tium sulphate, gr. 0.38; sodium sulphate, gr. 3.97; iron carbonate, gr. 1.95; calcium carbonate, gr. 13.66; sodium chloride, gr. 0.34; potassium chloride, gr. 0.24; silica, gr. 2.07; organic matter, gr. 1.03; aluminum sulphate, manganesium carbonate, and phosphoric acid, traces. Total, 27.78 grains. These waters have a useful application in debilitated states, especially when attended by intestinal torpor. They have rendered good service in anæmia and general debility. *James K. Crook.*

WATER (H_2O).—Even after it had ceased to be considered elementary, there was much ignorance concerning the composition of water. Thus when for the first time it was decomposed by the action of the electric battery, an acid was observed to form at one pole and an alkali at the other, in addition to the gaseous products oxygen and hydrogen. This acid and the associated alkali were supposed to be intimately related with the two gases in the structure of water, until Humphry Davy, by a series of brilliant experiments, showed that the acid and alkali were entirely adventitious and that water consisted of oxygen and hydrogen alone. Demonstration of its composition was also made synthetically by the explosion of a mixture of the two gases, such mixture being in the ratio of one volume of oxygen to two volumes of hydrogen.

Considered physically, an important property of water is its very great solvent power, and it is also noteworthy as the basis for specific gravity and specific heat. Moreover, it is employed as the metric unit of weight, the "gram" being the weight of 1 c.c. of water at the temperature of its greatest density, 39.2° F.

Chemically considered, the graphic formula for water, H—O—H, known as the "water type," constitutes the starting-point of the two great series of compounds known as "hydrates" and "oxides," the first being formed by the replacement of half the hydrogen of the "water type" by a metal (R—O—H), and the latter by its entire replacement (R—O—R). For our present purposes, however, it is the more practical and sanitary side of the question of "water" that should claim our attention; in other words, we should undertake some consideration of the wide field of inquiry covering *water supply.*

From remote antiquity the highest value has been set upon an abundant and pure water supply. Centres of population sprang up in ancient times around those points where it was readily available, and great expenditures of labor and treasure were made to carry it to places where it was not naturally plenty. Not only was a generous daily *per capita* allowance sought for, but we note in the centuries gone by unmistakable evidences of a keen appreciation of the dangers lurking in a polluted supply; and upon this point many of the ignorant consumers of our own day and generation would be benefited did they consult the wisdom of the past.

When considering the sources of water supply available for public or private use, we very properly first turn to such bodies of "stored water" as may be within reachable distances.

Nature provides enormous quantities of water stored up in lakes and ponds ready for human consumption, and man frequently supplements this by impounding surface and deep-seated waters in artificial basins when the natural reservoirs of the district are unavailable or are insufficient in size.

Lakes of such magnitude as to be properly considered inland seas—the Great Lakes of North America, for instance—furnish water of quite constant composition, free from the considerable vegetable contamination so frequently met with in small lakes and ponds.

Large as these Great Lakes are, the influence of the sewage from cities upon their shores is nevertheless beginning to be seriously felt. For instance, the pollution of Lake Michigan by the sewage of Chicago is a widely known fact, and the intakes, situated as they are miles from shore, are frequently reached by the ever-swelling volume of the city's refuse.

	Lake Superior, near Duluth, 40 miles out from shore, March, 1896.	Lake Erie, near Erie, Pa., 14 miles out from shore, October, 1897.
Free ammonia	0.03	0.045
Albuminoid ammonia	.02	.112
Chlorine	1.0	3.500
Nitrogen as nitrates	0.0	.080
Nitrogen as nitrites	0.0	Trace.
Required oxygen	1.15	1.250
Total solids	54.0	134.000

Much opportunity is given in large lakes for sedimentation to come into full play, and settlement is, in consequence, a very great item in the process of the natural purification of their waters; but so far as the American "Great Lakes" are concerned, a difference must be noted in this respect between Lake Erie and the other members of the group. Lake Erie is comparatively shallow and is stirred to its bottom by every gale. Therefore sedimentation advantages are at a minimum therein.

In small lakes and storage reservoirs vertical circulation commonly ceases below a depth of twenty feet, that being the usual distance to which wind and wave agitation extends. Fitzgerald found that Lake Cochituate, which has an area of seven hundred and eighty-five acres, is not affected by wind and wave action below twelve feet from the surface. Should a lake be protected from the wind, the aerated layer may extend temporarily only ten feet from the surface, and below this level the cold, stagnant water rests, until such time as the chilling of the upper layer increases its gravity to and beyond that of the lower layer upon which it floats. When this point is reached, readjustment of relative position is immediately instituted, in accordance with the change in specific gravity, and the water of the lake "turns over."

