pencil, laptop, or tablet. Water changes. You will be measuring changes. You can't trust your memory to keep track of the changes that may go on in seconds, hours, days, or months. Use your memory for something else, but use your notes for studying changes in the water. It's the history and continuing record that counts. Water, even water from a single well or spring, changes. Water changes as it flows along in a stream or river—it changes as it flows through a pipe. It changes while it is stored. In a large water supply, the water changes with population density, season, climate, and demand. In any watershed, changing population densities, water use patterns, drainage, land use changes, industrial development and other changes that people make, change the properties of water and they change the range of changes that go on. Even if there were no people, the streams, rivers, and lakes will change.

The properties of water are altered by very small amounts of dissolved or suspended materials. From the chemist's view, natural waters are extremely weak solutions—measuring the makeup of most waters, even polluted waters, requires that very low concentrations of chemicals be detected and ranked in value. Generally, you are looking for something that exists as a fraction of a milligram per liter to several hundred milligrams per liter.

Colorful Indicator Reactions

Analytical methods that involve color changes seem to be best for detecting very low concentrations common to drinking waters. There are other methods, but most are extremely rigorous and require expensive laboratory machines. For all-around studies of the properties of water and changes in quality, simple methods that give information that is sufficiently reliable, that are easy to use in the lab or in the field are the best. If a method is convenient to use, people are likely to use it, and data will be developed. If it is tedious and troublesome, people will avoid it and there won't be a record.

Remember, there are only special occasions that require highly accurate analyses. What is needed are repeated measurements, made in a pattern that will show the change in which you are interested. This is why the various water analytical kits are popular. A great deal of design work has gone into providing the best balance of sensitivity, specificity, convenience, durability, and cost to fit practical requirements. These monitoring kits are about as foolproof as they can be made, and best of all, they are portable and simple to use so that changes can be followed out in the field. It is easy to check important properties like pH, chlorine residues, calcium and magnesium hardness, bicarbonate and free CO_2, dissolved oxygen, nitrates, phosphates, silica, sulfates, sulfides, iron, copper and others. Some involve simple titration steps with colorimetric endpoints. Some compare intensity of color to give quantities. Color changes are always exciting and interesting; a lot of chemists got started because they found colors fun.

No matter what your tastes in colors or chemistry, the kit is there to make it possible for you to describe changes that go on in the water that you are studying. Everything you do with the kit should end up as numbers in your notebook. When you have enough numbers, they will show you what really happened.

Varying Water Requirements

In drinking water supplies, enormous engineering planning goes into making the water safe to drink up to the point that it leaves the faucet in the home. This takes a great deal of monitoring at the treatment plant, because the water coming to it varies—sometimes from minute to minute—and adjustments have to be made and tested in time to insure clean and safe water delivered to the mains. Beyond this there are monitoring programs to check water quality as it moves at different times of day, to different parts of the city.

Where water is used for manufacturing and in industrial processes, some properties may be more critical than they are for drinking. High pressure boilers are fussy about the water that they drink. Power plants check feed water for all of the components that may be corrosive at high temperatures and pressures, or that make trouble in the turbines and condensers. They have complete laboratories to measure the residuals of corrosion control additives, silica, phosphate, trace iron, sulfate, hydrogen, and so on. The data is recorded. Nothing is left to memory.

As customers of drinking water, we are usually less interested because someone else is making the analyses and we assume that he has things under control—as he does. But many homes have their own wells, and sometimes the well supply requires treatment to remove hardness, to reduce corrosion, to disinfect, to remove iron, and to make other improvements.

Some of these small treatment plants are automatic, but often simple analytical kits are used as handy devices to determine if things are working right and to make adjustment in dosing. But all waters, no matter what the treatment, change somewhat in going through the pipe, in tank storage, in heaters, and at other points while it is moving to you. Water that never changes isn't very interesting water.

This doesn't mean that you have to worry about water all the time. But you should at least know what is necessary for safety and comfort, and you should especially know what the changes that you note mean.

Using Analytical Results

After you have made a number of analyses, you will find that some of the changes are related. When the pH of the water goes up, for example, the iron content may drop, the hardness may rise, and the color may be lower. Hard waters may show less iron and copper in a house supply from wells, than a house supply from a soft water source. Chlorine may disappear more rapidly from a soft, slightly colored water, than from a hard, alkaline water (water high in minerals). The pH of a sluggish stream may go up after it plunges over some rapids—it may show a decrease in dissolved carbon dioxide and an increase in dissolved oxygen, too. Chlorinated waters may show less iron then they did before chlorination. These are the relationships that are interesting. Analysts at the water plant know the peculiarities of their intake waters very well; when one thing changes they look for changes in a related property, and they use the related changes to check the validity of any unusual feature that they have noticed.

Of course, sudden changes are always interesting, and they are often important—there can be a leak or contamination. But the slower changes are also important, and that's the reason for the record. For example, analyses for chlorides in a river made at a municipal water treatment plant over twenty-five years clearly show the effects of increased populations, paving, and the use of salt for ice control in upstream communities; sulfate tests taken over ten years at a power plant show the effects of acid mine drainage control efforts; the behavior of chlorine residual tests at a cannery during the working season shows the effects of increased well drought and the intrusion of new water from other aquifers.

Changing Nature of Water

Despite all sorts of evidence to the contrary, most people believe that well waters never change. It's easy to see that surface waters do—floods bring silt and pollutional loads,bright weather increases hardness, and blooms of algae produce other changes. But the prevailing belief seems to be that wells tap into the earth's core away from man's tampering and nature's whims. And this is in spite of the many incidents of the infiltration of well supplies with detergents, oil, brine, and other odd contributions. Wells yield wide ranges of water qualities—depending on rates and schedules of pumping, sources of renewal, long term climatic changes and alterations in the watershed.

There is much public apprehension about the effects of water pollution. As usual, there is much more discussion than analytical study. It is not difficult to analyze for common pollutants, but there is a marked shortage of people trained to make objective measurements. It is not true that streams, rivers, lakes and other waters get worse and worse—to the contrary, many major water sources have improved. To prove deterioration or improvement requires measurements that show the change.

We already have the analytical tools. The problem is to put them to work to build the information background in the notebook. The point of special studies in water technology is to be able to understand and to use the ways that the properties of water relate to one another, so that the work of measurement can be more efficiently used. People who know what the clues mean can get more facts from a few tests.

The measurements that will be made are those that are easiest to make. This is the special charm and value of analytical kits. The data can be taken on the spot, judged, compared with other data, repeated or extended as required. If the same person takes the sample, makes the analysis, records the data, compares the information and observes the water source, the interpretation is likely to be more reliable and useful than meanings taken from an extended chain of samples sent to a laboratory, analyzed, and reported back some days later. Less precise, approximate analyses, made in numbers at the site, by people who can see the water and what goes on, and who know the history of the water, are most satisfactory for practical work.

pH Measurements are Basic Keys

A very simple test is the pH test. You can measure hydrogen ion activity in a number of ways with varying precision. But you can't judge it by looking at the water or tasting it or sniffing it. Even the simplest pH measurement is better than that. Changes in pH give valuable clues. It can say that the caustic or acid feed to a treatment system is not performing as it should. It can reflect decomposition of organics in the water—or photosynthetic activity in surface waters. It can indicate

pollutants. One noted change, and you can be off like a bloodhound with other tests to discover what did happen and what it means.

