LECTURE ON WATER

DELIVERED BEFORE

The American Institute of the City of New York,

IN THE

Academy of Music, January 20th, 1871.

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[Extract from the Transactions of the American Institute for 1870-71.]

ALBANY:
THE ARGUS COMPANY, PRINTERS.
1871.

SCIÉNTIFIC LECTURE.

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BY CHARLES F. CHANDLER, PH. D.,
Professor of Analytical and Applied Chemistry in the School of Mines of Columbia College.

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COMPOSITION OF WATER.

Water is the sole product of the combustion of hydrogen in oxygen or the atmosphere. The Hindoos and the Egyptians considered water the element from which all other bodies were formed. Among the Greeks the idea was maintained, that water was the first or fontal element; that from it all other bodies were formed; that even plants and animals owed their origin to it. Aristotle regarded water as one of four elements, and this idea was maintained for more than a thousand years, though the old idea that water was the primal element, seems to have been mingled with this idea, for it was supposed that those four elements, fire, earth, air and water were mutually convertible. Heat converted water into invisible air; repeated evaporation, they said, converted water into earth, so that there seems to have been an original idea, that water was the only sole element.

Lavoisier, in 1770, tested experimentally the question of the conversion of water into earth. It had long been known that when water was placed in a glass retort or alembic, and distilled, there remained behind a small quantity of earthy matter, and if the water was returned to the alembic and distilled again, the quantity of earthy matter increased, and it continued to increase as often as the water was distilled from it. It was supposed, therefore, that the water was gradually converted into earth. Lavoisier distilled three pounds of water again and again, in an alembic provided with a condenser, the whole apparatus being hermetically sealed, that not a particle of water should be lost. At the close of the experiment, he found that while the quantity of water had not diminished in the least, he had a residue of twenty grains of earthy matter in the alembic. As the water had not diminished, he justly concluded that it had not come from the water; it must then have been derived from the alembic itself. On cleansing the alembic and condenser, and weighing them, it was found that they had lost seventeen grains. Seventeen grains of the earthy matter had, therefore, been produced by the action of the boiling water on the glass. The remaining four grains were attributed by Lavoisier to the natural impurities of the water. Scheele, the great Swedish chemist, tested the same question, and not only proved that the earthy matter was derived from the glass, but analyzed it and found it to consist of the same constituents, potash, lime, and silica. Dalberg repeated the experiment in a silver vessel and obtained no earthy matter. So the conversion of water into earth was proved to be a fallacy due to the action of the water upon the glass vessel.

Until 1781, water was considered an element. Hydrogen had been known in the fifteenth century; had been prepared by the action of dilute sulphuric acid upon metallic iron, and was supposed to be *phlogiston*.

Oxygen was discovered in 1774 by Scheele and Priestley; but it was not till 1781 that Cavendish proved water to be composed of oxygen and hydrogen; proved it to be a compound, instead of an element. He identified its constituents as the hydrogen long known and the oxygen which had been discovered a few years previous. The efforts of several of the most distinguished chemists were at once directed to the question of determining the proportions in which these elements were combined. Lavoisier investigated this subject, and made repeated analyses, but failed to arrive at the true proportions. Humboldt and Gay Lussac investigated the question, and decided that water contained eight parts by weight of oxygen, and one part by weight of hydrogen. In 1772, nitrogen was discovered in the atmosphere; and in 1775, Lavoisier proved that the air was a mixture of oxygen and nitrogen. So it is just 100 years since the great fundamental discoveries were made upon which chemistry rests, and all the sciences, geology, mineralogy, physiology, etc., which are based upon it. The discovery of the composition of the atmosphere and of water may be truly said to be the great fundamental discoveries upon which the whole system is based. They constitute the starting point in our system; and Lavoisier's experiment stands out in bold relief as one of the first experiments upon record in which the chemical balance was introduced; in which quantities were examined as well as qualities. The experiments of the alchemists, by which a large fund of fact had been accumulated, were all directed to the qualities of the products; but Lavoisier, when he introduced the balance, made the first great step in advance, and in this way decided the fate of the old phlogiston theory, and the many other theories which were based upon error.

The composition of water is beautifully shown by the decomposing action of the voltaic current. I have here a voltaic battery, the wires from which terminate in plates of platinum. In this glass jar is water, which has been colored pink to make it visible, and has been acidulated to make it a good conductor of electricity. The voltaic current decomposes the water, and the constituent gases are set free at the surfaces of the platinum plates, from which they ascend in bubbles and displace the water in the two vertical tubes. Notice that the hydrogen from the negative pole occupies twice the volume of the oxygen from the positive pole, but the oxygen being sixteen times heavier than hydrogen, this small quantity of oxygen weighs eight times as much as double the volume of hydrogen. I can show you the properties of these two gases by a simple experiment. Hydrogen is combustible. We have merely to cause it to escape by depressing this cylinder which contains it in a vessel of water, and apply a flame to indicate this fact. Now you see that the hydrogen is burning with a pale bluish flame. Thus we have a combustible gas produced by the decomposition of water. Oxygen is not combustible, but it is a supporter of combustion. We will now transfer our cylinder, which contains the gas liberated from the positive pole of the battery, to a vessel of water, and depress it, to cause the gas to escape from the cock which I will now open. You see the spark on my taper has been kindled into flame by the gas, and that as often as I extinguish the flame and bring the spark into the gas, it lights again.

You have now seen that the voltaic current decomposes water, setting free its component gases; the combustible hydrogen, and the supporter of combustion, oxygen.

Oxygen.

Oxygen is the most abundant element in nature. Almost every other element on the earth's crust occurs combined with oxygen, and really the earth's crust is composed of the ashes produced by the combustion of the other elements. Still there is an excess of oxygen which we find in our atmosphere. You see the changed character of the flame of the taper when introduced into this gas. Now I propose to burn a little phosphorus in one of these jars and some magnesium in another, simply to illustrate the character of oxygen in supporting combustion. In the atmosphere we have four volumes of nitrogen to every volume of oxygen, and the consequence is, that the combustion is retarded by this inert nitrogen. The nitrogen takes no part apparently in the chemical changes produced by the atmosphere. The rapidity of the combustion depends greatly upon the rapidity with which the oxygen comes in contact with the combustible body. By removing the nitrogen, or rather by preparing an atmosphere free from nitrogen we simply hasten the combustion. We will now introduce the burning phosphorus into the jar of oxygen. You see how wonderfully the combustion is intensified by the pure oxygen. The globe is now apparently filled with fire which it pains the eyes to behold. The white cloud which now fills the globe is phosphoric acid in the form of solid white particles, which will ultimately settle to the bottom, forming a layer like snow. This is the ashes of the phosphorus. When your eyes have recovered somewhat from the effect of the dazzling light upon them, I will set fire to this piece of magnesium and introduce it into a globe of oxygen. Now watch the burning metal, the light is whiter and more brilliant even than that produced by the phosphorus. This is the metal which exists in Epsom salt, and the white product or ash is magnesia.

The affinity of oxygen for phosphorus is so great that we may cause them to unite under water. In this conical glass we have a piece of phosphorus; on pouring this hot water upon it, it is melted, and now, on introducing a jet of oxygen you see we have the phosphorus actually burning under water; the phosphoric acid is dissolved by the water as fast as it is formed, so it is not visible as it was when we burned the phosphorus in dry oxygen gas. Many substances have the power to decompose water by robbing it of its oxygen, setting the hydrogen free. This metal potassium which I now project upon the surface of the water in the jar, rapidly appropriates the oxygen of the water forming potassa which dissolves, the hydrogen escapes and you see the heat of the reaction has set it on fire and it burns with a beautiful violet flame. The color of the flame is due to a portion of the potassium which has vaporized. The water is thus actually set on fire by the potassium.

By placing a bit of this metal on the priming of a cannon, and applying an icicle we fire the piece, I will spare you the shock of the explosion, by omitting the experiment. But the principle will be as well shown when I apply this icicle to the wick of my spirit lamp, on which I have placed a bit of potassium. For, see, it lights at once. We have, therefore, set an icicle on fire, and thus lighted the lamp.

Hydrogen.

In this jar we have the other constituent of water, hydrogen. As I hold the jar with its opening downward it will not readily escape, as it is the lightest substance known, being only one-fourteenth as heavy as air. Now, on bringing the burning taper near the mouth of the jar, you see the hydrogen burns where it is in contact with the air, while the taper is extinguished. As I withdraw the taper, it is relighted on passing through the flame of hydrogen.

This experiment illustrates the combustibility of the hydrogen, and its inability to support the combustion of the taper. The terms *combustible* and *supporter of combustion* are merely relative; in an atmosphere of hydrogen the oxygen would be combustible and the hydrogen the supporter, while the taper would be incombustible.

I have here a little apparatus containing zinc and dilute sulphuric acid, from which hydrogen is being evolved. I propose simply to burn a little of the hydrogen beneath this globe to form water by the combustion. In a few moments you will see the jar covered with moisture, which is water produced by the combustion. In fact, a spirit lamp will produce water in exactly the same manner, every substance that contains hydrogen produces water when it is burned in the atmosphere. You see, the jar has become dimmed and damp with the moisture, which is the result of this combustion of the hydrogen.

Properties of Water.

Water is the most important and the most remarkable of all our chemical compounds. It covers three-quarters of the earth's surface, in the form of ocean, lake and river, and in the higher latitudes snow, ice, glacier and iceberg. Rising in the form of vapor it produces by condensation clouds, fog, mist, rain and snow. In the vegetable kingdom it is ever present, varying in quantity from ninety-nine per cent down to fifteen or twenty. Dry wood contains twenty per cent of moisture. Animals consist largely of water. An average man, weighing 150 pounds, contains about 116 pounds of water. The rocks contain it; some hold it in large quantity. Gypsum contains twenty per cent of water, and even rocks, which are not hydrated compounds, contain it in moderate quantity, a fraction of a per cent. It is a bad *conductor* of heat, but has a great *capacity* for *heat*. A cubic mile of water in cooling one degree warms over 3,000 cubic miles of air a like amount. And when water freezes it evolves a large amount of heat. A cubic yard of ice, in the process of melting, absorbs the heat which it gives out in freezing; it takes up enough heat to change the temperature of 21,000 cubic yards of air from 52° to 32° Fahrenheit. On account of this great capacity for heat, this absorption of heat when ice melts and this evolution of heat when it freezes, water becomes the great regulator of the temperature of the earth.

Water combines with other substances, and at times plays the part of an acid with strong bases. When water is thrown upon quicklime we have produced the hydrate of lime, and the water plays the part of an acid, while in oil of vitriol we have water playing the part of a base.

A second degree of affinity of water for other substances is illustrated when substances crystallize from aqueous solutions. They lock up a certain quantity of water which we call *water of crystallization.* Such is the case with alum, borax, and carbonate of soda. A still weaker affinity is manifested in the process of solution. All substances are soluble in water to a greater or less degree. Solids and gases are taken up by it. Some of our ordinary reagents are simply solutions of gas in water, as ammonia, hydrochloric acid, and hydrosulphuric acid. Besides these three forms of combination, where water plays the part of an acid or a base, is secreted in crystals or acts as a solvent, we have other and weaker forms of combination. All solid substances contain more or less water. Rocks, when exposed to a temperature of 212°, lose in weight on account of the escape of the moisture which they contained. This is called *hydroscopic moisture.*

Natural Waters.

Water being a great solvent, dissolves to some extent, whatever it comes in contact with. Even atmospheric waters, the rain and melted snow are not pure. Rain, as it falls through the air, washes out the solid particles of dust, and the germs of animals and plants. And in addition to these it dissolves the oxygen, the nitrogen, and carbonic acid of the atmosphere, the oxygen to a greater extent than nitrogen. Air which is dissolved in water is much richer in oxygen than ordinary atmospheric air. This seems to be a special provision of nature for the fishes. They extract the small quantity of oxygen which is dissolved by the water from the air. The quantity is small. Twenty-five cubic feet of water take up only a cubic foot of oxygen. But this quantity is sufficient for the maintenance of life in the fishes; their gills enable them to absorb it, and they die without it.

Water which is collected from roofs in the city is never pure. It contains gases which are only develped in cities, sulphur compounds, products of the combustion of coal, and animal matter. After thunder storms, the rain water is always found to contain minute quantities of nitric acid produced by the electric sparks which cause the oxygen and nitrogen to unite.

Spring Waters.

Terrestrial waters are always impure. Rain falling upon the earth's surface is absorbed by the porous soil, and the material of which the soil is composed, being to a greater or less extent soluble, the water becomes contaminated with mineral matter. The character of spring water, therefore, depends upon the character of the soil through which it has passed before it issues as a spring. In New England, where the rocks are granitic, and the minerals, chiefly quartz, feldspar and mica, water is extremely pure. But in limestone countries where carbonate of lime and magnesia abound, we find the spring waters largely contaminated with these substances. These carbonates are rendered much more soluble in water by the carbonic acid present, which forms bicarbonates with them.

In this jar is some lime-water; a clear solution of lime. The carbonic acid water, which I now add from the syphon bottle, produces carbonate of lime, which makes the liquid milky; but you see it now disappears on the further addition of carbonic acid. The clear liquid now contains the bicarbonate of lime. To such solutions of bicarbonate of lime are due many curious phenomena in nature. Where they trickle down from the roofs of caves, the evaporation of a portion of the carbonic acid causes the separation of an equivalent quantity of carbonate of lime. Each drop, as it hangs for a moment and then falls, leaves behind a thin pelicle of solid spar, and finally, in years of dripping, a stalactite is formed. Where the drops strike the floor of the cave, corresponding stalagmites gradually spring up, often meeting the stalactites at last, and forming columns of glistening stone. Sometimes where the water falls from a crevice, a series or row of columns is produced, which finally becomes a solid wall or partition of spar.