The formation of this stagnant layer begins in April in this latitude, and circulation is partly re-established in October and completely so in November. With the advent of freezing weather a second period of stratification is inaugurated, which continues until the surface thaws again in the spring. Vertical circulation then progresses until the warm sun of later April renders the surface water so light as to float upon the colder layers beneath, when summer stagnation again begins.

Whenever the lower stagnant layer is brought in contact with decomposing organic matter, as is the case in reservoirs with bottoms from which the vegetation has not been removed, the dissolved oxygen present is quickly used up; quantities of extractive matters pass into solution and the water becomes foul in odor and dark in color.

Even though the bottom of a lake or reservoir be perfectly clean and sandy, the dissolved oxygen must surely diminish in the lower layers of water, for no water is without some oxidizable contents, but it will not be reduced to zero, nor will the water become damaged in quality.

Uniform experience goes to prove that good water may be preserved in properly constructed reservoirs without deterioration for indefinite lengths of time. It must be remembered, however, in this connection, that to keep a ground water in good condition it is necessary to cover the reservoir. Such waters are usually charged with mineral matter suitable for plant food, and the higher organisms will be very likely to grow therein unless light be excluded. Reservoirs used for storing filtered surface waters should be likewise dark, for the same reason.

Algæ depend for their development upon material furnishing nitrogen. Water containing a moderate amount of this element washed from natural sources will maintain but a small growth of such plant life, but where nitrogen is present in great quantity as nitrates, as is frequently the case in deep-seated waters, the development of algæ is often excessive during reservoir storage,

and the resulting smell and taste given to the water may cause widespread complaints.

It is true that no relation has ever been established between the occurrence of disease and the presence of the bad tastes and smells occasioned by abundant growth of algæ, but the results directly traceable to such growths will not be tolerated by the public, and the water purveyor constantly finds himself much more open to criticism through difficulties of that kind than through pollution of the supply by drainage from pathogenic sources.

Properly to conserve a water, to put it tersely, it may be said that if it be from a dark source it should be stored in the dark, and *vice versa;* filtered water being the exception and requiring dark storage irrespective of its source.

If dark storage be not practicable, then a water from an underground source should be delivered for use at the earliest moment possible to avoid the growths which the presence of light will encourage. With surface waters, on the other hand, open storage is always of benefit if the reservoir be clean.

It is an error to suppose that "stagnation" in a properly prepared reservoir is of itself harmful to the quality of water. Quite the contrary is true, and it is scarcely too much to say that rest rather than motion is the condition commonly leading toward the greatest amount of "self-purification."

Pathogenic bacteria tend to diminish by storage, both by reason of settlement and because of conditions which are adverse to their requirements for life; hence we note the beneficial value of the time element when dealing with impounded waters. Running streams, on the other hand, lessen the opportunities for sedimentation and their rapid flow hastens the delivery of the yet living disease germs to the unsuspecting consumer.

Let it not be thought, however, that the popular belief in the purification value of thorough aeration is based entirely upon error. Gases dissolved in the water and giving it objectionable odor—as the sulphureted hydrogen, for instance, in the artesian supply of northern Florida—are driven out by thorough exposure to air; and even algæ growths are often impeded by vigorous agitation. To such extent, therefore, falls and rapids and reservoir fountains are of advantage for the improvement of water; but the really serious item of pollution, namely, sewage admixture, cannot be disposed of by so simple a method as direct atmospheric oxidation, and any hopes that are based upon the supposed efficiency of such action will be doomed to disappointment.

A very large number of cities derive their water supplies from purely surface sources, such as rivers and streams—in Europe after careful filtration, but in America usually without such purification.

One of the important things for the consumer of such a water to bear in mind is that sudden and great changes in the character of the water are to be expected. Much will depend upon the weather and the amount of surface wash which naturally flows toward the drains of the district. A river which is clear to-day may be muddy and less fit for use to-morrow, and the turbidity will persist, even after its direct cause has ceased, until the river and its tributaries shall have emptied themselves into the sea. For it must be noted that the clearing of running streams has little to do with sedimentation and is almost wholly dependent upon a running out of the roily waters.

Another change, slow in operation but serious in results, is that induced by the establishment of sewerage systems in river towns, through the growth of a population which naturally sewers into the river. The difficulty is twofold. Not only does pollution increase with the multiplication of the people producing it, but the partial soil purification of the contents of the village cesspool is entirely eliminated when the sewers of the growing town turn the sewage in the raw state into the river.

