lower in efficiency than one which has been for some time in operation. Such a plant might be properly described as "at its best when at its dirtiest"; and, were it not that it finally becomes almost impervious to water, it would be better not to clean it at all. A new filter is of small use until it "ripens" for work; that is, until the "nitrifying" organisms have firmly established themselves and the zoöglœa jelly envelops the sand grains.

For proper working the thickness of the fine-sand layer should be made not less than thirty-six inches, and this depth should not be permitted greatly to decrease, by reason of the successive removals of layers of the upper surface for purposes of cleaning.

Usually filter plants are entirely open, but in those localities where the winters are severe it becomes necessary to throw over them a cover, which is commonly of concrete, resting upon columns of the same material. Thick ice renders it practically impossible properly to clean a filter by the ordinary methods, and the resulting imperfect purification of the filtrate is often coincident with increase in the death rate. This was noted in Berlin in the winter of 1889.

Hazen advocates the covering of filters in all localities where the mean January temperature is below the freezing-point.

The cost of constructing a filter bed must necessarily greatly vary, in direct ratio with the local cost of materials and with the difficulty of the engineering problem involved. Thus the open filters at Hamburg cost about $30,500 per acre, while the covered ones at Albany, N. Y., amounted to $45,600 for a like area.

The depths of water permitted upon filters of the English type are almost as various as the compositions of the beds themselves. Three and a half to four feet of water may be taken as the depth most commonly in use, and it is important that this depth, when once determined upon, should be maintained a constant.

With reference to the rate of filtration, the best practice places two and a half to three million United States gallons per acre per day, or four to four and a half vertical inches per hour, as the limit, beyond which the rate should not be pushed.

By direction of the imperial board of health, the maximum rate of filtration has been fixed in Germany at four vertical inches per hour.

For the purpose of cleaning a filter of the English type, a gang of laborers is set to work upon the drained bed, and by means of sharp shovels they pare off the upper half-inch of sand and pile the same into small heaps, whence it is removed by wheelbarrows to the sand washer. This thin upper layer of sand (the *Schmutzdecke* of the Germans) contains the greater bulk of the material separated from the water by filtration. It is quite compact, and is so distinctly separated from the sand below as to make the work of its removal very simple. It is liable to be quite membranous in character, and its imperviousness to water is what causes the filter to become "dead" and require cleaning.

The frequency with which filters have to be cleaned depends upon the condition of the water being filtered, and, for the same water, this condition will vary greatly with the time of year and character of the season. Roughly stated, it may be said that a filter becomes "dead" (*i.e.*, nearly impervious to water), and consequently demands cleaning, once every three or four weeks in summer and about half as frequently in winter; but it is not possible to lay down hard-and-fast general rules applicable to all filters. So many variable quantities enter the consideration that the question of proper time for scraping must be answered for each filter by itself, the final decision being based upon intelligent observation of the rate of flow, loss of head, and the obvious general efficiency. The average interval between scrapings at Albany is 25.1 days.

It is not customary nor desirable to have the newly scraped filter remain out of service until the sand removed is washed and returned to its place; for the fine sand layer should be thick enough to permit of a number of successive scrapings without impairment of its efficiency; therefore the sand taken off during a series of parings is all washed and returned at one time.

At Albany the sand layer, which is forty-eight inches thick, has been reduced as much as seventeen inches by successive parings before the normal thickness was restored by replacing the cleaned sand.

As to what may be expected from a sand filter in the way of bacterial removal, it may be said that during the year 1900 the Albany filters removed from 98.3 to 99.6 per cent. of all germs present in the raw water. Equally good results were accomplished by the beds at Altona, Germany, during the great outbreak of cholera at Hamburg in 1892. What such efficiency meant for the former city may be epitomized in the single word "safety."

It is not to be expected that municipal filtration plants will furnish the public with sterile water nor are we to look for perfect uniformity in bacterial efficiency, but it is a matter of fact that in those cities where modern filters have been established a very noteworthy reduction in the number of cases of typhoid fever has been observed. Thus in the city of Albany, where, previous to the introduction of filtered water, the average number of deaths from typhoid amounted to eighty-five per year, the influence of purified water is shown by a reduction of this number to less than twenty.

A modification of the English filter bed has been proposed, whereby filtration was to take place upward, and washing was to be done downward, the inlet for raw water and outlet for waste water being the same. By this arrangement the designer hoped to avoid all complications from ice, the ice cake being permitted to form freely and float clear of the sand bed. During washing a current of air was to have been let into the space underneath the bed, with a view to tumble the grains of sand and break up the sediment, so as to enable it to pass out with the wash water.

