AN INQUIRY

INTO

THE RELATIVE EFFICIENCY

OF

WATER FILTERS

IN THE

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A Special Report to the
"BRITISH MEDICAL JOURNAL."

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WITH FOURTEEN ILLUSTRATIONS.

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Professor Trevelyan, with the Authors' kind regards. 14/12/98.

PREFACE.

THE investigation, of which the results are given in this report, was undertaken at the desire of the late Mr. Ernest Hart, Editor of the BRITISH MEDICAL JOURNAL. As in the case of so many other questions affecting the public health, Mr. Hart recognised the danger to which the public were exposed through the use of inefficient filters, and knowing that so much attention had not been directed to the question in this country as in France and Germany, he suggested that we should examine, and report upon the relative efficiency of, a number of the filters in general use in this country and abroad in preventing the spread of waterborne disease.

The list of the filters to be examined at first consisted only of typical examples of the different forms, but it was from time to time found necessary to add to these in order that we might demonstrate clearly in each special case, by actual experiment, the inefficient action of the filter, until in this way the investigation finally assumed its present dimensions.

The necessity for carrying out such an investigation for the purpose of testing the efficiency of filters had for some time been a matter of urgency, as it was quite evident that the prevalent opinions regarding the efficiency of domestic filters in the prevention of infective disease had not kept pace with our advances in bacteriological knowledge.

In this country the attention of the public was first prominently directed to water as a source of disease by the cholera epidemic of 1849. The relation between the drinking of a chemically bad water and the origin of the epidemic was shown so strikingly on that occasion that what has been termed the "water theory" of the spread of *cholera Asiatica* and typhoid fever has ever since ruled, perhaps too exclusively, in this country. We know now that the organic matter which rendered the water chemically "bad" was not the cause of the disease conveyed by the water, but that its presence merely indicated sewage contamination, and that the infectivity of the water depended altogether on the presence of the specific disease germs derived from previous cases of the disease. The chemical examination, accordingly, only indicated the probability of sewage contamination and the liability of the water to become infected. It was a concomitant, but not the cause of the water acquiring its infective character — an indication of the water having dangerous relations, but not a proof of the presence of specific disease germs in the water.

It is no doubt true that a water which is chemically pure may generally be regarded as a good source of supply, and one which is not usually found to be associated with the spread of waterborne disease. Thus water which is obtained from a spring or a deep well is good, not merely from a chemical point of view, but also from that point of view which concerns itself with the possibility of its transmitting the germs of infective disease. This results from the fact that the surface water, which is frequently grossly contaminated, undergoes in its process of filtration through the upper layers of the soil not merely those chemical changes which render it pure from the chemist's point of view, but also a process of bacteriological filtration which can convert a dangerous water into a harmless one. The two processes do not, however, run precisely parallel, and it is now recognised that it would be most unwise to base an opinion on the results of a chemical examination only.

This principle of judging of the "purity" of a water by its chemical character has been applied to the case of domestic filters with most unfortunate results. It was found that a chemically bad water could be rendered chemically "pure" by filtration through animal charcoal, and it was concluded that a dangerous water had been converted into a harmless one. The chemical indications of contamination were no doubt got rid of, and it was assumed that the real source of danger—the disease germs—had also been removed. As will be seen, however, from our report, this is not the case. Charcoal which may render an impure water chemically good does not prevent the direct passage of disease germs, and accordingly does not lessen the risk incurred of acquiring infective disease when such a contaminated water supply is partaken of.

The only way of testing the efficiency of a filter is that of direct experiment, by feeding the filter with water containing disease germs, and by ascertaining whether these pass in an active condition into the filtrate. We have subjected all the domestic filters which are in extensive use to this test, and in this way have shown how far they can be relied upon to protect against the transmission of waterborne disease.

It was found during the course of our investigation that those filtering media which were capable of arresting the passage of disease germs possessed such very fine texture and small pores, that they were incapable of yielding an adequate supply of filtered water when used as non-pressure filters—that is, as table or pocket filters. In our opinion, if a water is regarded as open to suspicion, the whole of the water required for the household supply should be subjected to filtration if the process is to be relied upon. This is the real difficulty in the filter question, since most of the efficient filters, even when used on the tap with high pressure, are unequal to this requirement. Yet if a filter is to be used at all in connection with our public water supplies, it is essential that it should afford a full supply of filtered water, and that it should be capable of continuously functioning in this manner with a minimum of attention and trouble.

The confidence of the public in the statements made by manufacturers and vendors, as regards the power of their filters to render impure water innocuous, has not been attended with such danger when these filters have been used on our public water supplies, which in this country at any rate must as a rule be regarded as usually of good quality. The danger is more obvious when the various inefficient materials are used as pocket filters, recommended for the purpose of purifying pond water, or where table and domestic filters are supplied for use in our colonies and tropical countries. As will be seen in this report such filters, when inefficient, not merely allow the germs to pass into the water which is used, but may actually increase the risk run by those making use of it, as in the case of a pocket filter, which, once infected with polluted water, may continue to distribute the germs in the filtrate for a considerable period when afterwards used to filter purer waters.

The use of inefficient filtering media, such as charcoal, has in our opinion distinct disadvantages beyond the fact that they do not arrest disease germs. They provide a very favourable breeding ground for water organisms, and when a filter composed of such a medium has been in use for some time, the water obtained from it is teeming with countless thousands of these organisms. It would appear that water is so often a source of infection, because the organisms present in it frequently escape the antiseptic action of the gastric juice, by being passed on at once from the stomach into the intestines. The presence of these large numbers of water organisms in the water from such a filter is not, in our opinion, a matter of indifference, since these undoubtedly must set up fermentative changes, and thus tend to digestive disturbance. Inefficient table and domestic filters are not therefore merely incapable of obviating danger, but when used even with a good water, in all probability tend to render it unwholesome.

The evil resulting from the misleading statements of the filter vendors is most obvious when such filters are used for the purpose of purifying waters which are regarded as dangerous. Owing to the misplaced confidence reposed in these statements, the common-sense precaution of boiling water is omitted, and in this way they have worked unmitigated evil. When we read that one manufacturer alone has supplied no fewer than 17,000 of these inefficient pocket filters to our army, which were probably used for filtering waters open to contamination, the magnitude of the danger may, to some extent, be realised, especially as disease organisms once having gained access to the filter would be carried about from place to place.

As the outcome of this investigation, we believe that we are warranted in concluding that we have been able to settle the principle on which must be based the method of testing the efficiency of filters in preventing the transmission of water-borne infective disease. The method had already been suggested by Gruber and his pupils, but we have been able to carry out experiments on so many types of filters, and over such prolonged periods, that we may now hope that this vexed question has been finally set at rest.

We wish to take advantage of this opportunity to express our great indebtedness to the Laboratories Committee of the Royal Colleges of Physicians (London) and Surgeons (England) for placing so unreservedly at our disposal the facilities for carrying on so prolonged and extensive a series of experiments. We must also thank Mr. James Millar for the valuable assistance he has given in helping to carry out and to record the results of such a long and laborious investigation.

G. S. W.
G. E. C. W.

LONDON,
22nd February, 1898.

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THE RELATIVE EFFICIENCY OF WATER FILTERS.

PART I.

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THE purpose of the investigations of which this report gives an account was to decide by direct experiment the influence which the various domestic filters in common use exert in the purification of water, and to learn how far they may be trusted to prevent the communication of disease through the agency of water. This is a question which affects not merely medical men, among whom the most varying opinions are held as regards the utility of such filters, but also the general public, who, as a rule, purchase these filters without consultation with their medical advisers, and value them according to the extent and nature of the claims made by the makers, the distinguished persons who are said to be using them, and the numbers which are stated to have been sold.

Filters are used for the purpose of subserving one or more of the following purposes:

1. To remove all suspended material visible to the naked eye.
2. To chemically alter water, as in the case of the removal of hardness due to lime, etc.; to retain metals such as iron, lead, etc.; or to remove organic matter present in solution.
3. To aërate water, and thus render it sparkling and more palatable, especially in those cases where boiled or rain water has to be used for drinking purposes.
4. To remove micro-organisms from the water, especially those concerned in the spread of disease.

It may be stated at once that many of the filters which are here reported upon function very perfectly as regards one or more of these purposes (Nos. 1, 2, or 3), and, unfortunately, the testimonials given appear in almost all cases to be founded only upon the tests made to determine their action in regard to these three points, whilst the general public suppose, and very naturally, that the commendations refer also to No. 4—that is, in providing a safeguard against the passage of disease organisms.

In this connection we must point out the misleading nature of the testimonials given, often by eminent analysts and medical men, some of them evidently written many years ago, before bacteriological methods were in the habit of being applied to water, and even some of later date, when the method of such analysis was still imperfectly understood. As regards the conversion of a dangerous water into a wholesome one by the reduction of the organic matter present through the action of any of these filters, the out-of-date character of these testimonials cannot be too strongly insisted upon. The chemist no doubt, by informing us of the amount of organic matter present in water, places in our hands evidence of its dangerous or suspicious nature; but the removal of these substances does not necessarily imply the elimination of the real source of danger, as organic impurity is simply an indication of probable sewage or other contamination. It is now, indeed, generally accepted amongst hygienists that the small excess of organic matter which converts a good water into a bad one (in the opinion of the chemist) is not of itself capable of exerting any directly injurious influence, but merely of acting as an indicator that the water is probably open to contamination with sources of infective disease (microbes), or that the presence of this organic matter may, perhaps, render the water a more suitable medium for the growth of pathogenic organisms, should these gain access to it. Accordingly, any conclusion such as is drawn by the filter makers and the general public as regards the conversion of a dangerous into a wholesome water by the mere diminution in the amount of organic matter present, is based upon absolutely erroneous data, as such water can only be rendered harmless by the removal of the sources of danger present in it, that is, the micro-organisms.

We deal here only with No. 4, as being the function with which we are chiefly concerned from the hygienic point of view, as our present object is to determine precisely what safeguard each filter offers against the communication of disease. In every case we shall specify exactly the claims of the vendors or manufacturers of the filters, and then state how far these claims conform with the facts elicited by direct experimentation. In not a few cases the filter vendor, in his circular, points out the dangers of blood poisoning, and indeed of all the probable and improbable diseases which may originate from the drinking of impure water, or even in the use of filters supplied by other makers, which they maintain may actually greatly increase the danger, owing to their imperfect nature, as a consequence of which "it becomes easy to understand the terrible fact that the very filters relied upon as safeguards are frequently themselves actually the direct cause of blood poisoning." As most of the well-known firms are great sinners in this respect, it is unnecessary, and would perhaps be invidious, to individualise. In other circulars the statements are so general that we have not thought it expedient to quote them in detail; but inasmuch as the filters advertised are recommended as suitable for the purpose of purifying water and thereby rendering it suitable for drinking purposes, the necessity for reporting on these filters is obvious. In other cases, however, although no absolute statements are made by the filter makers as regards freeing the water from disease germs, the chief object of the filter being to aërate the water and render it pleasant and sparkling to drink, an examination and report on such filters was none the less necessary, as the general public naturally assume that even filters of this kind will confer a certain protection against disease organisms which may be present in the unfiltered water. In only one instance do the makers state expressly the incapacity of their filter to arrest germs.

General Structure and Mechanical Details of Filters.

In making a selection of filters for examination, we were guided by two principles: (1) We endeavoured to obtain a specimen of every filter that is in extensive general use. In order to obtain evidence on this point we made careful inquiries at the chief depôts, stores, etc., in London and elsewhere, as to which forms were most in demand. (2) We then made a collection of every type of filter which differed in any way, either in principle or in construction, as regards the material used or the way of using it, from any of the forms that we had already obtained. Thus in many cases filters which are absolutely identical as regards their essential structure are fitted with different casings, the filtering medium employed (usually a charcoal block) being obtained frequently from the same source, the earthenware jar or case, however, differing according to the taste or exigencies of the individual manufacturer or vendor. In obtaining information on these points, the assistance of several experts saved us much unnecessary labour.

We were thus able to obtain filters in which the following materials were used as filtering media:

1. Carbon in its various forms, either pure or compounded with some other chemical substance, as in the case of the silicated or manganous varieties:

   (*a*) As blocks, or in the powdered or granular form, used either separately or in combination.

   (*b*) Charcoal as fine powder deposited on asbestos cloth or placed in the interior of a stone block.

2. Iron in the form known as *spongy iron* or as *magnetic oxide* either:

(*a*) Alone, or

(*b*) Along with asbestos cloth.

3. Asbestos in various forms, either:

(*a*) Alone as a fine film, or

(*b*) As a film in combination with cellulose.

(*c*) Along with some finely powdered or granular medium.

4. Forms of prepared porcelain and other clays.

5. Natural porous stone, either:

(*a*) Alone, or

(*b*) With other substances such as powdered carbon, etc.

6. Compressed silicious or diatomaceous earths.

After most careful inquiry we have come to the conclusion that we have here specimens of all the materials and combinations of materials that have been used to any extent in the construction of filters.

This is, perhaps, the most convenient place in which to refer very briefly to the differences in the mechanical details of the different filters.

Taking, first, the "table" filters, one is at once struck by the almost invariable inefficiency of the plug by which the filtering block is fixed into the bottom of the funnel, and through which the delivery pipe passes into the receiver. In nearly every case the substance employed was a cork, usually of very inferior quality, so that in order to avoid the possibility of leakage, and to make certain that we were testing the absolute filtering value of the block under examination, we were obliged to make the joint perfect with a luting of shellac or electric cement. The junction between the delivery pipe and the filtering block, where such was used, was usually equally imperfect, and required similar treatment. In many cases such imperfect corks were replaced by tightly-fitting india-rubber bungs. Assuming that these filters possessed the power of arresting the microbes present in the water, the fittings as sometimes sent out, and certainly in the course of time in the case of others, would in many cases allow of the direct passage of unfiltered water from the upper reservoir to the lower receiver, thus frustrating the whole object of the filter.

In the case of the larger filters the taps are usually fitted into the receivers with corks which here also are open to the above-mentioned objection, in addition to which, as the filtered water lies in contact with them for some time, they must form very favourable breeding grounds for microbes, and so greatly enrich the bacterial contents of the water that is about to be drunk. Some of the filters were fitted with india-rubber corks, and these are to be preferred; but perhaps the best form of fitting that was sent out with any of the filters was a tap with a screwed stem, provided outside the filter and behind the shoulder of the tap with a washer of india-rubber, and a nut inside the filter, which when tightened fixes the tap in position, a minimum surface of the india-rubber being thus in contact with the water in the receiver.

Even the general public have now become alive to the fact that filters require frequent cleansing, on account of the unpleasant taste imparted to the water by a dirty filter. In spite of this now being generally recognised, the facility with which this cleansing may be carried out varies enormously in the different types of filter. Some are still constructed in such a manner that the removal of the filtering medium by the user is a matter of the utmost difficulty. Others, indeed, have the parts so fixed that the filter can only be cleaned and renewed by the makers; this being no doubt explained in some cases by the contention of the manufacturers or vendors that the filters are self-cleansing, and never get out of order.

Although, no doubt, considerable differences may be observed as to the period that the filtering media remain "sweet," it must be be borne in mind that the organic matter must either be retained in the filtering medium and undergo its normal decompositions *in situ*, or, as is probably the case in the so-called "self-cleansing" forms, pass through directly. Thus a self-cleansing filter must, from its very nature, have little or no filtering action.

We have also evidence that even the same filter block as supplied by any manufacturer varies within very wide limits as regards the fineness of its pores, as indicated by the amount of water that passes through in a given time. It has also been observed on several occasions that the permeability of the blocks seemed to be—at least initially—increased when kept in continuous use for some time. In addition to this, however, other factors beyond our control no doubt come into play in determining the amount of water passed in a given time, so that the figures given in the accompanying table must necessarily be taken as being merely approximate. Thus, for instance, the fact whether the upper reservoir is constantly replenished so as to keep up the maximum pressure or not naturally exerts a very important influence on the rate of outflow, whilst the size of the filter is, of course, of prime importance. It must be remarked, however, that the rate of flow bears no necessary relation to the efficiency of the process of filtration, as some of those filters which functioned most imperfectly as regards their filtering power had an exceedingly restricted rate of outflow.

Under the heading of mechanical details it is convenient to consider the power possessed by the various filters of keeping back fine suspended matter, which, previous to the "bacteriological era," was the only criterion by which filters could be properly tested. Although we can now place no reliance on this method of testing, still, inasmuch as the passage of the larger particles through a filter at once placed such filter out of court, we have utilised the method in carrying on rough preliminary experiments, as at once affording evidence as to the mechanical efficiency of the different filters. The substances used in these experiments were the finest gunpowder charcoal (Enfield) (particles 24 μ to 0.9 μ); artificial ultramarine (particles 16 μ to 0.6 μ, or even less in diameter) in suspension; and milk (minute granules and globules of fat 0.5 μ to 30 μ or more in diameter) freely diluted with water.

It should be noted in the case of ultramarine, that its absence from the filtrate of the spongy iron filter may ery possibly be due to a chemical interaction. The filter received repeated charges of these suspensions, as we observed, in the case of ultramarine, that this substance sometimes appeared in the filtrate only ofter the lapse of a certain time, the colour being detected only with certainty when a column of the filtrate was examined in a glass vessel. These repeated chargings could not, however, frequently be carried out in the case of the milk test, the filtering medium becoming clogged as in the case of the Wittmann filter, so that the negative result recorded cannot be regarded as altogether satisfactory. The number of crosses in the table indicates in each case the larger or smaller amount of the substance which appeared in the filtrate.

In the following table are given the results of these experiments, along with the rate of filtration and the proportion of organisms which the various filters allowed to pass through, as measured by enumerating the number of colonies developed in gelatine plates inoculated with a definite quantity of the filtered water. The filters were first sterilised in order to get rid of any micro-organisms that might already be present; then ordinary tap water was passed through them, and a comparison was made between the number of organisms in the filtrate with the number in the tap water, and from this was computed the percentage passed. These numbers are, of course, only approximate, especially in those cases where only a small proportion of those present passed into the filtrate. There are also other factors, such as the influence exerted by the depth of the filtering medium on the time required for the organisms to be washed through into the filtrate, which prevent any comparisons of this kind being absolutely accurate, but these disturbing factors are considered in greater detail elsewhere.

From this table it is at once evident that any filter which allows of the passage of the particles of any one of these substances fails to keep back micro-organisms, but the converse does not necessarily hold good that if these particles are kept back micro-organisms are also intercepted

TABLE I.

Name and Type of Filter.	Time (in Minutes) required for Filtration of 1 Pint of Water.	Presence or Absence of Carbon in Filtrate.	Presence or Absence of Ultramarine in Filtrate.	Presence or Absence of Milk in Filtrate.	Percentage of Organisms per c.cm. allowed to pass into Filtrate.
Silicated carbon table filter (glass)...	68	o	++	+++	7½
,, ,, Ascension table filter (glass)	120	o	+	+++	16
Silicated carbon pocket filter ...	Not recorded	o	+ (?)	+++	Not recorded
Doulton's pint table filter (solid block)	27	o	+	+++	20
Doulton's pint table filter (solid block and granular carbon)	18	o	+	+++	13
Doulton's carbon bottle filter ...	13	o	o (?)	+++	17
,, natural porous stone bottle filter	15	o	o (?)	++	31
Doulton's pocket filter	Not recorded	o	+	+++	Not recorded
Maignen's domestic Filtre Rapide...	4	o	o	++	o (?)*
,, table Filtre Rapide (glass)	32	o	o	++	4
Atkins's Admiralty filter (No. 1) ...	5	o	++	+++	20
,, pocket filter	Not recorded	o	+	+++	Not recorded
Nibestos filter	6	o	o	++	7½
Fr. Lipscombe and Co., new patent cylinder filter	23	o	++	+++	60
Fr. Lipscombe and Co., table filter (solid block)	30	o	+	++	45
Lipscombe Filter Company, table filter (powdered and granular charcoal)	7	o	++	+++	30
Lipscombe Filter Company, table filter (solid carbon block)	16	o	+	++	25
Spencer's magnetic domestic filter	9	+	+++	+++	15
Spongy iron table filter (glass) ...	14	o	o	+++	6
,, table filter (porcelain)	17	o	o	+++	10
Morris's 2-gallon domestic filter ...	2½	o	+++	++	12
Cheavin's Idiocathartes domestic filter	¾	+	+++	+++	57½
Crown Filter Co., table filter (quart)	3	o	+	+++	28
Barstow's table filter (quart)	35	o	+	++	27
Alcarazas domestic filter, No. 1 ...	57	o	o	+	o (?)*
Slack and Brownlow's compressed charcoal domestic filter	1	o	++	+++	26½
Wittmann's charcoal vase table filter	10	o	o	o	o (?)*
Defries and Son's carbon block glass table filter	19½	o	++	+++	23
Pasteur-Chamberland filter (single candle, style F.)	420	o	o	o	o
Berkfeld filter (single candle, No. 13)	140	o	o	o	o
London Pure Water Co., cistern filter	Not recorded	+	++	+++	Not recorded
Maignen's field service Filtre Rapide, A.M.D.	Not recorded	o	o (?)	++	Not recorded
Silicated carbon syphon filter, A.M.D.	Not recorded	o (?)	++	+++	Not recorded
Stoneware filter with sponge plug, A.M.D.	Not recorded	+	++	+++	Not recorded
Morris's 4-gallon domestic filter, A.M.D.	Not recorded	o	+	+	Not recorded

* As the number of organisms found in the gelatine plates came within the range of experimental error, a positive result could not be recorded, but, as will be seen later, when treated with suspensions of the test organisms, all these filters allowed of their direct passage.

Principles on which the Method of Testing Filters is Based.

The questions involved in the possible passage of a disease germ through a filter are partly physical in their nature and partly biological. Inasmuch as the disease germ has a certain size, shape, and weight, it conforms physically to any other material body having similar characters; but, on the other hand, as a living organism, in virtue of its motility and power of growth, it may comport itself under certain circumstances quite differently. The method too frequently adopted, at any rate in this country, of testing filters, consists in applying to them a fluid containing very fine particles in suspension, such as are obtained by the addition of ultramarine or barium sulphate to the water which is to be subjected to filtration. The obvious objection to applying any results obtained in this way to what would happen in the case of micro-organisms, arises from the fact that, first, the size of the particles varies greatly, and we do not know how far these particles approximate in size to the microbes in question; secondly, these chemical bodies may comport themselves quite differently as regards being mechanically entangled in the meshes of the filtering framework, or retained by the "surface action" of the walls of its channels, from the organic matter of the living microbes. Although, however, we cannot make use of the physical properties of the microbe in applying results obtained from similar small particles to what would occur in the case of living micro-organisms, we are quite justified under certain conditions in concluding that when any microbe of similar form and size *directly* traverses the substance of the filter, a corresponding disease germ would comport itself in a similar manner. In order that we may, however, more clearly realise the methods on which a filter is to be tested, we must consider briefly the way in which we suppose those filters which undoubtedly—at any rate temporarily—arrest the passage of germs are supposed to act.

No doubt the theoretically perfect filter would be one which might, so to speak, be infinitely thin, inasmuch as its meshes would be so close as to prevent the passage of any micro-organism. On the other hand, the physical conditions in this case would probably prevent the passage of the water, certainly at any of the ordinary pressures at our command. It is not, however, contended by the inventors of any of those filters which undoubtedly at first give germ-free filtrates that the pores are of so fine a nature that they act in this manner; but it is assumed rather that the microbes are arrested in the channels by a process of surface attraction (flächenattraktion) as it is called. It seems to us, however, very probable that the arrest of the microbes depends also in great part on a process of entanglement of the organisms in the channels of the medium. The organisms which are arrested in either of these ways in the substance of the filter are not killed, but may, under certain conditions, grow through and appear in the filtrate, which proves that the diameter of the pores is larger than the diameter of the microbes. This growth of the organisms usually present in water through the walls of all the filters which have as yet been subjected to scientific examination may occur even in the course of three or four days according to the conditions present, and it is as regards the significance of this fact that the difference of opinion in estimating the value of such filters in protecting from the passage of disease germs that a certain amount of divergence of scientific opinion still exists. We have to determine whether disease organisms, such as those of cholera and typhoid fever, can, in the course of time, traverse the walls of the filter in a similar fashion to the organisms normally occurring in water, and, if so, whether such conditions would actually occur under the circumstances in which these filters are ever brought into operation, and whether such growths can be arrested by any convenient means of cleansing not injurious to the filter. This question is of interest only as regards those filters which give a sterile filtrate when first put into operation, and will be discussed in full detail when we come to the consideration of such filters.

We shall now consider briefly the different ways in which a filter may function imperfectly and the causes to which they are due.

1. A filter when treated with a fluid containing micro-organisms may permit them to pass directly through the filtering medium into the filtrate. In this case it is obvious (unless the fittings are imperfect and allow part of the water to escape the filtering process) that the filtering substratum is itself pervious to the organisms, from the fact, in all probability, that its pores are much too large to exert their specific influence in arresting the microbes. This is the regular method of testing a filter, and unless a filter comes up to this standard it must be at once rejected. The process is usually carried out as follows: A culture of a well known and easily recognisable microbe is added to a quantity of sterile water, with which the filters to be examined are now fed; naturally an organism is chosen which it is highly improbable could have been originally present in the filter; this danger may however be entirely obviated by previously submitting the filter to a process of sterilisation. The microbes usually selected for this purpose are such as produce striking colours by their growth, and are thus easily recognised, for example, micrococcus prodigiosus, bacillus violaceus, and staphylococcus pyogenes aureus. Any filter which permits the direct pas-

sage of such microbes may be at once dismissed from further examination, as we may at once conclude that it would comport itself in a similar fashion towards disease germs; but in order that there should be no dubiety upon this question, each filter, in addition, has been treated with suspensions of the bacilli of cholera Asiatica and of typhoid fever, which passed through into the filtrate in a similar fashion.

2. Filters which have passed the first stage and have given a sterile filtrate when treated directly with microbe-containing fluids, may in course of time, under continued use, manifest their presence; this may be due to one of two causes—direct passage (*b*) or growth (*c*) of the micro-organisms into the filtrate.

a. It may occasionally happen that an imperfect filter can at first give a germ-free filtrate, owing to the fact that the filtering medium must receive a succession of charges, in order that the organisms may be washed through into the filtrate; such a mistake cannot occur, however, if the precaution be taken of collecting samples only after the filters have received a number of charges, unless in the case of those which filter extremely slowly.

b. The appearance of the microbes in the filtrate after continued use may be due to structural imperfections in the filtering medium which have been induced during its use,[1] such as cracks or faults in its substance. This is especially liable to occur in the case of those composed of compressed asbestos, and is attributed chiefly to changes in the water pressure to which they are subjected gradually breaking down their finer texture. Such a filter has then been reduced to Class No. 1, and if sterilised and treated with a suspension of our test microbes, would now allow of the direct passage of the organisms.

c. The organisms originally present in the water may gradually grow through the substance of the filter, and thus appear in the filtrate. This under certain circumstances occurs in the course of time in the case of all filters with more or less rapidity, according to the conditions to which they are exposed.