It is not unusual to find a city damaging its own water supply by its sewage outflow. Tidal action may carry the refuse of a town up stream from the sewer outfalls until the water works intake is reached; or else the currents produced in a lake by weather changes may accomplish the same result, as is noticed at Chicago.

The self-purification of streams is a topic which has been very fruitful of discussion. Pettenkofer held that sewage might be safely turned into any stream whose volume was fifteen times greater than the volume of the sewage, and whose velocity was not less than that of the sewage inflow. This is but an *ex-cathedra* statement of a rather widely spread belief in the ability of running water to purify itself after a comparatively short flow. That efficient purification by such means is far from being an established fact is attested by the many instances that might be quoted of typhoid infection having been carried many miles from the point of pollution to the city intake below.

How far such infection may be carried is uncertain and is governed by the velocity of the current, but the distance has been shown to be many miles. The germs of such a disease as typhoid fever do not find conditions suitable for their development in river water, hence they do not multiply therein and after a time they die out without causing disturbance, provided that they be not caught up by some down-stream intake before their death be accomplished. Hence the value of the element of time in rendering a polluted water again fit for consumption. Not infrequently an acceptable water may be found flowing from a lake of no great size, while the stream tributary to its other end may be distinctly polluted; the lapse of time and the advantages of sedimentation having united their efforts toward the promotion of purity.

While space cannot be here given to detailed accounts of the ravages that have been caused by infected water, yet a glance at a single instance may serve for general illustration.

The cities of Hamburg, Altona, and Wandsbeck are practically one and are separated by only imaginary boundaries which a stranger could not locate. In 1892 Asiatic cholera broke out in Hamburg with exceeding severity, the reported cases having been 17,020 with a death list of 8,605. The disease marched up to the invisible boundary lines and there stopped, confining itself almost exclusively to Hamburg. In one street, which for a long way forms the boundary, there was cholera on the Hamburg side, whereas the Altona side was practically exempt. There was one detectable difference, and only one, between the conditions obtaining in these adjacent cities—they had different water services. Hamburg took raw water from the polluted Elbe River; Altona used the same river water, still more polluted by the Hamburg sewage, but carefully purified it by sand filtration; Wandsbeck possessed an entirely different supply. How cholera located the boundary is best shown by a "spot map" of the reported cases. (Fig. 5031.)

Freezing is a means of natural purification of water upon which the popular mind lays great stress, and to a certain extent the general confidence in its efficiency is not misplaced. Ice is certainly purer than the water from which it is formed, often very greatly purer. The ice cake grows from the surface downward, the crystals as they form pushing away from them the material suspended in the water, bacteria included, and freeing themselves also from no small amounts of even dissolved impurities. Naturally some floating objects become entangled in the thickening mass, particularly so if the underlying water be shallow, and all must of necessity pass into the ice cake if the entire depth of water be frozen. An excellent idea of the exclusive action of the crystals may be had by examining a cake of artificial ice. It will be observed that the last part frozen, namely, the centre of the cake, shows marked inferiority, due to the floating objects having been driven inward by the forming ice, only to be at last caught by the final solidification of the central portion.

When ice is formed on a polluted but deep water, a large river, for instance, the amount of bacterial purification amounts to over ninety per cent., commonly over ninety-five per cent., and a further element of safety lies in the fact that storage in ice-houses during the months elapsing between the winter "harvest" and the summer distribution tends still further to reduce the number of germs present in the ice cake. Be that as it may, however, there is small excuse for the too common practice of cutting ice from grossly polluted waters, for with even a high percentage of exclusion some germs do enter the ice, and it has been shown that typhoid germs are at times capable of surviving a three months' imprisonment therein.

Touching upon this question of the ability of typhoid germs to withstand freezing, the instance of the epidemic at Plymouth, Pa., is a case in point. There the dejecta of a patient lay frozen upon a hillside from January until March, when they were washed by the melting snow into the city water system with most disastrous results.