The pH test is an important preliminary test. Small changes in pH, 0.3 units or less, are usually associated with relatively large changes in other water qualities—the solubility of iron, copper, calcium, manganese, and other metals, and the proportions of carbon dioxide, bicarbonate, and carbonate are greatly changed by small numerical changes in the pH measurement.

Biological processes in water—especially in ponds, lakes, and quiet waters—are indicated by pH changes. Dissolved oxygen measurements are also useful in tracking down biological processes in water. The carbon dioxide produced by respiration of animals and plants in water is sufficient to depress pH—the carbon dioxide and bicarbonate taken up by photosynthetic processes of aquatic plants is sufficient to raise pH. The same processes alter the dissolved oxygen content; oxygen drops during respiration and decomposition; it rises with photosynthetic activity. With these clues, you can go ahead to find other changes tied in with biological activity—changes in phosphate, iron, silica, ammonia and other materials that organisms take up with growth or yield from decomposition.

Turbidity

Turbidity is another simple test that can be used as a starting point. We can't see pH, but we can see turbidity. Turbidity is the milky or muddy look that comes with light scattering from very small particles in water. Sometimes it is mixed with color, but colored waters can be clear. Normally, we notice turbidity in water before we notice anything else.

But turbidity is not commonly measured, though it is easy to do so, and the results can be valuable for judging improvement or deterioration of water quality. There is a special panic that comes with the sudden appearance of yellowish turbidity in the hot water line, and a slight milkiness in a glass of water makes us question its fitness for drinking. Polluted waters are commonly turbid, and improvement of streams with time and flow is usually marked by greater clarity. Of course, good and useful waters may be turbid, and many clean rivers are never clear because they contain fine suspended minerals that never settle. But almost everyone prefers water that is so clear that you can see a clean bottom, and turbidity is a way of saying just how clear water is.

Water quality will inevitably be more critical to us. That is because we have to make water sources secondary to other factors as the nation grows. There are fewer choices; the abundant, good waters are already occupied. We have to take the water that we can get and make it drinkable and useful. Your notebook should tell you how you are succeeding.

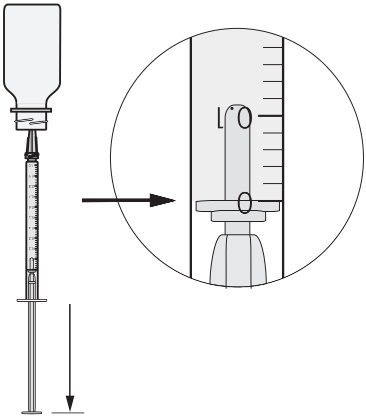
Analytical Equipment for Testing Natural Water Supplies

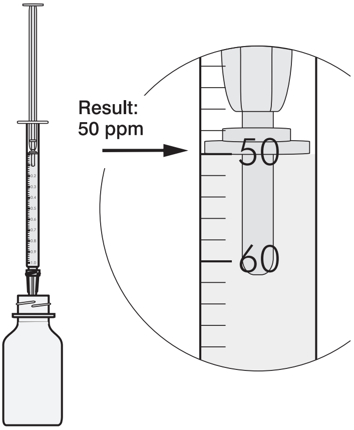
The equipment described in this manual employs one of two typical quantitative chemical test methods: colorimetric comparison with standards of known value or titration of the sample with solutions of known value. The reagent systems employed can also be used to make simple qualitative tests where the presence or absence (not the amount) of the factor being investigated is of concern to the investigator. These qualitative tests can be conducted in the field or in the classroom.

Colorimetric Comparison

The colorimetric comparison outfits provide a series of color standards of known values over the range of concentrations where the reagent system is most effective. If the color of the test sample does not match the color of one of the standards, but is between two color standards, the value assigned to the test sample is the midpoint between the two standards that bracket the color of the sample. For example, if the color of the test sample is between the colors of 0.2 ppm and 0.6 ppm, the result is read as 0.4 ppm. In the pH test, if the color of the sample is between pH 7.6 and pH 7.8, the result is read as pH 7.7. When the color of the test sample (other that pH) is greater than the standard of the highest value, the test is repeated on a portion of the test sample that has been diluted on a one-to-one ratio with distilled water. The values of the color standards are multiplied by a factor of 2 to compensate for the dilution. Dilutions of higher ratios can be made; however, it must be remembered that the values of the standards must be multiplied by the ratio of the dilution.

When the color of the reaction is less than that of the lowest value or when no apparent color formation has taken place, view the test sample by looking down through the column of liquid instead of across the column. Viewing the sample over a white surface will accentuate any color present. If no color is observed, it can be assumed that no trace of the material is present. Estimates of the value of the trace amounts of color can be made if the ratio of the tube diameter to the depth of liquid in the column is calculated in the estimate. If the depth of the column of liquid is five times the diameter of the tube, the value of the standard is divided by five.





A factor that must be considered when viewing the sample down through the tube is that some test reagents have a color of their own that is imparted to the sample and certain analytical reagents do produce faint traces of color even in distilled water. The amount of color formed by the reagents themselves can be determined by adding the reagents to the appropriate amount of distilled water in the same step-by-step procedure that is used in the test. Generally, trace amounts of approximately 20% of the lowest color standard value can be detected in the "view down" comparison method. Special comparator equipment has been developed for accurately reading faint colors.

Titration Equipment

The titration procedures can be carried out by means of a specially-calibrated Direct Reading Titrator which accurately measures the amount of titration reagent used; or the titration reagent can be added to the test sample one drop at a time from a pipet or dropping bottle that will deliver a drop of uniform size.

The Direct Reading Titrator is a syringe that has been specially calibrated for chemical testing purposes. The Titrator is filled to the zero mark from a special titration reagent dispenser bottle. The plunger is depressed to inject micro quantities of the titration reagent into a test chamber, until an "endpoint" color change takes place in the test sample. The Titrator scale interprets the volume of titration reagent dispensed in terms of the test factor concentration. Where the plunger tip meets the Titrator scale, the test result is read directly in parts per million or whatever unit of concentration is required for a particular test. The Titrator method permits direct reading of test results, with no counting of drops or calculations. It requires only small volumes of test sample and titration reagent. Mixing takes place in a sealed test vial, and the spill-proof reagent containers minimize atmospheric contact for longer shelf-life.

Water Quality Factors

Alkalinity

The normal conditions of the alkalinity of natural waters are associated with the carbon dioxide, bicarbonate, carbonate, and hydroxide components. These factors are characteristic of the source of water and the natural processes taking place at any given time. For particular industrial and domestic use, it is often desirable to change these characteristics by treatments such as aeration, neutralization, softening, etc. The particular treatment and the extent to which it is employed will depend upon the end use of the water.

Ammonia (Ammonia Nitrogen)

Ammonia Nitrogen is present in various concentrations in many surface and ground water supplies. Any sudden change in the amount of ammonia in a supply which has been of rather constant composition is cause for suspicion. A product of microbiological activity, ammonia nitrogen is sometimes accepted as chemical evidence of sanitary pollution when encountered in natural waters.

Ammonia is rapidly oxidized in natural water systems by special bacterial groups that produce nitrite and nitrate. This oxidation requires that dissolved oxygen be available in the water. (See Dissolved Oxygen section.) Ammonia is an additional source of nitrogen as a nutrient which may contribute to the expanded growth of undesirable algae and other forms of plant growth thus overloading the natural system and causing pollution.