On boiling solutions of bicarbonate of lime and magnesia, the excess of carbonic acid is expelled, and the carbonates having no longer a solvent are precipitated. In this way incrustations are formed in teakettles and steam boilers.

Spring water is generally very clear, although it may be quite impure. It holds its impurities in solution. The soil through which it has passed, although it has conferred upon it its impurities, has at the same time filtered it, and thus rendered it clear and sparkling. As it comes from below the surface, it is generally cool. For these reasons spring water has always been highly prized. Wells which are dug down below the surface, are supplied partly by springs and partly by local drainage. The water may be very pure, or, if the surrounding soil is calcareous or charged with the refuse animal matter of neighboring dwellings, it will be very seriously contaminated with impurities.

Artesian Wells.

Occasionally wells are sunk to great depths by boring. Such wells are called artesian wells, from the district in France where they were first bored.

The earth's crust consists in many localities of strata of gravel, sand or clay, resting upon sandstones, limestones or shales. In many cases these strata are in basins, and their edges often come to the surface at the margin of the basins. Some of these strata, which are porous, constitute reservoirs of water, and by boring down to them this water is reached. It may rise above the surface and overflow if the strata rise elsewhere to higher levels; otherwise it must be pumped. Often the pressure of gases forces the water above the surface. At Grenelle, near Paris, an artesian well was bored down 1,600 feet, or nearly one-third of a mile. The water rose eighty feet above the surface, and flowed at the rate of ninety cubic feet per minute. Coming from so great a depth, it is very warm, and must be stored in a reservoir to cool. At Rochefort, in France, is a well 2,676 feet deep, or more than half a mile. This is the deepest well in Europe.

Some of the deepest artesian wells have been put down in this country. At Louisville, Ky., there is one 2,086 feet deep, the water of which has a temperature of 82° Fahrenheit. But instead of being suitable for domestic purposes, the water proved to be heavily charged with chemical compounds, which give it a medicinal value. At Charleston, S. C., there is a well 1,250 feet deep, yielding similar mineral water. At Columbus, Ohio, an artesian well, at the depth of 180 feet, yielded sulphur water; but it proved to be hard water. At the depth of 675 feet salt water was obtained. As fresh water was required, the well was pushed down a half a mile, or 2,575 feet; but no water was obtained of satisfactory quality. At St. Louis a well was bored to the depth of 3,881 feet, or two-thirds of a mile; but no water of any consequence was obtained, and the well is a failure.

In many instances water which rises in artesian wells comes from great distances. At Tours, in France, the well is sometimes obstructed, and when the obstruction is removed, it is found that the leaves which come to the surface, and which caused the obstruction, do not grow within a hundred miles of Tours; showing that there is some subterranean communication by which the water, as well as the leaves, is brought from a distance.

Nature of the Impurities of Spring Water.

Ordinary spring waters (fresh waters, as they are generally called) contain salts of the alkalies and alkaline earths: Chlorides, sulphates, and bicarbonates of potassa, soda, lime and magnesia. The most common salts are the chlorides of potassium and sodium, the sulphates of soda and lime, and the bicarbonates of lime and magnesia.

Besides these alkaline and earthy salts, we almost invariably find silica, the substance of quartz, to the amount of a grain or less in a gallon. In wells which receive drainage waters, in the neighborhood of dwellings, we generally find nitrates, nitrites and ammonia salts, derived from decomposing animal matters in the soil.

I have here a sample of impure well water, in which you shall see some of the more common impurities. Carbonic acid is shown in this jar by the addition of lime-water, which forms carbonate of lime, visible to you now as a milky precipitate. Lime is apparent to you as a white precipitate, produced by the oxalate of ammonia, which I am now adding to the second jar of the water. Sulphates are shown by the white precipitate which will appear on the addition of hydrochloric acid and chloride of barium to this third jar. You see it forming now. Chlorides, common salt, etc., are now apparent in this jar, to which I have just added nitric acid and nitrate of silver.

There is a popular idea, originated by some itinerant temperance lecturer who pretended to analyze liquors, that chemical analyses are made with the aid of a machine, into which the liquid to be analyzed is poured, and from which on turning a crank the constituents flow successively. The lecturer referred to, employed such a machine in analyzing wines and liquors to terrify his audience, showing the logwood, fusil oil, strychnine, etc., which he supposed to be used in compounding them. You see, however, that reagents are employed to detect and separate the different constituents of the water. No machine will answer the purpose. Magnesia cannot be detected in the presence of lime; but I have here a sample of this water, from which the lime has been removed, and now on the addition of phosphate of soda you see the white precipitate of magnesia.

You have now seen me detect some of the common constituents of spring water. These reactions are produced by almost all spring waters; but their intensity varies with the quantities of the impurities.

Hard and Soft Waters.

Lime salts in water are the cause of what is called *hardness*. They decompose the soap used in washing, forming a flocculent insoluble compound, and destroying its detergent properties. In Glascow the saving to the people in soap, due to the introduction of the pure water of Loch Katrine, in place of the hard well waters previously used, is said to amount to $180,000 per annum.

You see before me two tall jars of water. One water is pure and soft; the other contains much lime and is hard. I will add to each a solution of soap in alcohol. You see now that on shaking this jar a fine froth or soap suds is produced. This is the soft water. Now I will shake the other jar, and you see we get no suds; but the liquid becomes white and milky. The lime has destroyed the soap. Soap is, therefore, an excellent reagent for testing water; a fact which is well known, though few but chemists understand that it indicates the lime compounds only.

As bicarbonate of lime is destroyed by boiling, with the formation of insoluble carbonate of lime, which does not act on soap, it is said to produce *temporary hardness*, while sulphate of lime, which is not affected by boiling, produces permanent hardness.

Organic Matter.

Another impurity which is always present in water, but whose exact chemical character has not been fully determined, is organic matter. This is undoubtedly a collective term for a great many different substances derived from decomposing vegetable and animal matters. I will show you a test which is often used for the detection of organic matter. It is the permanganate of potassa. You notice the beautiful pink color which is produced as I add a few drops of this reagent to this jar of water. But you see the color gradually fades away. This is because the organic matter takes oxygen from the permanganate, destroying it, and undergoing oxydation itself. The quantity of permanganate the water is capable of bleaching is a rough index of the proportion of organic matter present. A little time is required for the organic matter to bleach the permanganate; the sample of water before you received an addition of organic matter for the occasion, that you might not be obliged to wait long to see the color disappear. As the permanganate destroys the organic matter it is often used to purify impure waters, organic matters being the most objectionable impurities which occur in natural waters.

Pond, Lake and River Waters.

Pond, lake and river waters are generally purer than spring water, for the reason that while those bodies of water receive the waters of springs, they also receive a considerable quantity of water which has simply run *over* the surface of the earth. When a shower comes up, a portion of the water goes through the soil and issues as a spring; but a large portion of it runs over the soil, and goes into the lakes and rivers without taking with it much mineral matter. For this reason the waters of lakes and ponds are much purer than those of the springs in the same locality. One of the purest waters known is the water of the river Loka in Sweden, which contains only one-twentieth of a grain of impurities in a gallon. Rivers are more likely to be charged with *suspended impurities*, for the reason that their waters, which have not been filtered through the soil, carry with them a certain quantity of clay and organic matter. That is what we see in Potomac water; it has had no opportunity to settle, and has not been filtered out. When water flows into lakes and the sediment subsides, it becomes clear. But in streams where the water runs rapidly, it has no opportunity to settle, and becomes very muddy. The water of the Mississippi contains forty grains of mud per gallon; and it is estimated that this river carries 400,000,000 tons of sediment per annum into the Gulf of Mexico. The Ganges is said to carry down 6,368,000,000 cubic feet annually. This transportation of mud in suspension has produced large deposits at the mouths of these rivers. All of the State of Louisiana, and considerable portions of other States which border upon the lower Mississippi, have been formed by the deposition of these sediments brought from higher levels. This mud is rich in plant food, and the land which it produces is very fertile. The Mohawk flats are famous for their fertility; and the annual overflow of the Nile is the chief reliance of the poor Egyptians who cultivate the fields enriched by its sediments.

Living Organisms in Water.

In addition to the soluble and suspended impurities already mentioned, we find living organisms in water, animals and plants. I will call your attention to the diagram, on which you will see some of the most common forms of the Croton and Ridgewood waters. It was prepared by Dr. William B. Lewis for the Metropolitan Board of Health:

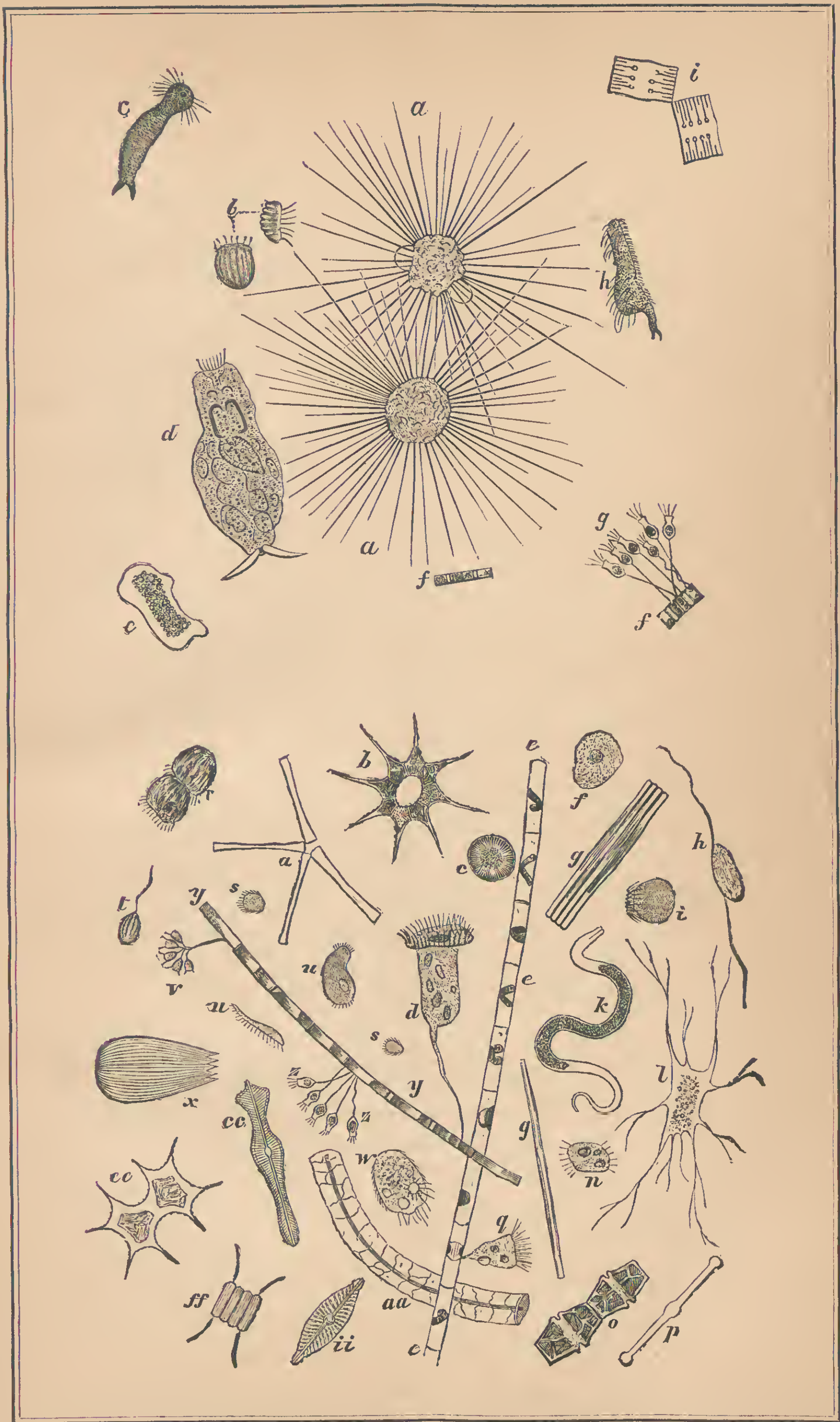
Catalogue of the animal and vegetable objects found in the sediment of Croton water taken from the Central Park and Fifth avenue reservoirs during October, November and December, 1869:

a. Asterionella formosa, vegetable, a diatom, × 312.
b. Pediastrum simplex, vegetable, a desmid, × 200.
c. Cyclotella astræa, vegetable, a diatom, × 200.
d. Vorticella ——, an animalcule, × 312.
e. Conferva, vegetable, "green scum," × 40.
f. Epithelial cell, probably from manure during freshet, × 200.
g. Fragillaria capucina, vegetable, a diatom, × 200.
h. Heteromita ovata, an animalcule, × 500.
i. Halteria grandinella?, an animalcule, × 200.
k. Anguillula fluviatilis, a minute water-worm, × 312.
l. Amoeba porrecta, an animalcule, × 200.
n. Diophrys ——, an animalcule, × 200.
o. Didymoprium borreri, vegetable, a desmid, × 200.
p. Tabellaria fenistrata, vegetable, a diatom, × 312.
q. A free vorticella, an animalcule, × 200.
r. Coccudina costata, dividing, an animalcule, × 312.
s. Monas umbra, an animalcule, × 312.
t. Cyclidium abscissum, an animalcule, × 312.
u. Chilodon cucullulus, an animalcule, × 200.
v. Epistylis nutans, young, animalcules, × 200.
w. Paramecium ——, animalcule, × 200.
x. Difflugia striolata, the lorica or case, an animalcule, × 200.
y. Conferva, vegetable, "green scum," × 312.
z. Vorticella microstoma, an animalcule, × 200.
aa. Fragment of dyed wool, × 200.
cc. Gomphonema acuminatum, vegetable, a diatom, × 200.
ee. Arthrodesmus octocornis, vegetable, a desmid, × 312.
ff. Scénodesmus quadricauda, vegetable, a desmid, × 200.
ii. Navicula rhynchocephala, ? vegetable, a diatom, × 200.