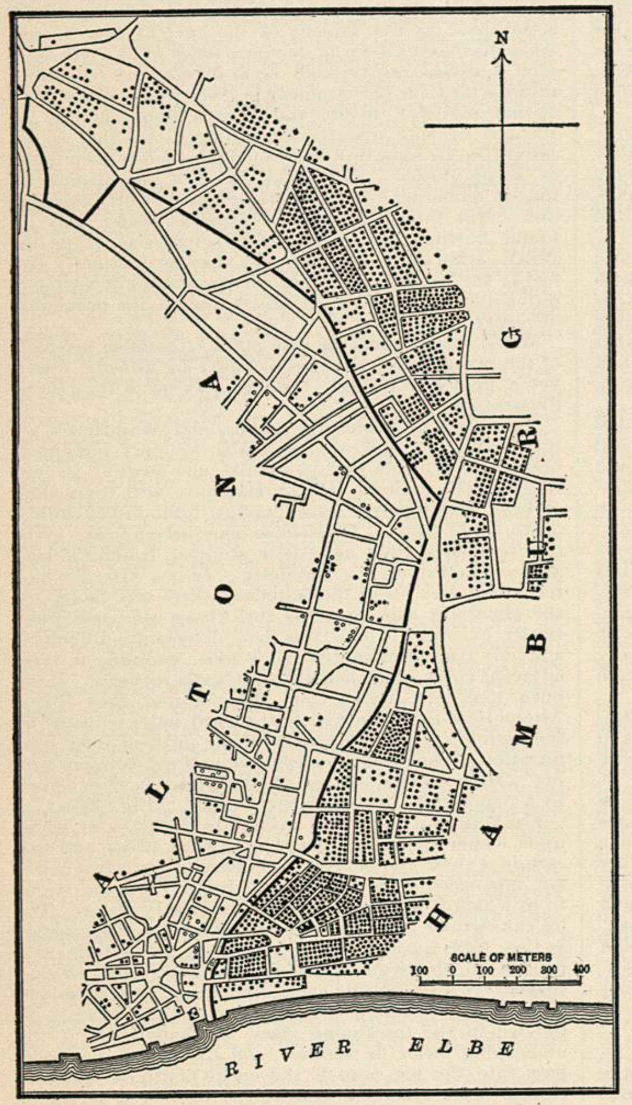

FIG. 5031.—Chart showing Distribution of Cholera Cases, in the Epidemic of 1892, at Hamburg and Altona. ▬, Boundary between the two cities; •, cases of cholera; ∘, cases imported from Hamburg.

Stress should be laid upon the fact that the large percentage of bacterial purification which results from freezing, as above referred to, is due to the mechanical exclusion of suspended particles by the growing crystals and not to a mere lowering of temperature. Even the intense cold of liquid air is but indifferently germicidal.

Beyond the ordinary wash caused by storms upon every water-shed, some rivers are exposed to sudden and great concentration of pollution through the sweeping away of piles of filth which accumulate upon their rocky fore-shores during periods of low water. The Tees, a river of northern England, is of such description. A study of the epidemic of typhoid which prevailed in that valley in 1891 proved of special interest, because the disease confined itself to those communities, aggregating 220,000 people, who used the river water, to the exclusion of a population of 280,000 of the same district who drank water from other sources.

A further point of interest lay in the striking manner in which a chart of the reported cases showed a rise in the number of fever patients about fourteen days after each heavy rainfall. (Fig. 5032.)

Streams in Europe are frequently polluted by the washing therein of infected linen, an out-of-doors laundry being common enough in the Old World, although quite the reverse in America. To such a cause was ascribed the great cholera outbreak at Messina in 1887, and a like epidemic at Cuneo in 1884 was traced to an entirely similar source.

"Deep-seated" is a term applied to water of a distant origin to distinguish it from "ground water" of an entirely local source.

Springs of small flow, such as trickle out of the country hillside, are properly classified with shallow wells; they furnish "ground water" only and are of local origin.

Quite another matter, however, are those natural fountains which reach the surface in great volume, possessed of a temperature radically different from that of the local subsoil, and holding in solution mineral materials that may be quite foreign to the neighborhood. Such water is always of distant source, and the gathering grounds where it originally falls as rain may be very far away indeed.

Picture the outcrop upon some rainy upland of a porous stratum, encased upon either side by strata impervious to water; let the strata be possessed of a moderate dip, then let them be cut transversely at some point below, either by simple erosion or by a geologic fault, and the conditions for a deep-seated spring would be complete. Rain water falling on the distant outcrop would pass down the porous stratum, picking up soluble material on the way, and would escape as a spring at the point where the strata were broken or eroded.

At the head of San Antonio River, not far from the city of San Antonio, Tex., is situated a mammoth spring of pure water, whose daily outflow is some fifty million gallons. This spring is but one of a group of great springs which "coincide almost exactly with the line of the great Austin Del Rio fault." A very curious instance of a spring of great magnitude caused by erosion cutting into the water-bearing stratum is to be found several miles out at sea off the coast of Florida, east of Matanzas Inlet.

There are reasons for believing that the Matanzas spring is due to a bursting of the confined waters through a hole in the upper hard rock layer. Successful sounding has recently been accomplished in the spring itself. In its immediate vicinity the ocean suddenly deepens from a depth of sixty to one of one hundred and twenty-six feet.