The conditions which chiefly influence the growth of bacteria through a filter appear to be the following: First, the temperature—the higher this happens to be (within reasonable limits) the more rapidly they grow, as the conditions are more favourable to their multiplication; secondly, the intermittent use of the filter—this allows the organisms time to develop undisturbed, and also probably aids in their detection by preventing their being washed away; the intermittent use of a filter also tends in most instances to induce the growth of micro-organisms, by the water in

[1] Such flaws or imperfections may, for example, be induced in certain cases by the process of periodical sterilisation by heat, which it is usually recommended all filters should undergo.

the filter attaining a higher temperature than that which it originally had; thirdly, the nature of the organisms present in the water exerts a great influence on the rapidity with which they traverse the walls of the filter. Naturally only those which multiply readily in the fluid can effect a passage, and of such micro-organisms those which are actively motile probably possess a certain advantage. On the other hand it has been suggested that motile organisms which possess flagella will on that account be more readily retained in the channels of the filtering medium.

The question now comes to be, would pathogenic organisms —disease germs—grow through the filter as the water organisms are able to do, and eventually appear in the filtrate? We know that many of the conditions which allow of the multiplication of the water organisms and favour their passage through the filtering substratum, would be wanting in the case of the much more susceptible and fastidious pathogenic germs. This question had not yet, in our opinion, been definitely decided, and still required further experimental investigation. Kubler assumed that the pathogenic organisms would comport themselves like the water organisms in growing through the filter; and Kirchner states that in his experiments they passed through into the filtrate, but unfortunately his suspensions of pathogenic organisms were obtained by the addition of broth cultures to water, and the addition of this highly nutrient fluid to the water of course introduces quite a new factor into the experiments. Gruber and his pupils, on the other hand, maintain that neither typhoid nor cholera bacilli are able to grow through the walls of a good filter. It was found that when the filters were fed with suspensions of these organisms in water obtained from the surface of an agar culture the filtrate remained free from them even up to the twentieth day. If, however, during the course of the experiment a small quantity of broth was added to the suspensions of the germ, the organisms appeared in the filtrate in the course of three or four days, but again gradually diminished in number if no more broth was added to the water. In Gruber's opinion the addition of the broth raised the nutrient capacity of the water to the same standard as regards disease germs as it originally had for water organisms, but that direct experiment had convinced him that even the most impure potable waters, or even diluted sewage such as occurs in the sewers of Vienna, did not supply the conditions necessary for the passage of these organisms through the walls of the filter. We shall, however, return to this subject when we repeat the experiments on the filters in question.

It is, therefore, already quite obvious that we must draw a marked distinction between those filters which allow of the passage of microbes into the filtrate due to cause *b* and those due to cause *c*, and we may briefly indicate here the means by which we can discriminate between these two causes.

1. Where the passage is due to growth through the filter, the organisms appear first in the filtrate after a certain definite time, according to the conditions to which they are exposed; and, when the filter is again sterilised, these appear in the filtrate only after the lapse of a similar interval. On the other hand, as already remarked, if the passage of organisms is due to an imperfection which has been induced in the filtering substratum by the sterilising process, the organisms appear at once in the filtrate. 2. As the passage of the microbes is due in the one case to their direct and continuous growth, if the filter and the water with which it is supplied is retained at a sufficiently low temperature, the filtrate obtained may remain sterile for an indefinite period. The quality of the filtrate obtained from imperfect filters, as the question here is purely a mechanical one, is not affected by the temperature at which they are held. 3. In the case of growth through the filter the number of organisms in the filtrate bears no relation to the number originally present in the water supplied. In addition, if the species which first appear in the filtrate are examined, it will be found that some of those species present in the original water appear much sooner than others; and usually not all the species originally present in the water, but only certain forms, appear able to grow through the walls of the filter. Where, however, the filter itself is faulty, the number of organisms found in the filtrate bears a direct relation to those present in the water from which they are obtained, and the different species occur in relatively similar proportions. 4. In the case of intermittent filtration, where the organisms have grown through the filter, we obtain a much larger proportion of organisms in the first portion of water which is passed through each day, as this contains most of the organisms which were in a position to be easily washed through, and as a consequence, under continued filtration, these diminish in number. This is not nearly so marked a feature in the case of imperfect filters.

Methods Employed in Testing the Filters.

From a purely scientific point of view any one of the first three tests employed would have sufficed in order that we might come to a definite conclusion as to whether a filter prevented the direct passage of micro-organisms, in which case we should only have had to investigate the further question as to whether or no disease germs could in course of time grow through the substance of the filter. In every case, however, the filters were treated not merely with one of the usual test organisms (No. 1), but in addition were tested with cholera and typhoid fever bacilli, in order that there might be no question as to the possible passage of these organisms.

The fourth test to which they were subjected was to treat them from day to day with water, so as to make the conditions as much as possible like those that occur when used for household purposes, in order that we might ascertain how far the filtering medium served as a breeding ground for the water organisms, since we know that under such circumstances the numbers of organisms in the filtrate may be actually much greater than those present in the water with which they were supplied.

No. 1.—Staphylococous Pyogenes Aureus and Yeasts.

In testing the filters as regards their power of keeping back organisms in the usual manner by means of a chromogenic organism (staphylococcus pyogenes aureus) it occurred to us that we might perhaps grade off the filters into different sets according as they allowed still larger organisms to pass. For this purpose the yeasts naturally suggested themselves as organisms which from their varying size would readily lend themselves to our purpose. A few tentative experiments, however, convinced us that a simple mixture of the staphylococcus pyogenes aureus and a white yeast supplied us with all the information that could be obtained in this way. The size of the staphylococcus varies from 0.75 μ to 1 μ, while the white yeast is usually 3 μ in diameter with a small proportion, one in every 10 or 15, of about one-third that diameter. This mixture supplies us with very interesting information, inasmuch as by comparing the relative proportions of these two organisms present in the fluid before and after filtration, we are enabled to come to a conclusion as to the relative preponderance of the channels of these two sizes, should such happen to be present in the filter. Thus, in several cases where the filter permitted of the passage of only a very small proportion of the organisms present in the fluid with which it was fed, but in almost their normal proportions, we were able to conclude that their passage was due to a small crack or fault, so to speak, in the filtering mechanism. The passage of the yeasts also afforded us a means of forming an opinion as to the passage of such amœboid bodies as are associated with malaria, and also, perhaps, as to the ova of certain of the tænia (tapeworms). The size of the malaria parasite, according to most observers, varies according to its age, from 1 μ to 10 μ, while that of the ova of the various tænia, although probably much larger, does not yet appear to be quite definitely settled. This question is of most importance as regards pocket filters, which are frequently used to exert their supposed purifying influence upon waters of a most suspicious nature.

The method by which our suspension of test organisms was obtained, not only in this case, but also in Nos. 2 and 3 was as follows: Fresh agar cultures of the organisms were treated with small quantities of sterile distilled water, and from the fine suspension of the micro-organisms obtained by gentle agitation of the tube, definite quantities were added to each litre of sterile tap water. In this way as little nutrient medium as possible was added with the organisms to the tap water, so that this factor, which in some cases might be of importance, was to a great extent eliminated.

No. 2.—Cholera Bacilli.

The filters were each treated with sterilised tap water containing a fine suspension of cholera bacilli made as above. The first filtrate obtained was not usually taken for examination, as early in our experiments we observed that this, sometimes, was comparatively poor in the test organisms, whereas later they occurred in much larger numbers. This is shown very clearly in the case of those filters which were examined on two successive days, as although on the second day the filters were fed with sterilised water without the addition of cholera, the number of colonies originating from 1 c.cm. of the filtrate had very much increased. In consequence of this the filtrate first obtained was repassed through the filter several times before the sample was taken for examination and cultivation purposes.

We have also made an attempt to determine how long the cholera microbe would remain alive in the filtering medium and capable of infecting the water when fed with what is considered a good potable water. On the second and each succeeding day for a week the filters (ten in number) were fed with unsterilised tap water and a portion of the filtrate taken and incubated by Koch's method for the separation of cholera bacilli from water. We modified Koch's method in one particular: instead of adding the 1 per cent. of peptone and of common salt in its solid unsterilised condition, we made up a concentrated solution of these two ingredients—which was then sterilised by heat—and added the required quantity of this to the water to be tested: this mixture was then incubated at 37° C. We found this a distinct advantage, as we were thus able to reduce the number of foreign organisms which were present along with the cholera microbe. The surface of the fluid, where the cholera bacilli specially collect, was then examined from time to time for the presence of cholera bacilli while undergoing incubation at this temperature. In all ten filters used cholera bacilli could be demonstrated with more or less ease up to the eighth day; after that the experiment was continued with two of the filters only—namely, a Lipscombe and Co.'s filter, as representing the carbon block type, and a Maignen's Filtre Rapide, as representing the combination of asbestos cloth and powdered charcoal. These two were examined at intervals for over a month; and, although the cholera bacillus was demonstrated sometimes only with considerable difficulty, secondary inoculations from the first fluids incubated being sometimes necessary, we were still able to separate it out in gelatine plates and cultivate it on the various media necessary for its cultivation and recognition.

The importance of this is at once obvious, when we consider the conditions under which cholera is propagated. Leaving out of consideration altogether the contentious question as to how far cholera bacilli can multiply in a potable water, or in the slimy mass of organic matter which accumulates in the substance of the filtering medium, and supposing only that instead of the consumers getting all the cholera bacilli at one dose, so to speak, they receive instead smaller quantities distributed over a longer period, let us consider what the probable difference in the risk would be. The history of cholera epidemics in former times indicates clearly that the human subject is not at all times equally susceptible to the disease; although the whole community may have been equally subjected to the infective agent (contaminated drinking water), yet only a certain proportion have been attacked, and these at different periods, which suggests that the organisms are able to set up the disease only under certain conditions, which probably usually consist in a disordered condition of the *gastro-intestinal* tract.

The perverted action of the stomach would probably influence the acid secretion of the gastric juice through which the bacillus may then pass uninjured, and thus the distribution of the dose over a more lengthened period would appear greatly to increase the risk of infection. It would seem, also, that a disordered condition of the intestinal mucous membrane (probably resulting in a serous effusion) is also usually necessary for the disease to be set up. Thus the recent observation made by Metchnikoff and others, that cholera bacilli may be demonstrated in the intestinal excretion of apparently healthy persons for several weeks without giving rise to the disease appears to us to establish this point quite conclusively.

This power of multiplication of the cholera organism in the contents of the apparently healthy intestinal tract is probably also of great importance in relation to the dose necessary to insure infection—a factor which we must now take into consideration. It is now recognised that in a number of diseases a certain number of organisms must be introduced to set up infection, whilst a smaller dose may only set up a passing indisposition, in fact may act as a vaccine. This, no doubt, holds good as a general rule where the microbe is introduced directly into the living tissues, and the vital activity of the cells comes into play; but it is probable in the case of such pure intoxications as cholera, or such a disease as typhoid fever, where the microbe can multiply undisturbed in the intestinal tract, that the quantity primarily introduced is a matter of little or no importance. We must accordingly conclude that the danger to the individual is immensely increased by spreading the dose of cholera over a more prolonged period, as in this way the material may be ingested at a moment when the conditions are favourable to their escaping the action of the gastric juice, and thus entail the possibility of the production of the disease; while the diminution in the number of organisms ingested involved in the distribution of the dose over a longer period probably exerts little or no influence on the risk of infection or the gravity of the disease which is set up. This danger of all imperfect filters, when once infected with a disease organism, of continuing to infect the water for a more or less varied period is most marked in the case of pocket filters, as when these have once become infected the disease germ may be carried for indefinite periods from place to place.

No. 3.—Typhoid Bacilli.

The filters were each treated with sterilised tap water containing a suspension of typhoid bacilli, obtained in the usual manner from an agar culture. When this had been passed through the filter two or three times, a sample was taken and gelatine plates were made from 1 c.cm. of the filtrate. Inoculations were made from the colonies which appeared in these plates on potatoes and milk, in order to demonstrate with certainty that this was the organism of typhoid fever. As we have, in the case of typhoid, no method similar to that which Koch has elaborated for the separation of cholera from suspected waters—Parietti's method, which we consider the best of those at present at our disposal, being very unsatisfactory—we were unable to carry out our experiments, as in the case of cholera, with unsterilised tap water to decide as to how long the typhoid fever bacillus could remain in the filter when in the presence of other water organisms. We have, however, carried out the experiment with *sterilised* tap water in the case of a carbon block from the Silicated Carbon Company, which we specially fitted up in a glass cylinder, closed at the other extremity with a cotton wool plug, in order that extraneous organisms might be kept out for as long a period as possible. This block, which had been treated on the first day with a suspension of typhoid bacilli in sterile water, and on succeeding days with sterile water alone, up to the eleventh day showed innumerable colonies of typhoid bacillus; but at this point the presence of other organisms, which had obtained an entrance from outside, interfered so seriously with their demonstration that the experiment was brought to a close, although no doubt, as in the case of cholera bacilli, the disease germ would remain capable of infecting the water for a much longer period of time than we were able to demonstrate.

No. 4.—Water.

In these experiments the filter was first carefully sterilised, and as this sterilisation in some cases presented considerable difficulties, in order that we might be quite certain of its condition, sterile water was passed through the filter and plates were made from the filtrate before the crucial experiment was made, always with negative results. The sterilised filter was now fed with the tap water of the laboratory, and after receiving five or six charges, a sample was taken from which gelatine plates were made. In some cases a sample was taken from the very first water passed, and this was naturally in most cases poor in organisms as the greater number of these were still retained in the upper layers of the filtering medium. On the succeeding three days two sets of plates were usually made on each date, the first sample being that collected from the first portion of water passed through the filter early in the day, the second being collected after the filters had received nine or ten charges of the tap water in the course of the day. In the first sample taken from the second day onwards we obtained not merely the organisms present in the tap water which had been passed through the filter but, in addition, many of the organisms which had been retained in the filter on the previous day and had undergone multiplication in the body of the filter. The second sample taken from the filter gives one a good general average of the bacterial contents of such a filter working under the most favourable conditions as regards continuous daily use. These experiments were continued only up to the fourth day, but they indicate sufficiently clearly how rapidly the substance of the filtering medium under examination becomes contaminated and able to add to the bacterial contents of the water. We have, however, had an opportunity of investigating several filters which had been in constant domestic use for several months without intermission, and the results obtained from these undoubtedly apply to those which we have had under observation.

The first two filters recorded in the following table had been in constant use in large public buildings for five or six months, while the third was one of unknown origin in private use, which had been in operation, without being cleansed, for a much longer period.

Number of Organisms in Water not unimportant.

It might at first sight appear of little moment whether the number of water or putrefactive organisms were few or many in the fluid which we drink. We must remember, however, that owing to the processes of cooking, etc., to which most of our food is subjected, it is ingested in a more or less sterile condition; and that, accordingly, the number of organisms which we are usually in the habit of taking into the

TABLE II.—*Tap Water.*

Name of Filter.	Average Number of Organisms per c.cm. Present in the Filtrate.	Average Number of Organisms per c.cm. Originally Present in the Tap Water.
Silicated Carbon Domestic Filter ...	800 to 1,000	30 to 40
Atkins's Admiralty Filter	600 to 800	40 to 50
Carbon Block Table Filter (unknown origin)	5,000 to 6,000	20 to 30

alimentary canal is by no means so great as one might at first sight suppose. The importance of sterilising the milk that is to be used for feeding children is now everywhere recognised. It has also been frequently observed that individuals who are in the habit of only drinking water which has been previously boiled, or who habitually drink mineral waters which contain few or no living micro-organisms, often suffer from gastro-intestinal disturbances when they happen to drink other waters. Whether this has become an acquired susceptibility of these individuals or not is of no importance; it indicates, at any rate, that the presence of such micro-organisms is not quite a matter of indifference. The organisms present in water have a much better chance of passing unscathed through the stomach to the alkaline contents of the lower straits of the intestine than those present in any other articles of diet. Thus we may frequently partake of water between meals when the stomach is empty, and this may be passed on into the intestines unaffected by the gastric juice, as has been clearly shown in some experiments made by MacFadyean,[2] to which far too little attention has been paid. He found that when he fed fasting animals in the early morning with suspensions of cholera bacilli in water, the bacilli passed in a living condition into the intestines, whereas if they were introduced with milk none appeared to escape the action of the gastric juice. The explanation of this is probably the very simple one that the stomach reacted with its secretion of gastric juice only to the food (milk), but simply passed the water on into the intestines. It is probable that it is partly on this account that water may so frequently serve not only as the carrier of disease germs, but also of those organisms which flourish in the intestines, and there set up their special fermentations.

It might at first sight appear possible to range the different filters in a scale as regards their filtering capacity according

[2] *Journal of Anatomy and Physiology*, vol. xxi.

to the proportion of organisms which they allow to pass into the filtrate. A merely cursory examination of the tables, however, shows that the figures obtained in this way would vary very considerably even in the case of the same filter. The precise number of organisms present in the sample taken for examination depends, indeed, upon so many conditions which we may regard in this respect as accidental that no great value can be attached to this feature. In an imperfect filtering medium which permitted of the direct passage of micro-organisms into the filtrate the following conditions would tend to diminish the numbers present: (*a*) A large quantity or great depth of filtering medium, which would require a succession of charges of water to wash through the organisms, many of which were at first retained in the upper layer; (*b*) the fineness of the pores of the filtering medium, which would only allow the microbes to be washed through after a certain time; (*c*) the pressure under which the water is passing through the filter at the time the sample is taken; this naturally depends on the height and capacity of the upper reservoir of the filter and the amount of water present when the filter is tested. The influence of the pressure on the number of micro-organisms passed is brought out very markedly in the case of the bottle filters, where the water practically diffuses through, and in the case of the cistern and pocket filters, where it depends on siphon action. If we compare these with table filters of similar composition, we find that the latter transmit a much larger proportion of micro-organisms.[3]

A consideration of the influence exerted by these three factors provides us with an explanation of the apparently varying action of the same filter at different times. Thus we constantly observe that the number of organisms passed into the filtrate on the second day in the cholera experiments is very much increased, and indeed in some cases appear to be even richer than the original material with which they were charged. This is no doubt chiefly due to the fact that the organisms in the previous charges are washed down and collect in the deeper layers of the filters, but may also in part be ascribed to the fact that groups and bunches of organisms are gradually disintegrated into their individual members. It is possible also that when filters are tested on the first day with material derived from an agar culture, the groups of organisms may plug up the larger portions of the filter, and themselves act to a certain degree as a filtering medium. We are accordingly of opinion that the best comparative test of an imperfect filter

[3] It is quite possible that under certain conditions imperfect filters with the first sample give a relatively germ-free filtrate, and this may be offered as an explanation and excuse for some of the testimonials and statements which are published by the vendors of these filters. These results, however, depend on imperfect methods of testing the filters.

is the proportion of water organisms which it allows to pass when first examined, but, as already mentioned, the result obtained depends greatly on the character of the filter and the number of charges which it has received. We must insist, however, that this question is of little or no importance, as any filter which permits of the direct passage of micro-organisms will probably allow, in course of time at least, the greater part of the pathogenic organisms which it has received to pass into the filtrate, and must accordingly be condemned.

We shall now give the results in detail of our examination of the various filters which have been brought under our notice. We have divided these into two groups:

A. Those filters which allow of the direct passage of disease organisms into the filtrate; and

B. Those which do not allow disease organisms to pass directly into the filtrate.

A. FILTERS WHICH DIRECTLY TRANSMIT DISEASE GERMS.

I.

THE SILICATED CARBON FILTER COMPANY, *Battersea, London*. —The filters of this firm, which are in very extensive use in this country, have the following claims put forward on their behalf. Their filter, they say, "renders the worst water pure and wholesome." "By means of this filter perfectly pure and wholesome water may be drunk from any pond or stream." These statements are so definite that we proceeded to test their accuracy on the following types of filter supplied by this company.

1. Plain pint glass filter containing a simple silicated carbon block.

2. Silicated carbon ascension filter, in which the outer and upper surface is covered with a coat of porcelain, which compels the water to pass upwards through the block before passing into the filtrate.

3. Silicated carbon pocket filter.

(No. 1.) PLAIN PINT GLASS FILTER.

TABLE III.—*Test Organisms*.

	Average Number per c.cm originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	1,000 to 2,000
Cholera bacillus (first day)	5,000 to 6,000	200 to 300
Cholera bacillus (second day)	—	6,000 to 8,000
Typhoid bacillus	20,000 to 30,000	4,000 to 5,000

TABLE IV.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day sample No. 2 ...	40	3
Second day, sample No. 1	50	100
" " " No. 2		20
Third day " No. 1	60	4,000
" " " No. 2		1,000
Fourth day " No. 1	25	Innumerable
" " " No. 2		"

(No. 2.) SILICATED CARBON ASCENSION FILTER.

TABLE V.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	5,000 to 6,000
Cholera bacillus	10,000	2,000 to 3,000
Typhoid bacillus	20,000	800 to 1,000

TABLE VI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	—	Not recorded
" " " No. 2 ...	30	5
Second day	—	Not recorded
Third day, sample No. 1...	50	60
Fourth day " No. 1	40	600 to 800
" " " No 2		200 to 300

(No. 3) SILICATED CARBON POCKET FILTER.

TABLE VII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	4,000 to 5,000
Cholera bacillus	10,000	2,000
Typhoid bacillus	10,000 to 15,000	600 to 800

4. A large block of carbon, 6 in. in diameter (siphon filter), apparently fitted up on the same system as the pocket filter, enclosed in a tin case with a perforated bottom, which was supplied to us through the courtesy of the Director-General of the Army Medical Department.

(No. 4.) Silicated Carbon Syphon Filter (Army Medical Department).

Table VIII.—*Test Organisms.*

	Average Nnmber per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	1 000

It is evident at a glance that none of these filters possess the power of intercepting the micro-organisms which may be present in the water, and accordingly cannot possibly render "the worst waters pure and wholesome." From what has already been said concerning the increased risk of infection through the use of an imperfect filter that has once become contaminated with disease germs, we must conclude that these filters not only confer no protection, but in all probability materially increase the risk of infection. We may state here also that we have examined their tap filter, which they affirm "yields absolutely sterile water at any pressure," but have found that this is not the case. The tap filters, however, will be treated in detail in a further report.

II.

Messrs. Doulton and Co., *Lambeth Pottery, London, S.E.*—The filtering medium supplied by this firm consists of their manganous carbon, which they maintain acts not merely mechanically but also chemically through the intervention of the manganese, which absorbing oxygen from the atmosphere, oxidises the organic impurities present which are thus burned up and destroyed. How far this contention accords with the accepted notions of modern chemistry we must leave the chemist to decide, as this lies outside the province of the present investigation. "*Manganese also exerts a preventive influence on the growth of organisms*, the result being that the media, purified by the treatment and increased immensely in the oxidising power by the carrying action of the manganese, *acts better and lasts longer than any other.*" This material is used not only for table and domestic filters, but is also supplied in suitable forms to be placed in cisterns and attached to taps. The filters are supplied in three forms: (*a*) simple granular manganous carbon; (*b*) block of compressed manganous carbon; (*c*) mixed filter, consisting of a block of manganous carbon surrounded by a layer of the granular material. They also supply a filter in bottle form consisting of manganous carbon and a non-corrosive metal, and also one consisting of natural porous stone. They manufacture, in addition, pocket, tourist, and army filters, which, as in the case of the bottle forms, are supposed to be suitable for rendering pond and other suspicious waters suitable for drinking purposes. We have examined the followlng forms of filters:

1. Simple block of compressed manganous carbon.

(No. 1.) Simple Block of Compressed Carbon.

Table IX.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylacoccus pyogenes aureus + yeasts	10,000 to 15,000	2,000 to 3,000
Cholera bacillus	10,000	3,000 to 4,000
Typhoid bacillus	10,000 to 15,000	800 to 1,000

Table X.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
,, ,, ,, No. 2	40	8
Second day ,, No. 1	50	50
,, ,, ,, No. 2		15
Third day ,, No. 1	40	1,000
,, ,, ,, No. 2		500
Fourth day ,, No. 1	25	Innumerable
,, ,, ,, No. 2		Over 1,000

(No. 2.) Mixed Filter (Compressed Block and Granular Carbon).

Table XI.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	30 to 40
Cholera bacillus	10,000	3,000 to 4,000
Typhoid bacillus	10,000 to 15,000	900 to 1,000

Table XII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	30	4
Second day " ...	—	Not recorded
Third day " No. 1	—	Not recorded
" " " No. 2	50	60
Fourth day " No. 1	50	800 to 1,000
" " " No. 2		200 to 300

(No. 3) Pocket Filter (Compressed Block and Granular Charcoal).

Table XIII.—*Test Organisms.*

	Average Number per c.cm originally Present in the Suspension.	Average Number Present per c cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	1,000 to 1,500
Cholera bacillus	10,000	800 to 1,000
Typhoid bacillus	10,000 to 15,000	2,000 to 3,000

(No. 4) Manganous Carbon Bottle.

Table XIV.—*Test Organisms.*

	Average Number per c cm originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10 000 to 15,000	500 to 600
Cholera bacillus	10,000	600 to 800
Typhoid bacillus	10,000 to 15,000	40 to 50

Table XV.—*Tap Water.*

	Average Number per c.cm originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	35	6
" " " No. 2		25

(No. 5.) NATURAL POROUS STONE BOTTLE FILTER.

TABLE XVI.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10 000 to 15,000	30 to 40
Cholera bacillus	10,000	50 to 60
Typhoid bacillus	20,000	600 to 700

TABLE XVII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	35	11
" " " No. 2		15

2. Block of manganous carbon surrounded by a layer of granular carbon.
3. Pocket filter (No. 24 of their list), consisting of compressed block and granular charcoal.
4. Manganous carbon bottle.
5. Natural porous stone bottle.

We have found no evidence confirmatory of the statement of the makers that the manganese present in their filters prevents the growth of micro-organisms, although it is quite possible that their blocks may remain "sweet" for a longer period than those from which it is absent. We must again insist upon the danger incurred through the manufacturer asserting that the filter is self-cleansing—an idea with which the public is only too ready to fall in. Such filters must probably either pass the impurities, at once, unaltered into the filtrate or retain them in the pores of the filter, where they undergo their natural process of decomposition, and then pass into the filtrate. As a consequence of such advice these filters are often used continuously without being subjected to that process of cleansing and sterilising which is in all cases so essential. It is quite certain that these filters confer no protection against the passage of disease germs, and the danger to which the public is exposed is perhaps most obvious in the case of the bottle form of filters, which it is expressly stated "are specially adapted for use in hot climates where the water supply is usually bad."

III.

