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DEPARTMENT OF CHEMISTRY.

WATER AND WATER ANALYSES.

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UNIVERSITY OF IDAHO.

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Water and Water Analyses.

Water is one of the most abundant things in the world. It forms 73.3 per cent. of the earth, divided into great seas or oceans of which the Pacific contains 49 per cent., the Atlantic 24 per cent., the Indian 20 per cent., the Antarctic 4.5 per cent., the Arctic 2.5 per cent. The oceans are the great water reservoirs of the globe into which finally all water that falls upon the earth finds its way to be evaporated again and again, distributed over the earth as vapor, clouds and fogs, to be condensed and fall as rain, dew, snow or hail—practically pure water.

Unlike rain water, or that of rivers and most lakes, the sea water is salt, bitter—indeed, undrinkable. Every 100 pounds of sea water contains 3.5 pounds of solid matter composed of

Sodium chlorid (common salt)	77.76	per cent.
Magnesium chlorid...........................	10.84	"
Magnesium sulfate (Epsom salts).........	4.74	"
Calcium sulfate (Gypsum)..............	3.60	"
Potassium sulfate............................	2.47	"
Calcium carbonate and all others......	.56	"

The sea thus contains in solution enough common salt to form a solid layer 126 feet thick over the entire globe.

Sea water freezes at about 28° Fahrenheit; its specific gravity varies from 1.022 in the North Atlantic to 1.028 in the Mediterranean. The density of pure water is 1; it is heaviest at 39.3° Fahrenheit or 4° Centigrade and its composition is shown by succeeding analyses.

CHEMICAL AND PHYSICAL PROPERTIES.

Pure water is composed of two gases chemically combined, oxygen and hydrogen, in the proportion by weight of 8 to 1 respectively. When water is decomposed by the electric current it yields two volumes of hydrogen and one of oxygen, chemically pure. Its chemical formula, therefore, is H_2O. These two gases when combined disproportionally are frightfully explosive and generate great heat, water representing 68360 calories. When burned as in the oxy-hydrogen blowpipe, the temperature is 5072° F. or 2800° C.

Water has great specific heat, that is, it requires more heat energy to warm a given quantity of water and yields more heat energy on cooling than an equal quantity of any other common substance. The heat energy necessary to raise a cubic foot of water (62.25 pounds) from the freezing to the boiling point would lift bodily a locomotive engine and tender (43.25 tons), 100 feet into the air. Again, when water is decomposed by the electric current, "it requires more electricity," says Professor Farady, "to decompose a drop of water than to charge a thunder cloud." Hence its value for heating buildings, its mechanical power in the form of steam, and for sanitary uses.

The maximum density of pure water is reached when at the temperature of 39.3° F. or 4° C. When the temperature passes either above or below this point, water expands. On freezing, at 32° F. or 0°C, it makes a sudden and great expansion, 12 cubic inches of water forming about 13 cubic inches of ice, hence will float. This is a most fortunate property of water, otherwise the ice as it forms would sink to the bottom of our lakes and rivers and they become a solid mass which the most prolonged heat of the summer's sun could not thaw. All aquatic life would cease and the now temperate regions of our globe would be uninhabitable.

Wonderfully interesting and instructive is water, surprising the chemist by the strength of its affinities! Though water is a common constituent of crystalline salts, an essential ingredient of many powerful acids employed in the arts and in the laboratory, it is not less an important part of the rocky crust of the globe. Aside from the immense deposits of ice as glaciers and icebergs which creep southward from the poles and run down mountain slopes, water enters as an essential component into the composition of gypsum, serpentine, chlorite slate, soapstone, talcose and other rocks. The magnificent crystals of our cabinets are a deposition of the mineral substance from a state of solution in water. Slowly but surely is Nature's law obeyed! The principle of crystallization is an active and ever present force though unquestionably thousands of years have been consumed in the formation of the gems that adorn our persons, beautify our cabinets and embellish our homes and public buildings. Mighty, marvelous and strange is water, and, though I have studied with care its chemical history, its physical properties and its relation to other substances, it is still to me a perfect enigma in nature.

A UNIVERSAL SOLVENT.

Water is almost a universal solvent, hence pure water is not found in nature, being charged with gaseous and solid matter as it falls through the atmosphere, trickles or percolates through the soil in its unremitting round to meet the law of supply and demand. Singularly miraculous and fascinating is water, the universal liquid of the globe, every drop of which has been an incessant wanderer since the dawn of creation. The theory of aqueous circulation is understood, but the deepest philosophy and the keenest science are not able to fathom and explain its details or to comprehend the fullness and magnitude of its power in the geological history of the world and in the civilization of man.

Water is an essential constituent of organic life. Some vegetables contain 97 per cent., while our common fruits average

80 per cent. water. The physical man has been described by one writer as consisting merely of a few pounds of solid matter distributed through six pailsful of water; fully three-fourths, by weight, of our bodies is water; indeed, the power that moves the world, the human brain, is 75 per cent. water.