Instances are by no means rare of the use of deep springs for water supplies of magnitude, such as the "Vanne" water, which supplies a part of Paris from

springs in massive chalk near Troyes, but deep seated water is much more commonly reached by special borings.

The expression "artesian" has been extended to include deep wells under all conditions, but without proper license, because the term originally came from the name of the French province where deep wells were first successfully established, and such wells were "flowing." It is therefore to "flowing wells" only that the expression "artesian" properly attaches. Wells of this class were first sunk, in Europe, at Lillers, in Artois, in 1126. In the Sahara and in China they have been known for many centuries. Whether, however, the well be a flowing one or one from which the water has to be raised by power, the conditions governing the storage of such water are essentially the same as have been already given when speaking of deep springs. An outcrop of a porous stratum in a rainy upland acts as the collecting area; this stratum is of moderate dip and is enclosed by other strata, impervious to water, lying above and below.

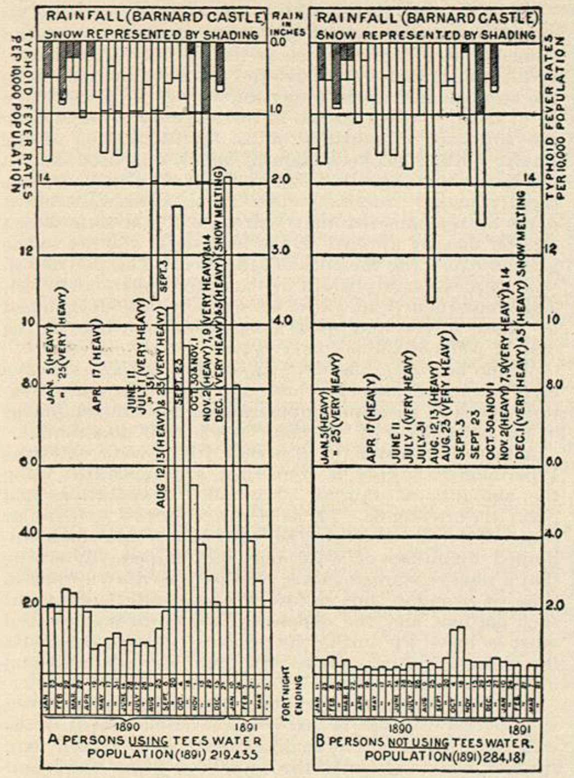

FIG. 5032.—Rainfall and Typhoid Fever in the Tees Valley, England.

Unless the strata form a basin or pocket, the water of the porous layer will find its natural outlet in a spring form where the layer is cut transversely by erosion or fault; but should a well be sunk at some intermediate point the water will rise in the same, or overflow, to a degree dependent upon the head to which it is subjected; that is, to the elevation of the gathering grounds above the well, and to the freedom with which the water can flow down the porous stratum and escape through the outlets below. (Figs. 5033 and 5034.)

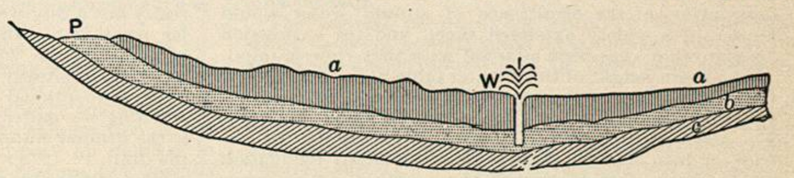

FIG. 5033.—Condition Favorable for Flowing Well. (After Hay.)

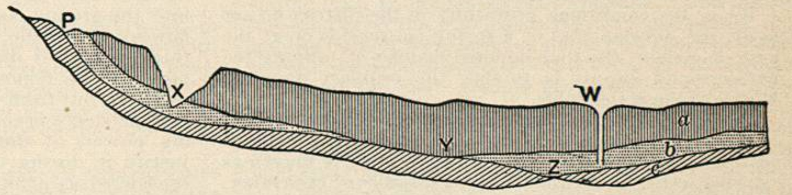

FIG. 5034.—Condition Unfavorable for Flowing Well. (After Hay.)

It must be remembered in this connection that the expression "deep" refers to the non-local character of the water rather than to the depth of the hole required for tapping the same. In fact, "deep water" may lie very near the surface in some places.

Contrary to the belief of many people, deep-seated water is not inexhaustible. If the porous layers containing it be extensive, an immediately available supply of large volume, which is the accumulation perhaps of ages, may be counted upon; but should the daily drain be larger than the natural reinforcement, the delivery must surely shrink in quantity and finally cease.