So far as principle is concerned, there may be little difference between upward and downward filtration, but in practice there would be serious objection to the former plan. Much difficulty would be experienced in securing uniformity of work over the whole area of the bed, owing to the impossibility of preventing the dirt layer falling off in spots, and it is well known that uniform action is of vital importance. It is moreover a dangerous practice to foul a filter in a place beyond reach of inspection and repair, for there is no way of determining whether or not the provided means of cleaning are working satisfactorily.

Mechanical Filtration.—Roughly outlined, this system consists in adding to the water to be filtered a minute dose of common alum or, better, aluminum sulphate, averaging nearly one grain per gallon, and then admitting the water to the filter, which is a tank of wood or iron, three-quarters full of uniformly fine sand. The carbonates present in the water decompose the alum, with the formation of a white flocculent precipitate of aluminum hydrate, quite jelly-like in appearance. For instance, the carbonate of calcium acts as follows:

$$Al_2(SO_4)_3 + 3CaCO_3 + 3H_2O$$
$$= Al_2(OH)_6 + 3CaSO_4 + 3CO_2.$$

The action of this aluminum hydrate is much the same as that of the white of egg in clearing coffee. It entangles all suspended matter, germs as well as inorganic material, and deposits the same on the surface of the sand, whence it is removed and driven into the waste pipe by a reverse current of filtered water at the time of cleaning the filter. Thus, it will be observed, the mechanical filter produces an artificial inorganic jelly to replace the "bacterial jelly," already alluded to, of the English filter bed.

A further action of the precipitated aluminum hydrate is to unite with the soluble coloring matter of the water, whereby the filtrate is rendered colorless. The proper "dose" of alum solution is administered by means of some small automatic measuring apparatus exterior to the filter; the solution flowing thereto from the dissolv-

ing tank, where the coagulant is prepared in the proportion of twenty parts of water to one part of aluminum sulphate.

For small establishments it is a convenience to make use of a "closed" or "pressure" filter, for the reason that it can be placed directly upon the service main, thus allowing no interruption in the line of the supply. It is not easy, however, properly to watch such a filter, and it is open to sundry other objections, notably a lack of uniformity in action. For purposes of public use it is inferior to the open or "gravity" type.

The rate at which water is passed through these filters is very great when compared with what is furnished by the English filter beds already considered. One hundred and twenty-five million gallons per acre per twenty-four hours may be taken as a fair index of what is to be expected of them.

It has been already said that alum is used in their operation. The necessity for the use of this or some other coagulant is imperative and should be impressed upon the mind, for, however well the straining action of the sand bed may clarify the water, the great rapidity of flow precludes the proper removal of bacteria unless they be entangled in the alumina jelly noticed above.

Alum is by no means the only "coagulant" that could be or that has been used in mechanical filters. Salts of iron were suggested some years ago as a cheap substitute, but it is only recently that their use has been extended beyond the experimental stage.

What amount of coagulant should be used is a question best answered by the attendant in charge; for not only will the proper "dose" vary with different plants, but even in the same plant it may differ from day to day, and certainly will change from season to season. One grain per gallon is a fair estimate for a rough one.

It is worth remembering that theoretically a "dose" of one grain per gallon of aluminum sulphate (containing seventeen per cent. Al_2O_3) will require about eight parts per million of "alkalinity" in the water for its complete decomposition.

Danger to health from the use of alum is a topic fruitful of discussion among the many who are not posted as to its manner of action; but those who are better informed know that free alum never reaches the filtrate in a well-ordered plant.

Alum in the filtrate means a useless waste of material, not to be excused. Reference to the equation already given shows that in order to produce the aluminum hydrate jelly, upon which successful filtration depends, the alum admitted to the water must be entirely decomposed.

The method of testing for free alum is very simple, and the filter attendant, constantly on watch for it in the filtrate, should so manage the "dose" employed as never to allow it to pass beyond the sand bed.

The amount of filtered water used for the purpose of cleaning a mechanical plant is an item for consideration, for it is, of course, lost to the regular volume of supply. At Rensselaer, N. Y., the average run between cleanings is about twenty-four hours, and the filters are washed with 3.75 per cent. of the filtered water. It takes eight minutes to wash each "unit" or separate filter.

One feature of mechanical filtration that has come into prominence of late is the addition of some form of settling tank. With certain waters it is essential that opportunity be given for sedimentation of a portion of the heavy magma produced by coagulation, otherwise the sand bed quickly chokes and the labor and expense of cleaning are greatly increased.

When the water is so soft as to be deficient in the necessary quantity of carbonates to decompose the alum added, the bed of ordinary filtering sand is sometimes replaced by a mixture of such sand and granulated marble, or else the water is hardened by passing it over broken limestone previous to the addition of the alum. A better plan is to add a suitable dose of "soda ash" to the raw water.