Since water, therefore, is such an important factor in the structure of the earth, yea, of the solar system, and enters so largely into the tissues of vegetable and animal matter; and the health of an individual, family, or community depends so largely upon the purity of the water supply, the sanitary examination of Idaho waters became an interesting question for early investigation by the Department of Chemistry of the Agricultural Experiment Station of Idaho.

CLASSIFICATION OF WATERS.

The consumption of water may be classified under five heads:

1.—Its use for domestic purposes.

2.—Its employment as a mechanical agent in the form of steam.

3.—Its medicinal value, because of special mineral ingredients which it may contain.

4.—Its utilization for irrigation purposes.

5.—Its utility as a highway for commerce.

Thus far the department has confined its investigation largely to the first two heads.

Early in November last a circular on potable waters—[Press Bulletin No. 2.]—was sent to all newspapers of the State for publication, with the request that their readers send to the department for analysis samples of well, or spring, or river water, the examination to be made free of charge when taken according to the following

DIRECTIONS FOR SAMPLING WATER:

1.—For sanitary analysis not less than two quarts should be sent; one gallon is preferred.

2.—Use only demijohns, jugs or glass bottles as containers; metalic vessels or casks must not be employed

3.—Thoroughly cleanse the vessel with warm water, then rinse several times with sample water. Treat the cork likewise, if not new. Firmly secure the cork in place.

4.—In all cases, secure an average sample and take the water direct from the spring, well or hydrant.

5.—The sample should be plainly and accurately addressed, and should be accompanied by a statement giving information on the immediate surroundings of the well or spring; depth of same; source of supply and whether abundant or meagre; effect of rainfall or drouth on the volume; temperature of the water; some account of the soil through which the well or flow has passed; and whether used for domestic purposes only.

6.—Such data should be positive and not hearsay information.

7.—Water sampled according to these directions will be analyzed free of charge.

Forward all packages by express, *charges prepaid*, to

AGRICULTURAL EXPERIMENT STATION,
MOSCOW, IDAHO.

FOR THE CHEMIST.

It is absolutely necessary that care be exercised in the sampling of water, otherwise the analytical results obtained are worthless. Results that would condemn a surface water may be unobjectionable when drawn from artesian water, as an excess of free ammonia, nitrates and chlorin is explainable in the latter case. Water taken from a well at various depths, at different times throughout the year, will vary in composition, depending upon the flow, its source, rainfall and atmosphere. In short, it is best to consult the analyst before sending a sample.

In response to the circular above referred to, several samples of water were received and submitted to a sanitary examination; the results may be found upon succeeding pages. The notes that accompanied some of these samples showed a deplorable condition of the immediate surroundings of the well which were regarded as of minor importance until the water began to "taste badly."

PURE WATER.

Pure water is a chemical compound composed of hydrogen and oxygen, "clear, colorless, odorless, and nearly tasteless." Its palatability depends mostly upon the gases absorbed, as oxygen, nitrogen, carbonic acid, together with certain minerals dissolved as it percolates through the soil. Some of these constituents impart to water not only an agreeable taste, but a sparkling brilliancy. Freshly distilled water is insipid, unpalatable and undietetic. Deprived of its oxygen and other gases by boiling it has been found to be prejudicial to health. Water that was originally organically pure and devoid of any disagreeable taste or odor when taken from the well, especially artesian water, may be polluted by long standing in a "standpipe" open to the access of birds or insects, or when remaining for some time in iron, lead, or zinc service pipes. Waters impregnated with nitrates, chlorids and carbonic acid, also ærated waters, will attack such metals and yield poisonous salts; but those waters containing sulfates and normal carbonates will tend to form insoluble hence harmless compounds. Pure water, therefore, must be free from these deleterious constituents.

IMPURE WATER.

Sanitary analysts agree that the dangerous constituents of water are the products of organic decomposition and the germs that feed upon them, hence water that has been contaminated by sewage, by seepage from out-houses, or by the presence of poisonous metals in the soil, as arsenic, lead, or an excess of iron salts, are uniformly condemned for potable use. A physical examination only will rarely reveal such dangers. Both a chemical and microscopical examination may be necessary. The writer once had his attention called to a well in Wisconsin that yielded an abundant supply of cool water of sparkling brilliancy and right color. An examination showed the water to contain an excess of chlorin, nitrates, albumenoid ammonia and carbonic acid.

Looking into the cause of the contamination, a secret slop-pool was discovered under a woodshed within twenty feet of the well. This was a neighborhood well, the residents having regularly consumed the water for several years, often noticing its peculiar taste. Thus people may habitually drink of impure water and live; but its continued use will eventually cause a disordered system, disease and death.