It is common knowledge that a great volume of water, some sixty-six million United States gallons, is drawn daily by the London water companies from deep wells in the chalk.

The serious effect of extending and heavily pumping these deep chalk wells supplying a portion of London is that "for every two gallons of water collected within the Lee valley London is withdrawing three from its reservoir in that chalk basin, and this quite apart from the amount every day required by the resident population of that area. The result of such a process can only be a steady, if gradual, exhaustion of water from the chalk and a progressive lowering of its plane of saturation."

Water from deep sources has commonly characteristics of its own, distinguishing it from the ground water of the neighborhood. One of the most easily recognized of these is high temperature.

Another peculiarity of deep water is the small quantity of dissolved oxygen which it usually contains. This is by no means due to the pressure to which it may be subjected, for increase of pressure favors the solution of gases, but is rather owing to the abundant opportunity for removal of oxygen by contact with such substances as organic matter, and compounds of iron and manganese, presented during the long underground journey of the water from its place of collection.

In point of composition the waters of deep wells are almost always highly mineralized, as would be expected in consideration of the items of long time, long distance of flow, high pressure, and elevated temperature. Sometimes the materials contained render the water unfit for use, even for boiler purposes, but more commonly the supply is such as to be considered a great boon to the fortunate possessor.

Perhaps as noteworthy an instance of a flowing well as can be quoted is that of Woonsocket, South Dakota. The boring is of seven inches in diameter and seven hundred and fifty feet deep. The water is of 63° F. temperature and is thrown above the surface to a height of eighty feet in a magnificent fountain, the entire discharge amounting to 11,500,000 gallons per twenty-four hours. The well is capable of furnishing a pressure of one hundred and forty pounds per square inch.

The circulation of the "ground water" in the soil is governed by gravity and surface tension, and the latter is in turn affected by the structure of the soil, its composition, and the per cent. by volume of the empty spaces between its particles.

The rate at which water will flow through a soil is dependent not only upon the aggregate volume of the voids, but also, and more particularly, upon their separate dimensions; for it can be readily seen that the inhibiting influence of friction will rapidly increase with the fineness of the soil grain.

Values are on record for the water-holding powers of various soils, but a word of caution seems proper here. It must be remembered that such figures show what the sands and soils will *hold*, not what they would *deliver*. No pump could extract that final portion of the contained water which would remain as "moisture," and its quantity would be a very respectable percentage indeed of the amounts given.

Wherever found, and under whatever circumstances, the water of the ground owes its origin to the rain or melting snow. Attention is called to this point because of a widespread notion that the wells of fresh water often existing in the immediate vicinity of the ocean are fed with sea water from which the salt has been removed by percolation through the sand of the beach. This inference is permitted in an engineering work of national fame. All along the shore of the Italian Riviera the traveller can see wells dug within one hundred and fifty feet of the surf. In such cases the fresh water found originates some considerable distance inland, and the wells intercept it on its way toward an outlet in the sea; in other instances its origin is due entirely to very local rains, and its storage in the loose sand is owing to its being specifically lighter than the surrounding sea water.

An instance of this kind is met with near the island of Heligoland. About a mile east of the island there is a long strip of sand raised but a few feet above the level of the ocean, extending some half a mile in length and but two hundred yards wide. It was formed and is maintained by ocean currents, and is covered by a scanty growth of grass. Anywhere upon this islet fresh water may be obtained by digging in the sand. Necessarily the water to be secured from such a source is limited in quantity.

A commonly received conception of the occurrence of ground water is that it moves in very definitely localized streams, and that, to be successful, a well must be sunk directly into one of these. Of course the conformation of the country may at times cause this popular notion closely to coincide with the truth, but a more general description of the occurrence of ground water would be that of a widely extended sheet, and the expression "water table" has been adopted with that view in mind.

The mean height of this "water table" (*i.e.*, its distance from the surface of the ground) is governed by the average rainfall and the opportunities for local drainage. The delivery being into the rivers and streams of the district, or into the sea, there is always a slight inclination of the water surface toward those natural drains, more especially in their immediate vicinity.

When the conditions prevailing in the district do not favor the development of a spring on the side or at the base of a slope, the time-honored manner of tapping the underground supply is to sink the ordinary domestic well into the water table.

For the delivery of large supplies the ground water cannot be conveniently tapped by ordinary dug wells, so that recourse is had in such cases to what is known as "driven wells," set within suitable distance of each other, and coupled to a general main through which the water is drawn by the pump.

Each well is but an iron tube, perforated at its lower extremity, which is driven through the soil to the water-bearing layer below. Single wells of this description, surmounted by a simple hand-pump, may be seen, in some instances, replacing the domestic well in the country dooryard, but the type is more commonly met with in "gangs" of very considerable number for the supply of cities or towns.