Should the water be highly colored as well as soft, the addition of alum should immediately follow that of the carbonate and a considerable interval should intervene before the filter sand is reached, in order to allow complete reaction and partial sedimentation to take place. The time element is of special importance in the purification of such waters, and is to be secured by the erection of large settling basins.

The cost of erecting a mechanical filter plant is somewhat difficult to give, for the reason that filter rights enter the estimate. Perhaps the fairest general statement that can be made is to place $10,000 per million gallons daily capacity as the basis price for a first-class plant, and to subtract from that sum such concessions as the special features of the case may be able to secure.

Filters can be erected for half the above amount, and they do good work for manufacturing purposes; but their bacterial efficiency is low and the water used for washing will be from eight to ten per cent. of the delivery instead of about three per cent., as found in the best forms of apparatus.

The question so frequently asked, as to which of the rival systems of filtration is better generally to adopt, is not capable of a direct answer. Local conditions must first be known. Slow sand filtration is likely to be the better for very large cities, while for the supply of towns the mechanical system is commonly preferable.

Either method of filtration, to be of value, requires constant attention. Careful watch must of necessity be kept of a mechanical plant, however small, to secure its running at all, while very inefficient supervision is the usual fate of the small English sand bed. Once constructed, it is commonly left to look after itself until cleaning is imperative, and then laborers are put upon the work who have never seen its kind before.

It is very doubtful policy to build an English sand bed unless the plant be large enough to maintain a skilled force constantly employed. It may be further generally said that, although relatively expensive for small plants, the English system rapidly lessens in cost, per unit of capacity, as the plant increases in size. This decrease is not so rapid for mechanical filters.

Other things being equal, English plants are perhaps better suited for clear waters, and mechanical filters for those of turbid or colored character.

The life of an English filter is practically unlimited, while that of the mechanical type is as yet undetermined.

Finally, it is an easier and cheaper matter to keep the mechanical filter nearer the present requirements as to capacity and to add to it by small extensions as circumstances may exact. So far as bacterial efficiency is concerned, either type will satisfactorily meet the demands.

Experiments of extended and costly character have been made with a view of securing data whereon to base a decision as to the merits of rival systems of filtration, and it is quite reasonable that the question should be asked, Why is it necessary to multiply such tests? Why cannot Louisville and Pittsburg results be made to do service elsewhere? To a large degree such use is possible, but it must be remembered that waters differ from one another more widely than the bulk of people appreciate. Thus the mere item of suspended matter is a case in point. Not only does the amount thereof greatly vary, but the character of the material causing the turbidity, and especially its degree of fineness, should command especial attention. Two equally turbid waters may look alike to the eye, but the fine suspended matter of one may be easily arrested by an English sand bed, while the other may give a filtrate of decided opalescence. Hence the demand for local experiments in important cases.

Nearly akin to the filter plants referred to above is a group of appliances among which the "Anderson process" is perhaps the best known. In this process the water is forced through purifiers consisting of iron cylinders revolving on hollow trunnions which serve for inlet and outlet pipes. On the inner surface of the cylinders are curved ledges running lengthwise, which scoop up iron borings or punchings and shower them down

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through the water as it flows through the cylinder. Iron passes into solution and is afterward rendered insoluble by exposing the water to the atmosphere. By filtration through sand this iron precipitate is subsequently removed, together with what suspended matter it may have entangled.

Excellent results are secured by the Anderson process, but an additional and expensive step is introduced in the item of revolving machinery, before the water is run upon the sand filters; and it is not proved that this further outlay of capital is necessary, in view of the cheapness of some of the other and simpler methods.

Household filtration on the domestic scale is in very general operation, yet satisfactory results are obtained in an exceedingly small percentage of cases.

The companies manufacturing the mechanical filters previously mentioned all make sizes intended for domestic use, but the skilled labor furnished by a city employee whose sole duty it is to attend to the public plant is very rarely obtainable in the average household; consequently the filter is neglected or mismanaged, or both. In short, filtration, to be effectual, should be municipal. A house filter that has come widely into use, and upon which very many people pin their faith, is the well-known "Pasteur." It is commonly operated under the pressure of the city mains, but may also be arranged to work without additional pressure beyond that of the atmosphere. For those unacquainted with its use, it may be said that it consists of a cylinder of fine unglazed porcelain (called "candle," on account of its size and shape) enclosed by one of metal; and that, connection havi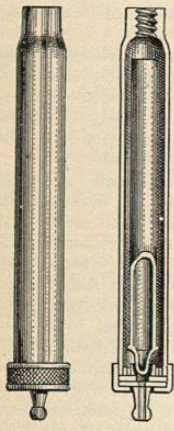ng been established between the latter and the supply pipe, the water is forced through the pores of the porcelain to the inside of the cylinder (the so-called candle), whence it drops into the reservoir, leaving the suspended matter as a coating upon the "candle's" exterior surface. (Fig. 5035.)