Calcium

(see Hardness Section)

Carbon Dioxide

Carbon Dioxide is present in water supplies in the form of a dissolved gas. Surface waters normally contain less that 10 ppm free carbon dioxide while some ground waters may easily exceed that concentration. Corrosion is the principal problem caused by high concentrations of carbon dioxide in water. This is due to lowering of the pH of the water when carbon dioxide dissolves to form carbonic acid.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Carbon Dioxide is readily soluble in pure water. Over the ordinary temperature range (0°C–30°C), the solubility is about 200 times that of oxygen. Calcium and magnesium combine with carbon dioxide to form carbonates and bicarbonates.

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 large rooted plants, utilize carbon dioxide in the photosynthesis of plant materials—starches, sugars, oils, protein, etc. The carbon in all these materials comes from carbon dioxide in water.

When the oxygen concentration in waters containing organic wastes is reduced, the carbon dioxide concentration rises. The rise in carbon dioxide makes it more difficult for fish to use the limited amount of oxygen present. To take on fresh oxygen,

fish must first discharge the carbon dioxide in their blood streams and this is a much slower process when there are high concentrations of carbon dioxide in the water itself.

Chloride (also see Salinity)

Chloride is one of the major anions to be found in water and sewage. Its presence in large amounts may be due to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from sea water or industrial and domestic wastes. Any change from the normal chloride content of a natural water should be reason for suspecting pollution from one of these sources. U.S. Public Health Service Drinking Water Standards recommend a maximum chloride content of 250 ppm.

Chlorine

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 temperature, pH, presence of other materials that react with chlorine, time, and 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 agencies and others concerned with the safety of public water supplies. Chlorine concentrations in the range of 0.1 to 0.4 ppm are usually maintained in municipal supplies.

Chlorine can be added in the form of chlorine gas, liquid sodium hypochlorite (bleach), granular calcium hypochlorite, or as organic chlorine compounds. Chlorine is not present in natural water supplies and if it is present it is the result of chlorination or a water supply or when chlorinated compounds are discharged as waste from industrial operations. The presence of chlorine in concentrations above 0.5 ppm should be considered evidence of pollution from chlorine treated effluents or from a process in which high concentrations of chlorine are used.

Chromium (Chromate)

Chromium may be present in water containing waste from industry such as the metal plating industry or in overflow water from large air conditioning units where chromate compounds are frequently added to cooling water for corrosion control. It is considered to be a toxic chemical and, if present in an amount of over 0.5 ppm, it is evidence of contamination from untreated or incompletely treated industrial waste. This calls for more careful waste disposal control by the offending plant.

Chromium is one of a class of heavy metals found in the bottom muds of polluted bodies of waters. Certain shellfish are capable of concentrating this element and thus endanger the health of its ultimate consumer—whether it be man or animal.

Color in Water

The term “color” is used to describe “true color” which is the color of water from which turbidity has been removed. The term “apparent color” includes the color due to substances in solution and also that color due to suspended matter or reflected from the slope or bottom. For example, rocks covered with algae impart a greenish color; clay particles impart a yellow color, blooms of phytoplankton lend a green tint to water. Compounds of iron, calcium and other metals cause color as does water draining from peat bogs containing humic materials. Water color also varies on a seasonal basis. It is generally agreed the matter of color production in water is very complex and lends itself to some interesting studies.

Copper

The copper content of drinking water generally falls below 0.03 ppm and a copper content as high as 1.0 ppm will impart a bitter taste to water. Waters testing as high as 1.0 ppm copper have probably been treated with a copper compound such as is used by the control of algae, or have become contaminated from untreated industrial wastes. The addition of copper sulfate to lakes causes an increase in the copper content of the sediments. Acid waters and those high in free carbon dioxide may cause the corrosion or “eating away” of copper, brass, and bronze pipe and fittings. This results in the addition of copper into the water supply.

Cyanide

Cyanide may be present in water containing waste from a metal finishing plant. It is very toxic and should not be present in water. A positive test is evidence of untreated or incompletely treated waste which calls for more careful disposal control by the offending plant.

Dissolved Oxygen

Oxygen is vital to the life cycle common to water. It is essential to keep organisms living, to sustain species reproduction, and for the development of populations. Oxygen is soluble in water in direct proportion to the partial pressure in the gas phase and solubility decreases as temperature increases. Salt water holds less oxygen that fresh water. Oxygen enters the water by absorption directly from the atmosphere or by plant photosynthesis. It is removed by respiration of organisms and by organic decomposition. During respiration and decomposition, animals and plants consume dissolved oxygen and liberate carbon dioxide. Organic waste from municipal, agricultural and industrial sources may overload the natural system causing a serious depletion of the oxygen supply in the water. Waters rich in nutrients produce algae in quantity which upon decomposition deplete the oxygen supply. Fish kills are often associated with this process of eutrophication.

Standards for dissolved oxygen vary but the following recommendations serve as a guide for fresh water fish. Habitats for warm water fish population should contain dissolved oxygen concentrations of not less than 4.0 ppm. Habitat for cold water fish population should not be less than 5.0 ppm.

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 for it to continue.

Dissolved Solids

Dissolved solids in a natural water are usually composed of the sulfate, bicarbonate and chlorides of calcium, magnesium and sodium. The U.S. Public Health Service recommends that the total solids of a potable water be limited to 500 ppm but if such a water is not available a total solids content of up to 1000 ppm may be permitted. From the standpoint of irrigation of agricultural crops, total solids of 175 ppm or less would be considered low, between 175 and 500 medium; 500 to 1500 high and above 1500 ppm very high. The term salinity is also used to describe the solids content of irrigation water. In addition to potable and irrigation uses, a high solids content is undesirable in most industrial process waters. While sodium-hydrogen zeolite softening and lime-soda softening may affect a reduction in dissolved solids, for complete removal, it is necessary to employ demineralization or distillation.

Fluoride

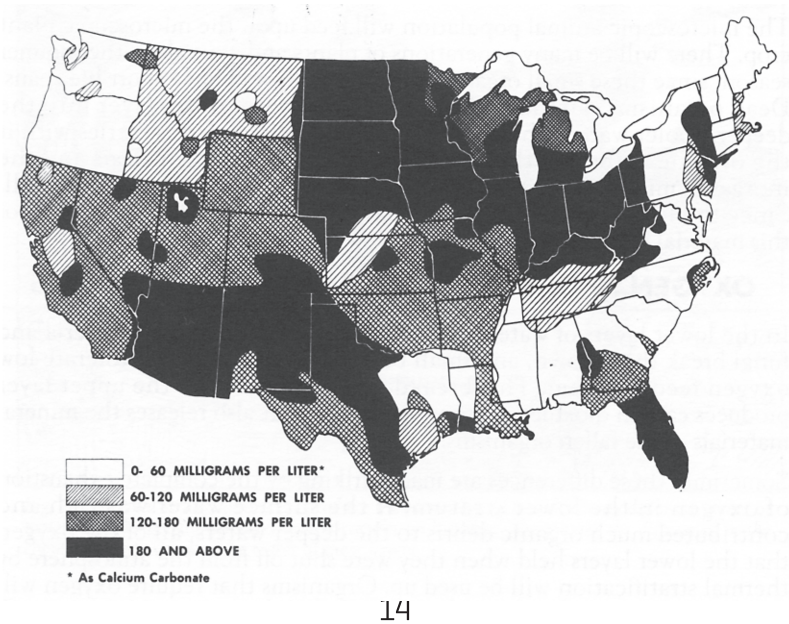
Fluoride may be present in natural water supplies as well as industrial and municipal effluents. Many municipal water supplies

are supplemented with up to 1.0 ppm of fluoride to strengthen teeth and reduce dental cavities. An excessive amount causes unsightly mottling of tooth enamel. The Public Health Service recommends limits between 0.80 ppm to 1.70 ppm. Some fluoride compounds are used as toxic agents for pest control and the residue of these compounds may appear in water.