MAIGNEN'S "FILTRE RAPIDE" AND "ANTI-CALCAIRE" CO., Limited, *255, Regent Street, W., and 34, Eastcheap, E.C.*—The method of filtration carried out in the many forms of filter which are sent out by this firm appears to be the same in all cases. The water passes first through a layer of granular carbon, which is protected from the direct onset of the water by means of a china screen or breakwater, then through a layer of very fine powder which has been deposited in the meshes of an asbestos screen, and finally through a sheet of asbestos cloth. The medium employed is known as "patent carbo-calcis." It is stated that this filter "will remove from water germs of disease, organic matter, and every trace of metallic poison." "The water that issues from the filter is clear and pure......a perfect beverage and a preventative against disease. The particles of the filtering medium are so small, they lie so close together, that nothing whatsoever that has a body, however small, can pass through......The water that issues from it is better than that of the finest spring, and a perfect guarantee against disease."

The forms of their filters with which we worked were:—

1. Cottage filter No. 1 (page 15 of their catalogue).
2. One pint table filter.

(1) Cottage Filter No. 1.

Table XVIII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	2,000 to 4,000	10 to 15
Cholera bacillus (first day)	5,000 to 6,000	40 to 50
Cholera bacillus (second day)	—	150 to 200
Typhoid bacillus	20 000 to 30,000	20

Table XIX.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm in the Filtrate
First day, sample No. 1	—	Not recorded
" " " No. 2	50	0
Second day " No. 1	60	3 to 4
" " " No. 2		4
Third day " No. 1	25	18
" " " No. 2		20
Fourth day " No. 1	30	400
" " " No. 2		100
Fifth day " No. 1 ...	—	Not recorded
" " " No. 2 ...	20	300

(2) One Pint Table Filter.

Table XX.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	50 to 60
Cholera bacillus	10,000	800 to 1,000
Typhoid bacillus	10,000 to 15,000	5 to 6

Table XXI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	40 to 50	0
,, ,, ,, No. 2		2

No. 3. Field Hospital Service Filter.

Table XXII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	100 to 150

3. Field hospital service filter, for the use of which we are indebted to the courtesy of the Director-General of the Army Medical Department.

As will be seen on comparing these results with those obtained from other table and household filters, the filtration is not nearly so imperfect as in many of the other cases. It will also be noted that the results obtained vary greatly in different instances; this requires a word of explanation. As it seemed to us very probable that the fine deposit of powdered carbo-calcis might easily be disturbed in the process of sterilising, and thus give rise to imperfect action on the part of the filter, we usually preferred in the case of the test organisms to use a fresh charge on each occasion without sterilising. The difference in action of the filters in the different cases is accordingly to be referred in part to the degree of perfection of the deposit on the asbestos screen, which had been formed in each case. There can be no doubt that this may vary in different cases, and is practically beyond our control even when the greatest care is exercised. It must also be observed that even where the filter appears to be acting at its best the pores are large enough to permit of the passage not merely of the staphylococcus pyogenes aureus, but also of the much larger white yeast in its true proportions, although it may be suggested that this was due to a minute crack or fault present on some part or other of the filtering surface. We must also point out that, as might naturally be expected in the case of a filtering medium consisting of fine granular particles, the organisms are gradually washed through into the filtrate on continued use, and appear in much increased proportions, as is shown in the case of cholera bacillus (Table XVIII) on the second day.

We have also carried out an extended experiment with Cottage Filter No. 1, to ascertain how long, having once been infected, it would remain capable of infecting with cholera when afterwards fed daily with ordinary tap water. From the following table it will be seen that Koch's cholera bacillus could still be separated on the 32nd day, but at the end of six weeks a negative result had to be recorded.

Table XXIII.—*Filtre Rapide, Cottage No. 1.—Cholera.*

2nd day.	4th day.	5th day.	6th day.	7th day.	8th day.	12th day.	16th day.	21st day.	28th day.	32nd day.	42nd day.
+	+	+	+	+	+	+	+	+	+	+	—

Although, as we have said, these filters act in a relatively much more perfect fashion than most of those with which we have had to deal, still it cannot be contended that they confer any protection against the communication of infective disease, inasmuch as, although a large proportion of the micro-organisms are undoubtedly retained in the meshes of the filter, yet in course of time, in all probability, these, or at any rate the greater number of them, pass into the filtrate, and are drunk by the consumer. Now as the manufacturers of these filters state as among the requisites of a good filter that it should include the provision to arrest "the suspended matter, large and small......even the spores of cholera and typhoid fever germs, algæ, diatoms, and all other microscopical and ultra-microscopical organisms"—we cannot agree with their statement that this filter possesses these qualities, and is "a perfect guarantee against disease."

IV.

The Atkins Filter and Engineering Company, Limited *(Contractors for Filters to H.M. Government)*, 65, *Farringdon*

Road, London, E.C., and Chepstow, Monmouthshire.—The filtering medium in the filters supplied by this firm consists of a block or plate of compressed charcoal, with or without the addition of an outer layer of coarse granular charcoal. We have examined two of these, namely :

1. Admiralty pattern (Fig. 1). The manufacturers state

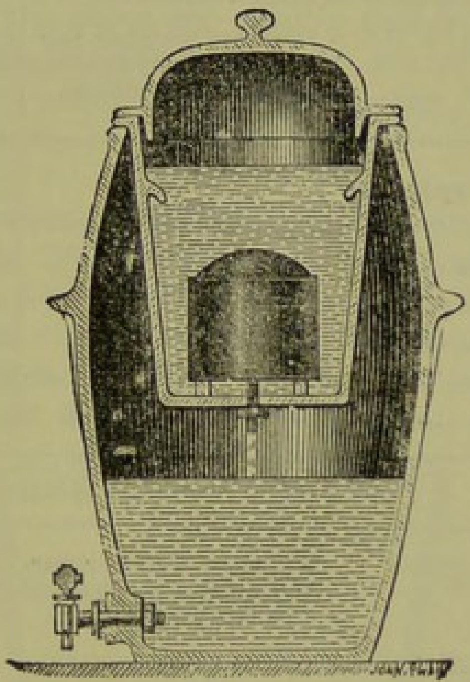


Fig. 1.

that over 5,000 of these have been supplied to Her Majesty's Government for use in military hospitals and barracks.

2. Pocket filter (the official War Office pattern). These are stated to be used largely in the army, no fewer than 17,000 having been supplied. Here also the filtering medium consists of a cake of compressed charcoal in which is embedded a metal tube, to one end of which a piece of india-rubber tubing is attached, the other end having a mouthpiece through which the water is drawn into the mouth.

The manufacturers of these filters insist upon the fact that many cases of blood poisoning, typhoid fever, diphtheria, measles, small-pox, etc., in private families are to be attributed directly to improperly constructed filters, or to what is the same thing (since one is the consequence of the other), the filters being kept not properly cleaned. They point out that in the country, frequently, considerable expense is incurred in obtaining a water supply from a distance where those closer at hand are contaminated, an expense which may be obviated by the application of their system of filtration to the impure water supply, and they state, "in all cases, no matter what the quality of the water, the Company's treatment has always been thoroughly successful, and the most foul, noxious water has been converted into a clear pure, and wholesome supply." Amongst the waters so treated they mention "pond water full of animalculæ, vegetable matter, and sediment"; "land drainage water containing many impurities"; "well water containing animalculæ, sewage matter, etc."

(1) Admiralty Pattern.

Table XXIV.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	800 to 1,000
Cholera bacillus (first day)	5,000 to 6,000	300 to 400
Cholera bacillus (second day	—	500 to 600
Typhoid bacillus	20,000 to 30,000	5,000 to 6,000

Table XXV.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	50	10
Second day, " No. 1 } " " " No. 2 }	60	{ 150 { 80
Third day " No. 1 } " " " No. 2 }	25	{ 200 to 300 { 100 to 130
Fourth day " No. 1 } " " " No. 2 }	30	{ 500 { 200
Fifth day, " No. 1	—	Not recorded
" " " No. 2	20	1,000

(2) Pocket Filter.

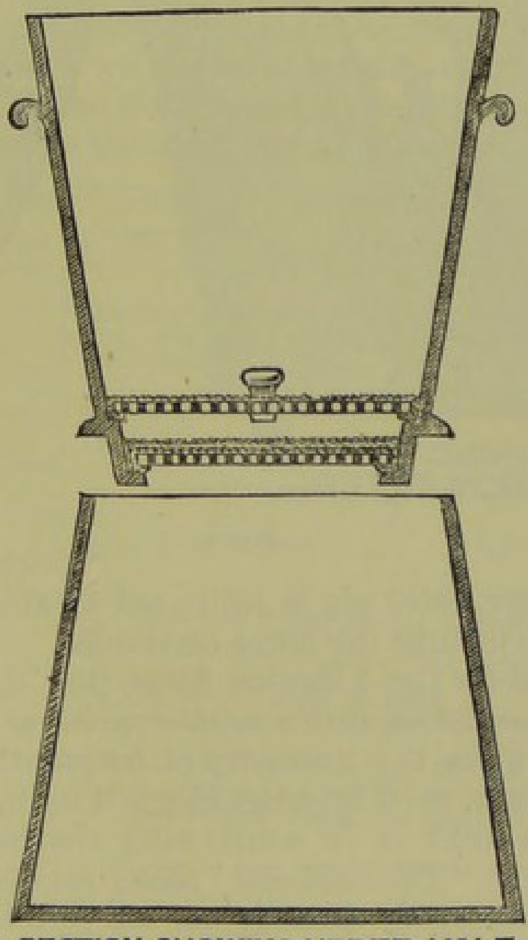
Table XXVI.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	4,000 to 5 000
Cholera bacillus	10,000	1,000
Typhoid bacillus	8,000 to 10,000	200 to 25

As will be seen from the above tables, these filters confer no protection against the direct passage of disease germs into the filtered water, and the danger attendant upon the adoption of such a filter as an army pocket filter, which would be relied upon to render dangerous waters wholesome, is at once obvious. As regards the danger of contaminations being added to the water as a result of the filter itself becoming polluted—a point upon which the manufacturers lay so much stress—although their own types appear to possess the advantage over many of the others which we have investigated, that the parts are readily accessible for the purposes of cleansing, the filter does not confer any protection against the direct passage of disease germs, which ought to be its chief function.

V.

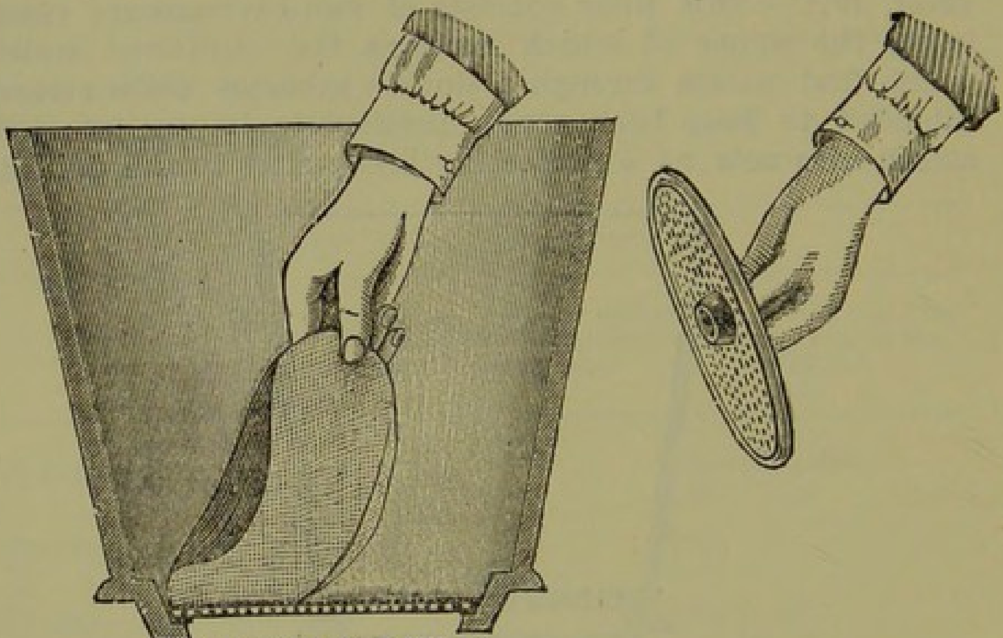
Messrs. the Nibestos Filter Company, *126, Charing Cross Road, W.C.*—This filter consists of two earthenware reservoirs, the upper of which receives the unfiltered water, which first passes through a double asbestos cloth screen, intended to keep back rough particulate impurities; this screen also acts as a protecting breakwater to the delicate



SECTION SHOWING UPPER HALF SLIGHTLY RAISED.

Fig. 2.

filtering layer proper, which consists of a film of purified asbestos, so treated that when the water comes in contact with it, it pulps and forms so fine a medium that it is claimed that no impurities, visible or invisible (microbic) can pass through it. This film is about one-twelfth to one-eighth of an inch thick, and appears to consist of some form of deposited asbestos; it is exceedingly delicate in its texture, as is seen when a small portion is teased out in water. This film rests on a pad of woven asbestos cloth which in turn is supported by the bottom of the upper reservoir, which is perforated with small holes (about one-sixth of an inch in diameter). After being carefully placed in position it is damped and pressed home with a soft brush or the back of the flexed fingers. The coarse upper asbestos screen is then fitted in position, where it is supported by a ledge which prevents it from coming into actual contact with the asbestos film. The interval between the two screens which commu-



REMOVING OLD FILM FROM FILTER.

Fig. 3.

nicates with the outer air is supposed to aid in aërating the water which falls into the lower reservoir.

It is claimed for the Nibestos filter that it is "*adjusted to remove all suspended impurities whether visible or invisible.*" Great stress is laid upon the necessity of frequently renewing the filtering medium, as it becomes clogged up by the impurities in suspension that it is continually abstracting from the passing water. "*The 'Nibestos' filters are constructed so that they can be thoroughly cleaned; the old filtering medium being taken out, thrown away, and replaced by new, with ease, rapidity, and at trifling cost.*"

From a circular which is issued by this firm (for private distribution only), the filters appear to have undergone an extensive series of tests at the hands of two scientific experts, who report that these filters in every case "perfectly removed all visible suspended matter." Their experiments as regards invisible suspended matter (microbes) were carried out on Thames water, taken from the river at Waterloo Bridge. "Plate cultures were made before and after filtration. The various samples of Thames water before filtration contained from 10,000 to 30,000 microbes in every cubic centimetre. After filtration neither of the samples contained any microbes whatever; no bacteria, no bacilli, no micrococci."

As regards the removal of visible suspended matter, these, with the exception of milk, were all completely removed, as will be seen on reference to the general table (No. 1) already given. This places the filter on a much higher level than most of those already examined. The finest gunpowder charcoal and artificial ultramarine were both apparently completely retained on the surface of the filter, but on the other hand milk (diluted) passed through into the filtrate. This affords evidence that the interstices of the filter are extremely fine. The experts who have reported on the filter seem to have carried out some of their experiments with the asbestos films alone, using them just as ordinary paper filters are used in chemical laboratories, experiments which we repeated, but we must draw our conclusions only from the results obtained with the film placed in the filter as it is ordinarily used, as this is the only way in which we can form an

THE "NIBESTOS" FILTER.

TABLE XXVII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	400 to 500
Cholera bacillus (first day)	5,000 to 6,000	1,500 to 2,000
Cholera bacillus (second day)	—	15,000 to 20,000
Typhoid bacillus	20,000 to 30,000	10,000 to 15,000

TABLE XXVIII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	40	Not recorded
" " " No. 2		3
Second day " No. 1	50	30
" " " No. 2		50
Third day " No. 1	60	400 to 500
" " " No. 2		150 to 200
Fourth day " No. 1	25	Innumerable
" " " No. 2		500

opinion as regards the manner in which the filter would function. The results of our experiments with test organisms and with water from the tap are given in Tables XXVII. and XXVIII.

It may be mentioned that the water collected for examination was not taken from the tap of the receiver, but was allowed to drip directly into a sterilised vessel placed underneath the film in the receiver. The whole arrangement of this filter is simple in the extreme, and the mechanical fittings are excellent.

It is seen at once that this filter does not keep back either water or pathogenic organisms, and it is evident that we have the same washing down process at work that has been noticed in the other filters. Some experiments that we made with films (used in the same fashion as ordinary filter paper, that is, as a funnel-shaped filter) gave somewhat different and more satisfactory results, but these require no further consideration in this report.

It is evident accordingly that this filter does not afford any protection against the communication of infective disease through drinking-water. At the same time, as a filter which removes all visible suspended material, it presents patent advantages over any of the other ordinary forms of domestic or household filters which are used for this purpose—none of which, as we shall presently see, afford any protection against infective disease—from the fact that the filtering media can be so readily removed, in consequence of which the most serious risk and objection to the use of such a filter is as far as possible obviated.

VI.

FR. LIPSCOMBE AND CO., *Water Filter Manufacturers to the Queen, the Prince of Wales, the Emperor of Germany, the Viceroy of Egypt, 45, Queen Victoria Street, London, E.C.; and 233, Strand, Temple Bar, W.C.*—The filtering medium adopted by this firm seems to consist of some form of carbon usually associated with a screen of asbestos cloth. We have examined two examples of the filters of their manufacture:

1. A simple solid block of carbon.

2. The new patent cylinder filter, which consists of

(*a*) An outer covering of asbestos cloth, which, it is contended, catches the impurities present in the water on its surface, from which they can be easily removed.

(*b*) A perforated earthenware cylinder containing some prepared form of charcoal.

(*c*) A second layer of asbestos cloth, which is also supposed to act as a strainer.

It is claimed that it is "the only filter which removes lead and sewage from water." The makers state that "all Lipscombe and Co.'s filters are made with their new preparation of carbon, wonderfully effective, far surpassing every other," and that the new patent filter "will purify most perfectly river, pond, rain, and spring water." The usual statements as regards the transmission of disease by means of water are made, and the desirability of a good water filter as a household necessary is insisted on.

(No. 1.) Solid Carbon Block.

Table XXIX.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	4,000 to 5,000
Typhoid bacillus	15,000 to 20,000	6,000 to 8,000

Table XXX.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	—	Not recorded
" " No. 2 ...	40	18
Fourth day, first sample }	50	{ Innumerable
" second sample }		{ 400 to 500

(No. 2.) New Patent Cylinder Filter.

Table XXXI.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	8,000 to 12,000	400 to 500
Typhoid bacillus	6,000 to 8,000	100 to 200

Table XXXII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	—	Not recorded
" " No. 2 ...	35	21
Fourth day, sample No. 1 }	40	{ Innumerable
" " No. 2 }		{ 500 to 600

A very cursory examination of the above tables indicates that these filters provide us with no protection against the passage of disease micro-organisms, and we have been able to detect no special advantages, in this respect, in their new patent form of carbon as regards microbes. Although the reduction in the amount of *soluble* organic matter, which is certified to by a well-known chemist, is of course quite within the limits of probability, this would certainly not warrant us in looking upon the water as in this way rendered "safe and wholesome."

VII.

THE LIPSCOMBE FILTER COMPANY, Ltd., *146, Oxford Street, London, Manufacturers to the Royal Family, H.M. Office of Works, the Navy, the Military Department, the London Hospitals, most of the Country Hospitals and Infirmaries, etc.*—The filters supplied by this firm appear to have, usually, as the filtering medium some kind of prepared charcoal, used in powder and in a granular form in layers, apparently combined with asbestos. These substances are used in slightly different forms in the different filters, but they exhibit no new principle which distinguishes them from many of the other filters which are at present in general use. This company also sends out a solid carbon block filter. These substances are supplied as domestic, pocket, cistern, and large supply filters.

We have examined an example of each of the following two forms:

1. In which the filtering medium consists of the combined powdered and granular charcoal, and
2. The solid carbon block filter.

The claims put forward for these filters by their manufacturer are more far reaching than are those made for any filter that has as yet been brought under our notice—that is, that it is "the only reliable filter for perfect purification"; that they "for simplicity, efficiency......durability, economy, and for security against typhoid fever, cholera, and blood poisoning are unequalled." They state that their patent easily-cleaned filters "are three times more efficient, and seven times more durable, than any other." They assert also that "more than 300,000 are in use."

(1) COMBINED POWDERED AND GRANULAR CHARCOAL.

TABLE XXXIII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	1,000 to 1,500
Cholera bacillus (first day)	5,000 to 6,000	300 to 400
Cholera bacillus (second day)	—	5,000 to 6,000
Typhoid bacillus	20,000 to 30,000	9,000 to 10,000

TABLE XXXIV.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
„ „ „ No. 2	40	12
Second day, „ No. 1 } „ „ „ No. 2	50	{ 60 50
Third day, „ No. 1 } „ „ „ No. 2	60	{ Innumerable „
Fourth day, „ No. 1 } „ „ „ No. 1	25	{ „ „

(2) SOLID CARBON BLOCK.

TABLE XXXV.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	800 to 1,000
Cholera bacillus (first day)	5,000 to 6,000	1co
Cholera bacillus (second day)	—	6,000 to 8,coo
Typhoid bacillus	20,000 to 30,000	5.000 to 6,000

TABLE XXXVI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
„ „ „ No. 2	40	10
Second day, „ No. 1 } „ „ „ No. 2	50	{ 60 40
Third day, „ No. 1 } „ „ „ No. 2	60	{ Innumerable „
Fourth day „ No. 1 } „ „ „ No. 2	25	{ „ „

It is also stated in their circular that "the only possible safeguard against the evil of contaminated water is efficient domestic filtration. You may by this means easily, and at a small cost, totally prevent all danger, from whatever source you derive your supply." They even go so far as to say that boiling the water is less efficient than the use of one of their filters. "Many housewives think that boiling the water is all that is necessary. This is an erroneous idea. The temperature of boiling water is not sufficient to destroy the vitality of certain species of germs. In fact, it has been proved by scientific research that water which contains much organic matter is even rendered more unwholesome by boiling, because the evaporation of a portion of the water by the heat only serves to concentrate that which remains."

A mere glance at the foregoing tables suffices to show how baseless are the claims put forward by the vendors as regards the action of their filters in safeguarding against the passage of the germs of "typhoid fever, cholera, and blood poisoning." These filters function, indeed, in no way differently from most of the other filters on the market, but we draw special attention to them for the reason that such pretentious claims are put forward on their behalf, which may no doubt have induced the public in many instances to place unwarranted trust in them. This is all the more unfortunate in that the practice of boiling water—the most efficient safeguard known to sanitary science—is discouraged, "as inefficient," whilst the public are encouraged to place implicit reliance on this special filter.

VIII.

The Magnetic Filter Company, *32a, Euston Square, London, N.W., and 17, Water Street, Liverpool.*—The magnetic carbide material which is used by this firm is supplied, not merely for the purposes of domestic filtration, but also for clearing and purifying town water supplies. The action of this filter,

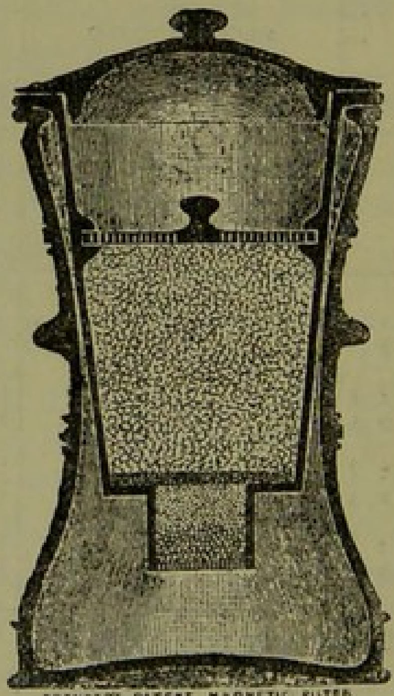


Fig. 4.

as stated by the vendors, is claimed to be both a physical and a chemical one, but more stress appears to be laid on the latter. At the same time it is asserted that this medium acts also bacteriologically (either chemically or physically) in arresting the germs of disease, as is shown by the following quotation: "Further, experiments made have conclusively shown that water containing disease germs, bacteria, etc., is rendered completely pure and harmless by being passed through the medium." Our examination was carried out with their domestic filter, style A, three quarts (Fig. 4), the results of which are appended:

TABLE XXXVII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	600 to 800
Cholera bacillus (first day)	5,000 to 6,000	100 to 150
Cholera bacillus (second day)	—	15,000 to 20,000
Typhoid bacillus	20,000 to 30,000	10,000 to 15,000

TABLE XXXVIII.—*Tap Water.*

		Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample	No. 1	40	Not recorded
" " "	No. 2		6
Second day "	No. 1	50	40 to 60
" " "	No. 2		16
Third day "	No. 1	60	Innumerable
" " "	No. 2		500
Fourth day "	No. 1	25	Innumerable
" " "	No. 2		500 to 1,000

As will be seen from the above tables these filters confer no protection against the passage of disease germs, and their claims in this respect must accordingly be rejected.

The following table shows that the filter, after being once infected with cholera organisms, gave evidence of their presence in the filtrate eight days later:

XXXIX.—*Cholera bacilli.*

	1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.
Filter infected with cholera bacilli.	+	+	+	+	+	+	+	+

IX.

SPONGY IRON FILTER COMPANY, *22, New Oxford Street, London, W.C., Sole Purveyors to Her Majesty the Queen by Appointment.*—The manufacturers of this filter state that their medium exerts a strong chemical action on the impurities which may happen to be present in the water. They urge that charcoal filters favour the growth of certain lower forms of life, and thus compare unfavourably with the spongy iron used as their filtering medium. The filtering mechanism consists, as seen in Fig. 5, of three parts: First, an upper layer of spongy iron; second, an intermediate layer of pyrolusite; third, a

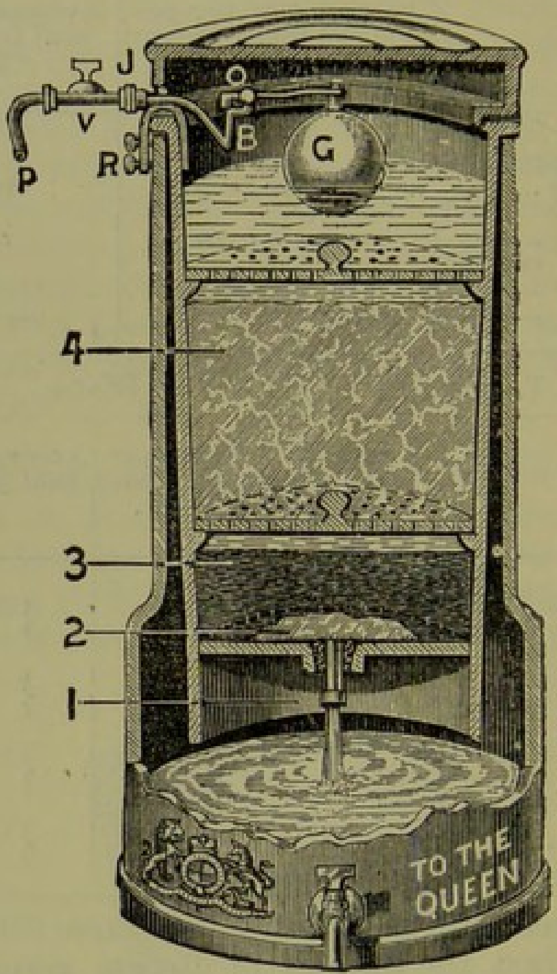


Fig. 5.

bag of asbestos cloth, on which the latter rests. No direct claims are put forward on its behalf as regards the prevention of the passage of disease organisms, but a quotation is made from a report of the Royal Prussian Military Administration, in which the non-recurrence of typhoid fever is attributed to the use of these filters under the heading "Zymotic Diseases Arrested by Spongy Iron Filters." This firm supply their filtering medium for use in table and domestic filters, cistern filters and pocket and tourist filters. Our examination was carried out on two of the quart table filters (No. 1 of glass and No. 2 of glazed porcelain). The results are given in the following tables:

On examining the tables it will be seen that, although at first a very large proportion of the organisms present is kept back, yet there can be no doubt that these ultimately find their way into the filtrate; thus in the case of cholera bacilli,

(1) Quart Plain Glass.