FIG. 5035.— Pasteur-Chamberland Filter.

Examination of the efficiency of the Pasteur filter has been thoroughly done by a number of investigators, with results that may be summarized as follows: Water can be completely sterilized by filtration through porcelain, but the filtration must not be continued for many days at a time. The length of time during which a sterile filtrate may be obtained will depend upon the temperature of the filter and its contents. Thus, according to Freudenreich, at a temperature of 59° to 64° F. the filtrate was sterile for from fifteen to twenty-one days, at a temperature of 72° F. it was sterile during nine days, while at a temperature of 95° F. it remained sterile only five days.

Water pressure is not a factor in causing germs to pass through the porcelain, for their method of penetration is one of development rather than a transporting of initial bacteria; in other words, they "grow" through the filter. Even when the pressure is nil they accomplish the passage in the usual length of time. This power of growing through the pores of the porcelain has been denied by a recent observer, but it is on the side of safety to hold to the earlier records.

From a consideration of these facts the line of management for a "Pasteur" becomes plainly evident. The "candle" and its rubber packing must be removed at least once a week, thoroughly washed, and then boiled for half an hour before being reset in position.

Especial care be taken that the rubber packing make a tight fit, as otherwise the water may pass around rather than through the porcelain. The filter should not be located in too warm a place.

The lateral connecting the filter with the supply main

should be of tin or iron, as the slow action of the filter allows the water to remain for a considerable time in contact with the metal.

Many types of household filters are of such character as to preclude the possibility of sterilization, and some of them it is even impossible to clean without the entire renewal of the filtering material. Such defects are necessarily fatal to proper filtration. The stone filters one sees at times, where the water is caused to drip through fine-grained sand rock, or similar material, act as mere strainers and are absolutely unreliable. Currier demonstrated that sponge filters, after use for even a single day, furnished a filtrate containing five hundred times as many germs as the unfiltered water. Household filters of many types are to be seen so seriously contaminated that a water cannot but be rendered worse by passage through them, and yet such appliances are in full use and greatly trusted on account of the apparent clearness of the water drawn from them.

Much stress is often laid upon the purifying effects of animal charcoal, and the great quantity of occluded oxygen the fresh charcoal contains fully justifies for a time the high praise given it, but such material is nearly impossible to cleanse, and it has been repeatedly shown that a more objectionable appliance could scarcely be found, from a sanitary point of view, than a neglected charcoal filter.

Aeration of water has always held in the public mind a position of prime importance as a means of purification. There is unquestioned benefit arising from the passage of water over falls and rapids, and from its being thrown into the air in fountains, but the benefit is not so great as is commonly believed.

Such treatment tends to prevent the abundant growth of algæ, with their objectionable tastes and smells, and undoubted improvement in the quality of the water results from the establishing of a fountain in, or otherwise blowing air into, a too quiet reservoir; but the expectations of those who hope thus easily to eliminate pollution of a more serious character will not be realized.

Aeration is of especial value in rendering some kinds of ferruginous well waters, which are otherwise pure, fit for domestic use. The iron is thereby oxidized to insoluble ferric oxide, and may be easily removed by filtration.

In these days of "applied electricity," it would be strange indeed if attempts were not made to harness up the "fluid" for the work of water purification, as an addition to the many other tasks already assigned to it.

One movement toward such an end consists in decomposing a weak solution of common salt by means of a current from a dynamo, and then adding the electrolyzed liquid to the water to be purified, in the proportion of about 10 grains per gallon of water or 1 part to 5,833 by weight.

The product of the electrolysis is fancifully styled "electrozone," but the germicidal power which it possesses is due to the well-known sodium hypochlorite formed during electrolysis, and not to the presence of ozone.

The sodium hypochlorite prepared by this method is not different from that made in the ordinary way, and in germicidal power it is equalled by an equivalent weight of the calcium salt, called "bleaching powder," the efficiency of each being measured by the amount of available chlorine present.

The insoluble salts resulting from the employment of "bleaching powder" would, however, be a disadvantage in its use unless opportunity were afforded for settlement, and, moreover, it would render the water harder.

To "disinfect" a water by the use of hypochlorites does not appeal to one as a suitable means for increasing its potability.

The actual application of ozone in the form of ozonized air to the purification of water has a number of earnest supporters, and we await with interest the further development of such a process. Up to the present, how-

ever, it is right to say that the experimental stage is scarcely passed, although the flattering results secured by experiments permit us to entertain expectations of ultimate success.

From a sanitary standpoint, the method for purification of water which excels all others in efficiency is distillation. The peculiar taste of freshly distilled water is, however, disagreeable to many, and for that reason the process is not likely to become speedily popular, even if the expense be not too great.