Hardness

Calcium, magnesium, and total hardness factors of a water are considered as a group since the total hardness of a water generally represents the total concentration of calcium and magnesium ions expressed as calcium carbonate. Other ions may contribute to the hardness of water but in natural waters all but calcium and magnesium are present in insignificant quantities. When the hardness of a water is greater than the sum of the carbonate and bicarbonate alkalinity, the amount in excess is called “noncarbonate hardness” and such waters may contain considerable amounts of chloride and sulfate ions. This is an important factor to consider when treating potable water by ion exchange methods. The hardness of water may range from zero to hundreds of parts per million, depending on the source of the water or the treatment to which the water has been subjected.

Calcium and magnesium may be added to a natural water system as it passes through soil and rock containing large amounts of these elements in mineral deposits. Waters containing small



concentrations are referred to as “soft,” those containing large concentrations as “hard.” The soft waters are mainly derived from the drainage of acidic igneous rocks, the very hard water from the drainage of calcareous sediments. Some industrial processes may also produce significant amounts of these elements that are later discharged into streams.

A knowledge of the hardness of water is of great importance in industrial uses since it is the chief source of scale in heat exchange equipment, boilers, pipe lines, etc. From the domestic standpoint, hard water consumes excessive quantities of soap, forming curds and depositing a film on hair, fabrics, and glassware.

Drinking water quality standards as determined by the U.S. Public Health Service set limits of calcium hardness at 200 ppm and magnesium at 150 ppm. Waters with a total hardness in the range of 0 to 60 ppm are termed soft; from 60 to 120 ppm, medium hard; from 120 to 180 ppm, hard; and above 180 ppm, very hard.

Magnesium Hardness is determined by subtracting the Calcium Hardness result from the Total Hardness result:

Total Hardness, ppm ($CaCO_3$ ppm) – Calcium Hardness, ppm ($CaCO_3$ ppm) = Magnesium Hardness, ppm ($CaCO_3$ ppm)

Iron

Most natural waters contain some iron. Its presence may vary from the smallest trace to very large amounts in water which is contaminated by acid mine wastes. For domestic use the concentration should not exceed 0.2 ppm and for some industrial applications not even a trace of iron can be tolerated. There are many means available for removing or reducing the iron content of waters. Water softening resins are effective for removing small amounts of iron and special ion exchange materials are selective for iron removal. High concentrations of iron can be removed by such chemical processes as oxidation and lime or lime-soda softening. Because of the many means of removing or reducing the amount of iron in water, the particular method employed will depend largely on the form of iron which is present and the end use of the treated water.

Magnesium

(see Hardness Section, page 8)

Manganese

Manganese is a trace element important to the life cycle of plants and animals. It may enter natural water as a result of organic decomposition, solution of mineral rocks or by industrial dumping. Manganese often exists in various forms of chemical composition, some of which add color to water. Public water supplies are limited to 0.1 ppm concentration. The low manganese limits imposed on an acceptable water supply stem from practical considerations rather than for toxicological reasons. Very small amounts of manganese in potable water cause objectionable stains which are difficult to remove

from plumbing fixtures. In treating municipal water supplies, special means of treatment are necessary for removal of this troublesome compound, such as aeration, chemical precipitation, superchlorination, or the use of special ion exchange materials.

Nitrate

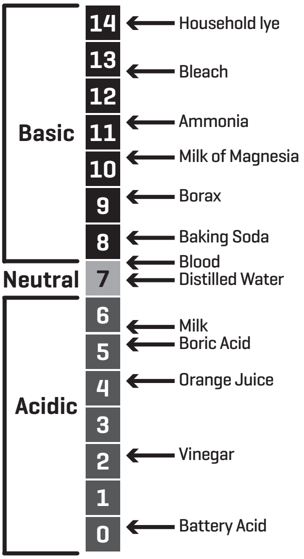
Nitrogen is essential for plant growth, but the presence of excessive amounts in water supplies presents a major pollution problem. Nitrogen compounds may enter water as nitrates or be converted to nitrates from agricultural fertilizers, sewage, industrial and packing house wastes, drainage from livestock feeding areas, farm manures and legumes. Nitrates in large amounts can cause "blue babies" (methemoglobinemia) in infants less than six months of age. It is an important factor to be considered in livestock production, where, in addition to causing methemoglobinemia, it is responsible for many other symptoms arising from the presence of high levels of nitrates in water supplies. Nitrates in conjunction with phosphate stimulate the growth of algae with all of the related difficulties associated with excessive algae growth.

U.S. Public Health Service Drinking Water Standards state that 10 ppm Nitrate Nitrogen is a limit which should not be exceeded. To the sanitary and industrial engineer, the concentration which is of concern is less than 1 ppm.

pH

The term pH (always written with a lower case p and an upper case H) is correctly defined as the negative logarithm of the hydrogen ion concentration. More simply, the term pH can be considered to be an "Index" of the amount of hydrogen ion present in a substance. This "Index" is important as it can be used to quickly identify the acid, neutral or alkaline (basic) nature of materials.

Most natural waters will have pH values from pH 5.0 to pH 8.5. The acidic, freshly fallen rain water may have a pH value of pH 5.5 to pH 6.0. If it reacts with soils and minerals containing weak alkaline materials, the hydroxyl ion concentration will decrease. The water may become slightly alkaline with a pH of 8.0 to 8.5. Natural sea water



will have a pH value of 8.1 and changes from this value indicate that water from an inland source is entering the body of sea water.

Waters more acid than pH 5.0 and more alkaline than pH 8.5 to 9.0 should be viewed with suspicion. Mine drainage and acid industrial wastes are the principal factors in increasing the acidity of water, and alkaline industrial wastes are the cause for high pH values.

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 quality studies. Sudden changes noted in pH values serve as warning signals that water quality may be adversely affected through the introduction of contaminants.

Phosphorus (Phosphates)

Phosphorus is an important nutrient for aquatic plants. The amount found in water is generally not more that 0.1 ppm unless the water has become polluted from waste water sources or excessive drainage from agricultural areas. When phosphorus is present in excess of the concentrations required for normal aquatic plant growth, a process called eutrophication takes place. This creates a favorable environment for the increase in algae and weed nuisances. When algae cells die, oxygen is used in the decomposition and fish kills often result. Rapid decomposition of dense algae scums with associated organisms give rise to foul odors and hydrogen sulfide gas.

Salinity

Salinity is defined as the concentration of all ionic constituents present including halides and all bicarbonate being converted to carbonate. Sea water contains about 20,000 ppm chloride and has a salinity of approximately 35,000 ppm. Brackish water ranges upward from 1000 ppm of dissolved salts, and Brine is any water containing more dissolved salts than sea water. For example, water in the Great Salt Lake contains over 250,000 ppm of dissolved salts. Intrusion of salts into fresh water supplies affect its use as potable water or for purpose of irrigation.

Many fresh water fish and plants have a low tolerance to any increase in salinity.

The salinity of water can be completely removed by distillation or demineralization by ion exchange resins. Much research is being done to remove salts from sea water by reverse osmosis to make it potable and to provide water that is suitable for irrigation.