Table XL.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4 000	50 to 60
Cholera bacillus (first day)	5,000 to 6,000	30 to 40
Cholera bacillus (second day)	—	120
Typhoid bacillus	20,000 to 30,000	3,000 to 4,000

Table XLI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	40	2 to 3
Second day " No. 1 } " " " No. 2 }	50	{ 16 { 3
Third day " No. 1 } " " " No. 2 }	60	{ 500 { 200
Fourth day " No. 1 } " " " No. 2 }	25	{ Innumerable { 500

(2) Quart Glazed Porcelain.

Table XLII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	80 to 90
Cholera bacillus	10,000	100 to 150
Typhoid bacillus	10,000 to 15 000	40 to 50

on the first day only 40 colonies per c.c. appeared in the plates made from the filtrate, but on the next day these had risen to 120, and would no doubt have appeared in still greater numbers on succeeding days, as the bacilli were gradually washed through into and from the deeper layers of the filtering medium. We have also found little evidence to support the statement that spongy iron does not "favour the growth of low forms of life" in the same way as animal charcoal and porous charcoal blocks do. Thus the water from the filters in both cases on the fourth day contained at least ten times as many germs as were present in the original tap water.

TABLE XLIII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	50	5
Fourth day " No. 1	45	Innumerable
" " " No. 2		400 to 500

We have also carried out an extended experiment with No. 1 filter, in which we were able with ease to distinguish cholera bacilli in the filtrate up to the eighth day, when the investigation was discontinued.

TABLE XLIV.—*Cholera bacilli.*

Date of Sample	1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.
Presence or absence of cholera	+	+	+	+	+	+	+	+

There can accordingly be no question that these filters allow of the free passage of disease germs; and that when either a domestic or a pocket filter once becomes infected, the filtered water will for a considerable time contain disease organisms, thus increasing enormously the risk of infection when any of the water used happens to have been infected.

X.

THE MORRIS TUBE COMPANY, LIMITED, *11, Haymarket, London, S.W. The Morris Patent "Circulating" Filter, as supplied to Her Majesty's Army and Navy, pronounced by the Medical Profession and Experts on Water to be the most scientifically perfect Filter ever offered to the public.*—"The special feature in this system is the bringing of each particle of water into contact with a great number of particles of carbon or other medium charged with air. . . . . . This condition is brought about by first causing the water to take a circuitous up and down course through various sections of filtering medium, the bulk of which is frely open to the air; and, secondly, by making the outlet freer than the inlet, so that the water is constantly escaping, and cannot accumulate in the centre of the filter and flood the medium."

The object of the filter is to oblige the water to pass through as deep a layer of filtering medium as possible—(1) finely granular, and (2) more coarsely granular charcoal—and at the same time to ensure its most perfect aëration. This result is undoubtedly obtained in a most ingenious manner. The vendors state that "any filtering medium can be used in the Morris filter, such as spongy iron, well-burned animal charcoal, etc., but manganous carbon has been selected, after careful tests, as being the most suitable." They claim, in addition, that "this filter possesses such great purifying power that after exhaustive competitive trials by Government experts it has been adopted by Her Majesty's Army and Navy," and their analyst says: "The action of the filter is simply wonderful; it has, in fact, rendered a horribly polluted and dangerous water an almost absolutely pure one, as far as organic contamination is concerned."

Our experiments were carried out on two of these filters:

1. A two-gallon domestic filter, which was charged with Doulton's manganous carbon.

2. A four-gallon domestic filter charged with charcoal of unknown origin, for the use of which we were indebted to the courtesy of the Director-General of the Army Medical Department.

As we received the latter filter when our investigation was drawing to a close, we subjected it to our preliminary test only—the passage of yeasts and staphylococcus pyogenes aureus, which indicates clearly, however, its permeability to micro-organisms. The results obtained will be found in the following tables:

(1) Two-Gallon Domestic Filter.

Table XLV.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000	30 to 40
Cholera bacillus	10,000	500 to 600
Typhoid bacillus	10,000 to 15 000	150 to 200

Table XLVI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	50	6
Fourth day " No. 1 }	45	} Innumerable
" " " No. 2 }		} 200 to 400

(2) Four Gallon Domestic Filter (Army Medical Department).

Table XLVII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	5,000 to 6,000	6 to 10

On examining the tables, it will be observed that only a very small proportion of the organisms originally present in the fluid appear in the filtrate when initially tested; but this is without doubt due to the depth of filtering medium through which the water has to pass, and had the filters been examined from day to day the proportion of organisms obtained would undoubtedly have rapidly risen as they were washed through into the filtrate. It may be noted that this filter functions admirably as regards the aëration of water, and may perhaps be used with advantage for rendering boiled and condensed water brisk and palatable. It cannot, however, in our opinion, be contended that these filters render unwholesome water less dangerous as regards the transmission of infective disease.

XI.

George Cheavin's New Patent Idiocathartes Removable Plate Water Filters, *under the distinguished Patronage of Her Most Gracious Majesty the Queen of England, His Royal Highness the Prince of Wales, His Majesty Leopold II, King of the Belgians; Her Majesty the Queen of the Netherlands, His late Imperial Majesty Napoleon III, Emperor of the French, etc.*—The filters supplied by this firm consist oi domestic, pocket, and cistern filters. The composition of the filtering medium is not stated, but, so far as we are aware, is the same in all patterns. It is stated by the vendors that "It is the only filter that can be depended upon to remove effectually from water all germs of disease, metallic impurities, lead, zinc, etc., dissolved in it, as well as all animal, vegetable, and earthy impurities held in suspension, and absolutely cleansing it from all particles of lead, zinc, lime, iron, sewage, organic, mineral, and saline impurities held in solution. It affords a certain protection against the dangers that lurk in the domestic water supply, and is guaranteed to remove all germs of cholera, typhoid, diphtheria, and all causes of blood poisoning, etc. It is the best possible preventive of cholera, typhoid fever, and all other diseases arising from drinking impure water. No water should be used for drinking or cooking without being effectually purified, and no house can be thoroughly furnished without such a filter. The 'New Idiocathartes,' which is prepared by means of recent and valuable improvements, has a wonderful power. It gives up nothing to the water, but, on the contrary, absorbs in and on its pores, and burns up, as it were, all matter capable of oxidation. It not only arrests microbes, and all other suspended matter, dead or alive, but also removes all noxious matter in solution, such as sewage or metallic poisons and deleterious gases. No filtering medium possesses so powerful and so

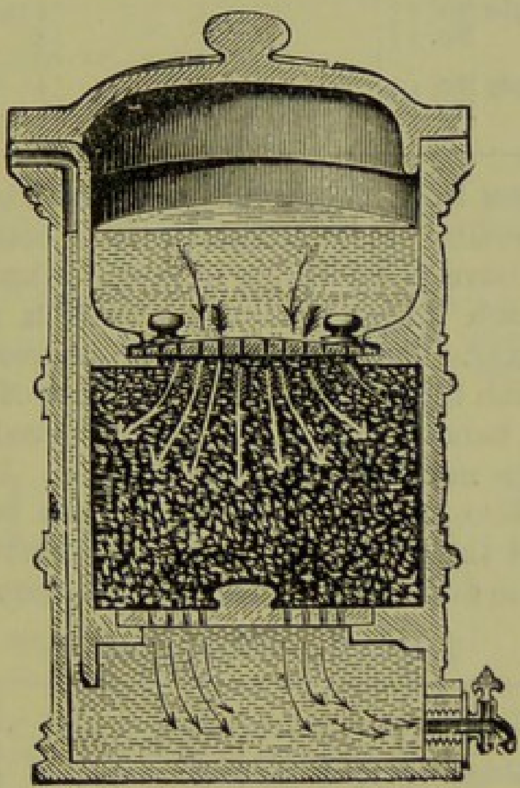


Fig. 6.

strong and absorbent and purifying a powder as our 'New Idiocathartes.' The water that issues from it is better than that of the finest spring."

We have tested the claims of this filter on domestic filter A of their catalogue, and the results obtained are appended in the accompanying tables.

TABLE XLVIII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	3,000 to 4,000	800 to 1,000
Cholera bacillus (first day)	5,000 to 6,000	1,000 to 1,500
,, (second day)	—	8,000 to 10,000
Typhoid bacillus	20,000 to 30,000	10,000 to 15,000

TABLE XLIX.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " No. 2	40	23
Second day, sample No. 1	50	400 to 500
" " No. 2		50 to 60
Third day, sample No. 1	60	Innumerable
" " No. 2		"
Fourth day, sample No. 1	25	"
" " No. 2		500 to 1,000

As will be seen from these tables, these filters exert no influence in arresting micro-organisms, a conclusion which might indeed have been drawn from the ultramarine experiments, the much larger particles of which readily passed through the filter. It was necessary, however, to repeat the experiments with disease organisms in view of the claims put forward on its behalf, and as will be observed these passed through in large numbers into the filtrate. An extended experiment was also carried out with cholera bacilli, in which the presence of the disease microbe was demonstrated in the filtrate up to the eighth day after one infection.

TABLE L.—*Cholera bacilli.*

Date of Sample	1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.
Presence or absence of cholera bacillus	+	+	+	+	+	+	+	+

From these experiments it is obvious to what risk the vendors of these filters expose an unsuspecting public by the truly remarkable claim as to the purifying properties that they make for this filter, which, so far as the evidence we have obtained goes, is absolutely without foundation.

XII.

THE CROWN FILTER COMPANY. *Manufactory and Show Rooms, 66, Bishop Street, Port Dundas, Glasgow.*—The filtering medium adopted by this firm appears to be some preparation of charcoal used either alone as a simple compressed block or combined with an outer covering of granular charcoal. We have examined only one form of this filter, the simple block of compressed charcoal, as our previous experiments with similar material had already indicated that a covering of loose charcoal only affects the time required for the organisms to be washed through, but affords no protection as a filtering medium. The specimen experimented with was a quart glass table filter.

TABLE LI.—*Test Organisms.*

	Average Number per c.cm. orginally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	4,000 to 5,000
Cholera bacillus	10,000	3,000 to 4,000
Typhoid bacillus	10,000 to 10,000	5,000 to 6,000

TABLE LII.—*Tap Water.*

	Average Number per c.cm. originally present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	—	Not recorded
" " " No 2 ...	50	14
Fourth day, " No. 1	45	Innumerable
" " " No. 2		1,000 to 1,500

In the circular issued by this firm the necessity of freeing water "from all pollutions that generate disease" is insisted upon, and the statement made that the only remedy is "regular and judicions filtration." It is claimed for their filters that "impure water is made sweet and wholesome." The results obtained in our experiments are given in Tables LI. and LII.

It will be seen from these tables that the compressed charcoal exerts no appreciable action as regards the retention of micro-organisms, and cannot accordingly render "impure water.........sweet and wholesome," as is contended by the manufacturers.

XIII.

JACOB BARSTOW AND SONS' PATENT COMBINATION NATURAL STONE AND CARBON FILTERS, *supplied to Her Serene Highness Princess Mary Victoria of Teck, the Empress Eugenie, the Prince of Monaco, the Belgian and other Governments, have never yet received a second or an inferior award at any time, but have won thirty-one Gold and other First Prize Medals, Filter Works, Pontefract, England.*—The filtering medium adopted by this firm consists of a combination of natural porous stone and carbon, which they assert "possesses the following advantages over every other filter: 1. The water passes through two distinct processes for its purification. 2. The vessel which holds the water to be filtered is made of a natural stone, through which the water percolates (leaving all the suspended impurities on the surface of the stone, from which they can be easily washed), and in hot weather acts as a first-class cooler. 3. The water is thus passed on to the next process perfectly clear and bright, and the impurities in solution can then be perfectly removed by the specially prepared carbon, and for a much longer period in consequence." The manufacturers fit up their combined filtering medium in all the forms which are in general use—table, domestic, cistern, tap, and pocket filters. We have examined one of their quart glass table pattern, and also a tap filter, but at present report only on the former. It is claimed for these filters that they "remove

QUART GLASS TABLE FILTER.

TABLE LIII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	8 000 to 10,000	200 to 300
Cholera bacillus	10,000 to 15,000	100 to 150
Typhoid bacillus	8,000 to 10,000	400 to 500

TABLE LIV.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	—	Not recorded
,, ,, ,, No. 2 ...	30	8
Fourth day, first sample	45	Innumerable
,, ,, second ,,		300 to 400

all impurity, whether in suspension or solution, such as lead, iron, copper, sewage, lime, all decomposed animal and vegetable matter, and bacilli, etc., from water." They also append an analytical report that contains the following statement: "The filter was tried with water containing a large number of a very discernible kind of bacilli. Even after the filtered water had stood for a long time, we could not find the bacilli again. Then the filter was completely disinfected, and water containing about 200,000 bacilli per gramme put into it. After filtration it was quite free from bacilli............ From these tests we draw the conclusion that 'Barstow's water filter' is excellently adapted for rendering even very impure water drinkable."

Tables LIII and LIV indicate at once that this filter possesses no power to prevent the passage of micro-organisms. It will be observed, however, that frequently a very large proportion of the microbes are retained in the filter, but this is to be accounted for by the fact that a certain time and successions of flushings are required to wash these into the filtrate, into which, however, they would undoubtedly pass in the course of time. At the same time, so far as regards the removal of suspended matter from the water and rendering it brisk and palatable, it possesses certain advantages over many of the other filters in common use, but as regards the prevention of the transmission of disease organisms the claims put forward on its behalf are absolutely without foundation.

XIV.

ALCARAZAS FILTER, PASTEUR'S PRINCIPLE, "ROCH-BRAULT" PATENT, *Agents, Hersey Brothers, Limited 70, Berners Street, W.*—The vendors state that "filtration by porcelain

TABLE LV.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus	8,000 to 10,000	20 to 30
Cholera bacillus	15,000 to 20,000	10 to 15
Typhoid bacillus (first day)	10,000 to 15,000	1 ?
Typhoid bacillus (second day)	—	400 to 500

TABLE LVI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	35 to 40	0
" " " No. 2		2 ?
Second day, " No. 1	"	Not recorded
" " " No. 2		50 to 60
Third day, " No. 1	"	600 to 800
" " " No. 2		600 to 800
Fourth day, " No. 1	"	2 000 to 3,000
" " " No. 2		1,500 to 2,000

is, according to Pasteur and his colleagues, the only method that effectually prevents the transmission by water of epidemic maladies, such as cholera, typhoid, diphtheria, etc. The Alcarazas Filter is constructed on this theory; the filtering material being composed of artificial porcelain......The material is an artificial product, in which the pores are determined to a definite degree (in natural stone the pores are never uniform; portions vary in density, consequently the filtration varies). The exact porosity required having been ascertained after exhaustive experiments with the double object of the material being sufficiently porous to filter the water to a given quantity, and at same time to be dense enough to entirely arrest microbes or germs......The system of filtration by prepared porcelain has been adopted by the French Government on the recommendation of M. Freycinet (War Minister), and is now extensively employed in the barracks and hospitals."

We must draw attention here to the extreme danger of drawing the conclusion that because Pasteur, after long and tedious experiment, has obtained certain results with a specially prepared form of porcelain that similar results will be obtained, as is assumed by some filter makers, by other forms of porcelain.

M. Pasteur has stated that the use of his name in connection with any filter except that which was worked out and tested in his own laboratory by M. Chamberland is made without his authority and against his will. The bare use of unglazed earthenware for filtration is, of course, considerably older than Pasteur, and its efficiency appears to depend, not only on the precise porosity of the medium, but also to some considerable extent on the surface tension, between its particular constituents and micro-organisms. The Alcarazas filter may or may not arrest microbes, but absolutely no inference that it does can be drawn from the fact of its being composed of earthenware. The statement as to the French Government is true only in respect to the Chamberland or Pasteur filters.

Our experiments have been carried out with the No. I type, fitted in a bamboo stand. It consists of a large unglazed porcelain bowl with a lower receptable provided with a tap. The fittings in this filter are excellent, and, so far as regards the removal of visible suspended matter and rendering the water cool and pleasant, it may, no doubt, function admirably were it not that the rate of filtration is very slow. We may remark that the prepared porcelain, which serves as a filtering medium, is apparently much thicker than that required in the Pasteur-Chamberland candles, which at once raises doubts as to its efficacy, since, unless the medium absolutely arrests the microbes, its mere depth simply affects the time required to wash them through into the filtrate.

Our examination has shown this to be the case, as although the first portions of filtrate passed were sometimes germ free, yet continued filtration and examination on the succeeding day always revealed the presence of the test organisms. We may also mention that the thickness of porcelain presents great difficulties as regards sterilisation with boiling water—a fact we observed on several occasions in our experiments.

We may mention here that this was the only filter in which we had any difficulty in determining as to whether it should be classed under heading "A" or "B," that is to say, whether or not it allowed of the direct passage of micro-organisms. The difficulty was undoubtedly due to the slow rate of filtration, and to the fact that the density and thickness of the porcelain necessitated a succession of changes of water to wash through the organisms. In Table LVI, containing the results of our experiments with tap water, it will be observed that after the second day the two samples which were taken contained approximately the same number of organisms—a result which at once distinguishes it from those obtained in the case of the other filters. This was no doubt due to the water organisms which had multiplied and accumulated in the filtering medium, being only slowly and regularly washed through into the filtrate instead of being (as is usually the case) concentrated in the first sample collected.

It is evident from our experiments that the Alcarazas filter does not act in the same way as the Pasteur-Chamberland filter, since the latter gives an absolutely germ-free filtrate when directly charged with test organisms. This filter accordingly confers no protection against the passage of disease organisms, and the assumption of the makers that it functions in the same way as the Pasteur filter is a very dangerous one for the general public, who are unable to distinguish between the two.

XV.

Slack and Brownlow, *Abbey Hey Works, Gorton, Manchester.*—The filtering medium adopted by this firm is some preparation of charcoal used either alone in its granular form, as a compressed block, or the two combined. They are put on the market as table, domestic, cistern, pocket, and bottle filters, the two latter being specially designed for use in foreign parts. We have experimented only with one of their large household filters, which was provided with a block of compressed carbon, as this would indicate sufficiently clearly how the filtering material would probably function in all cases. These filters appear to be in very extended use from the statement of the manufacturers that they "have been adopted by Her Majesty's Government for railway and transport service, by the Emperor of Russia, the President of the United States; by the Russian, Italian (who purchased 6,000 filters in 1887), Swedish, Chinese, and Japanese Governments; and have been found of the greatest service in all parts of the world," and by many "steamship and railway companies." They also state that the filters remove "every trace of lead, all organic matter, and the microbes and bacteria so frequently the cause of zymotic diseases." An analytical report is also appended, which states:

"I have been requested to examine two samples of drinking water, one unfiltered and the same filtered, and have submitted both to the most searching bacteriological examination under Koch's process of cultivation of bacterial germs, and find the unfiltered water contains several thousand germ colonies of bacteria per cubic centimetre of water, and is literally swarming with microbes. The effect of the filter is most satisfactory. The same impure water filtered is rendered perfect for all potable purposes."

TABLE LVII.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	180 to 200
Cholera bacillus	10,000	1,000
Typhoid bacillus	10,000 to 15,000	400 to 500

TABLE LVIII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	—	Not recorded
" " " No. 2	50	13
Fourth day, " No. 1	45	Innumerable
" " " No. 2		600 to 800

The results obtained as indicated in the foregoing tables show that these filters provide no safeguard against disease organisms as claimed by the vendors. The danger attending their use is most apparent in the case of the pocket and bottle filters (made of the same material as that which we have tested), which are supposed to be used for waters of suspicious origin such as occur in India and the Colonies, where these filters seems to be in extensive use.

XVI.

LONDON AND GENERAL WATER PURIFYING COMPANY, LIMITED, *157, Strand, London, W.C.*—This firm supplies domestic, portable, and pocket filters, which are fitted up on a system precisely similar to their siphon cistern filter which appears to be in greatest demand. We have examined the siphon cistern filter supplied by this firm. The filtering medium appears to consist of some preparation of charcool in a finely granular and in a more coarsely granular form. "The filter, charged solely with animal charcoal, through which the water passes when being drawn, by ascension, through a siphon is placed at the bottom of, and continues to act so long as any water remains in the cistern. It yields the water pure, limpid, aërated, and free from colour and taste. It arrests impurities in mechanical suspension, purifies the water by oxidation from organic contamination, and takes metallic oxides out of solution. The water is filtered at the last moment when required for use, and therefore is not liable to acquire fresh taint from standing, as is the case when drawn from most filters which require filling. The filter when once fixed requires no attention on the part of servants or others."

"The Company's patient cistern filter is patronised and used by Her Most Gracious Majesty the Queen (at Osborne), His Royal Highness the Prince of Wales (at Sandringham), His Royal Highness the Duke of Connaught (at Bagshot Park), His Royal Highness the Duke of Cambridge, the War Department, in Barracks, and Government Hospitals, the *élite* of the medical profession, at the London, Middlesex, Consumption, Fever, St. George's, St. Mary's, Small-pox, Evelina, and German Hospitals, in breweries, and other large establishments, and at the schools established by the School Board for London." They appear to lay great stress on the number of medical men by whom their filters are patronised, as is evidenced by their statement that "this company publishes a dated list (which can be had on application), corrected from time to time, of medical men who use the company's filters, which speaks more emphatically for their value than anything else."

The results of our experiments are given in the subjoined table:

TABLE LIX.—*Test Organisms.*

	Average Number per c.cm originally present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	8 000 to 10,000	1,000 to 1,200
Cholera bacillus	10 000	2 000 to 3,000
Typhoid bacillus	10,000 to 12 000	400 to 500

The table sufficiently indicates, as might have been expected from the nature of the filtering material used, that this filter offers no obstacle to the direct passage of disease microbes.

XVII.

Portable Stoneware Filter in Wicker Basket (lent by Army Medical Department).—The manufacturer of this filter and the medium used was not ascertained, but it appears to differ in no way from most of the other filters on the market. The upper plate of the filter had a central orifice plugged with a sponge, through which the water passed to the true filtering apparatus. As this plate was firmly fixed in position we were unable to ascertain of what material the filtering medium consisted. As we received this filter when we were finishing our investigation it was examined only as regards the passage of the first of our test organisms.

Table LX.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	8,000 to 12,000	200 to 300

The passage of both the yeasts and staphylococcus pyogenes aureus sufficiently indicates that this filter cannot be trusted to arrest the passage of disease organisms.

XVIII.

Messrs. J. Defries and Sons, *London Offices and Warehouse, 147, Houndsditch, E.C.; Filter Kilns and Factory, Surrey.*—The filters sent out by this firm are stated to consist of mineral carbon compounded with powdered pumice stone so as to form a solid block. The manufacturers are very guarded in their statements regarding the action of their filters alone in preventing disease from impure water. They say: "Such impurities are with certainty destroyed by boiling the water, and filtering it in a suitable filter before use. Neither boiling or filtration is by itself sufficient. Attention is drawn to the fact that means must be taken to periodically destroy the impurities which are abstracted by the filter from the water, or the filter itself will become an active source of danger, capable of infecting water which is otherwise pure. This applies to filters of every kind without exception. It is important that such means be simple, and that it be applied regularly."

Boiling the water is undoubtedly at present regarded by hygienists as an absolute safeguard against the communication of the diseases which are supposed to be propagated through this medium, and why this should not be "sufficient" without filtration we are not quite able to understand. However, the advice of the vendors to boil the water and periodically (every week) sterilise their blocks in boiling water should undoubtedly disabuse the minds of the purchasers of these filters of any rash confidence in their unaided efficacy in converting an impure into a wholesome water. We considered it desirable, however, to report on these filters, inasmuch as they appear to be in somewhat extended use in our Colonies, since it is not very probable that the directions of the makers would ever be carried out in actual practice.

Our experiments were carried out with a plain glass quart type of filter, the results of which are appended:

TABLE LXI.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	10,000 to 15,000	4,000 to 5,000
Cholera bacillus	25,000 to 30,000	2,000 to 3,000
Typhoid bacillus	10,000 to 12,000	1,000 to 2,000

TABLE LXII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	35	9
" " " No. 2		22
Fourth day, " No. 1	40	Innumerable
" " " No. 2		400 to 500

A mere glance at these tables clearly indicates that this filter provides us with no safeguard against the dangers arising from the consumption of impure water, although it should be stated that no such claim on its behalf is made by the makers, unless supplemented by previous boiling of the water.

XIX.

THE WITTMANN FILTER. *Agents: Messrs. Wittmann and Roth, 47, Great Marlborough Street, London.*—The filtering medium adopted in the "Wittmann" filter is stated to consist principally "of the finest spodium (that is, animal charcoal), with which no known substance can compare in capacity for absorbing all kinds of impurities." This material is moulded to form a vase or bowl, which acts as the reservoir to receive the unfiltered water. It is claimed that this form of filter allows the process of filtration to be both perfect and rapid, while at the same time it permits of the filtering medium being easily and effectually cleansed in

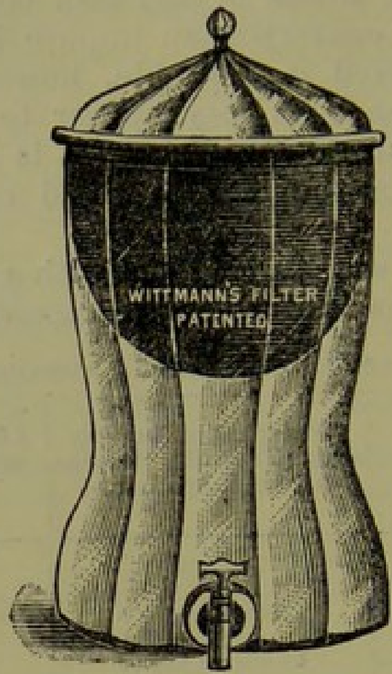


Fig. 7.

boiling water. They also state that: "It is absolutely unrivalled for use in the Colonies and other remote places, owing to its practically indestructible character; for where it is impossible to effect an exchange, it need only be fired in a space from which the air is excluded in order to become as good as new, and will then last for years."

It must be admitted that the structural simplicity of this filter, which possesses no fittings which can possibly go wrong, leaves nothing to be desired in this respect at any rate, and it undoubtedly compares very favourably with most of the other types constructed of the same or similar material.