It would seem that the attention of the public has been largely drawn of late to the question of the wholesomeness of distilled water for dietetic purposes, numerous articles having issued from the press under such captions as "Poisonously Pure Water" and the like. Much uneasiness has been created among those who have used such water, because of their being told that "distilled water is an active protoplasmic poison, due to its property of extracting salts from animal tissues and causing them to swell up by imbibition." Stress is, of course, laid upon the increased danger arising from its use by the young, whose tissues are in process of formation.

In consideration of the mixed character of human food and the amount of mineral salts naturally occurring therein and added thereto as condiments, the withdrawal of two or three grains of such salts per day, by the substitution of distilled water for that drawn from some natural source, would be a matter of too small importance for consideration.

Distilled water is used for drinking purposes on practically every vessel in the United States navy, and the surgeon-general says: "It may be stated that the medical officers of the navy recognize the great value of distilled water in the improvement in health that has followed its introduction, particularly on certain foreign stations."

The good old household remedy of boiling a suspicious water is always available, but unfortunately it is but seldom applied. As an illustration of its value it is worth noting that during the cholera outbreak at Lucknow, among the members of the East Lancashire Regiment, there was no cholera whatever in company E. This company was the only one which boiled the drinking-water.

Finally, let it be noted that there is no way of purifying a polluted water, as some people would have us do, by throwing a remedy into the well or cistern.

WATER ANALYSIS.—A great deal of popular misconception exists upon the subject of the analysis of potable water, and it is commonly supposed that such an examination may be looked upon from practically the same point of view as the analysis of an iron ore. In point of fact, however, it is a very different matter.

A water analysis is really not an analysis at all, properly so called, but is a series of experiments undertaken with a view to assist the judgment in determining the potability of the supply. Some of the substances reported, "albuminoid ammonia," for instance, do not exist ready formed in the water at all, and are but the experimental measures of the objectionable organic constituents, which our present lack of knowledge prevents our estimating directly.

It is not practicable to furnish the public with the means of fully understanding the numerical results as stated, nor is it possible to supply general "standards of purity" whereby a water may be rated as wholesome or otherwise, for the reason that figures which would condemn a water in one locality might be entirely without objection for a water derived from a neighboring county.

The examiner must be in full possession of all the facts concerning the water which he is asked to test, in order that his opinion as to its purity may be based upon the entire breadth of his past experience, for in no branch of analytical work are experience and good judgment better exercised than in the interpretation of a water analysis.

It is a great mistake to suppose that the proper way to consult a water expert is to send a sample of the water in a sealed vessel with no hint as to its source. On the contrary, he should be thoroughly acquainted with

the history and source of the water and, if possible, he should take the samples himself. For so important a matter as a town supply, he should unquestionably personally superintend their collection.

Finally, let it be said that a water analysis is, for purposes of economy, rarely made complete. For ordinary drinking-water the question is always asked, "is it wholesome"? To answer this, the analysis of the mineral residue left upon evaporation is not usually required, so that much time and expense may be saved by simply reporting this as "total solids." On the other hand, analyses of mineral waters deal with this feature of the examination very largely, and usually to the exclusion of those portions, such as "albuminoid ammonia," "required oxygen," etc., which are important in the "sanitary analysis." The same may be said of the analyses of waters for boiler use.

Large glass-stoppered bottles are best for sampling. After thorough rinsing with the water to be analyzed, fill the vessel to overflowing so as to displace the air, and then completely empty it.

If the water is to be taken from a tap, let enough run to waste to empty the local lateral before sampling; if from a pump, pump enough to empty all the pump connections; if from a stream or lake, take the sample well out from the shore, and sink the stoppered sampling vessel toward mid-depth before removing the stopper, so as to avoid both surface scum and bottom mud. In every case fill the vessel nearly full, leaving but a small space to allow for possible expansion, and close securely. Under no circumstances place sealing wax upon the stopper, but tie a piece of cloth firmly over the neck to hold the stopper in place. The ends of the string may be afterward sealed if necessary. Having secured the sample, the analysis should be begun at once, for the reason that water is liable to rapid changes in character during laboratory storage.

The results of the chemical examination should be stated in "parts per million" in weight. Water should not be filtered before analysis. If sediment be present, it should be equally diffused by thorough shaking before measuring. The reason for this is that a water analysis should represent the water as the consumer uses it, and not in a condition improved by filtration.

The analysis cannot be properly conducted in a general laboratory, because many of the tests would be ruined by the fumes common to such a locality. A separate room, reserved exclusively for water work, is the best arrangement.

The appearance and turbidity of a water are best determined by using a brass tube two and one-half inches in diameter and two feet long, closed at the ends by discs of quarter-inch plate glass held in place by screw caps.