Salt Concentration of Various Water Supplies, ppm

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

Silica

Silicon Dioxide, SiO_2, commonly known as silica, occurs in all natural waters in varying degrees of reactive form. Silica is of significance as a major nutrient for diatoms. A silica cycle occurs in many bodies of water containing organisms, such as diatoms. A silica cycle occurs in many bodies of water containing organisms, such as diatoms, that utilize silica in their skeletal structure. The silica removed from the water may be slowly returned to solution by the decomposition of the dead organisms. The major source of silica in natural waters is from the decomposition of alumina silicate minerals in the drainage basin from which the waters flow. Values may range from 0–75 parts per million.

The presence of silica is particularly objectionable in water used for boiler feed water purposes as it may lead to the formation of a hard, dense scale which has unusually high resistance to heat transfer. Serious loss of turbine efficiency results from insoluble silica turbine blade deposits caused by vaporization of silica from boiler water.

Sulfate

The most common mineral forms of sulfur are as iron sulfide, lead sulfide, zinc sulfide, and as calcium sulfate and magnesium sulfate. In most fresh waters, the sulfate ion is the second or third most abundant anion, being exceeded only by bicarbonate and in some cases by silicate. Sulfur in the form of sulfate, is considered an important nutrient element. Mineral springs are rich in sulfate and feed appreciable quantities of this compound to the watershed. Acid mine water drainage is a form of pollution which may contribute extremely large amounts of sulfate content to natural waters. Other sources of sulfate include waste material from pulp mills, steel mills, food processing operations and municipal wastes. Many bacteria obtain sulfur from sulfate for their synthesis of amino acids. In lakes and streams low in oxygen, this process of sulfate reduction causes the production of hydrogen sulfide (see Sulfide section) with its characteristic offensive odor. Calcium sulfate and magnesium sulfate contribute significantly to the hardness of water. Under natural conditions, the quantities ordinarily to be expected in lakes are between 3 and 30 parts per million.

Sulfide

Sulfide occurs in many well water supplies and sometimes is formed in lakes or surface waters. In distribution systems, it may be formed as a result of bacterial action on organic matter under anaerobic conditions. It may also be found in waters receiving sewage or industrial wastes. As an example, solutions used in the treatment of wood pulp in paper manufacture may contain large amounts of sulfite which is reduced to sulfide. Lake muds rich in sulfates produce hydrogen sulfide during periods of very low oxygen levels that result from summer stagnation.

Concentrations of a few hundredths of a part per million cause a noticeable odor. At low concentrations, this odor is described as “musty,” at high concentration, it is described as “rotten eggs.” Removal of sulfide odor is accomplished by aeration or chlorination. Hydrogen sulfide is a toxic substance acting as a respiratory depressant in both man and fish.

The water sample should be collected with a minimum of aeration. Not only is sulfide volatilized by aeration but also any oxygen which is taken up will destroy it by chemical action. Samples that are used only for total sulfide determinations may be preserved by adding zinc acetate solution (2M) at the rate of 2 mL per liter. This precipitates sulfide as inert zinc sulfide. Determination of dissolved sulfides and analyses of samples not preserved with zinc acetate should be commenced within 3 minutes of the time of sampling.

Turbidity in Water

Turbidity is an expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. It is not directly related to the weight of suspended material. Turbidity in water is caused by the presence of suspended particles such as clay, silt, finely divided organic matter, plankton and other microscopic organisms.

Zinc

Zinc is one of a number of trace elements considered essential to plant growth and the physiological function of organisms. The permissible limit for zinc in potable water is 5.0 ppm. At concentrations above 5.0 ppm, zinc can cause a bitter, astringent taste and turbidity in alkaline water. Zinc may be present in natural water as a result of the discharge of industrial waste.

Suggestions on the Use of Chemical Test Equipment

1. Follow all of the instructions carefully. Read to the end of each procedure before starting the actual work. Measure reagents and water samples accurately. Add the reagents in the order stated in the instructions. Observe the time periods required for maximum color development.
2. Handle the reagents with great care. Avoid contact between the reagents and the skin and eyes. Some of these reagents are capable of causing minor skin irritations if they are not washed off immediately after contact. None of the reagents should be taken internally. Read reagent labels. Read Safety Data Sheets (SDS) at *www.lamotte.com*.

3. Keep all reagent containers tightly capped. Replace the cap immediately after use. This prevents contamination and eliminates the possibility of loss of the reagent due to leakage or spilling. Do not interchange caps.
4. Carefully wash and rinse the sample bottles and test tubes after each use. Never put the equipment away without first making certain all items are clean and returned to their proper place in the kit.
5. Avoid storing the equipment where it will be exposed to extremes of heat and cold. Do not leave the reagents exposed to direct sunlight for a prolonged period of time. Store the equipment out of the reach of very young children.

Suggestions on the Collection of 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 be representative of the water source and be 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 can be subject to extensive oxidation as the sample is agitated in transit. Water samples can be obtained in either glass or plastic containers. In removing a small portion of the water sample from the sample bottle, it is important that the original container be gently inverted several times to ensure that any suspended or precipitated materials are properly represented in the small sample being tested.

Sample Preservation

1. For the following tests, all or part of the test procedure must be made at the time of sampling: Carbon Dioxide, Chlorine, Cyanide, Dissolved Oxygen, pH, Sulfide, Turbidity, Total Dissolved Solids.
2. No special treatment or time limitation for making test: Chloride, Salinity, Fluoride, Total Hardness, Calcium, Magnesium.
3. If the sample is kept refrigerated at 4°C, the following tests can be made up to the maximum holding periods noted: Alkalinity, 24 hours; Color, 24 hours; Sulfate, 7 days.
4. If the samples are treated with 40 mg Mercuric Chloride (1 mL 4% $HgCl_2$) per liter and kept refrigerated at 4°C, the following tests can be made up to the maximum holding periods noted: Ammonia, Nitrate, and Nitrite Nitrogen, 7 days; Phosphorus, 7 days; Silica, 7 days.
5. Treatment of filtered sample with 25 mL of 1:1 Nitric Acid will permit testing for the following dissolved metals for a period of up to 6 months: Chromium, Copper, Iron, Manganese.

Facts About Water

Water exists as a liquid between	0° and 100° Centigrade (32° and 212°Fahrenheit)
Water exists as solid at or below	0° Centigrade (32° Fahrenheit)
Water exists as gas at or above	100° Centigrade (212° Fahrenheit)
One gallon of water weighs	8.33 pounds (3.778 kilograms)
One gallon of water equals	3.785 liters
One cubic foot of water equals	7.50 gallons (28.35 liters)
One ton of water equals	240 gallons
One acre foot of water equals	43,560 cubic feet (325,900 gallons)
Earth’s rate of rainfall	340 cubic miles per day (16 million tons per second)

Drinking Water Standards

Drinking water quality standards as established by either the U.S. Public Health Service or the World Health Organization.

Calcium	200.0 ppm
Magnesium	150.0 ppm
Iron	0.3 ppm
Manganese	0.1 ppm
Chloride	250.0 ppm
Sulfate	250.0 ppm
Detergents (ABS)	0.5 ppm
Total of all Dissolved Solids	500.0 ppm
pH	7.0 - 9.0 ppm

Conversion Factors:

1 ounce = 28.35 grams
1 pound = 453.6 grams
1 gallon = 8.34 pounds of water
1 gallon = 3800.0 grams of water
1 cubic foot = 7.5 gallons
1 cubic foot = 62.4 pounds of water
1 acre foot = 43.560 cubic feet
1 acre foot = 327,000 gallons

Equivalencies:

1 ppm is equivalent to:
2.7 pounds per acre foot
0.0038 grams per gallon
0.0284 gram per cubic foot
1 lb in 1,000,000 pounds
1 gram in 1,000,000 grams

Glossary of Terms:

Absorption
Assimilation of molecules or other substances into the physical structure of a liquid or solid without chemical reaction.