No direct claim is made by the vendors of this filter as regards the prevention of disease through its use, but perhaps the ordinary public, on reading the circular issued by them, which has for its heading "Pure Water," and below a quotation from the late Dr. E. Lankester, that "one of the great sources of epidemics, which destroy the life of thousands every year, is impure water," would draw the conclusion that these filters by "purifying" the water obviate such risks.

The type of filter with which we experimented consisted of a bowl of moulded charcoal supported in a glass vessel, which was fitted with a tap at its base, as shown in the illustration, the bowl being surmounted by a glass cover. The results of our experiments are appended.

From the small number of organisms which appear in the first sample taken it would appear that the filtering capacity of this form of carbon is above the average, an idea which is confirmed by the fact that ultramarine is completely

TABLE LXIII.—*Test Organisms.*

	Average Number per c cm. originally Present in the Suspension.	Average Number Present per c cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts (first day, sample No. 1)	10,000 to 15,000	10 to 15
Staphylococcus pyogenes aureus + yeasts (first day, sample No. 2)		300 to 400
Staphylococcus pyogenes aureus + yeasts (second day, sample No. 1)... ..	—	2,000 to 3,000
Cholera bacillus	10,000	80 to 100
Typhoid bacillus	10,000 to 12 000	400

TABLE LXIV.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1	35	1 to 2
" " " No. 2		2
Fourth day " No. 1	40	Innumerable
" " " No. 2		200 to 300

separated from the water to which it has been added, while milk cannot be filtered, apparently owing to its immediately obstructing the surface pores of the filter. This more perfect action of the filtering medium exerts no influence as regards the ultimate communication of infective disease, but it indicates that most of the solid suspended impurities would be retained on the surface of the charcoal where they could be most easily removed. There can be no doubt, however, from these experiments that this filter offers no effective impediment to the direct passage of micro-organisms, and can accordingly afford no protection against infective disease conveyed through impure water.

B. FILTERS WHICH DO NOT DIRECTLY TRANSMIT DISEASE GERMS.

XX.

FILTRE CHAMBERLAND, SYSTÈME PASTEUR, *Sole Licences and Makers in this Country, J. Defries and Sons, Limited, 147 Houndsditch, London, E.C.*—The filtering medium employed by the manufacturers of these filters consists of a specially prepared form of porcelain formed by a mixture of kaolin and other clays, the exact details of which still remain a trade secret. The filtering mechanism is sent out under two forms: in the one candles marked "B" being used, in the other candles marked "F," the latter allowing of much more rapid filtration, and being those which seem to be in more general use, inasmuch as the English agents seem to be in the habit of supplying only this form in this country. In most of our experiments the "F" candle was used, but we obtained exactly the same results with the "B" candle, with the exception that the process of filtration went on much more slowly when the latter form was used. Although these candles find their most extensive use as tap or pressure filters, still, as they are supplied as ordinary table filters, or to be used with an air pump under atmospheric pressure, they must receive consideration in this part of the report. It is unnecessary to describe the various forms of filter which can be obtained, as these all consist of exactly the same filtering medium fitted up to act either as a simple drip filter, or by means of siphonage under a slight pressure. As the process of filtration as a non-pressure filter is extremely slow, a considerable number of candles connected, to constitute what is technically known as a battery, is required for the process to go on with any rapidity; under these circumstances reservoirs to hold the filtered water are necessary, in order that the filtration may go an continuously to provide a sufficient supply for domestic purposes. Such a principle of storage should without doubt, if possible, be avoided, since it is desirable that the water should be consumed as it passes directly from the filter.

The filtering mechanism consists of a hollow cylinder of prepared porcelain, closed at one extremity with the same material, and with a nipple-shaped open tube composed of glazed porcelain at the other extremity. The unfiltered water surrounds the outer surface of the unglazed porcelain, and, passing through this, issues as filtered water from the glazed nipple. In course of time (varying naturally with the purity of the water) the outer surface of the candle becomes covered with a slimy coating, and the rate of filtration becomes very much diminished. We may quote here the directions of the vendors as to what is to be done under these circumstances:

"The germs and other impurities, which are arrested on the outer surface of the tube, form a soft, slimy deposit. This must be cleaned periodically. The cleaning consists in brushing and rinsing off most of the deposit, which comes away readily, and in periodically destroying such part as sticks to the filter. Filters should be cleaned when the output has been considerably reduced. The brushing only takes a minute or two. The periodical destruction of the remaining germs can be quite simply effected by boiling, baking, or steaming the filter tube, or by passing through the filter a little cleaning substance as directed. Each operation is of the simplest and least troublesome character, and requires no skill whatever. The filters are made, if desired, with automatic brusher, so that the filter tube need not even be removed from its case, the residue being run off through a valve at the side."

The cleansing fluid supplied by the vendors is mixed with a dye, the latter being added so that the consumer can recognise by the absence of colour in the filtrate when the filter has been completely cleared of this substance. We shall reserve for consideration under the heading of pressure filters the results of our experiments with this cleansing fluid, and also the influence of brushing in restoring the rate of flow.

It is claimed for this filter that it is "a simple and effective precaution against typhoid fever, cholera, dysentery, and all diseases communicated through water." The vendors also state that "the Pasteur filter, though practically new to the public in this country, has been used in France on an enormous scale since 1886, and has been scientifically investigated in all countries. Both practically and scientifically it has been shown to absolutely arrest all germs of disease in water, and to prevent typhoid fever, cholera, malaria, dysentery, and all other diseases communicated by water. No other filter can be relied on to do this, and the large majority tend to actually favour the development of such diseases. These statements are made exclusively on the authority of Government reports and of independent investigations published in standard scientific periodicals and textbooks."

In addition, they assert that the Pasteur filter "for some years has been the only water filter permitted to be used in the French army, navy, schools, and Government service." As a result of its adoption they state that "the figures show a continuous and rapid decrease of typhoid fever, till more than 75 per cent. of the typhoid fever in the Paris barracks and more than one-half of that in the whole French army had been stopped in three years after the introduction of the Pasteur filter; and in 1892 M. de Freycinet, reporting a still further reduction, adds: 'Wherever the Pasteur filter has been applied to water previously bad, typhoid fever has disappeared.' The Minister of Education, as a preventive against the cholera epidemic of 1892, forbade the drinking in any school in France of any water which had not passed through a Pasteur filter. The schools were practically free from the epidemic even in infected districts."

Many other instances are cited of places where typhoid and other diseases had previously prevailed before the adoption of this filter, but which ceased after these had been brought into operation in filtering the water. The manufacturers draw special attention to the fact that porcelain filters in imitation of the Pasteur filter are on the market, which, however, confer no protection against disease and in support of this cite the following paragraph:

"The experiments undertaken by the jury of Class 64 (Exposition Universelle, 1889) have confirmed on every point those carried out by the Commission charged by the Minister of War to investigate the best process for filtering drinking water. They have likewise established the fact, already ascertained by that Commission, that the cylinders of porous porcelain made in imitation (or more properly in piracy) of the Pasteur filter in no way give the results as to freeing water from germs and microbes which are obtained by that filter."[4]

Most of our experiments were carried out with the candles fitted up in a lamp glass with india-rubber connections, as they are usually employed for laboratory experiments. In some cases, however, the candle was simply inverted in the fluid to be filtered, and the filtrate carried over under exhaust pressure, by means of an india-rubber tube, to a sterile reservoir.

In the table containing the results obtained with tap water, it will be found that the water organisms did not grow through the walls of the cylinder into the filtrate so rapidly as sometimes occurred when used as a tap filter, as will be seen later. It should be mentioned, however, in connection with this that water organisms may appear in

TABLE LXV.—*Test Organisms.*

		Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts,	first day	3,000 to 4,000	0
" " " "	second day	—	0
" " " "	third day	—	0
" " " "	fourth day	—	0
Cholera bacillus	... first day	5,000 to 6,000	0
"	... second day	—	0
"	... third day	—	0
"	... fourth day	—	0
Typhoid bacillus	... first day	8,000 to 10,000	0
"	... second day	—	0
"	... third day	—	0
"	... fourth day	—	0

[4] *Rapport à M. le Ministre de la Guerre: Commission Chargée,* etc., Fascicule No. 8, pp. 41-43.

the filtrate even on the fourth day, according to the conditions present. This occasionally longer period during which the filtrate remained sterile was undoubtedly due to the fact that when used as a table filter the cylinder was not kept constantly moist with the water—that is to say, the upper resesvoir was not kept supplied with successive charges of tap water. This allowed the cylinder to become more or less dry, a condition less favourable to the growth of water organisms through its wall. This question, however, is of minor importance since, as we have seen, the true criterion of an efficient filter is whether it permits or not of the passage of test organisms—such as cholera and typhoid bacilli which do not multiply readily (if at all) in water—into the filtrate.

TABLE LXVI.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day...	35 to 40	0
Second day	do.	0
Third day	do.	0
Fourth day	do.	0

From these tables it will be seen that the Pasteur-Chamberland candles do not permit of the direct passage of micro-organisms, and we may state here that we have tested over three dozen candles, and that in every case they gave a sterile filtrate when used directly. It may also be pointed out that the Pasteur-Chamberland has now for a number of years been the acknowledged standard filter in scientific laboratories, and that hardly any complaints regarding their reliability have been made public, and these complaints all occurred previous to the introduction of a test to which each candle is now subjected before it is allowed to be sent out. A candle is said to be efficient when it does not allow air at a pressure of 7 lbs. to pass through it. In the case of disease germs (Table LXV), it will be observed that the results are given only to the fourth day, and the question naturally arises whether these would not in course of time grow or be washed through into the filtrate. This is the crucial problem which has to be solved as regards all such filters, and will be discussed in full detail under the heading of tap filters. It may be mentioned here, however, that all our experiments go to show that any filter which does not permit of the direct passage (during two days) of test organisms permanently arrests disease germs. We are accordingly of opinion that this filter does prevent the communication of waterborne disease as is claimed by the vendors.

XXI.

THE BERKEFELD FILTER COMPANY, LIMITED, *Engineers and Contractors for Pure Water Supplies (Contractors to Her Majesty's Government), 121, Oxford Street, London, W.*—The filtering medium used by this company consists of silicious earth formed into a hollow cylinder, the common candles presenting a very similar appearance to those of the Pasteur-Chamberland type, whose model they appear to have followed. The candles in this case, however, are made in many different sizes, whereas the former are all of one pattern. The filtering medium consists of the microscopic silicious skeletons of diatomaceæ, which from their form "(ladder-like and interlacing) leave an enormous number of exceedingly minute pores, thus affording a free passage for the liquid, and at the same time stopping that of the minutest suspended organic or inorganic matter, while their hard silicious nature gives a firm and practically indestructible material."

The manufacturers state that "the great difficulty to be overcome has been the formation of a solid substance of this deposit," and the method by which this is secured appears to be still a trade secret. A microscopic examination of a portion of a candle, pulverised, showed that most of the skeletons were broken, and this suggests that the medium had been rendered solid by compression (either alone or after mixture with some foreign substance), so that the individual particles came within the sphere of their own molecular attraction. The hollow portion of this cylinder appears then to have been bored out, as this is frequently observed to be slightly excentric.

Although this filter finds its most extended use and application as a pressure filter, still it can be used as a table or non-pressure filter, and must accordingly receive consideration in this section of the report. As the filtering medium and its mode of use in the various forms of table and domestic filters are essentially alike, these will not here require further description. The manufacturers claim that the Berkefeld filter possesses the following advantages:

"1. It will filter large or small quantities according to pressure and number of cylinders.

"2. The filtered liquid is absolutely free from any solid particles and from germs.

"3. The filter can easily be cleaned, as all impurities remain on the surface, owing to the density of the material. One cylinder will last for years.

"4. Each cylinder can be thoroughly sterilised by being placed in warm water, and boiled for an hour."

The chief advantage which they claim for their filter over others which give a germ-free filtrate is that it gives a sufficiently rapid flow of filtered water, while at the same time the arrested impurities are retained on the "*very surface*," from which they can be easily washed or brushed away, when the initial filtering capacity of the cylinder is at once restored.

The vendors state that their filter "continuously sterilises water;" they also publish many testimonials which they have received regarding the power of their filters in arresting the passage of pathogenic and other organisms. They also give a number of extracts from scientific journals of the results of experiments carried out by bacteriologists on their filters in support of their claims. We find among these writers some of the most distinguished Continental bacteriologists and hygienists, and we may single out Professor Max Grüber, Director of the Hygienic Institute, Vienna, as one who speaks most highly of this filter. The English agents state that "these filters have been supplied among many others to H.R.H. the Prince of Wales, both Houses of Parliament, H.M. Government, Sir Henry Roscoe, Sir Andrew Clark, Dr. Parkes, Dr. Pasteur, Dr. Hutchinson, Dr. Theo. Acland, Dr. Ford Anderson, St. Thomas's Hospital, St. Bartholomew's Hospital, Guy's Hospital, London Hospital, Hospital for Diseases of the Skin, London Fever Hospital, St. Mary's Hospital, Dr. Klein, Fulham Infirmary and Workhouse, Midland Railway Company; Manchester, Sheffield, and Lincolnshire Railway Company; Lancashire and Yorkshire Railway Company, Manchester Royal Exchange, Eastman's Photo Material Company, etc."

The statements made on behalf of this filter we shall have to consider in more detail under the heading of pressure filters; we must limit ourselves for the present to recording the results of experiments similar to those which we have carried out on the other table filters. The experiments

TABLE LXVII.—*Test Organisms.*

		Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts,	first day	3,000 to 4,000	0
" " " "	second day	—	0
" " " "	third day	—	0
" " " "	fourth day	—	0
Cholera bacillus	first day	5,000 to 6,000	0
"	second day	—	0
"	third day	—	0
"	fourth day	—	0
Typhoid bacillus	first day	8,000 to 10,000	0
"	second day	—	0
"	third day	—	0
"	fourth day	—	0

recorded in this place were carried out with cylinders 13 and 14 of the vendors' list, the former being fitted up in the glass cylinder supplied by the makers, while the latter was fitted up in lamp glasses, as in the case of the Chamberland filter. The results of our experiments are given in the accompanying tables.

TABLE LXVIII.—*Tap Water.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm in the Filtrate.
First day	35 to 40	0
Second day	do.	0
Third day	do.	60
Fourth day	do.	200 to 300

It will be seen, on reference to Table LXVIII, that the claim of the vendors that their filter "continuously sterilises water" is not confirmed, and we may state that numerous experiments have proved, as might have been expected, under ordinary conditions of temperature, that on the third day water organisms invariably grow through into the filtrate, and sometimes even earlier. On the other hand, it will be observed that the test organisms are completely arrested, so that we must conclude that the Berkefeld filters may afford an efficient safeguard against the passage of disease germs. We shall, however, discuss more fully under the heading of pressure filters the relative advantages and disadvantages of this form of filter.

XXII.

AÉRI-FILTRE-MALLIÉ, THÉORIES PASTEUR, PORCELAINE D'AMIANTE, MAISON MALLIÉ, *155, Faubourg Poissonnière, Paris.*—This filter has attracted very considerable attention in France, where it has been recommended by such men as Gautier, Miquel, and Bouchard as the most perfect filter made as regards the exceedingly fine nature of the filtering medium. A Committee of the French Academy has reported very favourably on it, and as a result of this the Academy awarded it "Le Prix Montyon" for the year 1893.

The filtering medium used in the manufacture of these filters consists of some specially prepared form of unglazed porcelain, the pores of which it is contended are immeasurably more fine than those found in any other form of porcelain. The makers state that the three essentials of a filter are the following:

"1. The filtering material should be unputrescible and incapable of being altered (*inattaquable*).

"2. The filtering material should be impervious to all dangerous germs.

"3. Every filter should be capable of being at once and easily cleaned."

They state that no other filter subserves these three conditions so certainly, completely, and perfectly as those made of *porcelaine d'amiante.*

TABLE LXIX.—*Test Organisms.*

	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts, first day	3,000 to 4,000	0
" " " " second day	—	0
" " " " third day	—	0
" " " " fourth day	—	0
Cholera bacillus ... ...first day	5,000 to 6,000	0
" ... ...second day	—	0
" ... ...third day	—	0
" ... ...fourth day	—	0
Typhoid bacillus ... ...first day	1,500 to 2,000	0
" ... . second day	—	0
" ... ...third day	—	0
" ... ...fourth day	—	0

This firm send out their filtering material in the most varied forms—for example, domestic, table, tourist, and pocket filters. Our experience, however, of this medium as a non-pressure filter would lead us to believe that it is not well adapted for this purpose, owing to its very slow rate of filtration, which would place it much below even the Pasteur-Chamberland filter under similar conditions. These filters accordingly, in our opinion, must find their most extended use as tap or pressure filters, under which heading they will be considered in more detail. The results of our experiments with the table forms of filter will be found in Tables LXIX and LXX.

TABLE LXX.—*Tap Water.*

	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day...	35 to 40	0
Second day	do.	0
Third day	do.	0
Fourth day	do.	0

These tables indicate clearly that this material functions perfectly as a filter for microbes. The rate of filtration is, however, very slow, and our experiments were in all cases carried out, under pressure by means of a water pump. It must be admitted, accordingly, that these filters afford, so far as we can demonstrate, a complete safeguard against the communication of waterborne disease, but we must defer till later the full consideration of the relative advantages and disadvantages attending the use of these filters.

CONCLUDING REMARKS ON TABLE FILTERS.

In the present report we have given the results of the examination of the filters of twenty-one manufacturers and, as has been seen, have had to report unfavourably on almost all of them.

The following list contains the names of those firms whose filters, in our experiments, afforded no protection against the communication of waterborne disease:

MANUFACTURERS WHOSE FILTERS DIRECTLY TRANSMIT DISEASE GERMS.

THE SILICATED CARBON FILTER CO., *Battersea, London.*

DOULTON AND CO., *Lambeth Pottery, London, S.E.*

MAIGNEN'S "FILTRE RAPIDE" AND "ANTI-CALCAIRE" CO., Limited, *255, Regent Street, London, W.*

THE ATKINS FILTER AND ENGINEERING CO., Limited, *65, Farringdon Road, London, E.C.*

THE NIBESTOS FILTER CO., *126, Charing Cross Road, W.C.*

FR. LIPSCOMBE FILTER CO., *233, Strand, London, W.C.*

THE LIPSCOMBE FILTER CO., *146, Oxford Street, London.*

THE MAGNETIC FILTER CO., *32a, Euston Square, London, N.W.*

THE SPONGY IRON FILTER CO., *22, New Oxford Street, London W.C.*

THE MORRIS TUBE CO., Limited, *11, Haymarket, London, S.W.*

THE FULHAM POTTERY AND CHEAVIN FILTER CO., Limited, *Fulham, London.*

THE CROWN FILTER CO., *66, Bishop Street, Port Dundas, Glasgow.*

JACOB BARSTOW AND SONS, *Pontefract.*

ALCARAZAS FILTER "ROCH-BRAULT" PATENT: *Agents, Hersey Brothers, Limited, 70, Berners Street, London, W.*

SLACK AND BROWNLOW, *Abbey Hey Works, Gorton, Manchester.*

LONDON AND GENERAL WATER PURIFYING CO., Limited, *157, Strand, London, W.C.*

J. DEFRIES AND SONS, *147, Houndsditch, London, E.C.*

THE WITTMANN FILTER: *Agents, Wittmann and Roth, 47, Great Marlborough Street, London.*

COMPARISON OF INEFFICIENT FILTERING MEDIA.

From the very different forms of carbon blocks which we have tested, it is highly improbable that this medium will ever furnish a reliable filter. Those in which the filtering medium consisted of stone, iron oxide, or asbestos, have also proved ineffective; although it is possible that the latter medium may in the future be successfully applied to this purpose. It will also be seen that porcelain as a filtering medium does not necessarily produce the same results as have been obtained with certain specially prepared forms of this substance. Many of these filters, ineffective from the bacteriological point of view, however, are not used—by the purchasers, at any rate—so much with the object of preventing disease as of rendering the water clear and palatable. No doubt filters will continue to be used for such purposes, so that it is desirable perhaps to indicate from among the filters in general use those which are least liable to pass into a more or less putrescent condition, or which, if they should happen once to become infected, are least likely to continue distributing the contamination over a lengthened period. The Nibestos filter appears to us to function admirably as a purely mechanical filter, and inasmuch as its filtering medium is purely mineral and can be easily and cheaply renewed when its surface becomes covered with the impurities extracted from the water, the dangers attendant on the use of an imperfect filter are here reduced to a minimum. In the case of the charcoal filters it is much more difficult to decide on which are to be recommended, since this medium forms such a favourable breeding ground for many micro-organisms. No doubt if the medium were sufficiently often renewed or cleaned many of its disadvantages would be obviated, but the trouble and expense involved would certainly in most cases prevent this being carried out as often as is necessary. The Wittmann charcoal vase filter, inasmuch as it possesses no corks or other fittings which can go wrong, and can at the same time be more easily cleaned and sterilised than any other form, presents certain advantages over many of the other types of carbon filters.

The following list contains the names of those firms whose filters in our experiments appeared to afford protection against the communication of waterborne disease:

MANUFACTURERS WHOSE FILTERS DO NOT DIRECTLY TRANSMIT DISEASE GERMS.

FILTRE CHAMBERLAND, SYSTÈME PASTEUR; *Agents, J. Defries and Sons, 147, Houndsditch, E.C.*

THE BERKEFELD FILTER CO., Limited, *121, Oxford Street, London, W.*

AÉRI-FILTRE-MALLIÉ, PORCELAINE D'AMIANTE, MAISON MALLIÉ, *155, Faubourg Poissonière, Paris.*

These three filters which are all of foreign manufacture (*Pasteur-Chamberland*, *Berkefeld*, and *Porcelaine d'Amiante*), as we have seen, all appear, as table filters, to protect against the communication of infective disease through the agency of water. The rate of filtration is, however, in all these cases a more or less slow process, unless a number of candles are combined to form what is technically known as a battery. When these are made use of, however, the number of candles employed and the number of connections required multiplies the risk incurred from either an imperfect candle or one of the fittings going wrong, which in either case would frustrate the whole object of filtration. In all cases where such filters are required we should recommend their employment as tap or pressure filters wherever possible, as (1) it is essential that a sufficient supply of filtered water should be available to subserve all domestic purposes; (2) this should be effected with as little trouble as possible, otherwise the person or persons to whom this duty is relegated may be tempted to neglect filtering the water to be used for household purposes.

Remarks on Filter Manufacturers' Claims.

Before concluding, we may perhaps be permitted to make a few observations regarding the testimonials and statements published by the makers of the filters (imperfect from the bacteriological point of view) which we have reported on. These filters may, as we have already said, materially increase the risk of acquiring infective disease; but in addition they are to be looked upon as an unmitigated evil, in so far as they give rise to a false sense of security, which prevents the precaution of boiling the water being taken where necessary. We should recommend accordingly that the vendors should either withdraw these statements or at the very least satisfy themselves, by taking independent expert evidence, that they are justified in making these claims in regard to the prevention of disease by the use of their filters.

PART II.

Pressure Filters.

Under the heading of non-pressure filters we have already considered the principles upon which the method of testing filters is based, but it is obvious that the method of applying these principles must be modified in the case of tap or pressure filters. Before going further we are anxious to take this opportunity of again insisting upon the vital distinction which must be drawn between the direct passage, mechanically, of micro-organisms through a filter and the indirect passage of microbes, due to their growth into the filtrate through the walls of the filter, since in almost all the references made in the public prints to the first portion of the report on table filters, this distinction appears to have been completely misunderstood and misinterpreted. In the present part of the investigation we have again divided the filters into two classes: (*a*) the obviously imperfect filters which permit of the direct (mechanical) passage of micro-organisms; (*b*) the more perfect filters which do not allow of this direct passage of micro-organisms. We have already stated in Part I that, in our opinion, all filters which do not allow of such direct passage, will not allow the ultimate passage of *disease germs*, as this could then occur only by a process of growth through the walls of the filter. The experimental data on which this view was based (which entirely corroborates the work of Gruber and his pupils), were not given in our previous article, inasmuch as none of the table filters which prevented the direct passage of the micro-organisms appeared to us to be capable of being used practically as non-pressure filters, owing to the fact that the exceedingly close texture of the filtering media which is necessary to keep back the direct passage of the microbes, in all cases requires considerable pressure in order to give a reasonable amount of filtrate. The experiments which we have carried out in connection with this subject will now be given in more detail, but, as can be readily understood, we can refer only to some of the more characteristic results which have been obtained, since naturally a much larger number of experiments than are here detailed were carried out before we could arrive at a final decision on this most important point.

Methods of Testing Pressure Filters.

It is evident that our experiments on pressure filters could not always be carried out when they were affixed to taps and under normal conditions, in the same way as had been done in the case of the table filters. In the first place we could not introduce disease germs into the water supplying the filter without the obvious danger of most disastrous results ensuing. In the second place we could not supply the tap filters with definite emulsions of test organisms and water in which the number of germs present could be accurately determined, as we had been able to do in the table filter experiments. All we could do was to introduce a certain quantity of a rich emulsion of the organism to be tested into the reservoir of the pressure filter before it was affixed to the tap; the quantitative element is therefore entirely wanting in such an experiment, inasmuch as in the case of an imperfect filter the number of test organisms present in the unfiltered water would become less and less the longer the filter was allowed to run. Indeed, in order to make certain of demonstrating the presence of the introduced organisms in the filtrate, it was necessary to take a number of samples at different stages, since it was impossible to predicate how long it would take in the case of any particular filter for the organisms to be washed through, or how quickly they might have disappeared through having been all washed away. As a matter of fact in most cases little difficulty was experienced in this respect, large quantities of the test organisms were always taken, and no inconvenience resulted, since the experiment was in every case purely qualitative and not quantitative in character.

We have found the following method of testing a filter very convenient in those cases where we were able to sterilise with certainty the whole mechanism. It consisted in collecting in flasks a large quantity of the water filtrate (500 c.cm. to 1 litre), and incubating these for three or four days at the temperature of the room. If the flask originally had contained only one or two water organisms which had passed the filter, these would have multiplied after incubation to such an extent that 1 c.cm. of it made into a gelatine plate would contain several hundred colonies. The risk of the atmospheric impurities entering the flask during the process of collecting the sample may be practically neglected, as these organisms (chiefly fungi and yeasts) usually do not multiply in water.

Testing with Disease Germs.

Wherever disease germs were being worked with, the filtering medium to be tested was made use of as a table filter, and a pressure of 26 to 28 inches of mercury applied by means of a water pump. In these cases, of course, the filtration was necessarily intermittent, and the filters always attained the temperature of the room; these conditions, however, after all approximate to what would occur in actual practice where the same rise of temperature would take place in an intermittently-used filter. The table filter arrangement was also taken advantage of in many experiments in which non-pathogenic germs, such as pigment-forming organisms (where it was necessary to exclude the presence of other bacteria than those which were being experimented with), were used.