Animal and vegetable objects found in the sediment of Ridgewood water, during the months of October, November, and December, 1869.

a. Actinophrys sol, an animalcule, × 200.
b. Coccudina costata, an animalcule, × 200.
c. Chætonotus squamnatus, hairy-backed animalcule, × 200.
d. Notommata ——, a rotiferous animalcule, × 200.
e. Amœba guttula, an animalcule, × 200.
f. Melosira orichalcea, vegetable, a diatom, × 200.
g. Vorticella, microstoma, animalcules, × 200.
h. Chætonotus larus, hairy-backed animalcule, × 200.
i. Tabellario flocculosa, vegetable, a diatom, × 200.

I simply call your attention to one of them; this one lettered *l.*, the amœba porrecta. This is an animal which has no mouth, and yet contrives to put himself outside of his dinner by a very



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curious process. When a particle of food comes in his way, a little dimple is formed on his side, it does not matter which side. He thus very readily extemporises a stomach for his food. The soluble portion is absorbed, the insoluble portion is ejected, and the animal assumes his rotundity and goes on its way rejoicing. These animals, when magnified by the microscope are very frightful in appearance, but there is really no great objection to them. The plants even exercise a purifying influence on the water. It is stated by a celebrated English author, that the providential spread of the American weed Anachasis Alcinastrum, has saved thousands of lives by the purifying influence which it has exerted on the water courses in certain districts in England. These plants liberate oxygen which attacks poisonous dead organic matter and destroys it, thus purifying it of its most dangerous impurities.

The Ocean.

The ocean is the great and final receptacle of all waters which escape evaporation; and it consequently receives the mineral and other impurities which the rivers and smaller streams carry along in solution or suspension. From the surface of the ocean the water evaporates, rising into the atmosphere to fall again in the form of rain. Entering the soil, it again issues in the form of springs, with a fresh quantity of dissolved mineral matters, which it bears onward to the ocean. Thus, again and again, the rain drops have performed the voyage to the sea, each time laden with the little cargo of dissolved salts. In this manner the ocean has become very saline; it is the receptacle for the soluble matters which are washed out of the earth's crust.

Let me call your attention to an analysis of sea water, made by Von Bibra, which I have placed side by side with an analysis of the water of the Dead Sea, made by the Herepaths. The numbers represent grains in one U. S. gallon of 231 cubic inches.

	Atlantic Ocean.	Dead Sea.
Specific gravity................	1.0275	1.17205
Chloride of sodium.............	1671.34	6702.73
Chloride of potassium..........	....	682.63
Chloride of ammonium..........	....	3.35
Chloride of calcium.............	....	1376.75
Chloride of magnesium..........	199.66	4457.23
Chloride of aluminum	....	31.37
Chloride of iron................	trace	1.50
Chloride of manganese..........	....	3.35
Bromide of sodium.......... ..	31.16	156.53
Iodide of sodium	trace	trace
Sulphate of potassa.............	108.46	......

	Atlantic Ocean.	Dead Sea.
Sulphate of magnesia...........	34.99	......
Sulphate of lime................	93.30	38.07
Phosphate of soda..............	trace	......
Carbonate of lime..............	trace	trace
Silver.........................	trace	......
Copper	trace	......
Lead	trace	......
Silica	trace	trace.
Organic matter..................	trace	34.59
Bitumen........................	....	trace
Total in one U. S. gallon......	2138.91 grs.	13488.10 grs.
Per centage by weight...........	3.569	19.736
Water	96.431	83.264
	100.	100.
Weight of one gallon	59922. grs.	68352. grs.

You notice that chloride of sodium, common salt, is the predominating constituent. Next to this comes chloride of magnesium, then sulphate of potassa, sulphate of lime, sulphate of magnesia, etc.

As everything is soluble to a greater or less degree in water, we expect to find some of everything in the ocean.

An experiment was made on sea water to ascertain whether it contains any of the precious metals. It was found that a quantity of iron nails attached to the keel of a vessel separated from the water, a small quantity of silver, I forget how many tons of silver were estimated from this to exist in the ocean, but the per centage is so small that it would hardly pay to organize a stock company for its extraction.

The question arises, if these saline substances are being carried to the sea, is it not becoming much salter? A calculation has been made, by which it appears that about thirty-six cubic miles of water are poured into the ocean daily. But then this vast quantity of water is so small in comparison with the amount of water in the ocean, that it would take 30,000 years for all the water in the ocean to rise as vapor, fall as rain, and make the trip back to the ocean again.

Inland Seas.

Where evaporation is rapid, inland seas and lakes which drain considerable areas become even more salt than the ocean. The Dead sea and the Great Salt lake are examples. The Dead sea receives the waters of the Jordan. There are no outlets to this lake, and evaporation is rapid. The Jordan drains the surrounding country to a great extent, and pours its waters into the sea. By evaporation the saline matter is deposited. Thus, in the course of time, the Dead sea has come to contain a large quantity of salt. You see by the analysis on the diagram that this water contains 19736 grains of saline matter in a gallon, while the water of the Atlantic contains only 2139 grains. By referring to the small diagram on the right, you will see a comparison of the waters of some other inland seas with that of the ocean:

	Density.	Grains of saline matter in one gallon.	Ounces of saline matter in one gallon.
The Atlantic ocean...............	1.027	2139	4.89
The Dead sea....................	1.172	13488	30.86
The Great Salt lake..............	1.170	15203	34.72
Lake Oroomiah, in Persia.........	1.188	18209	41.60

You must not be surprised at the difference in the character of the salts contained in the Dead sea water and in the water of the ocean. The ocean receives the saline matters washed out of all the continents, while these inland seas are local in their sources of supply. They receive the washings of limited areas, and the salts they contain must necessarily partake of the character of those particular countries in which they are situated.

Mineral Waters.

Waters which contain unusually large quanties of any of the ordinary impurities, or which are characterized by unusual constituents, are known as mineral water. Such waters may be valuable for their medicinal properties, or as sources of the special substances which they contain. As examples of medicinal waters, we have sulphur springs, which contain sulphureted hydrogen, chalybeate springs, which contain iron, etc.; while brines and borax waters are valuable for the extraction of salt and borax.

Sulphur Waters.

Waters containing sulphureted hydrogen gas are found in many parts of the world. Those of Harrogate, Croft, and Aix la Chapelle, are renowned in Europe, while we have in the United States numerous examples, among which are the White, Red, and Salt Sulphur springs of Virginia, the White Sulphur springs of Ohio, and the Richfield, Sharon, Chittenango, and Florida springs of New York State.

The sulphureted hydrogen gives these waters a sweet taste and a very peculiar odor, which some consider offensive. These waters have the property of blackening silver; persons who visited these springs in the earlier days of the republic when specie was current, noticed a gradual darkening of their "change," which finally became quite black, owing to the formation of a black sulphide of silver.

If we add some acetate of lead to this jar of Chittenango water, we have at once a dense black precipitate of sulphide of lead as you see. If you will glance at this diagram you will see some analyses of sulphur waters which were made under my direction.

ANALYSES OF SULPHUR WATERS.*

In one U. S. Gallon of 231 cubic inches.	Chittenango, Madison Co., N. Y.			Florida, Montgomery Co., N. Y.
	White Sulphur spring.	Cave spring.	Magnesia spring.	Florida spring.
	Grains.	Grains.	Grains.	Grains.
Hydrosulphate of sodium (NaS, HS)	0·117	0·386	0·757	2·008
Hydrosulphate of calcium (CaS, HS)	......	1·123	0·929	......
Sulphate of potassa	......	......	......	1·390
Sulphate of soda	0·213	......	......	......
Sulphate of lime	81·420	106·126	115·085	......
Sulphate of strontia	Trace.	Trace.	Trace.	......
Sulphate of magnesia	1·953	7·589	12·718	......
Hyposulphite of soda	......	0·257	0·020	0·711
Bicarbonate of soda (NaO, HO, $2CO_2$)	......	......	......	22·143
Bicarbonate of lime	......	......	......	8·317
Bicarbonate of magnesia	22·017	23·973	20·779	6·972
Bicarbonate of iron	0·078	0·156	0·325	......
Chloride of potassium	0·156	0·233	0·333	......
Chloride of sodium	1·037	1·569	1·833	5·880
Chloride of lithium	Trace.	Trace.	Trace.	......
Alumina	0·082	0·222	Trace.	Trace.
Silica	0·286	0·519	0·577	0·793
Sulphur (in suspension)	Trace.	......	......	......
Sulphide of iron (in suspension)	......	......	......	0·176
Total solid contents per gallon	107·359	142·113	153·356	43·390
Total sulphur in the metallic sulphides and sulphuretted hydrogen.	0·339	1·397	2·4	1·91654
Cubic Inches of Gas per Gallon.				
Sulphuretted hydrogen gas	0·884	2·754	5·623	3·765
Carbonic acid gas	20·480	15·934	19·436	32·169

* Made by the writer with the assistance of W. H. Chandler and F. A. Cairnes, A. M.

With the exception of the following compounds, which are indicated by a star, the substances found in these waters are not essentially different from those contained in most spring waters:

Hydrosulphate of sodium .... (NaS, $H S$).
Hydrosulphate of calcium .... (CaS, $H S$).
Hyposulphate of soda .... (NaO, $S_2 O_2$).
Sulphur .... (S).
Sulphide of iron .... (FeS).
Sulphuretted hydrogen gas .... ($H S$).

To the last mentioned substance the peculiar odor of the water is due, while by the free sulphur, which is formed by the action of the oxygen of the air on this gas, the white milky turbidity is produced.

Saline Waters.

The chlorides of sodium, calcium and magnesium often occur in spring waters in such quantities as to cause a decided saline taste; agreeable in the case of the first mentioned salt, if not too intense, but bitter and disagreeable when caused by either of the others.

Sulphate of soda (Glauber salt) or of magnesia (Epsom salt) may be the cause of a saline taste. Brines, which are important sources of national wealth in many countries, belong to the first mentioned class. Nearly all the salt manufactured in the United States is obtained from salt springs or wells. This diagram exhibits analyses of some of the brines of Michigan and New York, made by Dr. C. A. Goessmann, of the Massachusetts Agricultural College:

Analyses of Brines.

	Michigan.		New York.	
	East Saginaw Co.'s well.	Bangor Co.'s well.	Syracuse.	Salina.
Chloride of sodium	16.86	19.86	15.36	14.94
Chloride of magnesium	0.96	1.26	0.14	0.13
Chloride of calcium	2.27	2.96	0.08	0.08
Sulphate of lime	0.15	0.07	0.57	0.59
Total saline matter	20.24	24.15	16.15	15.74
Water	79.76	75.85	83.85	84.26
	100.00	100.00	100.00	100.00

Similar brines occur in Kansas, Ohio, West Virginia and other States. You will realize their importance when I tell you that 9,000,000 bushels of salt have been manufactured in the neighborhood of Syracuse in a single season. The brine is here pumped up through artesian wells from a depth of 400 or 500 feet. It is undoubtedly derived from beds of rock salt, such beds having been already discovered in Canada, not very far distant. The famous St. Catherines spring in Canada contains larger quantities of the chlorides of calcium and magnesium, which gives them a bitter taste. The Kissingen bitter water illustrates the class of waters that owe their peculiar qualities to the sulphates of soda and magnesia.

Acidulous Springs.

Waters charged with such quantities of carbonic acid as to cause them to sparkle and effervesce as they flow from the spring, are called *acidulous.* Owing to the solvent power of this acid upon limestones and some other rocks, such waters generally hold considerable quantities of lime, magnesia and iron in solution in the form of bicarbonates; when the latter is present in quantities of a grain or more to the gallon, the spring is called a *chalybeate,* from the name of an ancient people who worked in iron at an early day, the *Chalybes.* These waters often contain considerable quantities of chloride of sodium, and frequently bromide and iodide of sodium, as well as bicarbonates of soda and lithia.

Such is the character of the most celebrated mineral waters in this country, the well known springs of Saratoga and Ballston in this State. These waters are so well-known to you that I will take the liberty of dwelling upon their peculiarities for a few moments. In the first place I will call your attention to this section of the Saratoga valley, which shows you the position of the rocky strata there.

Beginning with the uppermost, the rocks of Saratoga county are: 1. The Hudson river and Utica shales and slates; 2. The Trenton limestone; 3. The calciferous sand rock, which is a silicious limestone; 4. The Potsdam sand stone; and, 5. The Laurentian formation, of unknown thickness. The northern half of the county is occupied by the elevated ranges of Laurentian rocks; flanking these occur the Potsdam, calciferous and Trenton beds, which appear in succession in parallel bands through the central part of the county. These are covered in the southern half of the county by the Utica and Hudson river. slates and shales.

The most remarkable feature is, however, the break, or vertical fissure which occurs in the Saratoga valley, which you see indicated on my diagram. I want you to notice, specially, the fact that the strata on one side of the fissure have been elevated above their original position, so that the Potsdam sandstone on the left meets the edges of the calciferous sand rock, and even the Trenton limestone, on the right. It is in the line of this fissure, or *fault*, in the towns of Saratoga and Ballston, that the springs occur.

The Laurentian rocks, consisting of highly crystalline gneiss, granite and syenite, are almost impervious, while the overlying Potsdam sandstone is very porous, and capable of holding large quantities of water. In this rock the mineral springs of Saratoga probably have their origin. The surface waters of the Laurentian hills, flowing down over the exposed edges of the Potsdam beds, penetrate the porous sandstones, become saturated with mineral matter, partly derived, perhaps, from the limestones above, and are forced to the surface at a lower level, by hydrostatic pressure. The valley in which the springs all occur indicates the line of a fault or fracture in the rocky crust, the strata on the west side of which are hundreds of feet above the corresponding strata on the east.