Acid
A compound of hydrogen plus a metal. It reacts with a pH indicator to give a reading below pH 7.0 on the pH scale.

Acidity
The degree or level of the acid content of a water supply. Acidity is generally read in terms of pH. Very strong acids are measured in terms of percent.

Activated Carbon
Carbon which is "activated" by high-temperature heating with steam or carbon dioxide producing an internal porous particles structure. The internal surface area of granular activated carbon is estimated to be about 3600 square feet per grain.

Adsorption
Physical adhesion of molecules to the surface of solids without chemical reaction.

Aeration
A water purification process whereby air is introduced into the water. This may be accomplished by treating water supplies with large volumes of air or in a natural system as the water passes over rapids or a waterfall.

Algae
An aquatic plant of cellular structure that thrives on sunlight. It does not have roots, leaves, flowers, or seeds. When allowed to grow in water, it will give the water a greenish or brownish haze and if not controlled, a fur-like mat of slime will be found. Algae can be destroyed by heavy dosage of sanitizing chemicals (super chlorination) or by treatment with special compounds called algicides that are formulated for the sole purpose of destroying aquatic plants.

Algicide
A chemical compound that is capable of destroying algae. Copper and mercury compounds are used as well as a family of compounds known as the quaternary ammonium compounds.

Alkali
A chemical compound that reacts with a pH indicator to give a reading above pH 7.0 on the pH scale. Sodium Carbonate, Calcium Hydrate and Sodium Hydroxide (caustic) are alkali materials that are used in water treatment to counteract acidity and to raise the pH of water to the desirable, slightly alkaline level.

Alkaline
A condition in water where the water gives a reading above 7.0 on the pH scale when tested with a pH indicator.

Alkalinity, Total
The degree or extent of the alkaline nature of water. A pH indicator test will tell if the water is acid, neutral, or alkaline, however an alkalinity test is required in order to determine the exact amount of alkaline material that is present. The amount of alkalinity present is determined by a titration measurement. Alkalinity and pH readings are not the same. The pH reading is similar to a temperature reading on a thermometer that tells what the present temperature reading is while the alkalinity reading tells you much heat is needed to reach the desired temperature.

Alum
A general term referring to aluminum compounds of sodium, potassium, or ammonia. Alum is used in water treatment to aid in the flocculation (settling out) of small particles of impurities. It is a white powdered material and is usually dissolved in water before being added to the water that is to be treated. Flocculation is most effective at the near neutral pH range and consequently the control of the pH factor is important in order to achieve effective flocculation.

Aluminum Sulfate
A widely used alum compound that is selected because it dissolves easily in water, requires no special feeding equipment and because of its low cost. (See ALUM.)

Analysis
The examination of a water sample to determine its chemical composition and characteristics. A water sample can be analyzed or tested for a single factor, several key factors or the sample can be divided completely to determine all of its constituents. Qualitative analysis determines what materials are present. Quantitative analysis determines the amounts of the various materials present.

Anion
A negatively charged ion resulting from the dissociation of molecules in solution.

APHA
The abbreviation for American Public Health Association.

ASTM
The abbreviation for American Society for Testing Materials.

AWWA
The abbreviation for American Water Works Association.

Bacteria
One-celled microscopic organisms. They are found in two forms; pathogenic microorganisms that produce disease and non-pathogenic bacteria which do not produce disease in man or the higher animals.

Base
An Alkaline material. (See ALKALI.)

Biochemical Oxygen Demand
A measure of the organic matter present in a water which can be metabolized by bacteria in a given period of time, usually five days.

Biological Function
The role played by chemical compound or a system of chemical compounds in living organisms.

Buffer
A chemical compound or system capable of resisting abrupt changes in pH. It is also a compound used in chemical testing for the purpose of adjusting or maintaining a specific pH of the test sample so that indicator reactions can be carried out in the most desirable range.

Buret
A long, narrow titrating column that has been accurately calibrated to indicate the exact volume of liquid dispensed in the test procedure. Laboratory burets usually have a valve called a stopcock which regulates the flow of the titration solution from the column. Direct Reading Titrators are small burets that work on a plunger action similar to a hypodermic syringe.

Calcium
An element which when present in water under certain conditions readily combines to form a salt which is in turn deposited as scale.

Calcium Hardness
Determined by a chemical test and is that amount of calcium which is found present in hard water.

Calcium Hypochlorite
A granular form of a chlorine compound that is widely used to chlorinate water. The calcium hypochlorite used is readily soluble and is generally offered as a 70% available chlorine source.

Carbon
An important nonmetallic element in the structure of all plants and animals (living organisms). It is obtained primarily from the carbon dioxide in the air.

Cation
A positively charged ion resulting from the dissociation of molecules in solution.

Caustic
In water treatments, this refers to caustic soda which is Sodium Hydroxide. This product is added to the water to offset a low pH factor and to prevent corrosion caused by excessive acidity.

Chlorophyll
The pigment responsible for the green color of plants. It is important in photosynthesis in plants, the process by which sugar is manufactured from carbon dioxide and water.

CC
An abbreviation for cubic centimeter. There are 29.57 cubic centimeters in one fluid ounce. The terms “cc” and “mL” (abbreviation for milliliter) are used interchangeably although there exists a minute difference in the quantities represented by these two terms.

Cell (test cell)
A test tube or container in which a chemical test is made.

Chelates
A type of chemical compound in which a metallic atom is firmly combined with a molecule by means of multiple chemical bonds. These are soluble compounds. The term refers to the claw of a crab, illustrative of the way in which the atom is held.

Chelating Agents
Chemical compounds which have the property of withdrawing ions into soluble complexes so that they will not precipitate or settle out of solution.

Chlorine (Cl_2)
The sanitizing agent most widely used in water treatment. It is a member of the halogen family and exists as a greenish yellow gas. It is used in the form of a gas, a liquid (Sodium Hypochlorite) and as a solid material (Calcium Hypochlorite, Chlorinated Cyanuric Acid).

Chlorine Demand
The chlorine demand of a water is the difference between the amount of chlorine applied to a treated supply and the amount of free, combined or total chlorine remaining at the end of the contact period. The chlorine demand of any given water varies with the amount of chlorine applied, time of contact, pH and temperature.

Chlorine Residual
The amount of active chlorine present in a water supply. The total chlorine residual is the sum of the free available chlorine plus the combined available chlorine.

Clarification
Process of removing turbidity and suspended solids by settling. Chemicals can be added to improve and speed up the settling process through coagulation.

Coagulate
Congeal or form a jelly-like mass.

Coagulation
In water treatment this is a combined chemical and physical action whereby a compound is added to the water which gathers together the finely divided and suspended materials into large particles, called floc. These particles will settle rapidly and can be easily removed by filtering.

Colorimetric
A name given to a chemical test method where the result of the test is determined by the amount of the shade of the color developed. The pH test and phosphate test are examples of the colorimetric tests.

Color Standard
A liquid, solid, or printed item equivalent in color to the color developed when an indicator is added to a definite concentration of a chemical.

Coliform
A form of bacteria widely found in contaminated water that exhibits a pronounced and definite series of characteristics that make this form of contamination reasonably easy to determine. The determination of coliform bacteria in water should be conducted by or under the direction of a public health official.