One of the difficulties encountered in carrying out such experiments was the ease with which the filter may become contaminated with germs from the atmosphere or its surroundings. These foreign germs probably obtain entrance at those periods when the cotton-wool plug has to be removed from the reservoir, whilst a fresh charge of fluid is being supplied to the filter. This operation having to be performed more or less frequently, the chance of contamination in course of time became a not very improbable one; indeed, we not infrequently found, after the lapse of twelve or fourteen days that foreign organisms had obtained an entrance and grown through the filter into the filtrate; in consequence, the experiment had, as a rule, to be repeated, since the presence of these air organisms might possibly prevent our recognition of the test organism, especially if these latter should occur in small numbers. In the experiments with cholera we were able practically to eliminate this risk by the following method, by which we were enabled to assert, almost with certainty, that 300 or 400 c.cm. of the filtrate did or did not contain Koch's cholera bacilli. A concentrated sterile solution of peptone and salt was added in such quantity to the filtrate under examination that a broth of 1 per cent. of each of these constituents was formed; this was then incubated at 37° C., and examined for cholera. As Koch and many other observers have found that this method allows us to demonstrate the presence of comma bacilli when the usual methods fail absolutely, and since as has already been stated in the previous report, we were able in this way to demonstrate the presence of the cholera organism during a period of six weeks, in filters which had once been infected with cholera germs, it is highly improbable that we should fail to find them in our filtrates, which were open to much less serious contaminations.

Another difficulty encountered in the use of the Chamberland and Berkefeld candles as table filters was that, inasmuch as the filters could only be charged with fresh water from time to time, the candles were apt to become dry in the interval, and this might naturally interfere with the growth of the organisms through into the filtrate. This was obviated by closing the side tube of the exhaust bottle by means of a piece of india-rubber tubing and a spring clip. It was found that as the amount of filtered water accumulated in the bottle sufficient internal pressure was obtained to prevent further filtration, so that the filter might be left in this condition for several days without risk of the candle becoming dry. This method was taken advantage of in some of those experiments with pathogenic germs, where it was intended to extend the results over several weeks, the chances of contamination being thus minimised, as the reservoir required to be opened less frequently. Only a portion of the experiments, however, were carried out in this way, as they were open to the possible objection thut the gases collecting in the receiver might exert a negative *chemotactic* influence.

In considering the question of whether a filter can be a perfect safeguard against the passage of disease germs by means of their growth through the filter and into the filtrate we shall, before discussing the case of disease germs proper, commence by observing the manner in which these filters affect other organisms, as this casts great light upon the question.

Testing with Water Organisms.

The water supply (New River Company) with which the laboratories are provided always contained at least four varieties of micro-organisms, and the different way in which these conducted themselves towards different filters is very interesting and suggestive. In water filtered by means of a Pasteur-Chamberland candle attached to the tap, only one species of micro-organism could, as a rule, be recognised. This organism was a rod-shaped microbe, which normally liquefied the gelatine somewhat slowly, forming a funnel in which flakes of a distinct yellow colour collected. Although these were the characteristics of the organism when separated directly from the tap water, it presented an entirely different appearance when developed from the filtered water. The colonies, instead of appearing on the second or third day as a liquefying species, now frequently did not make their growth evident to the naked eye till the fifth or sixth day, and then only as non-liquefying colonies, the characteristic ferment action and colour being manifested usually only after the lapse of three or four weeks' cultivation. It is thus evident that only one out of the four species of organisms present was usually able to grow through the wall of the filtering candle, and that it had become so modified and attenuated that it required several weeks to recover, completely, its usual vital characteristics.

In water filtered through a Berkefeld candle at least two species of organisms appear in the filtrate after the second or third day; the first is the same yellow liquefying form just mentioned. This, however, at once exhibited its usual characters. The other is a rod-shaped organism which rapidly liquefied the gelatine and produced a green colour. It is thus apparent that the filtering medium used in this case offers much less resistance to the growth of micro-organisms through its pores, and also that these channels appear to exert no devitalising or attenuating influence on the organisms during their passage through the wall of the candle. These results at once indicate that all filters which do not permit of the direct passage of germs cannot at once be placed in one class, but that they exhibit varying degrees of perfection of action as regards the growth of organisms through their walls, which, as we shall see, may possibly in some cases be of considerable importance. They also suggest that any method which relies upon the use of a single germ in the testing of a new filter, may possibly lead to incorrect results when the conclusion is applied from the special case to the general question.

Testing with Chromogenic Organisms.

To determine more precisely the reaction of these two filters to well-known colour organisms which are generally used as test organisms, the following experiments were carried out :

Rich emulsions of staphylococcus pyogenes aureus, micrococcus prodigiosus, and bacillus violaceus were added to the reservoir of the filters before these were attached to the tap; the filtrate was then examined for these organisms immediately and from day to day. We were never able, in the case of either the Chamberland or Berkefeld filter to detect these organisms, although the filtrate was regularly examined for several weeks. Against such experiments it has been urged by Kubler,[2] and, more recently, by Johnston,[3] that the test organisms may be killed off by the water organisms which collect on the outer surface of the candle. This, however, is highly improbable and a much more pertinent objection which might be urged against the conclusiveness of these experiments would be that the large number of water organisms, which permit of only small quantities of the filtrate being brought under examination, might prevent the detection of the test organisms if they happened to be present in only small numbers. To eliminate this objection the experiment was carried out with the candles fitted up as table filters, every precaution being taken to prevent the ingress of foreign organisms. The filters were charged from time to time with fresh sterilised water and the filtrate was carefully examined, but, even after the lapse of three weeks, none of the test organisms could be separated from the

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[2] *Zeitsch. für Hyg.*, Bd. viii, p. 49.

[3] *Thesis for the Degree of D.Sc. of Edinburgh University*, August, 1894. Banks and Co., Edinburgh.

filtrate. In this experiment the water and the filter both attained the temperature of the room—a condition which would be much more favourable to the growth of these organisms than the temperature of the water from the tap. This negative result must be therefore regarded as still more conclusive. Inoculations from the reservoir of the filter on the termination of the experiment in every case showed the test organism to be still living and vigorous. A final experiment was carried out with a Chamberland and with a Berkefeld filter, in which each filter was fed with a mixed emulsion, containing the following organisms: Micrococcus roseus, micrococcus carneus, bacillus minaceus, bacillus mycoides roseus, bacillus violaceus, and staphylococcus pyogenes aureus. In this experiment the water was retained in the reservoir of the filter by means of a piece of india-rubber tubing and a spring clip, as already described, so that the filter could be left undisturbed until an examination of the filtrate was to be made. Samples of the filtrate were taken only on the second, third, and fourth weeks of the experiment. These all proved to be completely germ-free, as large quantities of the water were added to concentrated broth solution and incubated, with absolutely negative result. This experiment appears to us to prove in a very striking fashion the apparently impassable barrier which both these filters present against the passage of such organisms.

Experiments with Cholera and Typhoid Fever Bacilli.

The experiments with pathogenic germs, which were among the earlier carried out on this subject, at first gave aberrant results from those already described, inasmuch as it sometimes appeared as though typhoid or cholera germs, after the lapse of two or three weeks, passed into the filtrate. Subsequent investigations, however, disclosed that this was due to the india-rubber fittings of the filter giving way, owing to the intermittent strain imposed upon them when the filter was removed from or inserted into the neck of the exhaust flask, an operation which was being repeated at least once a day. The method of fitting up the candles was then modified, and after such modification had been made no results of this character ever again occurred.

Chamberland and Berkefeld candles, fed from day to day with cholera and typhoid bacilli emulsions in sterilised tap water, in no case allowed of the passage of the disease germs, as we have never been able to demonstrate their presence in the filtrate. We would lay special stress upon the experiments with cholera, inasmuch as in each experiment 300 or 400 c.cm. of the filtrate were mixed with the concentrated broth solution, and thus brought under examination. By this means the possibility of the disease germs passing through in very small numbers, and thus escaping observation, was tested most thoroughly. In addition to these results several experiments were carried out, extending over a much longer period, in which the danger of extraneous organisms gaining entrance during the frequent changing of the fluid to keep the filter moist was obviated by the use of the india-rubber tubing and spring clip already described. In this way sterile filtrates were obtained after the lapse of six and eight weeks from both Chamberland and Berkefeld filters, although inoculations from the outer surface of the candles proved that numerous living pathogenic germs still remained.

Influence of Addition of Broth to Tap Water.

We have repeated an experiment which was carried out by Schöfer,[4] under the direction of Gruber, in which Berkefeld filters which had been fed with emulsions of cholera and typhoid organisms in sterilised water, received on the fourth or fifth day the same fluid, enriched by the addition of a small quantity of broth, after which they were again fed with the usual fluid. They found that two days after the application of the broth-enriched fluid to the filter the disease germs began to make their appearance in the filtrate, and increased in number till they reached a maximum; they then gradually decreased, probably as the highly diluted broth was gradually washed away. The filter could now be again fed with the fluid enriched with broth, and the same series of phenomena were again observed, except that the number of colonies in the filtrate was enormously increased on the next day, this being due, no doubt, to the multiplication of the organisms which were already present in the pores on the other side of the filter. We have found that the addition to the water of even such a small quantity as one-fiftieth of its bulk of broth sufficed to permit the growth of both cholera and typhoid organisms through either Berkefeld or Chamberland candles into the filtrate. The Berkefeld candle allowed the disease germs to pass on the second or third day, while in the case of the Chamberland filter the growth through was always further delayed, the organisms exhibiting their presence on the third or fourth day after the enriched fluid had been added. We have never been able to observe that the filter cleared itself of the disease germs, and we would lay special stress on the experiments with cholera in this relation. By means of the broth method, the presence of cholera could be demonstrated for between three and four weeks after the filter had been once fed with the enriched fluid. These experiments therefore show clearly that under favourable conditions of temperature and medium (broth) disease organisms can go through the walls of these filters in a precisely similar manner and in almost the same period of time as in the case of those water

[4] Ueber das Verhalten von pathogenen Keimen in Kleinfiltern, *Centralbl. f. Bakt. und Parasitenk.*, Bd. xiv, No. 21, 1893.

organisms which can appear in the filtrate of the same filters.

We have always found that when a filter is fed with a culture of either typhoid fever bacillus or Koch's cholera bacillus in normal broth, the germ has grown through the walls of the filter and appeared in the filtrate in the course of two or three days, so long as the temperature at which they are held is sufficiently high to admit of the growth of these organisms, the filters in these experiments being retained at the ordinary temperature of the room. We should here mention that in neither the case of typhoid nor cholera germs did the organisms which appeared in the filtrate exhibit in cultivation any signs of weakness or attenuation. It must be concluded from this fact that the devitalising influence exerted by the action of the pores in the case of the Chamberland candle on water organisms requires for its exercise the assistance of other factors, probably being aided in producing this effect by the lower temperature of the water and the less favourable pabulum which it afforded. These experiments also show that, under certain favourable conditions—a suitable pabulum (for example, broth) and a sufficiently high temperature—disease organisms can traverse the walls of any filters that have yet been put upon the market. We have now to consider whether this could ever occur in actual practice. As regards temperature, it must at once be admitted that the necessary conditions might frequently come into operation. The question as to whether the conditions as regards medium (food) would ever be sufficient to allow of their passage through such a filter, must be considered under two headings—namely, (1) as to whether the water contained sufficient organic matter to raise it to the standard of a mixture of broth and water; (2) as to whether the slimy mass which collects on the walls of a filter, even in the case of a pure water supply, might not afford a sufficient pabulum for the growth of a disease germ through its walls into the filter. In the experiments to which we are about to refer, we shall have to consider the influence exerted by each of these factors alone and also when the two are operating in conjunction, as it was, of course, quite possible that, although neither of these alone might cause the passage of disease germs, when combined they might bring about this result.

Experiments with Cholera and Typhoid Fever Bacilli in New River Company's Water.

In our experiments we have taken as a type of a good water the water as supplied to the laboratories by the New River Company, and as a type of the worst possible water which would probably ever be used for drinking purposes—Thames water taken near Waterloo bridge at low tide. In the experiments carried out with the candles covered with a coating of slime, which had been left as the result of use on the tap for three or four weeks, those of one set were sterilised by being subjected to steam for several hours, while those of the other set were used in their "raw" condition, as it was just possible that the application of heat might have affected the value of the slime as a nutrient medium. In the experiments carried out with the sterilised candles the water employed to form the emulsion with cholera bacilli was previously sterilised at 100° C., but where the candles were used in their "raw" condition the normal unsterilised fluid was employed. In the following table may be seen the results of such experiments carried out on a Chamberland filter, with cholera bacilli after laboratory tap water had been passed through the candles for three or four weeks, from which we must conclude that the slimy covering does not enable pathogenic germs to traverse this filter. Similar experiments carried out with a Berkefeld filter gave precisely similar results. We may explain here that in this table and in the others which follow the + *(plus)* or – *(minus)* signs indicate that the organisms in question were or were not found in the filtrates under examination.

TABLE LXXI.—*Tap Water + Cholera Bacilli.*

Condition of Candle.	1st Day.	2nd Day.	3rd Day.	4th Day.	6th Day.	10th Day.	18th Day.
Chamberland candle, without slimy coating (sterilised) ...	–	–	–	–	–	–	–
Chamberland candle, slimy coating (sterilised)	–	–	–	–	–	–	–
Chamberland candle, slimy coating (unsterilised) ...	–	–	–	–	–	–	–

The same experiment was carried out with the typhoid bacillus, except that the unsterilised candle was not used, as a negative result in that case could not be relied upon, as we have at present no sufficiently reliable method for separating the typhoid bacillus from many of the water organisms. As the results were again negative it is unnecessary to give them in detail.

EXPERIMENTS WITH CHOLERA AND TYPHOID FEVER BACILLI IN CONTAMINATED THAMES WATER.

The experiments with Waterloo water *plus* cholera bacilli were carried out on the same plan with the exception that the slime on the candles was obtained by the filtration of a considerable quantity of tap water. The results, which were again negative, are given in the following table.

The experiments with Berkefeld candles yielded exactly the same results, and need not be given here in detail.

TABLE LXXII.—*Waterloo Water + Cholera Bacilli.*

Condition of Candle.	1st Day.	2nd Day.	3rd Day.	4th Day.	6th Day.	10th Day.	18th Day.
Chamberland candle without slimy coating (sterilised) ...	—	—	—	—	—	—	—
Chamberland candle, slimy coating (sterilised)	—	—	—	—	—	—	—
Chamberland candle, slimy coating (unsterilised) ...	—	—	—	—	—	—	—

Similar experiments were carried out with typhoid bacilli, with sterilised candles and Waterloo water, and the results obtained again gave no support to the view that the disease germ could, even in the presence of this highly polluted water, pass through into the filtrate.

EXPERIMEMTS WITH CHOLERA AND TYPHOID FEVER BACILLI IN LONDON SEWAGE.

As a final and conclusive test as to the possibility of disease germs traversing the walls of these filters, when fed with a water highly contaminated with organic matter, an experiment was carried out with undiluted sewage. The results, when the cholera bacillus was used, are to be found in the following table:

TABLE LXXIII.—*London Sewage + Cholera Bacilli.*

Condition of Candle.	1st Day.	2nd Day.	3rd Day.	4th Day.	6th Day.	10th Day.	18th Day.
Chamberland candle without slimy coating (sterilised) ...	—	—	—	—	—	—	—
Chamberland candle, slimy coating (sterilised)	—	—	—	—	—	—	—
Chamberland candle, slimy coating (unsterilised) ...	—	—	—	—	—	—	—

Similar experiments with Chamberland and Berkefeld candles (except with the unsterilised candles) were carried out, with sterilised sewage and typhoid bacilli, but as these again gave an absolutely negative result, they need not be detailed.

From a consideration of the experiments to which we have briefly referred, and bearing in mind that many other similar experiments were carried out at the same time under slightly varying conditions, the evidence against the possibility of either typhoid fever bacillus or Koch's cholera bacillus appearing in the filtrate from either of these filters becomes very strong indeed.

We have seen that the addition of even a comparatively small quantity of broth to tap water, enables disease germs to grow through the walls of these filters, but, on the other hand, waters naturally highly contaminated, and even sewage itself, do not appear to supply the disease germs with a sufficiently favourable pabulum to enable them to traverse their walls. We have accordingly every reason to believe, so far as experimental evidence would warrant us to dogmatise on such a question, that these filters provide a complete safeguard against the transmission of waterborne infective disease.

Influence of Filtration on Non-Specific Infection.

We have up to the present discussed only the influence which filters can exert as regards the transmission of specific infective disease; we must now consider the action which they may exert upon the spread of those more general gastro-intestinal disorders which are so frequently associated with a contaminated or suspicious water supply. These non-specific disorders resulting from the ingestion of water have perhaps never yet received that attention from the hygienist and general public which, from their importance, they undoubtedly merit. The influence upon the death-rate of cholera nostras and other allied conditions, due to this cause would probably, if it could be traced over the country at large, far transcend in importance even that due to typhoid fever.

If we consider the influence on morbidity exerted by this factor, its importance not merely from a hygienic but from a pecuniary point of view becomes still more striking, although unfortunately the statistics on this point are still very incomplete, and probably do not reveal more than a very small percentage of the cases affected.

Water as a Medium of Infection.

In the first part of this report[5] we have already suggested why water was so frequently the means of transmitting infective disease. Experimental evidence would seem to show that disease germs (for example, cholera bacilli) in water, taken on an empty stomach, might pass into the intestines unharmed by the gastric juice, while if taken in milk or with food none appear in the intestines, probably because the stomach "reacts" to the food with its acid gastric secretion, which latter exerts a distinct germicidal or antiseptic action on the microbes. It is evident from this that injurious germs

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[5] Part I., p. 18.

when present in water have a much better chance of arriving unharmed in the alkaline contents of the intestines, where, undisturbed, they can manufacture their poisonous products, and so give rise to gastro-intestinal disturbances. Our information upon the species of organisms which can, or usually give rise to such disorders, is at present exceedingly limited and unsatisfactory; indeed, it is very probable that such disorder may be due to many different species of organisms, acting under special conditions; thus only certain portions of the community, apparently all subjected to the influence of the same etiological cause, are attacked, and these, except in the case of epidemics, at different periods. In addition, it may very frequently be observed that a population exposed to such influences often seems to acquire a relative immunity to their action. Thus we frequently observe strangers to a locality affected by a water almost at once on their arrival, whilst those who have been constantly partaking of it experience no evil result, and refuse to acknowledge that the water can be the source of the mischief. Again, there is good reason to suppose that even those organisms normally present in the intestines can, under favourable conditions, give rise to serious disturbances of the intestinal tract. We are concerned here, however, only with those organisms which can be carried by means of water, and the influence which filters can exert on their transmission. Our means of testing this are, as has already been stated, not so definite as in the case of specific disease germs, since we are unable to demonstrate the germs which may give rise to these disorders, and test them directly as regards their power of passing through the walls of a filter.

Animal Experiments as a Test.

Our only means of approaching the question at present appears to be by estimating the degree of toxicity of the products which can be manufactured by such bacteria present in the water by the injection of these products into, and thus testing their action on, the lower animals. It has been pointed out by Blachstein[6] that if a tube of broth be inoculated with one cubic centimetre of a good drinking water, and incubated at 30° C. for 48 hours or longer, 2 cubic centimetres of this mixture of organisms and their products can be injected intravenously into a rabbit, or intraperitoneally into a guinea-pig, apparently without inconveniencing either of these animals. On the other hand, should the water used originate from a contaminated source, such as from the Seine, both animals usually rapidly succumb. This method has been modified by one of the present

[6] *Annales de l'Inst. Past.*, 1893, p. 689.

writers[7] in substituting subcutaneous for intraperitoneal injection in the case of guinea-pigs and taking the presence or absence of local reaction as the test of contamination instead of the lethal action. This was found necessary as it is quite exceptional in this country for the water supplies to be contaminated to such an extent as to exert a lethal action. We have found in the case of laboratory tap water that the effect on rabbits was *nil*, while in the case of guinea-pigs, at most only a slight swelling (œdema) was visible at the end of twenty-four hours, after which it rapidly disappeared.[8] Even when the organisms in the tap water are allowed to grow for weeks in the broth, and so heap up their products, their effect on animals is still practically *nil*. From this it would appear that these germs, which are all what may be termed water organisms—that is to say, microbes which are capable of multiplying and living in the purest potable waters—are not capable of producing any large amount of injurious toxic products. This is, indeed, what might naturally be expected, since it is not at all probable that the faculty of building up complex protoplasms from the most simple compounds which must be possessed by a water organism would go along with the power of disintegrating the more complex organic compounds which is usually associated with the production of toxins. In our application of this method to the testing of filtered and unfiltered water we have incubated the broth at 37° C., as this is the temperature at which the organisms would have to produce their toxins in the human body, such temperature in great part excluding the action of many of the ordinary indifferent water organisms. We have also taken advantage of the local reaction in guinea-pigs as affording evidence of less marked virulence and toxicity of the mixture in the very common case of the water being non-lethal for either guinea-pigs or rabbits.

Influence of Filters on Toxicity of Broth Cultures grown from Filtered Water.

In the case of the filtered water, in order to determine exactly the means through which the filter exerted its in-

[7] Circumstances under which Infectious Diseases may be conveyed by Shellfish with Special Reference to Oysters: Special Report to the British Medical Journal by G. E. Cartwright Wood: British Medical Journal, vol. ii, 1896, p. 853.

[8] Since these experiments were carried out we have observed that the action of the tap water supplied to us by the New River Water Company varies greatly at certain periods, the effect on guinea-pigs being much more marked at these times than at others, and this we found was due to the presence of the "potato bacillus" (Bacillus mesentericus vulgatus) on these occasions. Thus, for example, during the past summer the water contained this organism regularly and gave rise to a local reaction in guinea-pigs, whilst during the autumn months, after it had disappeared, the water again became innocuous. It is quite possible that during the summer months, when there is the greatest strain upon the supply, some other sources may be laid under contribution; this would account for the deterioration (from the bacteriological point of view) in the quality of the water.

fluence, it was necessary to investigate the following three factors, first, whether the filter by allowing only a diminished number of germs, although of the same nature as in the unfiltered water, to pass through, might tend to affect the animal in a lesser degree ; secondly, whether the same germs passing through into the filtrate might not have been attenuated in their passage and thus weakened in their effects on the animals ; or thirdly, whether the diminished effect of the filtered water might not be due to the filter allowing only those species which belong to the more innocuous water organism type, and thus relatively inoffensive (non-toxic), to traverse its walls. We have been able to answer the first question by incubating the broths for a day or two longer, which would amply compensate for the lessened numbers at the commencement of the operation, but invariably found that this was quite insufficient to account for the difference in the results. The influence of the second factor was tested by incubating the broth for a considerable period, and then from this inoculating fresh broths with which the animal experiments were then carried out. The result, however, proved that this was not the real or only explanation, although it is exceedingly probable that it may exert some influence. This leaves us with the third factor as alone capable of explaining the difference in the virulence of the filtered and unfiltered water. This conclusion is in perfect accord with what we have already stated as regards the power of the filter of allowing only certain of the species present to appear in the filtrate. This is, moreover, corroborated by the fact that the relative permeability of the Berkefeld and Chamberland filters for water organisms corresponds with a relative virulence in the action of their filtered fluids. In the following experiments the filters were fed with the water for two or three weeks in order that the filtrate might contain all those germs which would probably in course of time traverse their walls.

Animal Experiments with Tap Water.

In carrying out experiments with the laboratory tap water we were obliged to modify the method of procedure, since the unfiltered water, when mixed with broth and incubated for forty-eight hours, was practically innocuous, so that in order to obtain a positive result in this which was our control, we were obliged to incubate it for a period varying from a fortnight to three weeks. The filtrates from Chamberland and Berkefeld filters were then incubated for the same or a longer period, and the local results produced in guinea-pigs carefully compared with each other and with the control (Table LXXIV).

These experiments show that ordinary tap water, which, when incubated in broth for three weeks, may be injurious and distinctly irritating for guinea-pigs, when it has been filtered through either of these candles becomes practically inoffensive. This action of these filters in rendering the water inoffensive is shown much more markedly in the case of dangerous waters, as will be seen in the accompanying tables.

Animal Experiments with Contaminated Thames Water.

The filtration experiments with Thames water taken near Waterloo Bridge are exceedingly striking, and must be regarded as very important as indicating the remarkable influence which the above-mentioned filters can exert on the toxicity of a highly contaminated water. The results of two sets of experiments are given in Table LXXV.

Here the unfiltered water, which is so very virulent for both guinea-pigs and rabbits, becomes almost innocuous after filtration, and even when incubated for fourteen days exhibits only slight toxicity. The relative difference in the filtering efficiency of the Chamberland and Berkefeld filters in this respect is exhibited very clearly in the action on guinea-pigs of the broths which had been incubated fourteen days. In the former case the local action is evanescent, while in the latter it is quite marked, persists till the tenth day, and is accompanied by enlargement of the inguinal glands.

Animal Experiments with London Sewage.

We have also carried out some experiments with London sewage for the purpose of estimating the influence which these filters exert on the virulence of this fluid. In this experiment, as fresh samples of sewage could not conveniently be obtained from day to day, the filters were fed with the same stock solution during the whole period. The results obtained are found in Table LXXVI.

In these experiments a marked difference in the virulence of the Chamberland and Berkefeld filtrates is again evident, as seen by the results obtained on guinea-pigs.

We may now summarise the conclusions which we think we are justified in drawing from these experiments. There can be no doubt that these filters, and probably all those which prevent the direct passage of test organisms, exert a most remarkable influence on the toxin-producing capacity and virulence of the fluids which they filter. We have accordingly as good reason as experimental evidence can afford to insist that these noxious waters would be practically bereft of their harmful properties by this filtration. The varying degree of efficiency in the two filters experimented with is of great scientific and technical interest; but whether this influence would manifest itself under normal conditions in actual practice in the filtration of water as of any importance must at present be regarded as somewhat doubtful.

TABLE LXXIV.—*Tap Water.*

Nature of Material.	Age of Culture.	Species of Animal and Method of Inoculation.	Result.
Chamberland filtrate, taken after 6 weeks	Broth culture incubated at 37° C. for 3 weeks	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Slight œdematous swelling which had disappeared at the end of the second day; no loss of weight. Apparently unaffected; animal still living after one month; no loss in weight.
Berkefeld filtrate, taken after 6 weeks	Ditto	Guinea pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Slight œdematous swelling which had quite disappeared on the second day; very slight temporary loss in weight. Apparently unaffected; animal still living after one month; no loss in weight.
Unfiltered Tap water (Control)	Ditto	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Soft swelling with indurated margins; animal lost 30 grammes in weight during a week; still living after one month. Apparently unaffected.