A method of sinking them by the use of live steam was patented a few years ago, and, under some conditions of soil, may show considerable saving in first cost.

By whatever method the "driven well" is sunk, its mode of action is entirely similar to that of the common domestic well, from which it differs only in diameter, and it is supplied by the ground water of the district in the same manner as its longer-known progenitor. There is, in short, nothing gained in the majority of cases from the supposed exhaustion of air by the action of the pump. Much has been claimed under this head, and it has been urged that the zone of influence always widens rapidly under "suction" from an air-tight well; but it must be remembered that "air-tight" is a term which can be usually applied to the well only, and not to the ground overlying the zone of influence. The porous soil will unquestionably admit all the atmosphere required, and consequently the flow of water will be determined by those forces, and those only, which govern in the case of wells of the ordinary type.

When, however, the well passes through an extensive layer of impervious clay, and taps a water-bearing stratum beneath, then the opportunities for a development of the advantages of "suction" reach their maximum.

A fact often lost sight of is that driven wells, so far as a permanent supply is concerned, are dependent upon the amounts of rainfall, "run-off," evaporation, and plant requirements. There is not, contrary to popular conception, an underground reservoir from which unlimited quantities of water may be pumped. It is true that a reserve storage exists, that may be drawn upon in time of drought, but nature keeps a strict account of such matters, and the deficiency created in time of need must be made up during the period of plenty; otherwise the delivery of the plant will gradually diminish and ultimately entirely cease.

One very material advantage possessed by a driven well over a dug one is that it can be sunk deeper in the water-bearing sands at small expense, and, with a long strainer, can take water throughout a great fraction of its length. A dug well, on the other hand, has its construction hampered after water is reached, and its cost per foot is greater beyond that point; so that it commonly has to depend principally upon its bottom for supply, tapping, as it does, only the upper portion of the ground-water layer.

Closely related to the well systems already spoken of, the "infiltration gallery" stands as a widely used method for securing the water of the ground. Such a gallery is really but a dug well with one very long horizontal axis. Its position is usually near, and parallel to, the banks of some stream, such a site being chosen with a view of securing its supply from the water of the river. Except under exceptional circumstances, however, the water reaching the gallery comes from the landward side, and is the ground water of the district for which the river is the drain.

Rivers may indeed diminish in volume as they flow onward, and may even entirely disappear by sinking into the ground, as is the case with a number of streams flowing down the slopes of the Rocky Mountains, but this condition is distinctly exceptional. A river is commonly to be regarded as a drain, into which water is received, but from which none flows.

Dependence is constantly laid upon the excellent filtering powers of these underground galleries, and they justify it during the earlier periods of their use, but, considered as a filter, such a device is beyond cleaning and repair; it may clog, or, on the other hand, ruinous channelways may follow heavy pumping. In the first instance no water, and in the second instance polluted water, may result.

The opportunity for the contamination of well water, particularly that of the common domestic well, is often very great. No proper conception of the right location for the house well ever seems to enter the minds of most

of our rural people, and if water can be had from a spot conveniently near for general housework, inquiry as to the quality of such supply is usually considered quite superfluous.

In some towns the local boards of health determine the minimum distance to be allowed between a well and an uncemented privy vault, and such distance is most commonly fixed at fifty feet. The permitted distance in at least one instance is twenty-five feet, and in another the minimum distance allowed is twenty feet!

That any such distance of soil filtration can protect a well from pollution, provided the polluting source be constant in character, is beyond even hoping for, and many instances could be given showing how even considerably greater distances have also failed.

Two causes for failure are, first, overtaxing the purifying powers of the intervening soil by presenting a constant flow of more polluting material than can be oxidized; and second, the opening up of cracks in the subsoil whereby direct connection with the well is assured.

The serious Maidstone epidemic of typhoid was due to the latter cause. An unusual drought had occurred, which caused deep cracks to open in the stiff soil, so deep that the health officer thrust his cane into some of them without finding bottom. Later there was a heavy fall of rain which washed surface filth carrying typhoid excreta into these fissures and produced a material rise in the ground water. Of course there was lack of efficient soil filtration.

It is a fatal error to fancy that because a water has a bright, sparkling, clear appearance and a pleasant taste, therefore such water is wholesome. Carbonic acid gas is what causes the brilliancy and refreshing taste of a ground water, and to the solvent action of that gas is due the clearness of many waters which nevertheless hold much organic matter in solution. When it is borne in mind that carbonic acid is one of the products of sewage decomposition, the inference as to its possible source in the case of some well waters is not a pleasant one.