Comparator
A device for holding color standards and a test sample in adjacent positions so that the colors of each may be easily compared, one with the other.

Copper
A metallic chemical that is effective in destroying growths of algae in water. Excessively high copper levels in water are toxic when ingested and should be avoided.

Copper Sulfate
A blue granular or powdered material added to water for the purpose of killing algae growth. Also known as bluestone or blue vitriol.

Corrosion
A process of deterioration where metal parts are slowly eaten away by aggressive acid solutions or by acid water supplies (below the pH of 7.0). The corrosive tendencies of acid water can be controlled through proper pH adjustment of the water.

Cubic Feet per Second (cfs)
A measure of discharge; the amount of water passing a given point, expressed as number of cubic feet in each second.

Diatomaceous Earth
A fine siliceous earth made up of the skeletal remains of diatoms which are single-celled marine animals having a coating or sheath consisting principally of silica. It is an excellent filter media for processing water.

Discharge
Outflow; the flow of a stream, canal, or aquifer. One may also speak of the discharge of a canal or stream into a lake, river, or an ocean.

Dissolved Oxygen (DO)

The amount of oxygen dissolved in a water or waste.

Domestic Use

Water used in homes and on lawns, including use for laundry, washing cars, cooking, and swimming pools.

Drop Count

A titration test method where drops of a special titrant are added to an indicator-treated sample to bring about a color change that is keyed to an unknown component in the test sample. The number of drops required to bring about the color change indicate the amount of the component present.

Ecology

The science that deals with the interrelations of organisms and their environment.

Endpoint

The point in a titration procedure where a color change in the sample takes place. An endpoint indicator is added to the test sample to tell when a titrating solution has equalized the component being tested. When the sample changes color, it is said that the titration has reached the endpoint.

Environment

All external conditions that may act upon a soil, water, or organisms to influence its development. Such factors may include sunlight, temperature, moisture, chemical pollutants and various organisms.

Equivalent, Chemical

The weight in grams of a substance which combines with or displaces one gram of hydrogen, obtained by dividing the formula weight by the valence. Thus for Potassium with an atomic weight of 39.1 and a valence of 1, the chemical equivalent is 39.1 grams, whereas for Aluminum with atomic weight 26.98 and valence of 3, the chemical equivalent is 8.99 grams.

Equivalent, Milliequivalent (mEq)

A milliequivalent is 1/1000 of an equivalent. EXAMPLES: mEq for Aluminum is 8.99 milligrams and for Potassium 39.1 milligrams.

Erosion

The detachment or transport of soil particles by the action of wind and water. This great destructive force can be combated by cover crops, contour planting or terracing, gully control or wind breaks.

Eutrophic

Having concentrations of nutrients in solution optimal for plant or animal growth.

Evaporation

The process by which water is changed from a liquid to a gas or vapor.

Flocculate

By the addition of a special chemical, the tiny particles suspended in water coagulate or clump together forming larger particles which are then more easily removed on the filter media.

Flood

Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream.

Flood Plain

The lowland that borders a river usually dry but subject to flooding when the stream overflows its banks.

Food Chain
The dependence of one type of life on another, each in turn eating or absorbing the next organism in the chain.

Germicide
A substance which is used for the purpose of destroying disease germs.

Grain per Gallon (gpg)
A unit of measurement in water analysis and water treatment. One grain per gallon is equivalent to 17.1 parts per million (another unit of measurement in chemical testing).

Ground Water
That portion of the total precipitation which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity.

Hard Water
Water that has a high calcium or magnesium content. Hard water is undesirable because of its scale forming characteristics. Water that contains 8 or more grains per gallon is considered hard water.

Hardness, Total
The sum of the calcium hardness plus the magnesium hardness. Total hardness is determined by a simple titration procedure and results are given in terms of either grains per gallon or parts per million.

Hydrogen-ion Concentration
See pH.

Hydrology
The science of the behavior of water in the atmosphere, on surface of the earth, and underground

Hypochlorite
A water treatment compound containing a very large amount of available chlorine. Calcium Hypochlorite is a white granular material and Sodium Hypochlorite is a pungent liquid material. Both are used as a source of chlorine in water sanitation.

Igneous Rock
Rock formed from the cooling and solidification of magma, and that has not changed appreciably since its formation.

Indicator
A chemical reagent added to a test sample to bring about a color reaction.

Inorganic
Non-living matter, such as rock, clay, or sand as contrasted with organic or living matter such as plants and animals. The mineral fraction of soil is inorganic.

Insoluble
Incapable of being dissolved or liquified.

Ion
Atoms, groups of atoms, or compounds which are electrically charged as a result of the loss of electrons (cations) or the gain of electrons (anions).

Irrigation
The artificial application of water to the soil for the benefit of growing crops.

Leaching
The removal of soluble chemical elements by the passage of water through the soil.

Magnesium Hardness
That amount of magnesium which is present in a hard water sample. The magnesium hardness plus the calcium hardness equals the total hardness.

Marsh
Periodically wet or continually flooded areas with the surface not deeply submerged. Covered dominantly with sedges, cattails, rushes, or other water plants.

Microorganism
Minute particles of living matter that are invisible or nearly so to the unaided eye, but that are capable of growing rapidly under proper conditions, so that they can cause sudden cloudiness in the water.

Milliliter (mL)
One-thousandth part of a liter. There are 29.57 milliliters in one fluid ounce.

Muriatic Acid
Also called Hydrochloric Acid, this strong acid is used to reduce excess alkalinity in water. It is an extremely corrosive and dangerous chemical and should be handled with great care.

Neutral
A water sample is neutral if it has a pH reading of 7.0. It is not acid (below pH 7.0) or alkaline (above pH 7.0).

Parts per Million (ppm)
A unit of measurement used in chemical testing which indicates the parts by weight in relation to one million parts of water. One part per million is equivalent to 8.3 pounds of a material in one million gallons of water. 17.1 parts per million are equal to one grain per gallon (another unit of measurement used in chemical testing and in water treatment).

pH
This is a scale based on the Hydrogen Ion concentration by which water and other substances are measured to determine if they are acid, neutral, or alkaline. The midpoint of the scale is pH 7.0. Readings from 0.0 to 7.0 are acid and the lower the pH value, the more strongly acid the material. pH indicators react with water samples to give different colors at different values. These colors can be calibrated and duplicated in the form of permanent color standards.

Pipet
A "dropper" device that is usually calibrated for measuring small amounts of liquid. The pipet can have a graduated mark or series of marks or it may be calibrated in terms of the size drop that it delivers.

Potable
Water that is suitable for drinking.

Precipitate
An insoluble compound formed by chemical action between two or more normally soluble compounds in solution.

Precipitation
The settling of insoluble compounds formed in solution.

Primary Treatment
A process to remove substantially all floating and settleable solids in waste and reduce the concentration of suspended solids. This process includes screening, grit removal, sedimentation, sludge digestion, and sludge disposal.

Reagent
A chemical material in liquid, powder, or tablet form that has been especially prepared for use in chemical testing.

Residual
The amount or level of an unreacted material present in the water supply. For example, chlorine residual, iodine residual, etc.

Runoff
That portion of the precipitation on an area which is discharged from the area through stream channels. That which is lost without entering the soil is called “surface runoff” and that which enters the soil before reaching the stream is called “ground water runoff” or “seepage flow” from ground water.

Salinity
The salt content of natural water supplies. The salinity level is determined by a simple titration method.