For the purpose of measuring the amount of turbidity, a standard is prepared, consisting of 1 gm. of exceedingly fine kaolin (obtained by elutriation) suspended in one litre of distilled water. Each cubic centimetre of this preparation will contain 1 mgm. of suspended clay. Having nearly filled the duplicate observation tube with distilled water, enough of the "clay standard" is added to make the "turbidity" equal to that of the water under examination in the other tube. Knowing the volume of water operated upon and the amount of "clay standard" used, the "turbidity" expressed in parts per million can readily be calculated. For more rapid although less accurate observations, the tubes above mentioned may be replaced by a number of half-gallon bottles, in which a series of turbidity standards are kept ready for immediate use.

As used by the United States Geological Survey, the turbidity standard is a suspension of silica (infusorial earth) of such a fineness that a bright platinum wire 1 mm. in diameter can just be seen when the centre of the wire is 100 mm. below the surface of water which contains in suspension one hundred parts of such silica per million parts of water. The turbidity of such standard is rated as 100.

A turbidity rod with graduations based upon this

standard is prepared for the survey and is very convenient for use in the field.

When variations in turbidity are being watched in a locality where the suspended matter is colored, the "clay standards" should be prepared from local material.

The reaction of natural water is commonly slightly alkaline, although waters holding much free acid in solution, usually sulphuric, are by no means rare.

Determination.—Place 100 c.c. of the water in a casserole, and titrate with N/10 hydrochloric acid, using methyl orange as an indicator. Should the water be originally acid, make it slightly alkaline with a known amount of potassium hydrate before titration. It is convenient to report alkalinity as representing so many parts of $CaCO_3$ per million of water, and to note that such a form of result corresponds to fifty times the number of cubic centimetres of hydrochloric acid, used in the titration.

Acidity is best stated in the same terms using a negative sign.

Color.—Dissolve 1,246 gm. potassic platinic chloride and 1 gm. cobalt chloride in 100 c.c. strong HCl and dilute with distilled water to 1 litre. This solution has a color of 500.

By placing one, two, three, four, etc., cubic centimetres of such solution in 50 c.c. "Nessler" jars and diluting to the mark with distilled water, standard colors of 10., 20., 30., 40., etc., are obtained, and with these is compared a 50 c.c. "Nessler" jar filled with the water under examination. Turbid waters should be filtered before reading the color.

Total Solids.—Material dissolved or suspended in water is naturally derived from the strata through which the water passes or the surface over which it flows. Thus are obtained waters of all degrees of hardness and of great variety of color and turbidity.

Determination.—Thoroughly shake the vessel containing the sample and then measure out 100 c.c. of the unfiltered water by means of a pipette into a weighed platinum dish. Evaporate to dryness on the water bath, being careful to place a filter paper between the dish and the water in the bath in order to prevent any deposit of impurities on the under side of the dish. (A better plan is to make use of a porcelain water bath filled with distilled water.) When dry, place the dish and contents in an air bath and maintain the temperature at 105° C. for half an hour. Cool in a desiccator and weigh.

Comparates.—Average in sundry surface waters known to be pure, 74; known to be polluted, 194; average in sundry ground waters known to be pure, 144; known to be polluted, 642.

These averages are really of but small sanitary value, for the reason that a polluted water may be low in total solids, or *vice versa*, according to the character of the soil through or over which the water flows.

HARDNESS.—Before entering into the question of quantitative estimation, let it be premised here that "hardness" may be classified under two heads, viz., "Permanent" and "Temporary." The former is occasioned by the presence of calcium sulphate and other soluble salts of calcium and magnesium, not carbonates, held in solution by the solvent action of the water itself; such a water cannot be materially softened by boiling under ordinary pressure.

"Temporary" hardness is caused by carbonates of calcium and magnesium held in solution by carbonic acid present in the water. Boiling such a water expels the carbonic acid, whereupon the salts separate from solution.

Hehner's method for determining "permanent hardness" is very convenient: The measured water is boiled down with a known excess of Na_2CO_3. Precipitated $CaCO_3$ is filtered off, and the remaining Na_2CO_3 determined by titration with standard acid and methyl orange. The loss in Na_2CO_3 is calculated to a corresponding amount of $CaSO_4$.

"Temporary hardness" is usually equal to the "alkalinity," previously determined.

Should sodium or potassium carbonates be present,

the acid required to neutralize the water residue, after boiling down as above, will be greater than the amount corresponding to all of the standard Na_2CO_3 solution added, for no permanent hardness could be present in such a case. From such excess of acid the carbonates of the alkali metals can be calculated. Their equivalent in terms of $CaCO_3$ should be subtracted from the total "alkalinity" in order to state correctly the "temporary hardness."

Comparates.—The average hardness of good waters as given by the British Rivers Pollution Commission stands: Rain, 3; upland surface, 54; deep well, 250; spring, 185.