TABLE LXXV.—*Thames Water taken at Waterloo Bridge.*

Nature of Material.	Age of Culture.	Species of Animal and Method of Inoculation.	Result.
Chamberland filtrate taken after 2 weeks	Broth culture incubated at 37° C. for 48 hours	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Slight swelling, which had quite disappeared in 24 hours. Apparently unaffected, still living after the lapse of a month.
Ditto	Broth culture incubated at 37° C. for 21 days	Guinea-pig: 2 c.cm. subcutaneously	In 48 hours swelling completely disappeared.

TABLE LXXV. (*continued*).

Berkefeld filtrate, taken after 2 weeks	Broth culture incubated at 37° C. for 48 hours	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Swelling still visible after 24 hours; had disappeared on fourth day, leaving slight but distinct induration. Apparently unaffected; still living after lapse of a month.
Ditto	Broth culture incubated at 37° C. for 14 days	Guinea-pig: 2 c.cm. subcutaneously	Distinct swelling still visible on fourth day, which was followed by distinct induration, which was still visible on tenth day, and accompanied by enlarged and hardened condition of inguinal gland.
Chamberland filtrate, taken after 3 months	Broth culture incubated at 37° C. for 48 hours	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Swelling disappeared in 24 hours, and in 48 hours local lesion just discernible. Apparently unaffected.
Berkefeld filtrate, taken after 3 months	Ditto	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Swelling just visible after 24 hours, and local lesion just discernible on fourth day. Apparently unaffected.
Unfiltered Waterloo water (Control)	Ditto	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Diffused soft swelling in 24 hours, and found dead on second day. Died within 18 hours.

TABLE LXXVI.—*London Sewage.*

Nature of Material.	Age of Culture.	Species of Animal and Method of Inoculation.	Result.
Chamberland filtrate taken after 2 weeks	Broth culture incubated at 37° C. for 48 hours	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Slight swelling which persisted for several days, but had completely disappeared on tenth day. Animal still living after a month.
Berkefeld filtrate taken after 2 weeks	Ditto	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Marked swelling, which persisted till the tenth day, when it burst, forming small abscess with suppuration. Animal still living after a month.
Unfiltered London sewage (control)	Ditto	Guinea-pig: 2 c.cm. subcutaneously Rabbit: 2 c.cm. intravenously	Soft swelling extending over surface of abdomen followed by death of guinea-pig on third day. Died within 18 hours.

We now give the results in detail of our examination of the various pressure filters which we have considered it necessary to bring under the scope of our investigation. As in the case of the table filters, we divide these into two groups:

A. Those filters which allow of the direct passage of test organisms into the filtrate; and

B. Those filters which do not allow test organisms to pass directly into the filtrate.

A.—FILTERS WHICH PERMIT OF THE DIRECT PASSAGE OF DISEASE GERMS.

Reasons which guided us in the Selection of Pressure Filters to be Tested.

We have considered it unnecessary in this section to consider, further, pressure filters in which the filtering material consists of charcoal in its various forms, spongy or magnetic iron, or natural porous stone, where these have already been examined as table filters and found ineffective. We have included these in our investigations where the material or the method of its use differs from that adopted in the table filter, or where from their extensive use it was considered advisable to subject them to the direct test of experiment. It must, however, be distinctly borne in mind that by far the larger number of the pressure filters which are at present in use are composed of the inefficient filtering media which we have already reported on under the heading of non-pressure filters, and that their deficiencies are rendered still more manifest when they are used as pressure filters. We have stated in our previous reports on non-pressure filters that an ineffective filter might materially increase the risk incurred by those making use of an infected water; probably almost all the disease germs would in course of time be washed through into the filtrate, and thus continue to infect the water for a considerable period. This no doubt holds good for the very porous material which has to be made use of in the case of table filters, but as much denser filtering media *can* be employed in the case of pressure filters, there is no question but that many such filters, although imperfect, may permanently arrest even a large proportion of the disease germs, and in all probability in this way really lessen the risk of infection incurred by those making use of them. This fact is brought home to us by a cursory examination of the tables relating to imperfect filters, the filtrate from the table filters usually containing very large numbers of the test organism, whereas in the case of some of the imperfect tap filters, the proportion passing through is frequently comparatively small, and in some cases comparatively large quantities of the filtrate had to be examined before the presence of micro-organisms could be demonstrated. A number of these pressure filters in which these denser media have been made use of have recently been placed upon the market, we believe in consequence of our first report on filters; and in the case of one filter at least, the results which we have obtained are of such a character as to indicate that a new substance, natural stone, must be added to those which are capable of affording a germ free filtrate.

I.

THE SILICATED CARBON FILTER COMPANY, *Battersea, London.*—The tap filter supplied by this firm is fitted with the same medium as those which we have already tested, in the case of table filters, yet, inasmuch as the material is arranged in a different manner, and consists of a combination of solid and granular charcoal, we considered it advisable to bring this within the scope of our examination. Its structure and arrangement will be understood at once on reference to the diagram which is appended.

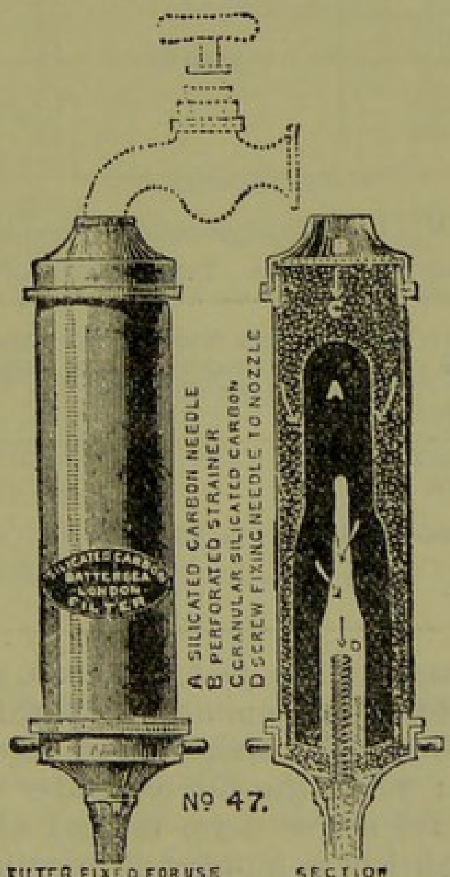

Fig. 8.

The vendors claim for this filter that it "yields absolutely sterilised water under any pressure." They also state that it "is invaluable in the tropics and in all climates as a safeguard against cholera, typhoid, and other zymotic diseases."

The rate of outflow in the case of this filter is very rapid, about one pint per minute being passed during the first day, and even after water has been running through it continuously for a fortnight, the filtration of a pint required little more than two minutes.

This filter was tested as a table filter with cholera and typhoid organisms, which at once passed through into the filtrate. These experiments need not be considered further here, as the experiment with staphylococcus pyogenes aureus carried out on the tap under the conditions of actual practice proved that these pathogenic microbes pass directly into the filtrate. The results obtained with the test organism and with tap water are given in the appended tables:

TABLE LXXVII.—*Tap Water.*

(Pressure 23 to 25 lbs. Temperature 19° C. to 25° C.)

Date of Sample.	Average Number per c cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day...	50 to 60	0?
Second day		26
Third day		60
Fourth day		200
Fifth day		1 000
Sixth day		Innumerable
Seventh day		,,

TABLE LXXVIII.—*Staphylococcus Pyogenes Aureus.*

(Pressure 23 to 25 lbs. Temperature 19° C.)

Date of Sample.	Average Number per c.cm. originally Present in the Suspension.	Average Number Present. per c cm. in the Filtrate.
First day, sample No. 1 ..	200,000	15 to 20
,, ,, ,, No. 2 ...		20
Second day		3

The direct passage of the test organism, as seen in these experiments, proves, in our opinion, that this filter confers no protection against the acquisition of waterborne disease (Table LXXVIII); while the filtered water when the filter has been in use for a few days, instead of being sterile, showed a very much larger number of microbes than the unfiltered tap water (Table LXXVII).

Since this first series of experiments was carried out we have received from the Silicated Carbon Company an improved form of their filter, with which we have carried out the following experiments. The essential character in which this filter differs from the former one consists in the fact that the carbon needle possesses much thicker walls and that its structure is very much denser and its texture finer. The fittings of the needle are also improved and are made much more secure. The rate of filtration with 25 lbs. pressure is very much slower than in the case of the earlier form—so slow, indeed, that this consideration alone would always militate against its coming into any very general use. The results of our experiments are given in the following tables:

TABLE LXXIX.—*On Tap. Pressure 25 lbs.*

Date of Sample.	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day	50	Nil
Second day		5
Third day		300 to 400

TABLE LXXX.—*Staphylococcus Pyogenes Aureus.*

Date of Sample.	Average Number per c.cm. originally Present in the Suspension.	Average Number present per c.cm. in the Filtrate.
First day...	400,000 to 600,000	2
Second day, Sample No. 1		3
" " No. 2		12
Third day "		Nil

We have also tested this candle fitted up as a table filter, feeding it with a rich emulsion of cholera bacilli. On incubating 200 c.cm. of the filtrate with concentrated broth, we had no difficulty in demonstrating the presence of the cholera bacillus in the filtrate.

From these tables it may at once be seen that these filters do not afford protection against the direct passage of disease germs.

II.

MAIGNEN'S "FILTRE RAPIDE" AND "ANTI-CALCAIRE" CO. LIMITED, *255, Regent Street, London, W.*—This filter consists (*a*) of a cylinder of stout coarse asbestos cloth, the use of which is to keep back all coarse particles of straw, dirt, etc.; (*b*) the filter proper, an accordion-shaped bag of fine asbestos cloth tied on to a rigid tube at each end, and firmly packed with carbo-calcis, each plait in the accordion-shaped bag being firmly bound with asbestos cord; through this bag filtration takes place from without inwards. Both these parts are contained within a large metal cylinder. The space within the iron cylinder not occupied by the two asbestos bags may be filled with carbo-calcis, but as it had already been found that carbo-calcis is by itself insufficient to keep back micro-organisms, it was thought better to test the essential parts of the filter alone. In order that the filter might get properly set, water was allowed to pass through it for fourteen days, after which the different parts were sterilised by passing through them a 10 per cent. solution of caustic soda.

In experimenting with this filter we had some difficulty in deciding as to the best means of sterilising it, as owing to its size, the application of superheated steam was out of the question. The best way out of the difficulty, although not free from objection, appeared to be to apply some antiseptic fluid which would not injure the filtering material, and then get rid of the antiseptic by washing it away by allowing water to run through the medium for a certain time. A strong solution of caustic soda was used as the antiseptic, the fluid being allowed to act upon the filtering medium for several hours before the tap water was allowed to enter so as to clear the filter of the disinfectant. The water issuing from the filter was tested with phenolphthalein for the alkali before it was considered ready for the experiment. The results obtained with tap water are to be found in the appended table.

Table LXXXI.—*Tap Water: Temperature 17° C.*

Date of Sample.	Average Number per c.cm. originally present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day	40 to 60	0
Second day		30 to 40
Fourth day		130 to 150
Eighth day		7,000 to 9,000

It will be seen from this table that the filtrate the first day after sterilising was sterile when tested in quantities of 1 c.cm. in plate cultures, but it is quite possible that this may not have been altogether due to the filtering capacity of the material, but may be ascribed partly, at any rate, to the charcoal still retaining some of the antiseptic in its pores. As will be seen from the table, on the second day the number of organisms in the filtrate is practically the same as in the unfiltered water; while on the third and fourth days the filtered water contains many more organisms than are present in the tap water.

The filter was tested as regards the passage of test organisms by being treated with an emulsion of staphylococcus pyogenes aureus. A number of samples were taken at different periods as, naturally, we could not foretell at what date the test organisms would appear in the filtrate. The results obtained on this occasion are rather surprising, as the test organism was detected only in the first sample examined, as will be seen from the appended table. This may have been due to the fact that the filter allowed the test organisms to be washed through almost *en masse.*

TABLE LXXXII.—*Staphylococcus Pyogenes Aureus.*

Date of Sample.	Average Number per c.cm. originally Present in the Suspension	Average Number Present per c.cm. in the Filtrate.
First day, sample No. 1 ...	500,000 to 800,000	6
" " " No. 2 ...		0
Second day, sample No. 1 ...		0
" " " No. 2 ...		

We have repeated this experiment with another test organism (bacillus prodigiosus), and were able easily to demonstrate its presence in the filtrate. This filter accordingly permits of the direct passage of the test organisms, and cannot, in our opinion, be relied upon to afford any protection against the communication of waterborne disease.

III.

WILLIAM DALTON, 9, *Dickson Road, Blackpool.*—We are not aware whether or not this tap filter has yet been placed upon the market, the specimen upon which we now report having been sent by the maker to the BRITISH MEDICAL JOURNAL for examination. The claims made for it are that it ensures perfect filtration of water or any fluids, while at the same time it makes provision for carrying away the deposit, left by the water or liquid filtered, by a special pipe by which its filtering capacity was supposed to be again restored; the water in the process of filtration passes first through asbestos gauze, then through charcoal, limestone, or other similar material, and thence through a perforated or gauze cover, whence it issues from the filter. The rate of filtration was at first very rapid, and, although the filter was allowed to run continuously, it still gave a pint in three minutes on the third day; but in the course of a week it required a quarter of an hour to filter this quantity.

We have tested this filter, affixed to the tap, as regards the passage of water organisms, staphylococcus pyogenes aureus and yeasts, and, fitted up as a table filter under pressure, as regards the passage of cholera bacilli.

The results obtained in these experiments are set forth in the two following tables.

As will be seen from these tables this filter offers no impediment to the direct passage of micro-organisms, and can in our opinion afford no protection against the communication of waterborne infective disease.

TABLE LXXXIII.—*Test Organisms.*

Test Organism used.	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	20,000 to 30 000	300 to 400
Cholera bacilli...	3,000 to 4 000	80 to 100

TABLE LXXXIV.—*Tap Water.*

(Pressure 14 to 16 lbs. Temperature 21° C. to 25° C)

Date of Sample.	Average Number per c cm. originally Present in the Tap Water	Average Number Present per c.cm. in the Filtrate.
First day..	40 to 50	20
Second day		30
Third day		80 to 100
Fourth day		100 to 150
Fifth day		150
Seventh day		200 to 300
Tenth day		300 to 400

IV.

JACOB BARSTOW AND SONS' Patent Combination Natural Stone and Carbon Filters, *Filter Works, Pontrefract, England, supplied to Her Serene Highness Princess Mary Victoria of Teck, the Empress Eugenie, the Prince of Monaco, the Belgian and other Governments, have never yet received a second or an inferior award at any time, but have won thirty-one gold and other first prize medals.*—The filtering medium used in the manufacture of these filters consists, as already stated in Part I of this report, of a combination of natural porous stone and carbon. The vendors state that their filter removes all "bacilli" from water, and "is excellently adapted for rendering even very impure water drinkable." The rate of filtration is very rapid; in fact, the filtering medium seemed to offer so little resistance to the passage of the water that on the first day its rate of flow was very similar to that at which it had issued from the tap previous to the fixation of the filter. On the third day, when the water pressure was 16 lbs. to the square inch, it required only ten seconds to filter a pint, and on the sixth day the filtration was still very rapid. We must state, however, that in the case of this filter it was not convenient to allow the water to pass continuously at full pressure, and that only a moderate flow was permitted; accordingly it must be borne in mind that under other conditions the filter might have become choked up much more quickly. We have carried out two sets of experiments; one, using the filter as a regular simple tap filter attached to the main; the other, in which an emulsion of yeasts and staphylococcus pyogenes aureus was poured into the reservoir of the filter before it was affixed to the tap. The results obtained in our experiments are found in the following tables.

TABLE LXXXV.—*Test Organisms.*

Test Organism used.	Average Number per c.cm. originally Present in the Suspension.	Average Number Present per c.cm. in the Filtrate.
Staphylococcus pyogenes aureus + yeasts	30,000 to 40 000	30 to 50.

TABLE LXXXVI.—*Tap Water.*

(Pressure 14 to 16 lbs. Temperature 16° C. to 17° C.)

Date of Sample.	Average Number per c.cm. originally Present in the Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day	30 to 40	5
Second day		25
Third day		250
Fourth day		300 to 400
Fifth day		400
Sixth day		400

It will be seen from Table LXXXVI. that the water organisms passed through the filter at once into the filtrate, and by the third day appeared in the filtrate in much larger numbers than in the control water. The water organisms which appeared in the filtrate were not all of one species, but comprised all the types present in the control water, and at any rate during the first days almost in a similar proportion. It will be observed also that the yeasts and staphylococci passed directly into the filtrate. It is impossible, of course, to give any idea of what proportions of these were allowed to pass into the filtrate, since we are unable to say how long it would take for the micro-organisms to be washed through the medium, and to appear in largest proportion in the filtrate. It is, however, quite sufficient for our purpose to be able to show that after the tap water had been running for two minutes these organisms appeared in considerable numbers in the filtrate. As our previous experiments had plainly shown that all filters which allow the direct passage of test organisms permit also disease organisms to be transmitted, we did not consider it necessary to make any experiments with cholera and typhoid bacilli. This appeared all the more unnecessary in this case, inasmuch as we had already tested the same material as a table filter, and found that it readily allowed the passage of these disease organisms.

We have accordingly no hesitation in stating that in our opinion this filter affords no protection agains the communition of waterborne infective disease.

V.

Piefke Filter, Arnold und Schirmer, *Gr. Frankfürter Str. 123, Berlin, N.O.*—This filter is supplied for the rapid filtration of large quantities of water for household or manufacturing purposes. It is supplied in different forms adapted for the special use to which it is to be applied. The forms we have seen consist (1) of a filter to be used in a cistern or well, the water being pumped through the filter. The other form (2) a pressure filter, with which we have experimented, is fitted to the supply pipe from a cistern, or from the main. The principle is the same in both cases. The filter is formed by a series of discs consisting of (1) stout cellulose paper, or (2) asbestos films, (3) either of these covered with a layer of deposited fine asbestos pulp. These discs are supported in series on perforated zinc plates, clamped together on fenestrated cups by a thumb nut on a central delivery pipe. This filter must, from the experimental point of view, be considered under three separate headings, inasmuch as two quite distinct kinds of filtration may be made use of, and a third form of filter can be constituted by combining two of the substances employed. We shall briefly describe these forms under three headings: (1) as fitted up with discs of compressed cellulose, of which two thicknesses are supplied; (2) the filter fitted up as in number one, but receiving a deposit of asbestos pulp before being used, by charging the first portion of the water with this material; (3) in which the filter is fitted up with thin discs of compressed asbestos of a bluish colour.

Piefke Filter No. 1.—As the filtering medium in this form consists practically of thick filtering paper, we naturally cannot expect anything more than a mere mechanical filtration, and, indeed, the manufacturers expressly state that deposition of asbestos on the filter is necessary for all finer filtration. As a mechanical filter the compressed cellulose functions admirably, retaining all the ordinary forms of finely suspended material on the surface of the discs, so that it might be relied upon to render almost any water clear and sparkling. The finest gunpowder charcoal, and ultramarine are both completely retained on the surface of the disc, while, on the other hand, milk passes through into the filtrate. The rate of filtration with 16 lbs. pressure is also ample, so that for many purposes, where water is required to be merely cleared of suspended material, this filter may be very conveniently used. From a hygienic point of view, the fact that the filtering medium (cellulose discs) may be so easily and cheaply renewed, is a point of considerable importance. This filter was, in the first instance, sterilised by allowing 5 per cent. carbolic acid to act on it for several hours; it was then attached to the tap, the disinfectant being removed by the water being passed through the filter for a short time before a sample was taken. The results obtained from these experiments are given in the following table:

TABLE LXXXVII.—*Tap Water.*

(Pressure 16 lbs. Temperature 12.5° to 14° C.)

Date of Sample.	Average Number per c.cm. originally Present in Tap Water.	Average Number Present per c.cm. in the Filtrate.
First day...	30 to 50	20
Second day		50
Third day		70
Fourth day		400
Fifth day...		500

As will be seen, these cellulose discs offer no barrier to the direct passage of water organisms, and accordingly would confer no protection against the transmission of waterborne disease. It will be seen that the number of organisms present in the filtrate did not increase so rapidly from day to day as has been observed to be the case in many of the other filters. It must be pointed out, however, that these experiments were carried out during the colder part of the year, when the temperature in the laboratory ranged from 12.5° C. to 14° C.

Piefke Filter No. 2.—In examining this filter considerable difficulty was experienced in carrying out our experiments, as we could not submit the apparatus to the ordinary process of sterilisation without running the risk of destroying the filtering mechanism. Thus the exposure to moist heat in the steam steriliser would very probably have weakened or destroyed the filtering capacity of the paper discs, and at the same time have disturbed the deposit of asbestos pulp. In the experiments with water carried out with the filter attached to the tap, recourse was had to the use of carbolic acid (as in the case of Piefke Filter No. 1). When tested in this way we were unable to obtain an absolutely sterile filtrate on the first day of the experiment, but as the number of organisms present in the filtrate came practically within the margin of error (taking into consideration the condition of the experiments), the results obtained could not be regarded as being absolutely decisive. We accordingly submitted this form of filter to a test in which a disease organism was used under the following conditions: The mechanism was fitted up, and, after attachment to the tap, was allowed to work for several hours. It was then detached from the tap, and fed with a rich emulsion of cholera organisms, the fluid being drawn through by means of the exhaust exerted by a water pump. At three different periods of the filtration a quantity of the filtrate, about 200 c.cm., was added to broth, incubated at 37° C., and examined for the presence of cholera bacilli. The result of these experiments will be found in the following table :

Table LXXXVIII.—*Tap Water + Cholera Bacilli.*

Number of Sample.	Presence or Absence of Cholera bacilli
Sample No. 1	+
" No. 2	+
" No. 3	+

The positive result obtained in this experiment warrants us in concluding that this form of filter does not afford protection against the communication of waterborne disease. We may also point out that, even if this experiment had given a negative result, this filter could not be recommended for use with a dangerous water, inasmuch as its character would vary from time to time, owing to the manner in which the asbestos pulp was deposited when the filter was freshly charged.

Piefke Filter No. 3.—In this type films of compressed asbestos are made use of as the filtering medium. In the experiments with water the filter was sterilised by allowing it to stand in contact with carbolic acid for several hours; the acid was then washed away by passing a considerable quantity of tap water through the filter. The gelatine plates made from this filtrate either remained sterile or developed so few colonies as to come within the range of experimental error. The result of the experiment must accordingly be regarded as inconclusive, and we do not accordingly append any table of results with tap water. Fresh discs were then inserted in the filter, and experiments with cholera bacilli similar to those in connection with Piefke Filter No. 2 were carried out. The results obtained will be found in the following table :—

Table LXXXIX.—*Tap Water + Cholera Bacilli.*

Number of Sample.	Presence or Absence of Cholera Bacilli.
Sample No. 1	+
" No. 2	+
" No. 3	+

We may here state that these discs were apparently able to retain a very large proportion of the microbes present in the water. To such an extent, indeed, was this the case that gelatine plates frequently failed to reveal their presence, although the incubation of larger quantities of the filtered water in broth gave a positive result. There is no doubt that asbestos supplies a very fine filtering medium which may, under certain circumstances, provide a germ-free filtrate, although, as we have shown in our experiments, neither of these filters when submitted to a stringent test could be relied upon to protect against the passage of disease organisms. In addition, even if these filters had in the first place been able to prevent the passage of test organisms, we should have been obliged to submit them to further and more prolonged investigation. Gruber states that asbestos filters gave in the first place a sterile filtrate, but in course of time, when used under pressure, the filtering medium became broken down and disorganised, so that organisms were passed directly into the filtrate. In his opinion, accordingly, such a filter is at first perfect, but in course of time and use becomes imperfect. In our experiments, by bringing larger quantities of the filtrate under examination, we have come to the conclusion that these filters, Nos. 2 and 3, were from the first imperfect, and accordingly found it unnecessary to carry the investigation further. The use of asbestos filters for the prevention of disease at present also labours under the disadvantage that the medium cannot be tested before being sent out, and warranted to provide a germ-free filtrate, as can be done in the case of porcelain candles.

We must accordingly conclude from our experiments that the Piefke filter does not afford protection against the communication of waterborne disease.

VI.

FILTRE UNIVERSEL. CHABRIER JEUNE ET CIE., *63, Rue de Maubeuge, Paris.*—The manufacturers of these filters make use of both charcoal and porcelain as a filtering medium, but we shall concern ourselves only with the latter, as we had already satisfied ourselves that the former could in no case give satisfactory results. The porcelain is constructed in many various forms, to supply pressure, non-pressure, and pocket filters. It is stated that the porcelain is of great hardness, and that it is baked at a very high temperature. After drawing attention to the fact that water contains many organisms, and often transmits typhoid fever, cholera, dysentery, etc., it is stated that "these filters are the only ones of their kind able to remove from water and other liquids injurious germs." The model on which we carried out our experiments was catalogued "No. 1." The wall of the porcelain bougie, while much shorter than that of the Pasteur-Chamberland candle, is much thicker. The bougie, which has a metal fitting instead of a porcelain nipple through which the water is delivered, is fitted into a metal case similar to those of the other pressure filters. The fittings as a whole are neither so simple nor so satisfactory as are those of several of the other filters examined. Indeed, the danger which is here incurred of the whole object of filtration being nullified by the "union" of the porcelain with the metal is, we believe, very great. Moreover, this arrangement renders impossible the cleaning of the bougies by baking or burning, which in almost all cases is undoubtedly the only practicable method of completely restoring the efficiency of a porcelain filter. The vendors state that this filter affords a supply of 5 to 25 litres per hour, according to the water pressure. In our experiments, with a pressure of 24 lbs. to the square inch, the initial output was between 4 and 5 litres in the hour. In the accompanying table will be found the results obtained with tap water:

TABLE XC.—*On Tap.*

(Pressure 25 lbs. Temperature 19° C.)

Filtre Universel on Tap.	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.
Presence or absence of Organisms	—	—	—	—	+	+	+

This porcelain candle thus prevented the direct passage of water organisms when 1 c.cm. of the filtrate was brought under examination, their appearance in the filtrate on the fifth day being due no doubt to their growth through the walls of the filter. In an experiment carried out with this filter during winter, when the temperature of the water is very much lower, the filter yielded a sterile filtrate for a much longer period.

TABLE XCI.—*Sterile Tap Water + Cholera and Typhoid Bacilli.*

Test Organism used.	1st Day.	2nd Day.	3rd Day.	4th Day.	6th Day.	10th Day.
Cholera bacillus	—	—	—	—	—	—
Typhoid bacillus	+	+	+	+	+	+

Two of the candles were fitted up as table filters, which could be used under the exhaust of a water pump. One of these was fed with sterilised water *plus* an emulsion of typhoid bacilli, the other with sterilised water *plus* cholera bacilli. The results are given in Table XCI.

The candle treated with typhoid bacilli allowed of their immediate passage from the first, while the one with cholera prevented their passage up to the end of the experiment. It is probable that the former result was not due to any imperfection in the candle, but rather to a breakdown in the fittings, but were such the case the objections which we have urged against the method in which the candle is fitted into the case are simply emphasised.