Ærated, distilled, filtered, or pure spring water is the nearest perfect universal drinking water; and to the consumers of such water who are afflicted with renal or bladder disorders it is a boon. Says Prof. Chas. Mayr, in New Jersey Board of Health, 1887: "Those who have never drunk pure water do not realize what an effect such water has on the kidneys; its effect is better than acetates, nitrates, opiates, or alcohol, and for a people with a tendency to kidney disease or dropsy there is no better drug than pure water. Of the thousands of chemical compounds and waste products found in the human system, many require pure water for their solution and elimination; and water so overloaded with salts as the average well-water is will not work satisfactorily."

Some mineral salts present in spring waters act as a laxative and, for some people, such water is wholesome.

"For culinary purposes, however, the quality of the mineral salts present is more important than the quantity. Water containing five or six grains of calcium or magnesium oxid is unfit for cooking leguminous vegetables; on the other hand it is an advantage in making tea or coffee to use slightly hard water. Farinaceous articles when cooked in water containing much sodium carbonate have imported to them a light golden tinge, owing to the action of sodium carbonate on starch. Hence such water is unfit for laundry use."—"*Potable Waters*," *Davis.*

If the amount of salts present is abnormal it is termed mineral water. Such waters are beneficial to health. If such waters are strongly chalybeate, sulfate or carbonate of iron is in excess, and may be detected by the deposition of rust upon the vessel or about the well or spring; sulfurous waters are charged with hydrogen sulfid; effervescing waters, with carbonic acid; saline waters, usually with common salt; and acidulous waters, with sulfuric or hydrochloric acids.

These waters have their own peculiar effect upon the human system. Saline waters if charged with sulfate and phosphate of sodium, potash, or magnesium have a cathartic action; carbonated waters while they are highly palatable are also beneficial to dyspeptic sufferers; an excess of hydrogen sulfid in water is likely to produce diarrhea; iron waters are frequently the cause of headache, indigestion and dyspepsia. According to Wancklyn, drinking water ought not to contain more than two-tenths grains of iron per gallon, and should contain less than one-tenth grain of lead or copper. Too much of the sulfates or chlorids of calcium and magnisium are likely to produce deleterious results on the system.

POLUTION OF WATER.

There are certain vegetable and animal organisms which pollute water and may best be detected with the aid of the microscope. As before stated, these germs usually feast upon the decomposing organic matter, therefore, the filtration of water, and artificial æration will largely diminute their numbers. Boiling water, from one to three hours, will surely exterminate all microbes.

One of the principal sources of vegetable contamination is fresh water *Algæ* which grow in nearly all water supplies. The disagreeable odor and taste of water, as "woody," "musty," or "fishy," can usually be traced to these plants. A microscopical examination of a sample of well water from the vicinity of Moscow, revealed the presence of hair, excreta and a species of infusoria. City water stored in a reservoir, or drawn from lakes or rivers, is rarely free from water-fleas, spongilla, and parasites of various sorts. So well known is their presence in water and so abundant in the water supply of large cities as to make the water a factor in the spread of disease, as cholera, typhoid fever, dysentary, diphtheria, malaria, etc. The out break of cholera in

Russia and Hamburg in 1892, and the frequent outbreaks of typhoid fever and diphtheria in our own country are striking examples.

Says Dr. V. C. Vaughan in the "Pharmaceutical Era" for May: "About fifty thousand persons die annually in the United States from typhoid fever and more than ten times this number are sick with this disease. The greater number of these cases are due to the drinking of infected water." It behooves a city, therefore, to guard well its public water supply, and during warm weather, to have the same inspected weekly. Should the supply be taken from a river which receives the drainage from a farmer's barnyard, a closet, or the sewage of other cities the necessity of its frequent examination becomes apparent. Even a night's rainfall, under such conditions, and they are not rare, may infect the supply with a most virulent poison.

PURIFICATION OF WATER.

Impure or polluted water may be made usable by processes of purification. These processes may be termed natural and artificial.

NATURAL.

Sedimentation. Streams may be cleansed, in part, of their impurities by the tides backing up the water at the mouths of large rivers, by the expansion of the rivers into lakes, as Lake Pepin in Minnesota, Lake Geneva in Switzerland and elsewhere, causing a diminution of the current, thus permitting sedimentation

Dilution. River water may be diluted and made available for house use by the commingling of streams of different degrees of purity. This is illustrated at Lewiston, Idaho, where the milky waters of the Snake River are diluted by the clear waters of the Clearwater which is in turn rendered purer by the pure, sparkling waters of the Potlatch and other mountain streams.

Æration. The organic impurities in water may be oxidized by the absorbed oxygen taken from the air in the tumbling of river water over falls, rapids, and a stony bottom. In this way the Mississippi River purifies itself between Winona and La

Crosse; and the Hudson River, according to Dr. C. F. Chandler, disposes of its organic matter in the six-mile flow from Troy to Albany. Of course when the river is iced over this source of depuration is greatly lessened.