Salts
Dissolved chemical substances in water; table salt (sodium chloride) is but one of many such compounds which are found in water.

Scale
A hard, crusty deposit which may be found on the inside of pipes, valves, filters, and heaters. Scale deposits on equipment result from the calcium and magnesium salts present in the water.

Scale Forming
Water which contains the chemical compounds capable of leaving scale deposits.

Secondary Treatment
Process to reduce the amount of dissolved organic matter and further reduce the amount of suspended solids in sewage. The effluent from the primary treatment process is given additional treatment with processes such as activated sludge or trickling filter.

Sediment
Fragmental mineral material transported or deposited by water or air.

Sequester
To tie up chemically in a more desirable form. (See CHELATE.)

Shelf Life
The length of time that an analytical reagent can be stored without its chemical composition deteriorating or its undergoing some change that will make the reagent unacceptable for use. The shelf life of each reagent varies. Two factors that adversely effect the shelf life of all test reagents are exposure to prolonged elevated temperature and exposure to direct sunlight.

Soft Water
Water that has a very low calcium and magnesium content—less than 6 grains per gallon (less than 100 parts per million).

Soluble
Substance which is easily liquified or dissolved.

Test Tube
A glass or plastic tube in which a sample of water is treated for testing purposes, also called a comparator tube, sample tube, or test cell.

Tidal Flats
Areas of nearly flat, barren mud periodically covered by tidal waters. Normally these materials have an excess of soluble salts.

Titration
A chemical test method using a reagent that is chemically keyed to the unknown factor being tested. Usually an indicator is added to the test sample and then the titrating solution is added in measured amounts. When sufficient titrating solution is added to bring about a color change in

the sample (the endpoint), the amount of solution is added is noted and its volume is equivalent to the factor being tested. Titration methods employ accurately calibrated burettes or Direct Reading Titrators or may follow drop count procedures.

Titrator, Direct Reading

A simple device that provides extremely accurate titration readings on small water samples. It replaces less accurate drop count methods. The titrating reagent is discharged from the titrator by a plunger action and the result of the test is read directly from the scale on the barrel of the titrator.

Transpiration

The process by which water vapor escapes from the living plant and enters the atmosphere.

Turbidity

The reduction of transparency of a liquid due to the scattering and absorbing effect of light by suspended particles.

Underground Runoff (seepage)

Water flowing toward stream channels after infiltration into the ground.

Water Table

The top of the zone of saturation in the ground.

Weathering

All physical and chemical changes produced in rocks, at or near the earth's surface, under the influence of climatic factors of water, heat, and air.

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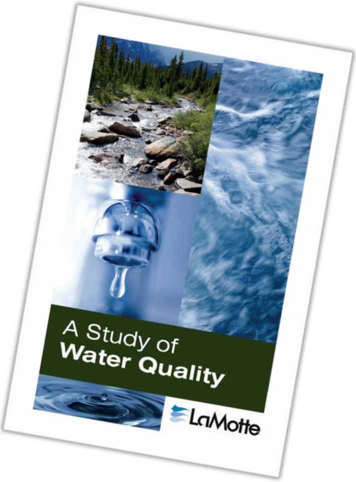


A Study of Water Quality

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

Order Code 1532

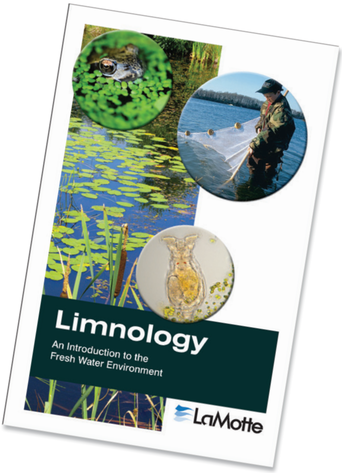
This text covers the factors that determine the quality of water. It studies the "life cycle" of water, beginning with water in its purest form found in nature, observing it as it is altered by its contact with the atmosphere and the earth and continuing the study through the basic treatments involved in the production of high quality water suitable for use in industry and in the home. The problems of scale formation, corrosion, and staining are discussed as are the objectionable characteristics of taste, color, and turbidity in water.

Our Environment Battles Water Pollution

Dr. Charles E. Renn, Professor of Environmental 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, detaining 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.

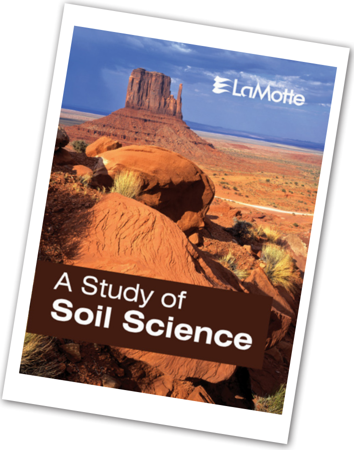


Limnology: An Introduction to the Fresh Water Environment

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

Order Code

This text is an authoritative booklet written expressly for instructors and students interested in studying fresh water supplies. The information is presented in a straight forward manner and there are 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), 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.

Water Analysis Report Form

Notes:

1. See page 20 for information on collecting water sample.
2. Describe in detail the source of the sample being examined. (Examples: Prepared sample from kit, provided by instructor, from school water supply, swimming pool, home water supply, rain water, spring, stream, pond, lake, bay, ocean, etc.)
3. These sensory observations should be made as soon as possible after collecting the sample.
4. Describe the “smell” of the sample. (Example: Musty, chemical, rotten eggs, none, etc.)
5. Color can best be observed by viewing the water sample against a white background. The greater the depth of the liquid being viewed; the easier it is to detect the presence of color. The amount of color in water can be accurately measured by comparing it with standards of known color values. As an aid to the detection of color in the sample, fill a matching container with an equal amount of distilled water and compare both samples against a white background.
6. Turbidity is a haziness caused by finely divided particles that are suspended in the solution. Turbidity can be measured accurately by determining the amount of the sample required to obliterate a marker in a calibrated system. The detection of turbidity can be determined in the same manner as that used for color in Note 5.
7. The results of the quantitative tests are recorded numerically. The results of the qualitative test are recorded “negative,” “trace,” or “positive.”
8. In this space, record any unusual characteristics noted in the water samples (scum, pollen, oil, foam, etc.). If undesirable water quality factors were noted, what sources of contamination do they suggest?

Water Analysis Report Form

1. Name:

Class:

Date:

2. Describe Source Of Sample:

3. Characteristics:

4. Odor:

5. Color:

6. Turbidity:

7. Chemical Analysis:

Alkalinity
Ammonia-Nitrogen
Calcium
Carbon Dioxide
Chlorides
Chlorine
Chromium
Copper
Cyanide
Dissolved Oxygen
Dissolved Solids
Fluoride
Hardness
Iron
Magnesium
Manganese
Nitrate
Nitrite
pH
Phosphate
Salinity
Silica
Sulfate
Sulfide
Zinc
Other

8. Observations:

Water Analysis Report Form

1. Name:

Class: Date:

2. Describe Source Of Sample:

3. Characteristics:

4. Odor:

5. Color:

6. Turbidity:

7. Chemical Analysis:

Alkalinity
Ammonia-Nitrogen
Calcium
Carbon Dioxide
Chlorides
Chlorine
Chromium
Copper
Cyanide
Dissolved Oxygen
Dissolved Solids
Fluoride
Hardness

Iron
Magnesium
Manganese
Nitrate
Nitrite
pH
Phosphate
Salinity
Silica
Sulfate
Sulfide
Zinc
Other

8. Observations:

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