The mineral waters probably underlie the southern half of the entire county, many hundred feet below the surface; the accident of the fault determining their appearance as springs in the valley of Saratoga Springs, where, by virtue of the greater elevation of their distant source, they reach the surface through crevices in the rocks produced by the fracture.

The common origin is also shown by analysis; all the springs contain the same constituents in essentially the same order of abundance, they differ in the degree of concentration merely. Those from the deepest strata are the most concentrated. The constituents to which the taste of the water and its most immediate medicinal effects are due are: chloride of sodium, bicarbonate of lime, bicarbonate of magnesia, bicarbonate of soda and free carbonic acid. Other important, though less speedily active, constituents are: bicarbonate of iron, bicarbonate of lithia, iodide of sodium and bromide of sodium. On this large diagram are my analysis of many of the most important of these waters. You will notice that the waters in the last four columns are from artesian wells. During the great petroleum excitement, a New York capitalist conceived the idea of finding oil at Ballston, so he selected a spot on the margin of the Kayaderosseras creek, a stream which flows through the village of Ballston into Saratoga lake. Here this patient but ill-advised seeker after petroleum bored down through sand, clay and hard pan fifty-six feet till he struck the solid rock. He tubed the well down to the rock with an iron tube six inches in diameter, and then continued the boring with a five-inch drill. For a considerable distance the drill passed through the Hudson river shales; then it penetrated the Trenton limestone, then the calciferous sand rock, and probably passed some distance into the Potsdam sandstone. At a depth of 571 feet, a vein of mineral water burst into the well, but, as oil was the object of the search, it was not heeded. Finally, our zealous borer was spared further labor in this direction by the steel reamer, which became so firmly fastened in the rock at the depth of 651 feet, that it could not be extricated. No oil making its appearance and further progress in the well being out of the question, attention was directed to the mineral water, when it was found that the most remarkable water of the county had been discovered. While the strongest natural springs of the county contain from 600 to 800 grains of mineral matter per gallon, this water contained over 1,200 grains. It is so concentrated that it will actually bear dilution with an equal volume of croton water, which is more than one can say of our city milk, though the experiment is often made by the milkmen.

Like the enterprise of sending warming pans to Cuba, this venture turned out an unexpected success. The well is now known as the "Ballston artesian lithia spring." Soon after the "Franklin" and "Condi-dentorian" wells were bored at Ballston, and more recently the "Geyser spouting well" at Saratoga. All these have been successful in bringing up very concentrated waters of the same chemical character as the natural springs. It is probable, therefore, that water can be obtained anywhere in the southern portions of the county by tapping the underlying Potsdam sandstone. In all of these wells the water rises to and above the surface. Down in the rocky reservoir the water is charged with gases under great pressure. As the water is forced to the surface, the pressure diminishes, and a portion of gas escapes with effervesence. The wells deliver, therefore, enormous volumes of gas with the water, a perfect suds of water, carbonic acid and carburetted hydrogen.

But we have neglected the analysis. While you are looking at them I will tell you about the High Rock spring, the greatest natural curiosity of the county.

Since this lecture was printed, the following analysis of the water of the Congress Spring has been made in the lecturer's laboratory.

ANALYSIS OF CONGRESS SPRING WATER,

BY C. F. CHANDLER, PH. D., AND F. A. CAIRNS.

One United States gallon of 231 cubic inches contains:

Chloride of Sodium	400·444	grains.
Chloride of Potassium	8·049	"
Bicarbonate of Magnesia	121·757	"
Bicarbonate of Lime	143·399	"
Bicarbonate of Lithia	4·761	"
Bicarbonate of Soda	10·775	"
Bicarbonate of Baryta	0·928	"
Bicarbonate of Iron	0·340	"
Bicarbonate of Strontia	a trace.	
Bromide of Sodium	8·559	"
Iodide of Sodium	0·138	"
Sulphate of Potassa	0·889	"
Phosphate of Soda	0·016	"
Silica	0·840	"
Fluoride of Calcium, Biborate of Soda, Alumina,	each a trace.	
Total	700·895	grains.
Carbonic Acid Gas	392·289	cubic inches.

A comparison of the above with the analysis made by Dr. John H. Steel, in 1832, proves that the Congress Water still retains its original strength, and all the virtues which established its well-merited reputation.

Its superior excellence is due to the fact that it contains, in the most desirable proportions, those substances which produce its agreeable flavor and satisfactory medical effects —neither holding them in excess, nor lacking any constituent to be desired in this class of waters.

As a Cathartic water its almost entire freedom from iron specially recommends it, many of the other springs contain so much of this ingredient as to seriously impair their usefulness.

New York, *Aug.* 17*th*, 1871.

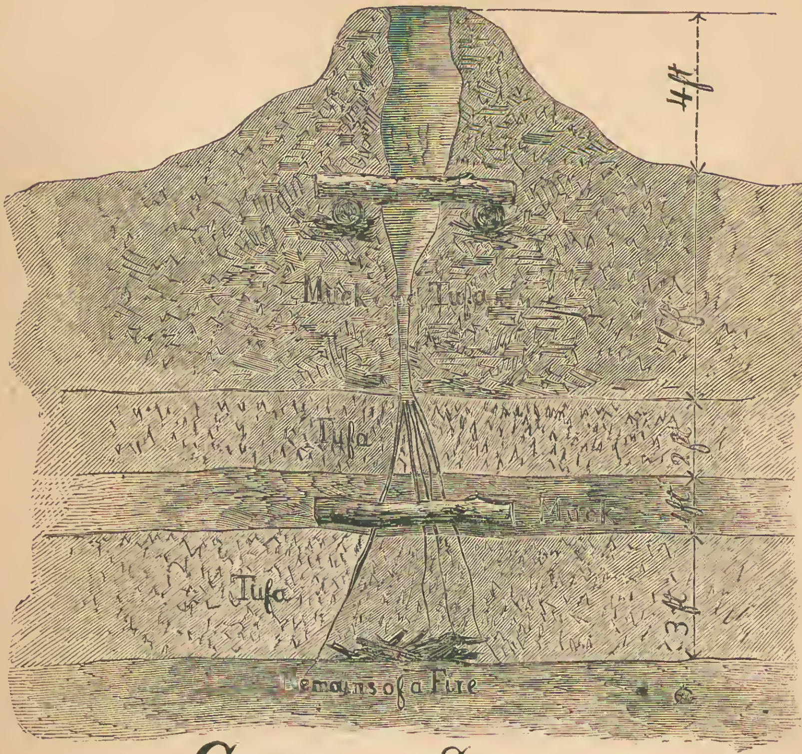
Analyses of some of the springs and wells of Saratoga county, N. Y.

Compounds, as they Exist in Solution in the Waters.	In Saratoga.								In Ballston.		
	Star spring.	High Rock spring.	Seltzer spring.	Pavilion. spring.	United States spring.	Hathorn spring.	Crystal spring.	Geyser spouting well.	Ballston Artesian Lithia well	Franklin Artesian well.	Conde Dentonian Artesian well.
Chloride of sodium	398.361	390.127	134.291	459.903	141.872	509.968	328.468	562.080	750.030	659.344	645.481
Chloride of potassium	9.695	8.974	1.335	7.660	8.624	9.597	8.327	24.634	33.276	33.930	9.232
Bromide of sodium	0.571	0.731	0.630	0.987	0.844	1.534	0.414	2.212	3.643	4.665	2.368
Iodide of sodium	0.126	0.086	0 031	0.071	0.047	0.198	0.066	0.248	0.124	0.235	0.225
Fluoride of calcium	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Bicarbonate of lithia	1.586	1.967	0.899	9.486	4.847	11.447	4.326	7.004	7.750	6.777	10.514
Bicarbonate of soda	12.662	34.888	29.428	3.764	4.666	4.288	10.064	71.232	11.928	94.604	34.400
Bicarbonate of magnesia	61.912	54.924	40.339	76.267	72.883	176.463	75.161	149 343	180.602	177.868	158.348
Bicarbonate of lime	124.459	131.739	89.869	120.169	93.119	170.646	101.881	170.392	238.156	202.332	178.484
Bicarbonate of strontia	Trace	Trace.	Trace.	Trace.	0.018	Trace.	Trace.	0.425	0.867	0.002	0.189
Bicarbonate of baryta	0.096	0.494	Trace.	0 875	0.909	1.737	0.726	2 014	3.881	1.231	4.739
Bicarbonate of iron	1.213	1.478	1.703	2.570	0.714	1.128	2 038	0.979	1.581	1.609	2.296
Sulphate of potassa	5.400	1.608	0.557	2.032	Nonc.	None.	2.158	0.318	0.520	0.762	None.
Phosphate of soda	Trace.	Trace.	Trace.	0.007	0.016	0.006	0.009	Trace.	0.050	0.011	0.003
Biborate of soda	Trace.	Trace.	Trace.	Trace,	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Alumina	Trace.	1.223	0.374	0.329	0 094	0.131	0.305	Trace.	0.077	0.263	0.395
Silica	1.283	2.240	2.561	3.155	3.184	1.260	3.213	0.665	0.761	0.735	1.026
Organic matter	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Total per U. S. gallon	617.367	630.500	302.017	687.275	331.837	888.403	537.155	991.546	1,233.246	1,184.368	1,047.700
Carbonic acid gas	407.650	409.458	324.080	332.458	245.734	375.747	317.452	454.082	426.114	450.066	358.345
Density	1.0091	1.0092	1.0034	1.0075	1.0035	1.009	1 006	1.011	1.0159	1.0115	1.010
Temparature	52° F.	52° F.	50° F.	....	....	....	50° F.	46° F.	52° F.	52° F.	49° F.

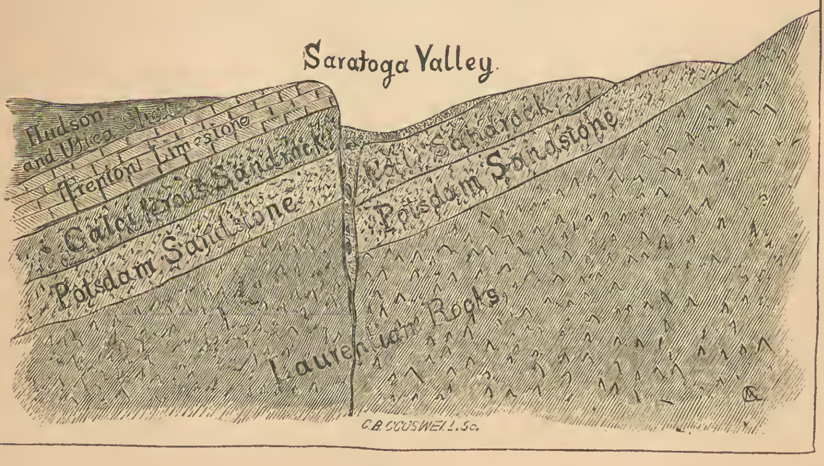
Analyses of some of the springs and wells of Saratoga county, N. Y.

Bases and Acids, as actually found in the Analyses, uncombined.	In Saratoga.								In Ballston.		
	Star spring.	High Rock spring.	Seltzer spring.	Pavilion spring.	United States spring.	Hathorn spring.	Crystal spring.	Geyser spouting well.	Ballston Artesian Lithia well.	Franklin Artesian well.	Conde Dentonian Artesian well.
Potassium	7.496	5.419	0.949	4.931	4.515	5.024	5.326	13.039	17.653	18.104	4.833
Sodium	160.239	163.216	61.003	182.084	57.259	202.058	132.006	251.031	299.005	286.221	263.769
Lithium	0.163	0.202	0.093	0.976	0.499	1.179	0.445	0.720	0.798	0.698	1.082
Lime	43.024	45.540	31.066	41.540	32.189	58.989	35.218	58.901	82.326	69.942	61.698
Strontia	Trace.	Trace.	Trace.	Trace.	0.009	Trace.	Trace.	0.211	0.430	0.001	0.094
Baryta	0.056	0.292	Trace.	0.517	0.537	1.026	0.429	1.190	2.292	0.727	2.799
Magnesia	16.992	15.048	11.051	20.895	19.968	48.346	20.592	40.915	49.480	48.731	43.363
Protoxyd of iron	0.491	0.598	0.689	1.040	0.289	0.456	0.824	0.396	0.639	0.651	0.929
Alumina	Trace.	1.223	0.374	0.329	0.094	0.131	0 305	Trace.	0.077	0.263	0.395
Chlorine	246.357	241.017	82.128	282.723	90.201	314.037	203.292	352.825	470.997	416.278	396.096
Bromine	0.443	0.568	0.489	0.767	0.656	1.188	0.322	1.718	2.829	3.623	1.839
Iodine	0.106	0.072	0.026	0.060	0.039	0.166	0.055	0.208	0.104	0.197	0.189
Fluorine	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Sulphuric acid	2.483	0.739	0.256	0.934	None.	None.	0.992	0.146	0.239	0.350	None.
Phosphoric acid	Trace.	Trace.	Trace.	0.004	0.008	0.003	0.004	Trace.	0.025	0.006	0.002
Boracic acid	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Carbonic acid, in carbonates	56.606	62.555	44.984	60.461	50.380	104.928	54.984	112.880	125.973	136.133	110.019
Carbonic acid, for bicarbonates	56.606	62.555	44.984	60.461	50.380	104.928	54.984	112.880	125.973	136.133	110.019
Silica	1.283	2.260	2.561	3.155	3.184	1.260	3.213	0.665	0.761	0.735	1.026
Organic matter	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Water in bicarbonates	23.160	25.591	18.405	24.736	20.613	42.929	22.496	46.183	51.543	55.696	45.013
Oxygen in KO (SO_3)	0.496	0.148	0.051	0.187	....	....	0.199	0.029	0.048	0.070	....
Oxygen in LiO (HO, $2CO_2$)	0.187	0.232	0.105	1.116	0.570	1.347	0.509	0.824	0.911	0.797	1.237
Oxygen in NaO (HO, $2CO_2$)	1.206	3.323	2.803	0.358	0.444	0.408	0.959	6 785	1.136	9.011	3.277
Oxygen in 2 NaO (HO, PO_5)	....	....	....	0.001	0.002	0.001	....	....	0.006	0.001	Trace.
Total per U. S. gallon	617.367	630.500	302.007	687.275	331.837	888.403	537.155	991.546	1,233.246	1,184.368	1,047.700
Total residue by evaporation.	537.600	542.350	238.970	602.080	260.840	740.550	459.670	832.483	1,055.730	992.540	892.670

Section of the High Rock



Geological Section at Saratoga Springs.