Precipitation. Rivers charged with iron and other poisonous salts and acids may be neutralized by water containing bicarbonate of lime gathered in the flow of the stream through limestone regions. The lime and iron are almost completely precipitated by the resulting chemical reaction.

Crystallization. When water freezes a portion of the suspended matter is eliminated; but much of the organic matter and microbes remain to pollute the ice. Dr. C. P. Pingra, of the Michigan Board of Health, clearly proved, by a series of experiments, that "water, in freezing, is only freed of about fifty per cent. of its organic crystalloids, twenty per cent. of its colloids, forty per cent. of its mineral salts, and ninety per cent. of its bacteria."

Soil Filtration. The soil may act as a mechanical agent—a filter—in clarifying water. The city of Winona, Minnesota—and other cities similarly situated—takes its public water supply from the Mississippi River. The water filters through fifty feet or more of gravel and sand into two large wells from which it is lifted into a standpipe and distributed over the city.

ARTIFICIAL.

Boiling. Water may be freed of microbes by boiling. Usually a few minutes will suffice to destroy the *Fungi* and *Algae;* but, according to Professor Birdge, of Wisconsin, some *Bacteria* are very tenaceous of life during certain periods of their development and to ensure their destruction the water should be boiled from one to three hours. This prolonged operation will thoroughly sterilize the water.

Distillation. Water may be cleared of its solid matter by distillation. This process consists of converting the water into steam, then condensing the steam. But distilled water is insipid and not entirely healthful. If again ærated it becomes palatable. Distilled water is largely consumed on shipboard and on oceanic islands where fresh water is not obtainable.

Æration. The artificial æration of water has been practiced upwards of a century in Europe, but only recently introduced into this country. It is now quite generally employed in our large cities and manufactories whenever the water supply becomes offensive, or during the summer months. The process consists in forcing air, under pressure, through the water confined in reservoirs until thoroughly agitated. The oxygen of the air mixes with the water and burns or oxidzies the organic matter present. In this way, offensive and dangerous waters have been made clear and sparkling.

Filtration. This process of purifying potable waters is so well known as to require no explanation here. It has been in use centuries until now the methods and varieties of filters in use are many. Unless the filter is kept *scrupulously clean*, however, the filter may be a breeder of microbes instead of annihilating them.

Sedimentation. River water is likely to contain much sediment during the rainy reason and at times of high water. Wells and springs may be similarly affected. The Missouri River at St. Louis is reported as containing at certain periods as high as one and eight-tenths per cent. of the bulk of the water; ninety-five per cent. of this sediment is disposed of within twenty-four hours, with the aid of large "settling pans." If carbonates are present, boiling will aid in clarifying the water.

Precipitation. Various chemicals have been employed for precipitating the impurities in water. Those in common use are borax, alum, lime-water, sal soda, iron chlorid, and potassium permanganate. Sodium carbonate and lime-water are employed for softening water. Other methods are resorted to for the purification of water, but the above are those in general use.

CHEMICAL TERMS EMPLOYED IN WATER ANALYSIS.

Salts. A salt, chemically considered, is formed by the action of an acid upon a base. An acid has a sour taste and reddens blue litmus; a base has properties almost exactly the opposite of those of acids. Chlorids, therefore, are salts formed by the actions of hydrochloric or muriatic acid upon a base or metal: sulfates, by the similar action of sulfuric acid; sulfites, by the action of sulfurous acid; sulfids, by the action of hydrogen sulfid; nitrates, by the action of nitric acid; nitrites, by the action of nitrous acid; carbonates, by the action of carbonic acid; phosphates, by the action of phosphoric acid; silicates, by the action of silicic acid, etc.

Oxygen is a colorless gas, odorless and tasteless. It supports combustion and life; is heavier than air of which it forms one-fifth by volume, eight-ninths by weight of water, one-half of minerals, three-fourth of animal tissues and fourth-fifths of vegetable tissues; in short, about two thirds of the earth.

Hydrogen is also a colorless, odorless. tasteless gas, when pure. It does not occur free; it is the lightest substance known, being about fourteen and one-half times lighter than air; it is very inflammable and does not support combustion or respiration. Hydrogen is not poisonous, but destroys life, just as water does, by shutting out the oxygen. The lungs may be inflated with *pure* hydrogen with safety. Hydrogen is a constituent of all acids.

Nitrogen is a gas, colorless, odorless, tasteless. It forms, by weight, four-fifths of the atmosphere; is not inflammable; is a non-supporter of combustion and respiration; is not poisonous but destroys life like hydrogen, by shutting out the air. Nitrogen is a very inert element; combined with hydrogen it forms ammonia gas; with oxygen it forms "laughing gas," an anæsthetic employed by dentists; it is a constituent of nitric acid. Nitrogen occurs in water as ammonia, nitrates, etc.