Chlorine.—Water is rarely found free from chlorine, yet, notwithstanding its almost constant presence, there is hardly a factor in the sum total of water analysis toward which attention is more quickly turned or regarding which there is closer scrutiny.

In most instances chlorine is present in the form of common salt, washed from the air or soil, or added as one of the constituents of sewage. Salt itself is, of course, unobjectionable in the quantity usually present, but, it being so largely used in our food, there is always warrant for suspecting sewage contamination where the figures for chlorine run high.

True it is that those figures are at times misleading, but they, like other data in water analysis, must be considered with judgment, and due weight be accorded the character of local surroundings.

If the district whence the water comes be naturally rich in salt, as is the case with the deep-seated waters of Central New York, such fact must be borne in mind when formulating an opinion as to quality. Variation in the chlorine contents of rain water always occurs inland, although not to the same degree as upon the coast. Ground water is more directly influenced than rain water by the presence of human habitation.

The determination of chlorine in water is extremely simple. It depends upon the fact that if to a solution of a chloride which has been colored yellow by addition of a little potassic chromate a solution of silver nitrate be added, white silver chloride will be produced until the last trace of chlorine shall have been disposed of, whereupon red silver chromate will begin to appear.

The reagents required are:

Standard Silver Solution.—Prepared by dissolving 4.8022 gm. of crystallized silver nitrate in 1 litre of water. Each cubic centimetre of such a solution is of a strength sufficient to precipitate 1 mgm. of chlorine.

Potassium Chromate, Indicator.—Dissolve 2 gm. of the pure salt in 100 c.c. of distilled water.

Sodium Carbonate Solution.—Dissolve 50 gm. of the pure salt in 300 c.c. of distilled water.

Determination.—One hundred cubic centimetres of the water to be examined are placed in a large "Nessler" jar; 1 c.c. of the potassic chromate solution is added, which will give a distinct yellow color, and then the standard silver solution is run in from a burette until the red tint of the silver chromate just appears. From the known amount of silver solution used the amount of chlorine present is obtained, and this, multiplied by ten, will give the chlorine in milligrams per litre or parts per million.

To determine with accuracy the first appearance of the red tint, it is best to make the examination in yellow light, either by the use of a photographic "dark-room" lantern with a front of yellow glass or by simply looking through a plate of such glass. Reflection from a porcelain tile throws the light through the length of the "Nessler" jar, and side light is cut off by a black screen.

For the sake of accuracy it is better, during the titration, to have a second jar of the water, also colored with potassic chromate, in order that the formation of the red tint in the vessel operated upon may be, by contrast, more readily detected.

Many waters possess such deep color or such turbidity as to interfere with proper titration; under such circumstances it is best to shake the water with recently precipitated and washed aluminum hydrate and then filter it,

or allow it to stand twenty-four hours in a tall glass cylinder. The coloring matter or turbidity is thus sedimented and the water cleared for use.

Comparates.—Average in sundry surface waters known to be pure, 3.57; known to be polluted, 6.06; average in sundry ground waters known to be pure, 3.2; known to be polluted, 91.7.

NITRITES.—Whether the presence of nitrites be considered due to reduction of pre-existing nitrates in the presence of organic matter or caused by direct oxidation of organic nitrogen, it becomes a necessity to estimate their quantity, for in either case the initial cause is probably contamination.

Of the several methods used of late for the determination of nitrites, the second one suggested by Griess seems to be the most deserving of favor. It depends in principle upon the red coloration ("azobenzolnaphthylamine sulphonic acid") produced whenever "sulphanilic acid" and "naphthylamine hydrochloride" are added to an acidified solution of nitrite. The test is exceedingly delicate and is capable of distinguishing one part of nitrogen as nitrous acid in one thousand million parts of water.

The reagents are prepared as follows:

Sulphanilic Acid.—Dissolve 1 gm. of the salt in 100 c.c. hot water. The solution keeps well.

Naphthylamine Hydrochloride.—Boil 0.5 gm. of the salt with 100 c.c. water for ten minutes, keeping volume constant. Place in glass-stoppered bottle. The solution tends to grow slightly pink on standing, but not sufficiently so to interfere with its use.

Standard Solution of Sodium Nitrite.—Sodium nitrite may be bought, but its purity is always to be questioned, and, moreover, it is too deliquescent a salt to be weighed with ease and accuracy. It is better, therefore, to prepare the silver salt, which may be readily handled, and from it the solution required may be made.

To a cold solution of commercial sodium or potassium nitrite add a solution of silver nitrate as long as a precipitate appears. Decant the liquid and thoroughly wash the precipitate with cold water. Dissolve in boiling water. Concentrate and crystallize the silver nitrite from the hot solution. Dry in the dark at the ordinary temperature (using vacuum is better) and keep it in a black bottle.