The High Rock spring was the first to attract attention. It was well known to the Indians, who highly prized the medicinal virtues of its waters. The Indian name Saraghtoga means *place of salt.* In 1767 they brought Sir William Johnson to the spring on a litter. The spring rises on a little mound of stone, three or four feet high, which appears like a miniature volcano, except that sparkling water instead of melted lava flows from its little crater. When Sir William Johnson visited the spring, and in fact until quite recently, the water did not overflow the mound, but came to within a few inches of the summit; some other hidden outlet permitting it to escape. The Indians had a tradition, however, which was undoubtedly true, that the water formerly flowed over the rim of the opening.

A few years ago the property changed hands, and the new owners, convinced that by stopping the lateral outlet they could cause the water again to issue from the mouth of the rock, employed a number of men to undermine the mound, and with a powerful hoisting derrick to lift it off and set it one side, that the spring might be explored.

If you will examine this diagram which presents a vertical section of the spring, you will be able to follow me as I tell you what they found.

Section of the High Rock.

Just below the mound were found four logs, two of which rested upon the other two at right angles, forming a curb. I hold in my hand a piece of one of them. Under the logs were bundles of twigs resting upon the dark brown or black soil of a previous swamp. Evidently some ancient seekers after health had found the spring in the swamp, and to make it more convenient to secure the water had piled brush around it, and then layed down the logs as a curb. But you inquire how came the rock which weighed several tons above the logs? The rock was formed by the water. It is composed of tufa, carbonate of lime, and was formed in the same manner as the stalactites and stalagmites I described, were formed. As the water flowed over the logs, the evaporation of a portion of the carbonic acid caused the separation of an equivalent quantity of insoluble carbonate of lime which layer by layer built up the mound. I hold in my hand a large fragment of the rock; it contains leaves, twigs, hazel nuts and snail shells, which, falling from time to time upon it, were incrusted and finally imprisoned in the stony mass.

Analysis of a Fragment of the High Rock.

Carbonate of lime	95.17
Carbonate of magnesia	2.49
Sesquioxyd of iron	0.07
Alumina	0.22
Sand and clay	0.09
Organic matter	1.11
Moisture	0.39
Undetermined	0.46
	100.00

Below the rocks the workmen followed the spring through four feet of tufa and muck. Then they came to a layer of solid tufa two feet thick, then one foot of muck in which they found another log. Below this were three feet of tufa; and there, seventeen feet below the apex of the mound they found the embers and charcoal of an ancient fire. By whom and when could the fire have been built? The Indian tradition went back only to the time when the water overflowed the rock, how many centuries may have elapsed since, even the logs were placed in position? A grave philosopher of the famous watering place, remembering that botanists determine the age of trees by counting the rings on the section of the stem, and noticing the layers in the tufa rock, polished a portion of the surface and counted eighty-one layers to the inch. He forthwith made the following calculation:

High Rock, 4 feet, 81 lines to the inch	3,840	years.
Muck and tufa, 7 feet, low estimate at	400	"
Tufa, 2 feet, 25 lines to the inch	600	"
Muck, 1 foot	130	"
Tufa, 3 feet	900	"
Time since the fire was built	5,870	"

As I have seen half an inch of tufa formed in two years on a brick which received the overflow from a spout of water containing only twenty grains of carbonate of lime in a gallon, I am inclined to think our antiquarian's estimates are not entirely reliable.

There are springs in the Auvergne, in France, in which the natives are in the habit of suspending little wire baskets containing egg shells, or craw fishes, or medallions, which become thickly incrusted with tufa in a few days. I hold in my hand now such a basket, containing four empty goose eggs, which are petrified, as it were, with solid carbonate of lime. You may inquire why I have not included in my table of analyses the well-known Congress and Empire springs. I reply, simply because the analyses of them, which are published, were made in the early days of analytical chemistry, and are not, therefore, very reliable. On this diagram you will find some partial analyses which I have made of nearly all the mineral springs of the county, which are sufficiently complete for comparison. The numbers represent grains in our United States gallon of 231 cubic inches.

WATERS OF SARATOGA COUNTY, N. Y.

TABLE *showing the total quantities of mineral matter left by evaporation, and of some of the more important constituents.*

SPRING.	Total solids as left by evaporation.	Chlorides of sodium and potassium.	All other solids left by evaporation; carbonates of lime, magnesia, etc.	Bicarbonate of lime ($CaO,HO,2CO_2$).	Bicarbonate of magnesia ($MgO,HO,2CO_2$).	Bicarbonate of iron $FeO,HO,2CO_2$).
Ballston Artesian Lithia well.	1,055·74	783·30	272·43	238·16	180·60	1·58
Franklin Artesian well.......	992·54	693·27	299·27	202·33	177·87	1·61
Conde-Dentonian well.......	892·67	654·70	237·97	178·48	158·35	2·29
Geyser Spouting well.......	832·48	586·71	245·77	170·39	149·34	0·98
Hathorn's spring....	740·55	519·55	221·00	170·65	176·46	1·13
Hamilton spring............	611·71	411·00	200·71	144·84	104·80	1·80
Congress spring............	588·82	408·49	180·33	143·40	121·76	0·34
High Rock spring...........	542·35	399·10	143·25	131·74	54·92	1·48
Washington spring..........	353·23	215·00	138·23	110·23	40·56	2·40
Excelsior spring............	611·05	473·00	138·05	90·38	72·27	2·84
Pavillion spring.............	602·08	467·56	134·51	120·17	76·73	2·57
Putnam spring...............	354·79	220·50	134·27	110·72	60·01	3·97
Columbian spring....	353·08	219·00	134·08	104·89	78·05	3·26
Star spring..................	537·60	408·05	129·55	124·46	61·91	1·21
Crystal spring...............	459·67	336·79	122·88	101·88	75·16	2·04
Eureka spring...............	280·16	171·00	119·16	94·02	63·75	3·36
United States spring.........	260·84	150·49	110·35	93·12	72·88	0·71
Empire spring...............	460·32	355·16	105·16	113·54	48·10	1·34
Seltzer spring................	238·97	135·62	103·35	89·87	40·34	1·70
Red pring...................	155·53	73·50	82·03	79·80	27·84	2·51
Village spring, Ballston......	153·09	75·00	78·09	65·08	21·59	2·00

Thus you see we have springs to suit all tastes from the concentrated artesian waters to the mild Saratoga Seltzer, which is used with wines, as our German friends are in the habit of using the original Seltzer, from the spring of the late Grand Duke of Nassau. Hathorn's spring is the strongest natural spring yet discovered in the county.

CHALYBEATES.

Almost all natural waters contain minute quantities of iron, generally in the form of bicarbonate. In the analyses of the Saratoga waters you see recorded from one to three grains of this compound of iron per gallon. All these waters are therefore chalybeates; but the properties of the iron are masked to a greater or less extent by the much larger quantities of other materials. I have before me a sample of water which contains about two grains of iron to the gallon; and I will prove the presence of this metal by the same test that old Pliny employed before the destruction of Pompeii and Herculaneum.

I will pour into the water a little tincture of nutgalls. You see it has become black. The tannic acid of the nutgalls has formed ink with the iron. In fact, these ferruginous waters are characterized by a styptic or inky taste, due to the iron which they contain.

Acid Waters.

It occasionally happens that springs are characterized by the presence of free mineral acids, such as sulphuric and hydrochloric. The river Vinagre, in South America, is supplied by such springs; and it is stated that this stream carries to the ocean daily an amount of acid equal to 82,720 pounds of oil of vitrol, and 69,638 pounds of concentrated muriatic acid. There is a celebrated spring of this character in New York State, known as the Oak Orchard acid spring, an analysis of which is shown on this diagram.

Analysis of the Oak Orchard Acid Water, by Professor Porter.

One gallon contains:

Sulpuric acid	133.312
Proto-sulphate of iron	32.216
Sulphate of magnesia	8.491
Sulphate of lime	13.724
Sulphate of alumina	6.413
Sulphate of potash	2.479
Sulphate of soda	3.162
Chloride of sodium	1.432
Silicic acid	3.324
Organic matter	6.654
Total grains	211.207

Alum Waters.

In several localities waters occur charged to a greater or less extent with alum, which is a double sulphate of alumina and potassa. These waters frequently contain free sulphuric acid; and it is probable that they were all first charged with this acid, which, acting on feldspathic rocks or slates, has dissolved the alumina, potash, etc., forming the sulphates found in them as they issue at the surface. The Rockbridge alum spring, and the Church Hill alum spring, in Virginia, are examples of this class of waters.

Borax Waters.

Minute quantities of borax (biborate of soda) are found in many mineral waters; as, for instance, the waters of Saratoga; but in a few localities waters occur so heavily charged with this salt as to make it worth while to extract it for manufacturing purposes. Instead, however, of evaporating the waters to extract the borax which they contain, the borax gatherers content themselves with collecting the crystals formed by natural evaporation along the margins and on the muddy beds of the borax lakes. For many years considerable quantities of borax, called tincal, were brought from a salt lake in Thibet. More recently, California has thrown down the gauntlet by developing borax lakes of great size, in which occur enormous quantities of this valuable salt. No complete analyses of the waters of these lakes has yet been published; but, according to G. E. Moore, the water contains 535 grains of borax per gallon. Near the borax lake is situated a wonderful hot spring, from which, and perhaps from others of similar character, the borax of the lake has been derived. I will call your attention to this diagram, on which is recorded an analysis of this spring, made by Mr. Moore:

Analysis of a Borax Spring, California.

	Grains in a gallon.
Chloride of potassium	Trace.
Chloride of sodium	84.62
Iodide of magnesium	.09
Bromide of magnesium	Trace.
Bicarbonate of soda	76.96
Bicarbonate of ammonia	107.76
Biborate of soda	103.29
Sulphate of lime	Trace.
Alumina	1.26
Carbonic acid (free)	36.37
Silicic acid	8.23
Matters volatile at a red heat	65.77
Total grains in one United States gallon	484.35

Siliceous Waters.

Almost all natural waters contain small quantities of silica, in the neighborhood of one grain in a gallon; but the waters of hot springs, especially those which contain alkaline carbonates, are largely charged with silica, and in the neighborhood of their outlets, large masses of siliceous tufa are formed.

The water of the famous Geyser in Iceland, contains twenty-four grains of silica in the gallon. This fragment of siliceons tufa which I hold in my hand is from one of the hot springs of the Azores.

Water for Manufacturing Purposes.

For manufacturing purposes, pond or river water is generally selected, not only because it can generally be obtained in unlimited quantities, but also because it is generally softer than spring water. The impurities of waters are objectionable in several ways. When used in stationary or locomotive boilers, impure waters produce incrustations which often form a complete lining. I saw 1,300 pounds of calcareous incrustation taken from the boiler of a single locomotive on the N. Y. C. R. R.

These stony masses which I hold in my hand, and which you see are from one to two inches in thickness, are incrustations from boilers, fed with hard water. These incrustations are very poor conductors of heat. Their presence in boilers, causes, therefore a great waste of fuel. It is estimated by the French engineers that forty-five per cent of the fuel burned under locomotive boilers, is required to overcome the nonconducting power of the incrustations. Furthermore these scales prevent the contact of the water with the plates of the boiler, the metal becomes therefore overheated, and is rapidly burned out, making frequent repairs necessary. Boiler explosions are sometimes attributed to the presence of incrustations; the metal becoming very much overheated, causes the scale to crack, which permits the water to come in contact with the hot metal; a great quantity of steam being at once generated, the boiler is burst. These incrustations vary somewhat in character with the impurities of the waters by which they are produced. Their chief constituents are carbonate of lime, carbonate of magnesia and sulphate of lime. On this diagram you will see some of my analysis of incrustations from locomotives on the N. Y. C. R. R.

Analyses of Boiler Incrustations.

SOURCE.	Structure.	Thickness.	Sulphate of lime.	Carbonate of lime.	Basic carbonate of magnesia.	Oxyd of iron and alumina.	Water.	Organic matter.	Silica.	Total.	
1. Stationary engine, boiler shop, Syracuse; hydrant water	Compact and crystalline.	3-16ths inch.	74.07	14.78	9.19	0.08	1.14	undet.	0.65	99.91	Fair average representatives of the usual incrustations.
2. * Stationary engine, machine shop, Rochester; canal water, 10 months, well water, 2 months	do	2 inches.	71.37	......	....	§26.87	......	.... .	1.76	100.00	
3. Locomotive, No. 211. Freight, both roads. Syracuse	do	1-32d inch.	62.86	12.62	18.95	0.92	1.28	undet.	2.60	99.23	
4. Locomotive; surrounding a brace	do	1-4th to 1-3d in.	53.05	......	....	§42.16	......	......	4.79	100.00	
5. Locomotive, No. 127. Freight, both roads. Syracuse	do	1-32d inch.	46.83	......	....	§47.85	......	......	5.32	100.00	
6. Locomotive, No. 202. Freight, both roads. Syracuse	do	1-4th inch.	30.80	26.93	31.17	1.08	2.44	undet.	7.75	100.17	
Average	....	....	56.49	18.11	19.77	0.69	1.62	undet.	3.81	......	....
7. † Stationary engine, Niagara Falls; river water	Friable and granular.	2 inches.	4.95	86.25	2.61	1.03	0.63	undet.	2.07	97.54	Exceptional incrustations, the only ones of their kind analysed.
8. ‡ Stationary engine, Townsend's Furnace, Albany	do	1¼ inches.	0.88	93.19	¶2.84	0.36	0.15	1.96	0.62	100.00	
9. Locomotive, No. 122; Rochester to Buffalo	Powder.	....	4.81	......	....	§92.27	......	......	2.92	100.00	
10. Stationary engine, Barhydt and Greenhalgh, Schenectady	do	....	30.07	. ....	....	§61.69	......	......	8.24	100.00	

* A mass weighing twenty-one ounces, which had apparently filled the space between three tubes.