Carbon is a very abundant element. It largely composes the volatile matter of water solids, and the carbonates of limestone and marble. We know it, pure and crystallized, as the *diamond;* as *graphite*, a mineral greasy to the touch, erroneously called "black lead;" and as *amorphous carbon*, uncrystallized. In this form it is the chief part of mineral coal, charcoal, coke, peat, boneblack, soot and lamp-black. Carbon occurs in water as a carbonate; combined with oxygen and dissolved in water, under pressure, it forms "soda water."

Chlorin. This element does not occur free in nature, because of its great chemical affinity. It combines with nearly all the elements and is best known in combination with sodium with which it forms table salt; with hydrogen it forms hydrochloric acid. Chlorin is a yellow, heavy, suffocating gas, and is used for bleaching. It occurs in water as a chlorid.

Sulfur is found native in volcanic regions of Idaho and elsewhere, and in combination with lead, iron, mercury and zinc. It burns in air from which it takes oxygen, forming sulfur dioxid. Sulfur is used in the manufacture of matches, gunpowder, in bleaching straw and woolen goods, and as an antiseptic and disinfectant. Sulfur occurs in water as sulfids, sulfates and sulfites.

Phosphorus is a waxy, semi-transparent solid. Exposed to the air it slowly oxidizes and takes fire. It must be kept under water; it is very poisonous. It is used in the manufacture of matches and exists in bones, the ash of plants, soils and water as phosphates.

Silicon. Next to oxygen silicon is the most abundant element in nature and is never found free. One-fourth of the earth's crust is silicon oxid or silicates. Combined with oxygen it forms silica, white sand or quartz. Amethyst, agate, flint and opal are impure forms of silica. Silica and certain silicates are soluble in water containing alkaline carbonates.

METALLIC POISONS IN WATER.

Lead. Its presence is made possible by the distribution of water through leaden service pipes, which are readily corroded by water containing free acids, alkali, nitrates and oxygen. Sugar of lead and white lead are familiar compounds. Lead salts act on the system as a virulent, cumulative poison.

Arsenic is best known in the form of "white arsenic" and as an ingredient of Paris green. Both the fumes and the soluble salts of arsenic are deadly poisonous. It is found in the soil and as an impurity in lead, copper, zinc and glass vessels.

Zinc. Galvanized iron pipes and solder are a source of this poison. Water that has stood a long time in zinc-lined vessels is open to suspicion. Zinc chlorid is sometimes used by tinners in soldering cans.

Copper. This poison is most familiar to the public under the name of blue vitriol, or copper sulfate. It is extensively employed in galvanic batteries and in the preparation of Paris green. Copper nitrate is used in calico printing; copper acetate, or verdegris, accumulates about copper vessels containing acids, hence fruits, jellies, pickles, vinegar or fats should never be put in copper or brass utensils.

Iron is present in nearly all soils hence found in most waters. A common salt is iron sulfates or green vitriol. Iron is largely used in medicine as a tonic and becomes suspicious in water when it exceeds three-hundreths parts per hundred thousand. Artesian water may contain large quantities.

Tin is really iron ware coated with tin. Tin is often adulterated with lead, and is attacked by certain waters. The chlorids of tin are poisonous.

ALKALINE EARTHS AND ALKALIES.

Calcium is a prominent constituent of most soils, waters and bone in the form of a carbonate, sulfate or phosphate. The sulfate is know as gypsum; dehydrated it is plaster of Paris; as a chlorid it is used as a disinfectant and for bleaching; the phosphate is a fertilizer. The hardness of water is due largely to lime sulfate or carbonate.

Barium is sometimes present in very hard waters as a sulfate or carbonate.

Magnesium is found like lime in each of the natural kingdoms, though less abundantly. The principal compounds are the oxid and the carbonate, the latter causing the temporary hardness of water.

Potassium salts are a natural product of certain mines and the ash of plants; the carbonate is obtained by leaching ashes. Potash salts are a commercial product, used in making soft soap, glass, etc. As a hydrate it is "caustic potash," as a carbonate it is "saleratus," as a nitrate it is "salt-petre," the uses of which are known to all. Potassium salts are easily soluble hence are always found in potable and mineral waters.

Sodium is less active than potassium. Its chief compound, sodium chlorid or common table salt, is obtained from immense deposits or beds, from saline springs, and from sea water and salt lakes by evaporation. Sodium chlorid is always present in artesian waters. The carbonate and the sulfate form the basis of the alkali plains of southern Idaho and elsewhere. Caustic soda makes hardsoap.

Alkalimetry. An alkali is the opposite of an acid, turns red litmus blue, has the power to attack and decompose organic matter, neutralize acids, and has generally a soapy taste and feeling, hence is an undesirable constituent of some of our soils and waters. Quick lime (oxid of calcium), and lye (caustic soda or caustic potash), are good examples of an alkali. Owing to the carbonic acid in the air these substances usually exist in the carbonate form, and are then termed "mild alkalies."

STATEMENT OF RESULTS.