Weigh out 0.22 gm. of the dry silver nitrite. Dissolve in hot water. Decompose with slight excess of sodium chloride, cool if necessary, and dilute to 1 litre. Allow the precipitated silver chloride to settle, remove 5 c.c. of the clear solution, and dilute the same to 1 litre. This second dilution (which is the standard solution to be used) will contain an amount of nitrite per cubic centimetre equivalent to 0.0001 mgm. of nitrogen.

Determination.—Place 100 c.c. of the water to be examined in a "Nessler" jar. Acidify with one drop concentrated HCl. Add 1 c.c. of the sulphanilic-acid solution, followed by 1 c.c. of the hydrochloride of naphthylamine, mix, cover with watch glass, and set aside for thirty minutes. Prepare at the same time other "Nessler" jars containing known amounts of the standard solution of sodic nitrite and diluted to the 100-c.c. mark with *pure* distilled water, adding the reagents as above. At the end of the time stated (thirty minutes) examine the depth of the pink color formed, and by comparing the unknown with the known an accurate determination of the amount of nitrogen present as nitrites may be made.

If much gas be burning in the room, nitrites will be in the atmosphere. Hence cover the jars or remove them from the room during the half-hour interval before reading.

Nitrites are sometimes found in deep-well waters of good quality, but in ground or surface waters their presence should be always regarded with suspicion.

Comparates.—Average in sundry surface waters known to be pure, 0.000; known to be polluted, 0.006; average in sundry ground waters known to be pure, 0.000; known to be polluted, 0.003.

NITRATES.—Nitrates present in water are but the

further step in the oxidation of nitrogenous organic matter. They are more liable to indicate putrefaction of animal rather than of vegetable tissue, not only because of the greater quantity of nitrogen present in the former, but also on account of its more ready decomposition.

Rain water washes a very considerable amount of nitric nitrogen from the air, while in the soil the atmospheric nitrogen is fixed through the agency of the roots of certain plants, such as peas, the process being aided by bacterial action.

Such fixed nitrogen eventually enters the ground water, and a knowledge of the local "normal" for nitric nitrogen is consequently of advantage when studying the domestic well waters of a neighborhood.

Surface and ground waters of good quality are low in nitrates, for the reason that such material is quickly absorbed by growing vegetation, but waters from deep wells often give large figures for that item.

When phenolsulphonic acid is brought in contact with a nitrate, and ammonia is afterward added to alkaline reaction, yellow ammonium picrate is formed.

The intensity of this yellow color, produced in the water under examination, is compared with colors of known strength, and the quantity of nitrate present thus determined.

The interference of chlorides with this process results in readings lower than the truth, but if the chlorine be below ten parts per million such interference is not material.

The solutions required are:

Phenolsulphonic Acid.—Sulphuric acid, pure and concentrated, 148 c.c.; distilled water, 12 c.c.; pure phenol, 24 gm.

Standard Potassium Nitrate Solution.—Dissolve 0.7221 gm. pure KNO_3 in 1 litre distilled water. This solution contains 0.1 mgm. of nitrogen as nitrate in each cubic centimetre.

Determination.—Evaporate 100 c.c. (or less, according to nitrate contents) of the water to dryness on the water bath, having previously added a few drops of sodium carbonate solution to prevent loss from volatilization of nitric acid. Thoroughly moisten the residue with 3 c.c. of the sulphonic acid. Add an excess of ammonium hydrate. Make up to 100 c.c. in a "Nessler" jar, and compare the depth of color with those produced by operating upon different amounts of the standard nitrate solution, which have been evaporated and treated under precisely similar conditions.

In order to economize time, when dealing with waters low in chlorine, it is convenient to use a standard "nitrate color solution." This is made by evaporating 25 c.c. of the standard potassium nitrate solution, followed by addition of the other reagents in the way already detailed.

The yellow liquid produced is diluted to 1 litre and kept in stock. Each cubic centimetre thereof corresponds to 0.0025 mgm. nitrogen as nitrate. Much time is saved by diluting measured volumes of this "standard color" to 100 c.c. for the preparation of the comparison tubes.

The solution keeps its normal strength of color quite well, but should not be trusted after having been a few weeks in stock.

Before evaporating for the nitrate determination it is best to clear the water with aluminum hydrate as under "chlorine."

Comparates.—Average in sundry surface waters known to be pure, 0.139; known to be polluted, 0.749; average in sundry ground waters known to be pure, 1.4; known to be polluted, 11.9.

Mallet found in thirteen samples of water "known to be pure" the nitrogen present as nitrates averaged 0.42 (the extreme limits being 0 and 1.04), while in twenty samples of water believed to be objectionable the average figures ran 7.239 (the extreme limits being 0 and 28.403).

Organic Matter.—It is here that water examination loses its analytical features and becomes experimental in character. Organic matter cannot be determined directly