† A mass weighing fourteen ounces, evidently detached from a tube.

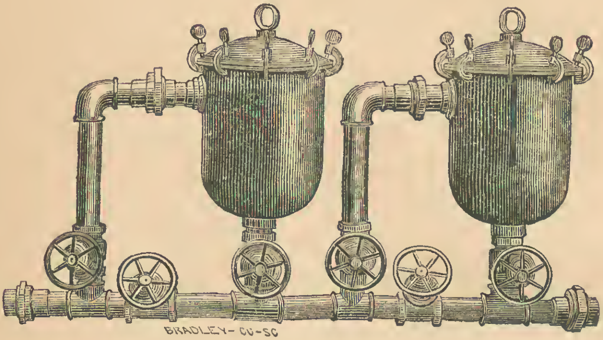
‡ A mass weighing sixteen ounces, evidently detached from a tube.

§ This number includes those belonging to the two preceding and the two following columns, as obtained by difference.

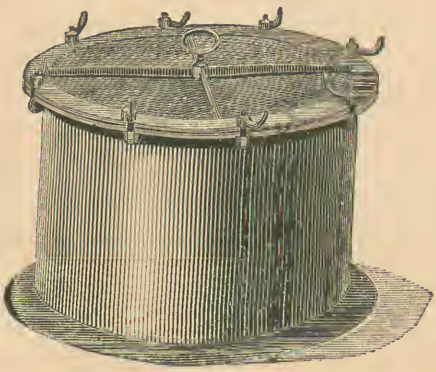
Various substances are employed to prevent the formation of these incrustations in boilers, some of which are very effective. Amylaceous, saccharine and extractive matters tend to prevent the carbonates of lime and magnesia from forming a hard scale, causing them to separate as a loose mud, which can be easily washed from the boiler at convenient intervals. Potatoes, molasses, extractive matters, or substances which yield them, as logwood sawdust, are consequently employed with varying success. Astringent substances, which contain tannic acid, have a similar action. To this class belong catechu extract, oak sawdust, tan bark, etc. Solid particles, as sawdust, clay chopped straw, etc., serve to diminish the formation of hard scale by presenting nuclei, upon which the earthy carbonates are deposited. For the decomposition of sulphate of lime, carbonate of soda and chloride of barium are employed. Sal ammoniac is sometimes employed to convert the carbonate of lime into soluble chloride of calcium, and thereby prevent its being deposited. The substances which I have enumerated are placed in the boiler from time to time and allowed to act there. An English chemist, Mr. Clark, proposed purifying the water beforehand by adding lime water, on the principle of *similia similibus curantur;* but, unfortunately, more than a homœopathic dose is required. The carbonate of lime in the water is held in solution by carbonic acid as a bicarbonate. The lime, which Mr. Clark adds, takes this extra carbonic acid, forming an insoluble carbonate, and at the same time precipitating the lime of the bicarbonate as insoluble carbonate. The magnesia present is also precipitated by the lime water; but the sulphate of lime, which forms the hardest and most crystalline incrustations, is not removed by this process. The real objection to this process arises from the vast quantities of water required in practice. A locomotive consumes on the average about forty-five gallons of water for every mile that it runs, and on the New York Central railroad alone about 300 locomotives are employed. As at least twenty-four hours are required to enable the precipitated lime to settle from the water, enormous reservoirs or tanks would be required to contain a sufficient supply for a railroad. An excellent device has been patented by Stillwell, to be used in connection with stationary boilers. It is simply a box containing a great number of horizontal shelves. The water for supplying the boiler passes through this, and the exhaust steam from the engine is also admitted to it. The exhaust steam causes the water to boil, and most of the lime, which it contains in the form of bicarbonate, separates as

SPONGE FILTERS.

House Filters.



Constant House, Hotel, Steam Boiler and Paper Engine Filter.



Steam Paper Machine Filter.

insoluble carbonate, lodging on the shelves or being caught by a filter of straw at the bottom of the box.

Great annoyance was formerly experienced by marine engineers, whose boilers were fed with sea water. Not only was there formed a very hard strong scale of sulphate of lime, often an inch or more in thickness, but even the salt separated, sometimes entirely filling the spaces between the tubes. By noting the density of the water in the boiler with a hydrometer, and blowing out a portion of the concentrated sea water from time to time, the engineer was able to prevent the separation of salt; but the separation of sulphate of lime could not be prevented. This became so great an evil, causing the very rapid destruction of the boilers, that the use of sea water had to be abandoned. Marine boilers are now provided with condensers, by which the steam, after doing its work in the cylinder, is condensed to water again and returned to the boiler. A supply of fresh water is taken on board before leaving port, and is used over and over again, until the vessel reaches her destination.

Often for washing or for cleaning cotton, wool or other fabrics, the impurities of water are a great objection; they destroy soap, they affect colors in dyeing; for sugar refineries and in brewing, the character of the water is of great importance. In fact the highly prized flavor of some of the English ales, is attributed to the impurities in the water used.

Filtering Water.

Filtration is one of the simplest methods for purifying waters; its action is limited to the suspended impurities such as mud, animal and vegetable substances, etc. Any porous material may be employed in the construction of a filter, the selection being generally governed by the magnitude of the operation. For city supplies, reservoirs are constructed which are provided with porous partitions, or so arranged that the water is obliged to percolate through beds of sand and gravel. I hold in my hand a very simple filter, which has recently been devised for domestic use. It contains, in the first place, a little cup filled with coarse charcoal and provided with a net work of wire gauze. Above that is placed a common sponge pressed firmly into its place so that it entirely fills the space. This is encased in a little perforated cup and is placed over the charcoal vessel. The water which passes through this is, therefore, obliged to pass through the sponge, and then through the charcoal. Although it acts as a perfect filter, it does not seriously interrupt the flow. The advantage of this filter is, that when it becomes clogged and the flow of the water is impeded by the impurities separated, it is merely necessary to open it and take out the sponge, wash it and return it to its place. I have here a little bottle of impurities which were filtered out of the Croton, in a comparatively short time by one of these filters.

Filters are constructed on the same principle for use in manufacturing establishments. Here is one suitable for a large factory or hotel. As there are really two filters, either one may be cleansed without interfering with the flow of water through the other, as you see by the arrangement of the cocks.

Here is a much larger filter, containing six chambers for holding sponges, each six inches in diameter, which is designed for paper factories where large quantities of water are used.

Another filter which is often attached to faucets in houses, is the common sand filter. It is attached in the same way, and by and by when it becomes clogged, it is merely necessary to reverse it when the first glass of water passing through, cleans it. This does not permit so free a flow of water as the sponge filter, and, moreover, it is liable to become permanently obstructed by impurities.

Boiling Water.

Impurities of animal and vegetable origin, are often rendered inert and harmless by simple boiling, and travelers in malarious countries consider this simple precaution a very efficient protection against some of the diseases peculiar to the locality.

Distillation.

Distillation is really the most effective method for purifying water, but it is only applicable in special cases. The analytical chemist, the photographer, and sometimes the pharmaceutist are compelled to resort to distillation to obtain water sufficiently pure for certain of the operations incident to their respective professions. We have already alluded to the use of condensers on steamships. Almost all vessels are now provided with an apparatus by which the sea water may be distilled for drinking purposes in case of a long voyage or deficient supply of fresh water.

Other Methods of Purifying Water.

Charcoal has the property of purifying water contaminated by organic matters. On this account, water-casks are generally charred on the inside to the depth of an eighth of an inch or so, and it is a common practice when rain water cisterns become foul, to throw in a bushel or two of fresh charcoal.

Permanganate of potassa, commonly called chameleon salt, is very effective in destroying organic matter in water. Travelers are advised to carry with them a small vial of the crystallized salt. A small particle added to a glass of water, renders it pure, and in a few moments, oxydizes or burns up the impurities, which taken into the system might produce typhoid fever or dysentery. Running streams undergo purification by the oxygen which they absorb from the air. Very impure waters when placed in casks on shipboard frequently undergo a kind of fermentation by which the impurities are worked off, and the waters rendered sweet and wholesome. This phenomenon has been noticed in the case of Thames water. Contact with iron, as when water is stored in iron tanks, effects a speedy purification.

Water for Domestic Purposes.

For domestic purposes the water of springs is generally selected, because it is cool and clear, having undergone a natural underground filtration; but, as already shown, spring water generally contains a larger quantity of dissolved impurities, hence it is generally harder, than river or pond water. Ordinary wells receive their supply of water partly from springs and partly by drainage. They are, therefore, very liable to be contaminated with the soluble impurities of sewage, and frequently serve to disseminate special diseases, such as cholera and typhoid fever. I have in these jars a sample of such a well water, and will show you some of the peculiar impurities which it contains. To the water in this first jar we will add some of what is called Nessler's solution, a compound of iodide of mercury, with iodide of potassium. You see the liquid has assumed a deep orange color, a proof that the water contains a considerable amount of ammonia. In this jar is some of the same water, which has been previously concentrated and mixed with strong sulphuric acid. Now on adding to this protosulphate of iron (copperas), you see a deep brown color is produced. This is due to the nitrates and nitrites which are contained in the water. Both the ammonia and the nitrates are derived from infiltration of animal matter, from the soil around the well. In the water of a clear and delightfully cool spring, highly prized by the people of the neighborhood, which flowed from a side hill adjacent to a graveyard, phosphate of lime was found by suitable tests, which was derived undoubtedly from the bones of the departed.

Deep artesian wells, which bring water from deep lying strata, supplied from a distance, are free from organic impurities, though they often contain so much mineral matter as to give them medicinal qualities. This is the case with Dupont's artesian well in Kentucky. Recently, the tube or drive well has become quite popular; a simple iron tube or pipe is driven down through the soil, and in some cases a continual flow of water is obtained, otherwise, a pump is applied, but of course you get the drainage water, though not to the same extent as in an open well. The drive well is, I believe, an American invention; it was extensively employed by the British army in Abyssinia.

For the supply of water-works of cities and large towns, ponds or rivers are resorted to, as furnishing the purest water in sufficient quantities, though, in a few cases, artesian wells have been relied upon.

Characteristics of a Good Drinking Water.

The characteristics of a good drinking water may be enumerated as follows:

The temperature should be at least ten degrees lower than the temperature of the atmosphere, but it should not be much lower than forty-five degrees Fahrenheit.

It should be free from taste, except, perhaps, a slight pungency from oxygen and carbonic acid, which is an advantage. Taste is, however, a poor guide. When one becomes accustomed to a certain water, pure water tastes flat by comparison; fifty grains of chloride of sodium in a gallon would hardly affect the taste perceptibly.

A third requirement is freedom from smell. This should not be apparent, even when a bottle is half filled with the water, placed in a warm place for a few hours, and then shaken.

It should be transparent; not that it is necessarily poisonous if not transparent, but it is preferable to take our solid food in other forms. Sometimes water may contain peaty matter from swamps, or vegetable matter from new reservoirs which is not necessarily unwholesome.

With regard to the total quantity of impurities admissible in good drinking water, the sanitary congress which met at Brussels decided that water containing more than thirty-five grains of impurity in one gallon is not wholesome, and that there should not be much more than one grain of organic matter. Thirty-five grains is a large quantity for city water, though drainage wells frequently contain more. The quality of the impurities is more important than the quantity. It is found that five or six grains of lime or magnesia render water unfit for the cooking of leguminous vegetables. On the other hand, it is a great advantage in making tea or coffee to use water of about five degrees of hardness; that is, containing about five grains of carbonate of lime or its equivalent in the gallon. A person of very nice taste can tell the difference in tea or coffee made with water in which the difference is not more than two or three grains of lime or magnesia to the gallon. It is on this account that certain wells have a great reputation as "tea wells." In olden times there were two or three such wells in New York, and a boy was kept by the corporation to pump water for the benefit of the natives. The fine flavor of the tea made with such water is due to the fact that the five or six grains of carbonate of lime prevent the water from dissolving the astringent matter contained in the tea, without interfering with the extraction of the theine and the other desirable constituents of the leaf.

Magnesia in large quantities is objectionable, as are also lime salts. They are liable to cause dyspepsia. It is said that horses acquire a rough coat if supplied with water containing a large quantity of sulphate of lime. Goiter and cretinism are attributed to these impurities in the water; at least the facts observed make this extremely probable. The goiter appeared in the Darham jail, afflicting a large proportion of the convicts. The spring water with which they were supplied was analyzed, and found to contain seventy-seven grains of lime and magnesia salts per gallon. On substituting for this, a water containing only eighteen grains of these salts, it was found that the old cases rapidly improved, while no new cases made their appearance. In the limestone districts of England, Switzerland and central New York, this goiter has been traced over considerable areas. At Goruckpoor in India, where the waters are quite calcareous, ten per cent of the adults are afflicted with goiter, and many of the children are cretins. Even the cats and dogs are said to be afflicted with cretinism, which is a kind of idiotic insanity. It is a curious fact that in Ireland on the Waterford side of the Suir, where sandstones and slates prevail, goiter and cretinism are almost unknown, while on the Kilkenny side, where limestones abound, goiter is not uncommon. Perhaps the idiotic behavior of those famous Kilkenny cats is attributable to the calcareous impurities of the water with which these unfortunate quadrupeds slaked their thirst.