A chemical analysis may be either qualitive or quantitive; the former determines the *nature* of the constituents of a body; the object of the latter is to determine the *amount* of these constituents. The results of the analysis may be given either as oxids or as salts of the metals. Below, by way of illustration, is the University water recorded in both forms. The water was drawn from the faucet in the chemical laboratory May 28, and analyzed the same week. It is an average sample of the artesian water which supplies the city of Moscow. The wells are from 94 to 105 feet deep, five in number; the water has a temperature of 53° F.:

AS OXIDS OF THE METALS.

	(Parts per 100,000.)
Total solids	26.59
Volatile matter	8.74
Mineral matter	17.85
Silicon oxid	4.40
Iron oxid	1.89
Calcium oxid	2.48
Magnesium oxid	1.12
Sodium oxid	1.76
Potassium oxid	.47
Lead oxid	.01
Sulfuric acid	2.59
Carbonic acid	2.07
Chlorin	1.03
Free ammonia	.002
Albuminoid ammonia	.005
Total hardness	12.00
Permanent hardness	9.20
Temporary hardness	2.80

AS SALTS OF THE METALS.

Total solids	26.59
Mineral matter	17.85
Iron sulfate	1.94
Calcium carbonate	7.05
Calcium sulfate	2.26
Magnesium carbonate	3.39
Sodium silicate	4.11
Sodium chlorid	1.62
Sodium sulfate	3.17
Potassium chlorid	.43
Lead chlorid	.02

HARDNESS.

This is a condition of water due to the presence of the carbonates or sulfates of lime, strontium, barium or magnesium, and is based upon the soap destroying power of the water. Hardness is measured in degrees, a degree on Clark's scale being one grain of lime carbonate, or its equivalent, per gallon of water. Good waters vary from 3 to 20 degrees, though they are not designated as hard waters unless they exceed 8 degrees. According to Dr. C. B. Fox, each degree of hardness signifies the destruction of 12 pounds of the best hard soap by every 10,000 gallons of water.

Total Hardness is determined by pipetting Clark's solution into a difinite quantity of the cold water under examination until a permanent lather is formed.

Permanent Hardness is caused by the presence of earthy sulfates and may be ascertained by boiling a sample of the water for twenty or thirty minutes, replacing, when cold, what is lost as steam with distilled water. Examine with soap test.

Temporary Hardness is the difference between the total and permanent hardness, and represents the softening effect of boiling. The carbonates of lime, strontium, barium or magnesium are precipitated by boiling. The "fur" upon the tea-kettle is a precipitated carbonate; remove with an acid.

BOILER WATERS.

The total solids in waters intended for boiler or steam purposes should be low; but the nature of the material is more important.

Boilers may be injured by the formation of a deposit or "fur," and by corrosion. The total and permanent hardness will determine whether a deposit will be formed; and this will be due to the presence of the sulfates and carbonates of lime and magnesium.

In the case of corrosion, three conditions may be the cause: (a) Boiling water may attack the iron. (b) The gases held in solution and which are liberated by boiling, may corrode the metal. (c) The salts and gases formed by the decomposition of the solids by the heat may have a caustic action on the iron. A chemical analysis will usually determine the quality and quantity of such corroding materials.

The artesian water of the city of Moscow being high in carbonates and sulfates of lime and magnesium is an inferior boiler water. The coating or "fur" formed on the interior must not be allowed to accumulate or the pipes will be ruined and fuel wasted. For potable uses, however, it is an excellent water.

Since the above was written the boilers and feed pipes to the same in the Moscow city water works have been inspected by State Boiler Inspector Gundaker. The interior of the boilers were found to be badly coated and the feed pipes ruined, being almost entirely filled with the "scale." The deposit varied in composition, but that which was analyzed contained:

Sand and silicates	19.77	per cent.
Iron and alumina	24.79	"
Lime	30.00	"
Magnesia	7.93	"
Carbonic acid	14.70	"
Sulfuric acid	2.13	"

Acids would only partially dissolve this scale, and to effect complete solution, fusion had to be resorted to.

WATER ANALYSES.

The following table presents a comparative view of potable waters sent in for analysis. The analysis of well water at this Station has thus far been confined to chemical tests looking to an excess of foreign matter from barns, closets and service pipes.