It is often objected that certain well waters have been in use for many years without bad results following. Possibly; but it must be remembered that the imbibition of sewage derived from healthy sources may be quite harmless, unless it be in too concentrated a form, however undesirable it may be from an æsthetic standpoint. The serious part of it all is that the sewage which contaminates the well water may, during an epidemic, suddenly become pathogenic in character, and then the well becomes a distributing centre for disease. A city well is always to be suspected, and if, upon examination, its water is found impure, it should be forthwith ordered closed, particularly under circumstances such as threaten invasion of epidemic disease.

An excellent way to determine the probability of objectionable drainage material entering a well is to place a quantity of a solution of common salt, of lithium chloride, or of fluorescein at the point whence contamination is supposed to come. The normal composition of the water being known, there will appear an increase in "chlorides," a spectroscopic test for lithium, or a decided fluorescence in the water if there be drainage from the source in question.

Although of somewhat uncertain reliability as to quantity, rain water is universally looked upon with much favor because of its assumed excellence as to quality, and yet even a casual inspection will often show it to be a long way from pure, and it may possibly be polluted to an extent quite surprising to the collector of the supply.

The roof upon which rain is caught is a twofold cause of impurity in the collected water; first, because of the material of which the roof is constructed, and, second, because of the foreign substances that may settle thereupon.

In cities the amount of street dust blown upon the roof and afterward washed into the cistern is much greater than is commonly supposed. Soot, excrement of birds (often a large item), fallen leaves, and various mossy growths are among the sundry additions to be found in a roof-collected water.

It is exceedingly important that every cistern should be inspected and cleaned frequently, and upon no point does the public require more instruction than this.

While its softness recommends it for use in the laundry, and while the absence of lime salts renders it desirable for cooking, rain water is, on the whole, not to be considered so suitable as a pure ground or surface water for general domestic supply.

Ice, especially in America, is certainly to be reckoned as an article of food, and the prevalent belief that water purifies itself during the act of freezing is so well fixed in the public mind that the source whence ice is harvested is in consequence usually considered unimportant. This belief is not without support in fact, as we have seen, but, like many another partial truth, it is a very uncertain foundation upon which to erect the best form of sanitary procedure.

As has been already stated, we may depend upon the growing ice crystals mechanically excluding much of the germ life during the process of freezing, and such exclusion would appear to lie between ninety and ninety-five per cent. of all bacteria present in the water, or, more strictly speaking, the above percentages would represent the bacterial purification from all causes during freezing, of which causes mechanical exclusion is one.

ARTIFICIAL PURIFICATION OF WATER.—Pure water is becoming more and more difficult for many of our towns to secure, so that the best that some of them can hope to obtain is a polluted water which has been efficiently purified by art. It is a question, sometimes, whether it would not be better policy, considering the rapid changes in the density of population, to accept a moderately polluted source and thoroughly purify its water, rather than go to large expense in obtaining a faultless supply which might have to be purified in its turn at some later day.

Further, it must be borne in mind that, outside of any question of wholesomeness, the water which a part of our people are content to use at present will not be considered suitable in a few years to come. The tendency is toward a general demand for a clear and colorless water, and water purveyors must be prepared to meet it.

Filtration of surface water, before delivering the same for public consumption, is now specifically ordered by the laws of Germany, and rules are laid down for its proper accomplishment. Such legislation is not improbable in this country, thus still further making it the part of wisdom to anticipate the artificial improvement of some waters which are now possibly considered beyond impeachment.

The method of purifying water on the large scale which deserves first attention on account of its early use and wide application is that of "slow sand filtration," commonly known also as

The English Filter-bed System.—Briefly described, an English filter bed is a tight reservoir, suitably underdrained, and containing some five or six feet of stratified filtering material, of progressive degrees of fineness, beginning at the bottom with broken stone or gravel, and ending with an upper layer of fine sand. Through the fine-sand layer the water slowly and evenly passes, leaving the bulk of its suspended impurities upon the surface to form the *Schmutzdecke*, or "dirt cover," of the Germans.

Beyond the mere gradual accumulation of suspended matter strained from the water, this *Schmutzdecke* is in part composed of slimy, jelly-like material, produced through bacterial agency, which serves to entangle and hold bacteria and other suspended substances of all kinds.

It must not be thought, however, that the extreme top layer of sand, with its cover of slime, does the entire work, so far as purification is concerned. Each grain of sand of the body of the bed becomes covered with a sticky coating of the zoöglœa jelly, and these grains collectively are to be credited with a large share of the results accomplished.

A filter recently disturbed by the process of cleaning is