The products of the decomposition of animal matter in water, is, however, the most objectionable impurity. Organic matters, produced by the decomposition of vegetable substances, are not especially dangerous, but the products of decomposing animal substances are highly dangerous, even when in minute quantities. These impurities do not make themselves apparent to the taste. On the contrary, such waters are frequently considered unusually fine in flavor, and persons go a great distance to procure them. Nevertheless, they contain an active poison. Many diseases of the most fatal character are now traced to the use of water poisoned with the soakage from soils charged with sewage and other animal refuse. Sudden outbreaks of disease of a dysenteric character, are often caused by an irruption of sewage into wells, either from a break in the sewer or cess-pool, or from some peculiarity of the season. Such contamination of the water is not indicated by any perceptible change in the appearance of the water. The filtered sewage, clear and transparent, carries with it the germs of the disease. At a convent in Munich, thirty-one out of 121 of the inmates were affected with typhoid fever. It was found upon investigation that the well was polluted by sewage, and the disease disappeared as soon as the proper repairs were made.

At Pittsfield, Mass., typhoid fever suddenly broke out in a large boarding-school for young ladies. The water was found to be contaminated with sewage owing to a leak in the cess-pool.

At Edgewater, on Staten Island, in 1866, the inmates of a small block of houses were afflicted with typhoid fever, several deaths occurring. On making investigation, the health officers found that a neighbor, through whose land the underground drain passed, had taken the liberty of closing up the drain, thus sending its contents back upon this block of houses, contaminating the well, and thus actually murdering the unfortunate victims with sewer poison.

Dr. Stephen Smith, one of the health commissioners of this city, describes an interesting case that came to his knowledge. He visited an old schoolmate, a clergyman, in the country, and in the course of conversation his friend told him of a family in which typhoid fever had made its appearance, three members having already died, while the rest were not yet convalescent. The physician called the attention of his friend to the fact that typhoid fever is now attributed to the poisoning of the water by animal refuse. This was new to his friend, the clergyman, who had not thought of attributing it to anything else than to the visitation of Providence. They went together to visit the locality, and found that in the autumn, when the laborers on the farm were busy taking in the crops, one of the valves of the pump got out of order. Being unable to get their usual supply of water, and being too busy to send for the pump maker, they sent a man down to a neighboring spring to draw water, but finding that it was not easy to dip the water of the spring, from the shallowness of the pool, drew his supply from a brook near by. They found that this brook received the drainage from the barnyard of a neighboring farm.

It is a common saying in villages and towns that "There was health in the old houses, while there is death in the new." This is owing to the fact that when villages were first settled, the houses were supplied with water from the springs on the hill side, while, as the dwellings multiplied in number, these sources of supply proving insufficient or too distant, wells were sunk in the valley, which, of course, received the drainage of the locality. Hence diseases such as typhoid and typhus fever, diphtheria, etc., which were unknown to the early settlers, ultimately become prevalent.

I might multiply illustrations without end, of cases in which diseases have been directly traced to impure water. I have here a little diagram which illustrates a case that occurred in the little town of Charmouth, in England, a little village situated on the side hill, at the mouth of the Char. The houses are supplied from surface wells, sunk in the gravel and marl.

Typhoid fever broke out. My friend, from whom I obtained the facts, was a scientific man, and knowing that it was not safe to drink the water from these wells, so informed his friends, whom he directed to draw their supplies from the spring above the village. My friend had half a dozen children. Two or three of them were strong enough to manage the pump, and against this express order they drew the water from the well, and drank it. They got the disease as a consequence; but none of the children who could not use the pump, and none of the neighbors, who drew water from the springs, were affected.

This city, during the last century, and before the introduction of sewers or the Croton water, was ravaged every few years by deadly epidemics, which are now believed to have been favored and invited by the defilement of the wells then in use, by sewage and fœcal soakage. No such visitation has occurred since the introduction of the Croton water, and the completion of the very perfect system of sewers.

Cholera, though it does not originate from polluted water, is disseminated chiefly by the aid of wells, and other impure water supplies.

At Exeter, England, in 1832, 1,000 deaths occurred from Cholera. A purer supply of water was then introduced from a locality two miles higher up the river, above the point at which it received the sewage of the town. When the Cholera again invaded the city in 1849, only forty-four cases occurred, and in the Cholera season of 1854, there was hardly a case.

In London, in 1854, the water supplied by the Southwark Company contained much sewage, while that supplied by the Lambeth Company was very pure. Both companies had pipes in the same streets, supplying water indiscriminately on both sides. Among those who used the Southwark water, the deaths amounted to 130 in 10,000, while among those who drank the Lambeth water, they amounted to only thirty-seven in 10,000; 2,500 persons were destroyed by the Southwark water in one season. On the previous visitation of 1848–9, the case was the reverse. The deaths from the Lambeth amounted to 125, while those from the Southwark amounted to 118 in 10,000. At that time, the Lambeth company took their water from a point lower down the river.

Another very striking instance occurred in London. The famous Broad street pump supplied water in one of the most fashionable localities of the West end. During the visitation of 1848–9, this pump killed 500 persons in a single week, by disseminating cholera. The wealthy people of the West end went to Brompton, a fashionable summer resort, about five miles up the Thames, and soon the cholera broke out among them there. The health officers soon discovered, on investigation, that these people had been in the habit of sending to the Broad street pump for tea-water, and had brought the cholera with it. A curious case was that of an old spinster, who had moved to Hempstead, three miles from the pump, but who sent her maid daily, for a kettle of the highly prized tea-water. She and her maid were the only persons who suffered from cholera at Hempstead.

A similar story might be told of an outbreak of cholera in a shanty village, west of Central park, and another in a shanty village on the heights across the river. In both cases, it was clearly shown that the cholera germs were distributed among the unfortunate squatters by the waters of the single well in each village. There is a famous pump in the twelfth ward of Brooklyn, at the corner of Van Brunt street, from which over fifty families obtained their water supply. In 1866 cholera broke out in five or six of these families, but the spread of the disease was prevented by the prompt action of the health officer, who removed the pump handle.

From these facts, it is seen that water aids in disseminating two of the most fatal diseases which affect the human race; the typhoid fever and the deadly cholera. During the ten years from 1856 to 1866, there were 21,000 deaths from cholera in England and Wales, and 150,000 deaths from typhoid fever. There is every reason to believe, that at least three-fourths of these deaths might have been prevented had proper attention been paid to the purity of the water supply. This poisoning by bad water is now fully established, and must awaken communities to the vital importance of securing a pure and unfailing supply of this indispensable beverage. Shakespeare describes blood poisoning as graphically as if he were describing the effects of bad water, when he says:

> "Whose effeet
> Holds sueh an enmity with the blood of man
> That, swift as quieksilver, it eourses through
> The natural gates and alleys of the body,
> And with a sudden vigor it doth posset,
> And curd, like eager droppings into milk
> The thin and wholesome blood."

Besides the diseases which I have mentioned, it may be considered as fully established that the ova of entozoa (the eggs or embryos of parasitic worms) gain entrance to the body by the water we drink. We have no reason to believe, however, that the animalculæ to which I have already called your attention, as existing in the Croton and Ridgwood waters, and which you saw in all their activity projected on the screen, by the compound microscope, are such embryos; or, in fact, that they are in any way objectionable.

In Iceland, however, it is stated that one-sixth of the deaths are caused by hydatids in the liver. These are the larval forms of the tania or tapeworm of the dog. Young leeches, contained in drinking water, sometimes fix themselves on the pharynx. In a march of the French in Algiers, 400 men were in the hospital at one time from this cause.

Metallic Impregnations.

Water is frequently rendered impure by the metallic tubes used to conduct it. Organic matter, nitrates, nitrites, chlorides, etc., and in some cases even pure water attack certain metals, causing them to dissolve. Cases of sickness have occurred caused by water drawn through copper pumps, copper having been actually detected in the water. Lead is by far the most common material used in the construction of service pipes for water, and this metal is the one which is the most easily dissolved by water, and at the same time most poisonous in minute quantities, being a cumulative poison. A celebrated case occurred in the royal family of France, at Claremont, where one-third of the persons who drank of the water were affected. This water contained only one-tenth of a grain of lead in a gallon.

As little as 1-100 of a grain of lead to the gallon, has been known to produce palsy in persons who habitually drank it. It is a great pity that the peculiar advantages of lead as a material for the manufacture of water pipes, is more than counterbalanced by the danger of lead poisoning.

When the Croton water was first introduced into New York, it contained considerable lime derived from the mortar of the recently constructed aqueduct. This prevented, to a considerable extent, the action of the water on the lead pipes, and it was stated at that time, that no lead was taken up by the Croton water, but as the lime of the mortar became carbonated, the water ceased to dissolve it and began to act upon the lead pipes. Recently, the attention of the Metropolitan Board of Health having been called to the frequent cases of chronic lead poisoning which occurred in the city, I was requested to investigate both the Croton water, and the various hair tonics, invigorators and washes in common use, with a view to discovering the probable cause of the poisoning. For the benefit of the ladies I will say, that the latter preparations almost invariably contained lead, some of them in very large quantities, and that their efficiency in coloring the hair, and restoring its original color, depends upon the proportions of the poisonous metal they contain.

If they will glance at the diagram on the wall, they will see the number of grains of lead which I obtained from one fluid ounce of each of several of the more popular cosmetics of this character.

Grains of Lead in one Fluid Ounce.

Clark's Distilled Restorative for the Hair	0.11
Chevalier's Life for the Hair	1.02
Circassian Hair Rejuvenator	2.71
Ayer's Hair Vigor	2.89
Prof. Wood's Hair Restorative	3.08
O'Brien's Hair Restorer America	3.28
Gray's Celebrated Hair Restorative	3.39
Phalon's Vitalia	4.69
Ring's Vegetable Ambrosia	5.00
Mrs. S. A. Allen's World's Hair Restorer	5.57
L. Knittel's Indian Hair Tonique	6.29
Hall's Vegetable Sicilian Hair Renewer	7.13
Dr. Tebbett's Physiological Hair Regenerator	7.44
Martha Washington Hair Restorative	9.80
Singer's Hair Restorative	16.39

Examinations were also made of Croton water, which had been in contact with lead for different lengths of time, under usually occurring circumstances, of which the following are the results:

1. A gallon of Croton water from a lead-lined cistern, in which it had stood several weeks, was found to contain 0.06 grain of metallic lead.

2. A gallon of water which had remained six hours in the lead pipes of my residence yielded 0.11 grain metallic lead, a considerable portion of which was visible to the eye, in the form of minute white spangles of the hydrated oxycarbonate ($PbO,HO+PbO,CO_2$).

3. Water drawn from one of the hydrants of the School of Mines laboratory, in the middle of the day, when the water was in constant motion, yielded traces of lead. This water reaches the school through about 100 to 150 feet of lead pipe.

These results indicate the source of many hitherto unaccountable cases of lead poisoning, and are of a character to alarm the residents of New York, and to lead them to adopt precautionary measures for protection against this insidious cause of disease.

Certainly no pains should be spared to impress upon servants the importance of allowing the water to run for a few minutes before taking it for drinking or cooking purposes, specially early in the morning, after the water has stood all night in the pipes. The habit of filling the tea-kettle from the boiler, or of using water from the boiler for any purpose except washing, is very dangerous.

My second experiment explains a case which recently occurred in New York. An elderly gentleman was completely prostrated with paralysis or palsy. His physician at once suspected lead poisoning from his symptoms, and instituted inquiries which developed the fact that the patient had been using wheaten grits for dyspepsia, and that the first duty of the cook in the morning had been to soak them, preparatory to boiling them. She had therefore used daily the water which had stood all night in the pipes. The occurrence of a considerable portion of the lead in experiment No. 2, in suspension, instead of solution, is an additional argument for the use of filters, though it will of course be useless to employ them unless they are frequently reversed, that they may be cleansed.

Manufacturers of lead pipe have frequently appeared in the New York papers with theoretical arguments to prove that the Croton water cannot possibly dissolve lead; but I believe that my simple facts outweigh folios of theory.

Dr. Lardner made an elaborate statement to his audience why a steamer could never cross the Atlantic ocean; but before the audience dispersed his conclusive argument was completely shattered by the scream of the newsboy, "The steamer has arrived!" Various substitutes have been suggested for lead, as for instance wrought iron, which generally makes the water rusty; galvanized iron, which is said to be objectionable on account of the zinc which is readily taken up by the water, rendering it unwholesome, though of this I am not fully satisfied; gutta percha, which is not durable; brass, which I fear is not wholesome; glass, porcelain, etc. None of these substances possess the peculiar flexibility, softness and other desirable qualities of lead, which makes it so easy to cut and bend and join and fit pipes of this metal. The problem, therefore, is to provide a pipe which shall possess all the good qualities of lead, and be free from the one great objection, namely, the danger of lead poisoning from its use. This has been achieved by the invention of the *lead incased block tin pipe*, or as some call it, the *tin lined lead pipe.* This is essentially a pipe of pure tin, surrounded by a lead pipe to which it is firmly and perfectly united by an intervening alloy or solder composed of the two metals. The water comes in contact with the pure tin surface only, and cannot therefore be contaminated with lead. That tin is harmless, it is hardly necessary to argue, as vessels covered with this metal are extensively used for culinary purposes throughout the civilized world. It has been argued that commercial tin contains arsenic; but if we can consume daily, with impunity, food which has been boiled and stewed in tin pans, notwithstanding the arsenic contained in the tin coating, I think we need have little fear of poisoning from the trace of arsenic which may possibly be present in the tin lining of this sanitary pipe. My conviction that the tin lined pipe fully realizes all that is desired as a service pipe for aqueduct water, is not based upon theory alone, as I have tested it side by side with ordinary lead pipe, and have found that waters which take up from one to two-tenths of a grain of lead per gallon from the lead pipe, are not perceptibly affected by remaining for considerable lengths of time in the tin lined pipe. It was at first thought that the expense of the tin would interfere with the introduction of this pipe, but it is found in practice that the great strength of the tin makes it possible to reduce very materially the thickness of the pipe, so that the tin lined lead pipe need not weigh more than half as much to the cubic foot as lead pipe in order to possess an equal degree of strength.