Laboratory Number.	Owner or Renter of Well.	Postoffice.	Date Collected.	Parts per one hundred thousand: Total solids, at 100° C.	Volatile matter.	Mineral matter, at red heat.	Chlorin.	Free ammonia.	Albuminoid ammonia.	Total hardness. (Clark's scale)	Permanent hardness.	Lead.	Depth of well
No. 1	W. F. Rayburn	Moscow	9-24	24.66	10.36	14.30	.035	.001	.002	*8.55	2.60	......	32 feet
No. 2	Prof. L. F. Henderson	Moscow	9-30	23.64	9.56	14.08	.005	Trace	.001	7.73	3.94	......	30 feet
No. 3	Pres. F. B. Gault	Moscow	10-15	23.30	8.00	15.30	.014	.016	.028	8.80	7.60	......	45 feet
No. 4	Pearson's Spring	Nampa	12-8	18.10	9.50	8.60	.092	.006	.015	5.80	4.00	......	Filtered ditch water.
No. 5	Ditch water	Nampa	12-8	26.30	9.50	16.80	.088	Trace	.013	4.20	3.20	......	Open
No. 6	Mr. Stearns	Nampa	12-8	24.50	9.00	15.50	.177	.003	.044	6.40	5.10	......	72 feet
No. 7	Mr. J. J. McDonald	Nampa	12-8	28.00	5.40	22.60	4.951	.006	.016	12.30	6.20	......	12 feet
No. 8	Mr. H. L. Coats	Moscow	12-24	14.20	6.32	7.88	.106	.001	.002	5.20	3.60	......	110 feet
No. 9	Mr. C. E. McCormick	Moscow	12-24	12.56	5.00	7.56	.124	.002	.012	5.20	4.50	......	103 feet
No. 10	Station No. 3, cistern	Idaho Falls	1-2	17.32	3.40	13.42	1.062	.006	.018	7.10	5.20	......	Filtered ditch water.

No. 11..	City water	Idaho Falls	1-2	24.96	5.40	19.56	2.122	.003	.003	12.60	7.00	......	From Snake River.
No. 12..	Mr. A. Cox	Moscow	1-6	33.12	13.00	20.12	1.415	.001	.220	6.60	4.70	.....	50 feet
No. 13..	Mr. Wm. Taylor	Moscow	1-18	84.85	23.40	61.45	30.418	.001	.008	18.00	14.40	.....	Spring; much iron.
No. 14..	Mr. Wm. Taylor	Moscow	1-18	19.25	3.25	16.00	1.149	.003	.180	10.50	2.60	.....	100 y'ds from No. 13, bottom land.
No. 15..	Mr. H. E. Matterson	Grangeville	2-8	19.48	8.28	11.20	1.592	.050	.065	5.60	2.90	......	15 feet
No. 16..	Snake River	Lewiston	5-20	23.48	6.28	17.20	1.061	.110	1.810	9.65	6.75	......	Taken at boat landing.
No. 17..	Clearwater	Lewiston	5-20	7.48	1.28	6.20	.707	.105	1.20	2.60	2.00	......	Taken at Ferry.
No. 18..	City water	Lewiston	5-20	4.60	1.01	3.59	.354	.040	.069	2.80	2.20	Trace	Raymond House.
No. 19..	Mr. M. J. Wessels	Lewiston	5-20	28.81	7.71	21.13	3.537	.206	.800	14.25	11.00	......	50 feet
No. 20..	Hotel Snyder	Juliaetta	5-20	27.30	3.30	24.00	2.475	.006	.551	13.15	6.89	......	26 feet
No. 21..	Mr. H. H. Hoff, farm well	Montpelier	5-14	33.40	2.40	31.00	3.184	.055	.745	19.10	12.05	.....	25 feet
No. 22..	County Poor House	Moscow	6-2	31.48	8.92	22.56	6.72	.026	1.65	16.00	12.20	.....	20 feet
No. 23..	District No. 15	Montpelier	6-15	14.75	4.32	10.43	.177	.075	.255	21.60	16.0	.....	25 feet
No. 24..	Mr. F. E. Mix	Moscow	6-18	13.60	5.20	8.40	.707	.060	.825	10.00	8.80	......	20 feet
No. 25..	C. A. Christopher	Genesee *	6-25	39.85	19.00	20.80	5.66	.810	2.50	19.60	14.80	......	33 feet
No. 26..	Patrick Kinnier	Lenville	7-3	19.80	8.20	11.60	.354	.040	1.35	13.10	8.00	......	Spring.

* Degrees of hardness: 1°-5°, soft; 5°-10°, medium; 10°-15°, hard; 15° and above, very hard.

SOLID AND GASEOUS MATTER IN WATER.

Color, odor, taste. Water of the highest purity should be clear, colorless, odorless and nearly tasteless. If recently distilled it will have an insipid or flat taste.

Total solids. This is the residue remaining after a given quantity of water has been evaporated to dryness over the water bath and exposed to a temperature of 100°C. for several hours. Sanitary authorities have fixed the limit at 60 parts per 100,000. Many good artesian waters, however, exceed this limit.

Volatile matter. This represents the loss by ignition at red heat; the percentage should be small, the lower the better.

Mineral matter. This is the difference between the total solids and volatile matter, and varies greatly in quantity and quality, especially in mineral waters.

Free ammonia. This gas is the result of absorption, and of the putrifactive fermentation of nitrogenous organic matter.

Albuminoid ammonia. This is obtained by treating the water remaining in the retort, after the free ammonia has been expelled, with alkaline potassium permanganate. It indicates an excess of nitrogenous matter; if of animal origin the analyst condemns the water as unsafe for potable use, if high.