We have now fully discussed the application of water to manufacturing and domestic purposes. There is, however, another use to which we have not alluded. I do not refer to the use of water for navigation, either slack water, river or marine, nor yet to the use ot this important fluid for the extinguishing of fires, but to one of the most lucrative applications. I refer to the adulteration of milk. Investigation has shown that for every three quarts of milk brought into the city of New York, the milkmen serve out a full gallon to their customers, an average of one quart of water being added to every three quarts of milk.

This little watering operation nets the milkmen of the city, or the farmers, as the dilution is largely effected before the milk reaches the city, the nice little sum of $10,000 a day or $3,000,000, per annum. I know of no application of water which brings in so large a return in so small an area. When the milkmen heard that the health department was investigating the subject, with the view to preventing the introduction of diluted milk into the city, they expressed themselves highly delighted, averring that at present the dairymen water the milk so extensively that there is no chance left for them, and that they think that it is time they had their turn.

The Croton Water.

Few cities are more fortunate in the quantity and quality of their water supply than are New York and Brooklyn. The Croton water is brought to the city of New York by an aqueduct forty-five miles long, which was completed in 1842, the water having been admitted on the 4th of July of that year. Where the water enters the aqueduct, a dam 230 feet wide and forty-five feet high was erected in the Croton river, by which the Croton lake was formed. This serves as a great reservoir or sedimentary basin. The average quantity of water supplied to the citizens of New York is 65,000,000 gallons daily. Eighty or ninety million gallons could be supplied were none allowed to flow over the dam. Mr. Jarvis, the enginer, gauged the river at its lowest period, and found its minimum flow to be thirty-two million gallons daily. In long continued dry weather, a deficiency of water occnrs, for the simple reason that there is not at present sufficient storage capacity in the reservoirs. The capacity of the reservoirs is shown on the diagram:

	Gallons.
Fifth avenue reservoir	20,000,000
The old reservoir in the Central park	38,000,000
The new reservoir in the Central park	1,000,000,000
Total	1,058,00,0000

Equivalent to sixteen days supply.

Mr. Craven, chief engineer of the Croton department, carefully examined the region drained by the Croton and its branches, and found several points at which, by the erection of dams of moderate dimensions, enormous storage reservoirs could be formed. The aggregate capacity of the fifteen reservoirs which he indicated as practicable amounted to 67,000,000,000 gallons, or three years supply for the city of New York! It may be asked does a sufficient quantity of water fall in the region to fill such a series of reservoirs? I answer that the average rain-fall is somewhere in the neighborhood of fifty inches, or about thirty-one gallons on every square foot, or nearly a thousand million gallons to the square mile.

The area which is drained by the Croton river and its tributaries, or, in other words, the Croton water-shed, measures 338.82 square miles, with an elevation of from 250 to 600 feet above the sea level. One of the reservoirs planned by Mr. Craven has been nearly completed, at Boyd's Corner, in Putnam county, by Gen. Geo. S. Green. The dam is placed across the west branch of the Croton, twenty-three and three-quarter miles from the Croton dam; it is 650 feet long and sixty-four feet high, and the reservoir, when completed, will cover an area of 303 acres. It will hold 3,369,000,000 gallons of water, a quantity sufficient to supply the city fifty-five days, with its present population. This reservoir alone will carry the city through the longest drouth which is liable to occur. As the population of the city increases, it will merely be necessary to construct a new reservoir from time to time. The present supply of water is very liberal, amounting to sixty-five gallons per head daily. Imperial Rome received, however, from 300 to 340 gallons per head daily.

Few cities at the present day are as liberally provided as New York, the supply of

	Gallons.
Manchester, in 1852, was	50
Liverpool, " 1862, "	30
Edinburgh, " 1852, "	30
Glasgow, " 1862, "	50
London, " 1862, "	50
New York, " 1870, "	65
Imperial Rome	300 to 340

It has been frequently proposed of late to place water meters in every building in the city, and tax the citizens in proportion to the quantities of water actually drawn through them. This measure, it is claimed, will prevent the present waste of water. There is an air of justice, too, in the proposition to charge the customers for the water actually used. Persons may be wasteful if they choose, but they must pay for the privilege.

In my opinion, however, this proposition cannot be too strongly condemned. Pure water is hardly second to pure air as a life-giving and life protecting agent. It is the most potent servant the sanitary authorities can call to their aid. To measure out and sell, by the gallon, this bountiful gift of the Creator would be a crime against the people. It would be in direct opposition to the current of modern civilization, only to be compared, though really a much more serious act, to the tax on windows, which, not a great while ago, compelled people to exclude the blessed light of day from their dwellings, and led architects to adapt their style of architecture to the obnoxious law.

We have already seen that the water-shed of the Croton, with its 339 square miles of area, is capable of supplying water for a city of 5,000,000 of people, and that the erection of a few dams will secure reservoirs capable of storing this supply. Let the money then that would be spent in purchasing costly water meters, which are five times as expensive as gas meters, be spent in constructing one of these dams, to give us all the water we need. In truth, the reservoir at Boyd's Corner, which can easily be completed within a year, will, alone, enable the Croton department to give us all the water we need. There is no earthly reason why our water supply should be limited, unless possibly for the benefit of the owner of some patent meter. I speak advisedly on this subject, having been over the ground and seen the sources of supply with my own eyes. We should never consent to see the poor deprived of so essential a source of health and happiness, as pure and abundant water. On the contrary, there is no object for which the public funds can be more legitimately expended, than for increasing the facilities for using water, by the establishment of free public salt and fresh water baths. Why should we, of free America, in the nineteenth century, be behind Rome in the days of the Cæsars?

The importance of an abundant supply of pure water is now so fully appreciated in England, that the city of London is about to go to an enormous expense to obtain it. Two plans are under discussion; one involves bringing water from Wales, a distance of 220 miles, at a cost of £10,000,000; the other of bringing it 250 miles, from Cumberland, at a cost of £13,000,000. The purity of the Croton water is remarkable; if you glance at this diagram, you will see the quantities of the different substances obtained from one United States gallon of 231 cubic inches, in 1870:

Solids contained in one gallon of Croton water.

	Grains.
Soda	0.326
Potassa	0.097
Lime	0.988
Magnesia	0.524
Chlorine	0.243
Sulphuric acid	0.322
Silica	0.621
Alumina and oxyd of iron	a trace
Carbonic acid (calculated)	2.604
Water in bicarbonates (calculated)	0.532
Organic and volatile matter	0.670
Total	6.927
Less oxygen, equivalent to the chlorine	0.054
	6.873

These acids and bases are probably combined in the water as follows:

	Grains.
Chloride of sodium	0.402
Sulphate of potassa	0.179
Sulphate of soda	0.260
Sulphate of lime	0.158
Bicarbonate of lime ($CaO, HO, 2CO_2$)	2.670
Bicarbonate of magnesia ($MgO, HO, 2CO_2$)	1.913
Silica	0.621
Alumina and oxyd of iron	a trace
Organic matter	0.670
Total	6.873

On evaporating a gallon of this water, a residue of only 4.78 grains is obtained, the bicarbonates of lime and magnesia being left as simple carbonates.

The following tabular statement shows how favorably the Croton compares with the waters supplied to other cities:

Purity of City Waters.

Impurities contained in one wine gallon of 231 cubic inches, expressed in grains.

City.	SOURCE.	Inorganic matter.	Organic and volatile matter.	Total solids.
New York	Croton, average for 13 weeks, 1867 (C. F. Chandler)..	3.90	0.66	4.56
New York	Croton, average for 3 months, 1868 (C. F. Chandler)..	3.31	1.14	4.45
New York	Croton, average for 6 months, 1869 (C. F. Chandler)..	4.11	0.67	4.78
New York	Well west of Central park (C. F. Chandler)	38.95	4.55	43.50
Brooklyn	Ridgewood, average for 3 mos., 1869 (C. F. Chandler).	3.37	0.59	3.92
Boston.........	Cochitnate (E. N. Horsford)	2.40	0.71	3.11
Philadelphia ..	Fairmount. Schuylkill (E. N. Horsford)............	2.30	1.20	3.50
Philadelphia ...	Delaware (H. Wurtz)................................	2.93	0.55	3.48
Albany	Hydrant (E. N. Horsford)............................	8.47	2.31	10.78
Troy...........	Hydrant (W. Elderhorst)	6.09	1.34	7.43
Utica...........	Hydrant (C. F. Chandler)	5.50	0.96	6.46
Syracuse.......	New reservoir (C. F. Chandler)	12.13	1.80	13.93
Cleveland......	Lake Erie (J. L. Cassels)............................	4.74	1.53	6.27
Chicago.... ...	Lake Michigan (J. V. Q. Blancy)...................	5.62	1.06	6.68
Rochester......	Genesee river (C. F. Chandler)......................	12.02	1.23	13.25
Schenectady ...	State street well (C. F. Chandler)..................	46.88	2.33	49.21
Newark......, Jersey City .., Hoboken ...., Hudson City.	Passaic river (E. N. Horsford)	4.58	2.86	7.44
Trenton........	Delaware river (H. Wurtz)...........................	2.93	0.55	3.48
London	Thames (Dr. H. Letheby)...	15.55	0.83	16.38
London	Well, Leadenhall street (Dr. H. Letheby)..........	90.38	9.59	99.97
Dublin...	Lough Vartry, new supply (Apjohn and others).....	1.77	1.34	3.11
Paris	Seine, above the city (Bussey, Wurtz and Ville).....	7.83	1.00	8.83
Amsterdam	River Vecht (V. Baumhauer and Van Moorsel).... .	14.45	2.13	16.58
Amsterdam	Deep well at the Keisersgracht......................	64.55	4.38	68.93

You see by this table that the Croton compares very favorably in purity with the water supplied to other cities. I will call your attention specially to the fourth water on the list, that of the well west of Central park. This water, you see, contains forty-three and one-half grains of impurities in one gallon, of which over four and one-half grains are organic matter. You will not be surprised when I tell you that this well is situated in a shanty village, where cholera was a few years ago extremely fatal.

No one who has ever examined the district of 338 square miles which supplies the Croton river, will be suprised at the purity of the water as shown by analysis. Mountains and hills of laurentian gneiss receive the rain fall, which is quickly absorbed and filtered by the pure siliceous sands and gravels, to gush out in numberless springs, feeding the brooks which bear the sparkling waters to the ponds, which serve as natural storage reservoirs. From these flow the large streams, which, by uniting, form the Croton river. This is finally expanded, by the dam at the head of the aqueduct, into a broad deep lake, the *fountain reservoir, or Croton lake*, in which the quiet waters deposit the finer sediments, and thus undergo a final purification before they are admitted to the aqueduct.

Nowhere along the streams can anything be found which can render the waters impure. Rugged rocks or bright green pastures generally border them. A few factories have been located at points where the water power is available, but a careful examination failed to reveal any pollution of the water by them.

Ridgewood Water.

Time does not permit me to give any details with regard to the water supplied to our Brooklyn neighbors. A glance at the diagram will enable you to see that the Ridgewood water is even purer than the Croton, though the difference is so slight that it would hardly make it worth while for us to emigrate across the East river for better water.

Conclusion.

Water is the great mechanical power in nature. It is the great leveler; it moves mountains and fills valleys. All our stratified rocks, sandstones, slates and limestones, were formed by the action of water. To the solvent power of water and its chemical action, we owe our useful minerals, our metallic deposits, our iron, copper, zinc, gold and silver ores, and even coal. To its physical properties its relations to heat, we owe all the phenomena of clouds, dew, rain, fog, snow and frost. It supports the plants, brings them their mineral food from the soil, and protects them from excessive heat. Animals are equally dependent upon it. Yet, after all, it is only the agent of the sun; it is sun power that make plants grow; it is sun power that moves everything in the world, and water is merely the sun's agent.

The loss of water would produce the same condition of things on the earth that we notice now in the moon. Although we have such a vast quantity of water, yet it is only $\frac{1}{24000}$ part of the earth or 0.0042 per cent. The crystalline rocks at the earth's surface now contain a larger quantity of water than this, and the moment our earth cools enough to absorb four thousandths of one per cent of moisture, the ocean will disappear. If we should lose our ocean, we should lose our atmosphere also. The openings or pores in the rocks will receive it by gravitation, and we shall have the same condition of things as exists now in the moon.

I have endeavored, as far as it is possible in a single lecture, to sketch the important relations of this all-pervading fluid, and have shown you that it is the scource of all our health and well being; but I shall have failed in my effort if I have not fully impressed you with the great truth that it may bring disease and death instead of health, and that our sources of supply cannot be too carefully studied.

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LECTURE ON WATER

DELIVERED BEFORE

The American Institute of the City of New York,

IN THE

Academy of Music, January 20th, 1871.

By C. F. CHANDLER, PH. D.,

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[Extract from the Transactions of the American Institute for 1870-71.]

ALBANY:

THE ARGUS COMPANY, PRINTERS.

1871.