Chlqrin. If the water be of deep origin the quantity of chlorin present, principally as common salt, may be high, since its origin is mineral or vegetable; but if it is of animal origin any excess of the limit should be regarded with suspicion.

INTERPRETATION OF RESULTS.

Leffmann and Beam give the following table as a guide:

	PARTS PER ONE HUNDRED THOUSAND.			
	RAIN WATER.	SURFACE.	SUBSOIL.	ARTESIAN.
Total solids	5 to 20	15 upward	30 upward	45 upward
Nitrogen as free ammonia	.2 to .5	.00 to .03	.00 to .03	Gen'ly high
Nitrogen as alb. ammonia	.8 to .20	.05 to .15	.05 to .10	.03 to .10
Chlorin	Traces to 1	1 to 10	2 to 12	trc. to excess

According to Wanklyn, the total solids should not exceed 57.14 parts per 100,000, (40 grains per gallon).

The presence of chlorin alone does not necessarily indicate organic contamination.

If chlorin is absent, but free and albuminoid ammonia present, the source of contamination is vegetable.

Chlorin in excess of 7.14 per 100,000 (5 grains per gallon), providing more than .80 parts of free ammonia and 1.00 part of albuminoid ammonia accompany it, the contamination is clearly animal,—sewage, decaying animal matter or urine. Such water should be condemned.

If the free and albuminoid ammonia exceed the parts above named, even without chlorin, the water should be regarded with suspicion.

When the albuminoid ammonia exceeds 1.5 parts per 100,000 in potable water, such water is absolutely unsafe.

An examination of the preceding analyses indicates that numbers 7, 13, 16, 22 and 25 ought to be condemned as absolutely unfit for house-hold use. Numbers 22 and 25 are filthy and the wells from which the samples were taken should be thoroughly inspected, together with their surroundings, to ascertain the cause of the contamination. Samples numbers 12, 14, 15, 17, 19, 20 and 26 should be considered suspicious; while numbers 1, 2, 3, 6, 8, 9 and 23 are excellant waters at the present time. Boiling the water, then allowing it to cool and settle before using, would greatly improve the quality of the objectionable samples. Parties sending samples of water for analysis should follow strictly the directions on page six.

SCALE OF PRICES.

The Board of Regents at its last annual meeting adopted the following scale of prices for the analysis of water not coming within the provence of the Station work:

For Sanitary analysis	$5.00
" Complete qualitive analysis	$5.00
" Complete quantitive analysis	$25.00
" Complete analysis of mineral water	$100.00

Summary.

1. Pure water is composed of oxygen and hydrogen, by weight 8 to 1, volume 1 to 2 respectively. It freezes at 32°F., boils at 212°F., sea level, or about 207°F., altitude of Moscow.

2. Water is heaviest at 39.3°F., below or above this temperature it expands; when it freezes it makes a sudden expansion, resisting great force, 12 cubic inches of water forming about 13 cubic inches of ice.

3. Water composes about three-fourths of the weight of the globe; is an essential component of most rocks; some vegetables contain 97 per cent. of water; fruits average 80 per cent; and our bodies and our brains each contain about 75 per cent. water.

4. Water may be used for domestic purposes, for mechanical and heating purposes, for medicinal purposes, for irrigating purposes and for commercial purposes.

5. When sampling waters for analysis, use only clean demijohns, jugs, or glass vessels for containers; send from two quarts to one gallon for analysis; secure an average sample; send full data and prepay all charges.

6. Strictly chemically pure water is not healthful, but should contain some mineral matter and absorbed gases to make it palatable and dietetic. It should be free of metallic poisons and should contain but small quantities of nitrogen and chlorin compounds.

7. Pure spring or well water is an excellent remedy for renal disorders, for cleansing the system of poisons, for improving the health and increasing the flesh of those who use it.

8. Mineral waters have their own peculiar effect on the system, which can only be determined by analysis and use.

9. Water may be polluted by exposure to birds, insects, microbes, and ingrowing water plants; by long standing in reservoirs and service-pipes; by sewage, seepage and wooden curbing.

10. Water may be purified by processes of sedimentation, dilution, aeration, precipitation, filtration, boiling and distillation.

11. Hard water attacks the teeth, is unfit for boiler or laundry purposes, and is not good for cooking leguminous vegetables; but is an advantage in making tea or coffee, as it tends to impart an agreeable taste and aids in settling the same.

12. To understand the meaning and results of a chemical analysis of water a careful study of the terms employed should be made.

13. The injurious agents contained in potable waters are compounds of chlorin, nitrogen, lime, magnesium, certain metallic poisons and microbes. Their presence in quantities above certain limits renders the water suspicious if not absolutely dangerous.

14. The analyses of waters for individuals or corporations, intended to advance their pecuniary interests, must be paid for; but work that will tend to improve the health of a family, community, public schools or institutions within the State will be done free of charge.

CHAS. W. MCCURDY,
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