Even could this filter be absolutely relied upon to prevent the passage of disease germs, the smallness of its output (due no doubt to the thickness of the walls of the candle), and the difficulty of restoring the initial output by means of cleansing, would prevent it from ever coming into serious competition with several other similar forms already in use.

B.—FILTERS WHICH DO NOT ALLOW DISEASE ORGANISMS TO PASS INTO THE FILTRATE.

VII.

FILTRE CHAMBERLAND, SYSTÈME PASTEUR. SOLE LICENSEES AND MAKERS IN THIS COUNTRY, J. DEFRIES AND SONS, LTD., *147, Houndsditch, London, E.C.*—From the accompanying illustrations of the filtering candle and case of this well-known filter, the method of fitting and use will be readily understood. In the first part of our report, which deals with non-pressure filters, we have already considered in some detail the claims put forward on behalf of these filters, and some of the evidence which has been adduced in support of these statements. It is sufficient to repeat here that the vendors of the Pasteur-Chamberland filters claim that this filter is the only one which has been proved in practice to protect against the transmission of typhoid and other waterborne diseases. This filter has for long been regarded as the standard filter for scientific purposes in the laboratory. In considering the Pasteur-Chamberland filter under the heading of non-pressure filters we did not enter into detail, nor did we give those special experiments on which we based our conclusion that this filter, along with others, might be regarded as furnishing an effective safeguard against the acquisition of waterborne disease, inasmuch as these filters give such a small output of filtered water when used without pressure (unless combined to form a battery, against which there are serious objections) that they could, as a rule, find their practical application only as tap or pressure filters. In the introduction to this part of the report we have already given, in a general manner. the data which, it has appeared to us, warrant us in supporting the view that those filters which do not permit of the direct passage of test organisms afford a permanent protection against the passage of disease germs. We shall here give some of these experiments in greater detail, and shall then bring under consideration some of those mechanical and physical details which are of so much importance in the practical application of any system of water filtration.

We have already stated in our previous report that when this filter was used as a table filter the filtrate was still germ free on the fourth day, but at the same time we pointed out

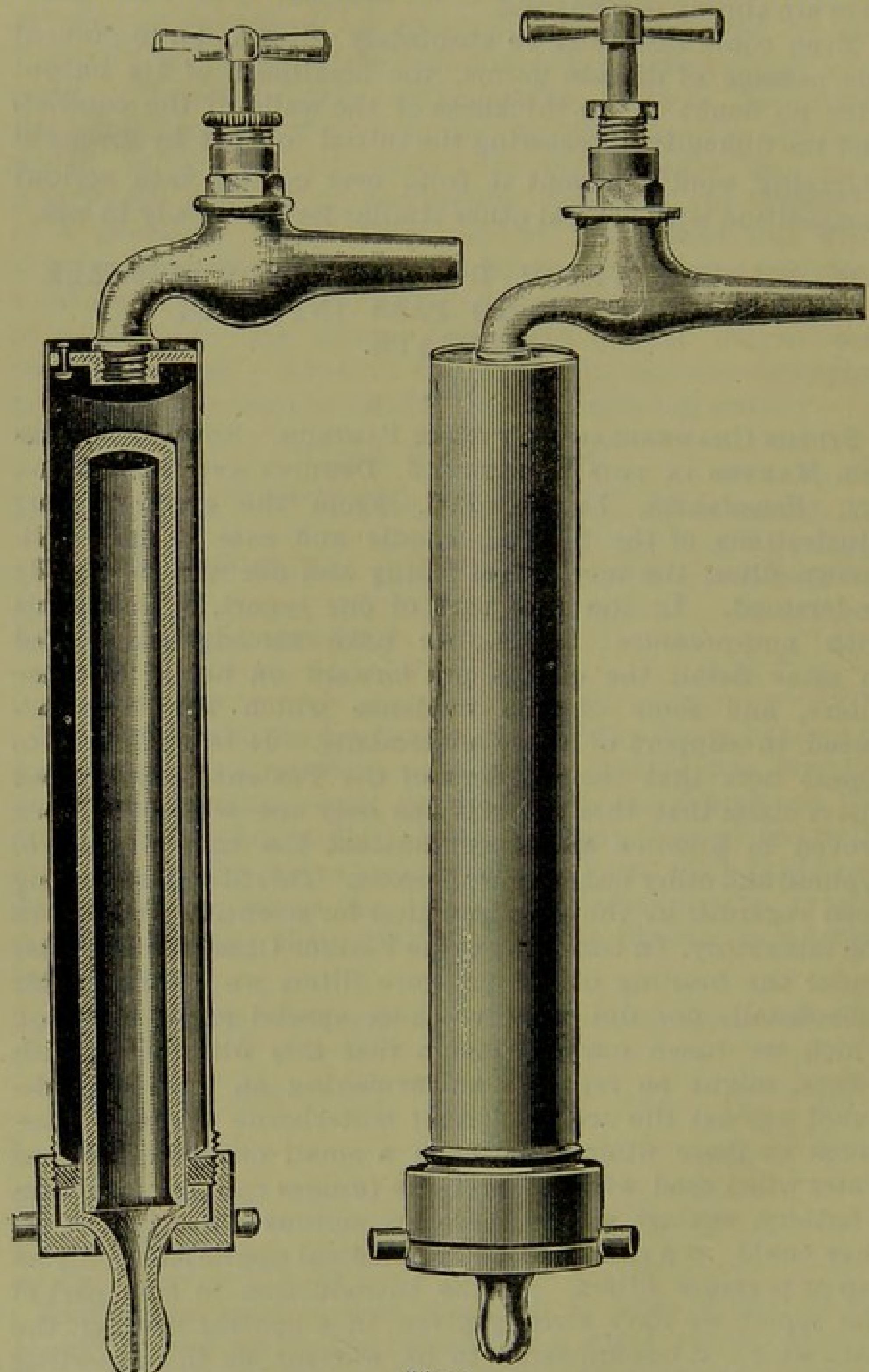

Fig. 9.

that, inasmuch as the candles were not kept constantly moist by being continuously fed with fresh water, the conditions were not the most favourable for the passage (by growth) of the microbes through their walls. It may now be asked whether the pressure to which the filter is subjected when attached to the tap exerts any influence on the rate at which the microbes pass through into the filtrate. Our experiments lend no support to this view; the only factor which appears to exert any influence seems to be that of temperature. The higher the temperature (within reasonable limits) naturally the more quickly organisms grow through the walls of the candle, while a lower temperature may not only prolong the period of sterility, but when the temperature is lowered while a filter is in use, and the water organisms have grown through the wall of the candle, the effect is so marked that the filter seems to clear itself in the course of two or three days; those organisms on the inner side of the walls, being washed away, are apparently not replaced by fresh or continued growth owing to this lowering of the temperature.[9] It is, perhaps, as well to explain here that in the above and the following tables, as elsewhere, the "first day" of the experiment signifies that the sample was taken within an hour or two of the filter being set in action; the "second day" of our table, therefore, means that the filter had been running for twenty-four hours, and had not really been in action for two days as might be supposed.

Arrest of Disease Organisms.

The following experiment carried out with twelve Chamberland candles, fitted up as a battery and fed with an emulsion of cholera bacilli in sterilised tap water, will indicate not merely the possibilities of disease germs passing through such candles, but it also gives data concerning the equal quality of the twelve fresh candles employed, and an indication as to the reliability of the connections when fitted up in such a battery. In the first two experiments carried out with this apparatus the disease germ appeared to pass directly into the filtrate, and, as this had not occurred previously with Chamberland candles when the fittings were intact, our attention was at once directed to this point. Tests were made in two ways: first, by the addition of ultramarine to the water, which is always retained on the surface of the porcelain; secondly, when air is forced through the outlet of the submerged battery it at once bubbles out through any leak which may be present in the fittings, thus indicating precisely the part at fault. In the first experiment the leak was found to have originated in a small aperture in the iron framework, which was easily remedied by soldering; in the second it was due, apparently, to the fact that we had failed to make two of the india-rubber connections sufficiently tight; this latter defect was made good by firmly wiring all the connections. These accidents clearly indicate the dangers resulting from a multiplicity of fittings attendant upon the use of a battery, a point to which we have already drawn attention.

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[9] It is very doubtful if the candle ever really clears itself, as we have found that when a larger amount of the filtrate (200 to 300 c.cm.) was taken and incubated for three or four days, we could always demonstrate the presence of numerous water organisms.

During the course of the experiment the battery was placed in a room kept at a temperature of from 25° C. to 30° C., and after being once filled with the sterilised water, to which cholera emulsion had been added, was refilled three times daily with its own filtrate. The experiment was continued for ten days. It was, of course, impossible to prevent the rapid multiplication of impurities in the water, and it was not considered necessary to extend the experiment longer, as the number of extraneous organisms had then increased to such an extent as practically to leave little probability of detecting the cholera organism even if present. In addition, the favourable conditions as regards temperature would probably by this time have permitted of the passage of the disease germ had such been possible under these conditions.

TABLE XCII.—*Sterile Tap Water + Cholera Emulsion. Temperature 30° C.*

Date of Sample.	Average Number of Colonies Present in 1 c.cm. of Filtrate.	Presence or Absence of Cholera Bacilli in Filtrate *plus* Peptone Solution.
First day	*Nil*	*Nil*
Second day	*20 to 30 impurities	,,
Third day...	400 to 500 impurities	,,
Fourth day	Thousands of impurities	,,
Fifth day	,,	,,
Sixth day	,,	,,
Seventh day	,,	,,
Eighth day	,,	,,
Ninth day...	,,	,,
Tenth day...	,,	,,

* The appearance of impurities on the second day, a period too short to permit of the growth of the organisms through the walls of the Pasteur-Chamberland filter, was probably due to the battery not having been completely sterilised when the experiment was started, an operation attended with obvious difficulties in the ease of so large a piece of apparatus.

This experiment appears to us to establish very decisively that these candles afford complete protection against the passage of disease germs.

In the introduction to this part of the report the experiments with typhoid fever bacillus and other test organisms have already been mentioned; and it now suffices to repeat that on every occasion where the fittings were intact these pathogenic organisms appeared unable to pass into the filtrate. We may conclude accordingly that so far as experiments can guide us in such a matter, the Pasteur-Chamberland candles provide a perfect safeguard against the passage of disease organisms. We may state also that the testing to which the candles are subjected before sending out appears to exclude the possibility of any imperfect candles being put on the market, since we have had occasion to test over 150 candles in these and other experiments, without being able to satisfy ourselves that any single one of them was imperfect when supplied to us.

CHAMBERLAND CANDLES AS TAP FILTERS.

From the large number of experiments which were carried out with the Chamberland candle as a tap filter we are enabled here to make a few observations as to the time required for water organisms to penetrate into the filtrate. In most cases such organisms appeared in the filtrate on the fourth day, but sometimes not till the ninth or tenth day, or even longer, this depending, apparently, directly on the temperature of the water. In some cases, however, where several filters were started under apparently similar conditions, one of them would give a sterile filtrate for a considerably longer period than the others. This we at first attributed to differences in the quality of the candle, but resterilisation of the candles and repetition of the experiment convinced us that, in addition, some factor which we had not taken into consideration must also come into operation. We have already referred to the remarkable influence exerted by the temperature, as shown by the fact that a sudden fall in the temperature of the water will permit of filters which were discharging organisms into the filtrate to apparently clear themselves and remain sterile until the temperature again rose. We may mention that the makers of these filters have recently placed on the market an arrangement of the candles with the object of permanently obtaining a sterile filtrate. They seek to attain this end by obliging the water to pass through two candles, but in our experiments this arrangement simply slightly prolonged the time required for the organisms to grow through into the filtrate. These questions as to the passage of water organisms are, however, of more technical interest than of any practical value, since they only serve to reinforce our argument regarding the distinction between the direct passage of germs and their growth through the filter into the filtrate. They need not, accordingly, receive further consideration in this report. We give, however, in the following table a typical example of this process.

TABLE XCIII.—*Pasteur-Chamberland Candles on Tap (Pressure 24 lbs.; Temperature 18° C.).*

Quantity of Filtrate Examined.	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.
1 c.cm. in gelatine plate... ...	—	—	—	+	+	+	+
10 c.cm. in broth	—	—	—	+	+	+	+

RATE OF FILTRATION.

We have now to consider the output of the Chamberland candles when used as tap filters, and the means of renovating them when they have been in operation for some time. In our experiments the candles were worked at a tap pressure of 16 lbs. and 24 lbs. to the square inch, according to the floor or storey of the laboratories on which they were being used. The difference in the amount of output under these pressures with the same candle was such that on an average, with the higher pressure, about one-third more initial output was obtained than at the lower pressure.

It should be noted, however, that exposure to high pressures appears to reduce the output more rapidly than when less water pressure is brought to bear. This is due, in the first place, to the larger quantity of water filtered, and, accordingly, the larger amount of suspended matter which is deposited on the candle; and, secondly, to this suspended matter being driven by the high pressure into the pores of the candle, and thus greatly reducing its output of filtered water. When the water has been allowed to flow continuously for a certain number of days, the output of a filter appears to reach a minimum, where it remains almost constant for a practically indefinite period of time. While in this state a curious phenomenon may occasionally be noted. We observed that on certain days the output of all the filters rose slightly, and, on investigating the conditions, we found that this corresponded with a sudden fall in the barometric pressure, which would, of course, increase to that extent the effective pressure of water in the taps. It is possible that this influence of the barometric pressure may, in certain localities, where the condition is a constant one, exert an effect on the filtering capacity of the candle which may have to be taken into practical consideration.

We have also investigated the question as to the extent to which individual candles varied in their output when tested under precisely similar conditions. These candles have apparently varied considerably in their structure at different periods, so that for this purpose twelve new candles which had been recently purchased were tested in succession under precisely similar conditions on the same tap at 24 lbs. pressure. The results are to be found in the appended table.

As will be seen from this table, the candle which filtered most rapidly gave an output more than three times as great as that which filtered most slowly, and that such a variation with these candles was not unusual is confirmed by a very extensive experience of their use for laboratory purposes. We have frequently observed in the case of broken candles that their thickness varied within very wide limits, some being nearly three times as thick as others. In addition, it is not unusual, on examining a section of the wall of a cylinder, to find an imperfection in the form of a large air bell, which reduced the thickness of the filtering medium in that position to at least one-half of that elsewhere. As such candles protected absolutely against the passage of disease germs, we have every reason to believe that a layer of porcelain only half as thick as that used would serve our purpose efficiently, while probably permitting of a correspondingly larger output of filtered water. We cannot, of

TABLE XCIV.—*Filtering Capacity of Chamberland Candles at 24 lbs. Pressure.*

Number of Candle.	Average Filtrate in 5 minutes.	Average Time Required to Filter 1 pint.
1	400 c.cm.	7 minutes 6 seconds
2	520 ,,	5 ,, 28 ,,
3	600 ,,	4 ,, 44 ,,
4	680 ,,	4 ,, 10 ,,
5	715 ,,	3 ,, 58 ,,
6	780 ,,	3 ,, 38 ,,
7	780 ,,	3 ,, 38 ,,
8	780 ,,	3 ,, 38 ,,
9	830 ,,	3 ,, 25 ,,
10	1 080 ,,	2 ,, 37 ,,
11	1,100 ,,	2 ,, 23 ,,
12	1,440 ,,	1 ,, 58 ,,

course, express an opinion as to the difficulties which might be encountered in the manufacture of such candles, or as regards their strength and durability in practice. These questions could, naturally, only be determined by direct experiment.

AVERAGE QUANTITY FILTERED.

We give in the following table the average quantities of filtered water which can be obtained when storage tanks are made use of, although, as we have already observed, the use of such, when placed under the tap, is not, we think, to be recommended:

TABLE XCV.—*Average Quantity Filtered by Chamberland Candle F.*

Chamberland Candles.	1st Day.	2nd Day.	3rd Day.
No. 1. Time taken to filter 1 litre	10 minutes	$13\frac{1}{2}$ minutes	20 minutes
Calculated quantity filtered in twenty-four hours	122.5 litres, or 27 gallons	86 litres, or 19 gallons	64 litres, or 14 gallons
No. 2. Time taken to filter 1 litre	$4\frac{1}{2}$ minutes	$5\frac{3}{4}$ minutes	$14\frac{1}{4}$ minutes
Calculated quantity filtered in twenty-four hours	201 litres, or 62 gallons	144 litres, or 32 gallons	93 litres, or 20 gallons
No. 3. Time taken to filter 1 litre	$4\frac{1}{6}$ minutes	$8\frac{1}{3}$ minutes	$16\frac{7}{8}$ minutes
Calculated quantity filtered in twenty-four hours	230 litres, or 51 gallons	115 litres, or 25 gallons	69 litres, or 15 gallons

METHOD FOR RESTORING OUTPUT.

The methods of renovating the output of these filters recommended by the vendors consist of, first, removing the film from the surface by means of a brush; secondly, by the use of a cleansing solution which they supply. We have not succeeded by the use of the cleansing fluid in obtaining satisfactory results. By the use of the brush, however, in the case of a new candle, the output was usually almost completely restored, but in course of time this method becomes less and less efficacious. This is due no doubt to the passage of the vegetable matter into the pores of the filter. which is not then, of course, removed by the process of brushing the surface. The only efficient means at our disposal of restoring the filtering capacity of these candles is, we find, to subject them to a process of baking at a red heat. This is carried out most efficiently in the laboratory by means of a small muffle furnace, but even where every care is taken to dry the candles previously, a certain amount of breakage takes place; moreover, the process is not one which could conveniently be carried out in practice.

In addition it is necessary to retest each candle after it has been subjected to this process, as the heat may have destroyed its filtering efficiency by causing cracks or other defects in the porcelain. This is done by subjecting the candle when submerged in water to an air pressure of 7 lbs., when the efficiency of the candle is manifested by the pressure being maintained, and by absence of air bells in the fluid.

These results bearing on the output of the Chamberland candle and on the process of renovation by means of cleaning, were obtained chiefly with water supplied by the New River Company; in addition a few experiments were carried out with the Lambeth Water Company's water, which gave very similar results. As the London water is supposed to undergo a rather better process of sand filtration than elsewhere, it is probable that rather better results may be obtained with it than with most other waters. It must be remembered, however, that the slimy coating which in time envelops the candle and restricts the output is usually derived in great part from the growth in the mains and pipes of vegetable organisms which are carried to the filter, and not so much from the particles which have escaped the sand filter. We have also observed that sediment in the pipes derived apparently from reparation of the mains or even from the cleaning of cisterns, may lead to a sudden diminution of the output. We are convinced, therefore, that what we have described may be taken as a fair sample of what might be expected of these candles under the most favourable conditions. On the other hand, where the filters are used in the army for camp purposes, where turbid water must frequently be supplied to the filters, some experiments carried out with the Thames water taken at Waterloo Bridge (see p. 83 *et seq.*), indicate that the candle would require to be burned at frequent intervals if anything like their initial output is to be maintained.

We must accordingly conclude from our extensive experiments with the Pasteur-Chamberland filter, and from the experience of the French War Office of their use in the army that these candles afford complete protection against the communication of waterborne infective disease.

VIII.

THE BERKEFELD FILTER COMPANY, LIMITED, *Engineers and Contractors for Pure Water Supplies, Contractors to Her Majesty's Government, 121, Oxford Street, London, W.*—In our first report on non-pressure filters we gave in detail the claims put forward on behalf of the Berkefeld filter in preventing waterborne disease, and we stated that our experiments confirmed the claim that these filters did indeed appear to confer protection against the transmission of disease germs, but we also expressed our opinion that owing to their comparatively small output as table filters, they must find their chief use as pressure filters. We have already considered the experiments on which we base our conclusion that these filters, although permitting of the rapid growth through their walls of water organisms, still supply an effective barrier to the passage of disease germs into the filtrate. We shall here simply make the addition of a few details to these results, and then consider more fully those physical and mechanical details which are of so much importance in the practical application of any system of water filtration.

When the Berkefeld filter was used either as a table filter or as a tap filter, it was found that water organisms might pass into the filtrate as early as the second day, and appeared at latest on the fourth or fifth day of filtration. The organisms made their appearance in the filtrate, independently of the temperature (which varied from 11° C. to 18° C.). In the case of the Chamberland candles used at the lower temperature, the filtrate sometimes remained sterile for apparently indefinite periods of time, when 1 c.cm. of this filtrate was brought under examination. This must be ascribed to the combination of two unfavourable conditions: the low temperature and the devitalising influence exerted by the pores of the porcelain; these together preventing the growth of the organisms through the Pasteur-Chamberland filter into the filtrate. Where the latter condition is wanting, as in the Berkefeld candle, in which the channels are apparently not nearly so fine, the low temperature is insufficient to prevent

TABLE XCVI.—*Berkefeld Candle No. 14 on Tap (Pressure 24 lbs.; Temperature 18° C.).*

Quantity of Filtrate Examined.	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.
1 c.cm. in gelatine plate... ...	—	—	—	+	+	+	+
10 c.cm. in broth	—	—	+	+	+	+	+

the passage by growth of water organisms through the filtering medium of the wall. In the following table we give an example of the action of this filter (candle "No. 14" of the old list) when attached to the tap.

Arrest of Disease Organisms.

In addition to the experiments already given, on which we base our opinion that these filters do not permit of the passage of disease organisms, we may here give an experiment carried out with a composite battery of twelve Berkefeld candles fed with cholera emulsion and sterile tap water. As these candles are supplied in many different forms and sizes, we tested a battery made up of three each of forms Nos. 1, 2, 8, and 14.

This battery was kept in a room maintained at a temperature of 30° C., and after being once fed with the emulsion of cholera mixed with sterilised water was refilled three times daily with its own filtrate. The impurities which, of course, could not be excluded from the water multiplied very rapidly at this temperature, so that it was considered unnecessary to continue the experiment beyond the sixth day. The results obtained are shown in the appended table.

Table XCVII.—*Sterile Tap Water + Cholera Emulsion. Temperature 30° C.*

Date of Sample.	Average Number of Colonies Present in 1 c.cm. of Filtrate.	Presence or Absence of Cholera in the Filtrate added to Peptone Solution.
First day	*Nil*	*Nil.*
Second day	40 to 50 impurities	"
Third day...	Thousands of impurities	"
Fourth day	" "	"
Fifth day	" "	"
Sixth day	" "	"

The negative result recorded in this experiment appears to indicate that this filtering material, which is made up in so many different forms and sizes, is remarkably uniform in its quality, as a defect in any one of the candles would have been detected at once on the first day of the experiment. We may here state that we have at various times examined over fifty of the Berkefeld candles, and have in no case been able to satisfy ourselves that any one of them was imperfect as regards the prevention of the direct passage of test organisms.

Rate of Filtration.

We must now briefly consider the rate of filtration of the Berkefeld filters, and the means of renovating their output when they have been in operation for some time. The tap filters specially experimented with were, first, that described as Fig. F in the maker's list fitted with candle No. 14; and secondly, that described as Fig. H, fitted with candle No. 1 of their list. The candles were exposed to a tap pressure of 16 lbs. or 24 lbs. to the square inch, according to the floor or storey of the laboratories on which they were being used. The difference in the amount of output under these pressures with candle No. 14 was such that on an average with the higher pressure about one-third more initial output was obtained than at the lower pressure. It is necessary to to point out here that it is not advisable to use a greater pressure than 35 lbs. to the square inch since the suspended materials present in the water are driven into the pores by excessive pressures, and thus rapidly block the filter and necessitate cleansing.

We have also tested the various candles as regards variations in the output of individual cylinders by trying six new candles under precisely similar conditions. The results are to be found in the appended table:

TABLE XCVIII.—*Filtering Capacity of Six Berkefeld Candles No. 14 at 24 lbs. Pressure.*

Number of Candle.	Average Filtrate in 5 Minutes.	Average Time required to Filter 1 Pint.
1	3,350 c.cm.	51 seconds
2	3,400 "	50 "
3	3,500 "	49 "
4	3,625 "	47 "
5	3,850 "	44 "
6	4,440 "	38 "

TABLE XCIX.—*Filtering Capacity of Berkefeld Candles (No. 1) at 24 lbs. Pressure.*

Number of Candle.	Average Filtrate in 5 Minutes.	Average Time required to Filter 1 Pint.	Pints per hour.
1	5,357 c.cm.	31 seconds	116
2	5,769 "	29 "	124
3	6,000 "	28 "	130
4	6,000 "	28 "	130
5	6,250 "	27 "	133
6	6,666 "	25 "	144

Similar experiments were carried out with candle No. 1 fitted up in Fig. H. of maker's list, an exceedingly good model, which seems to us to subserve the functions of a filter more perfectly than any we have yet seen described,

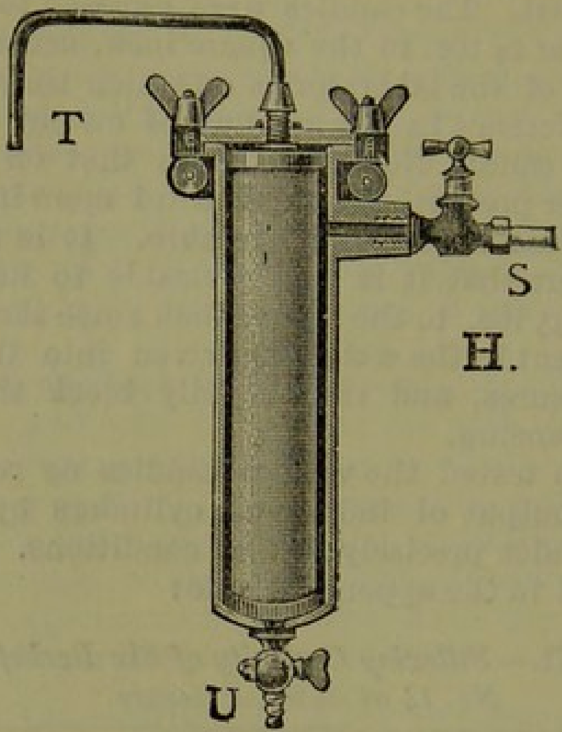

Fig. 10.
Section of Berkefeld Filter. S, inlet; T, outlet; U, cleansing tap.

inasmuch as the filtered water finds its exit from the upper part of the case, thus obviating any chance of contamination with unfiltered water due to leakage. The candle in this filter is much larger than the one already described, being 10 inches in length and 2 inches in diameter, and is stronger in a corresponding degree. An experiment was made with six of these candles to test their average rate of output. The results obtained are set forth in Table XCIX.

As will be seen from this table, the rate of filtration is very rapid—in fact, the output is so large that there is no reason why such filters should not supply sufficient water to meet all household requirements. We have already stated that any filter to be really satisfactory must supply all the water which is necessary for domestic requirements.

Average Quantity Filtered.

The next point to be considered is how far the output is maintained under continuous operation, and the total amount of water filtered before the output is seriously diminished. This can be seen in the following table, where the experiment was carried out with three candles of form No. 14.

These candles give a large output, but unfortunately are very fragile, and accordingly are frequently broken during the process of cleaning. In consequence of this the manufacturers have replaced this type by another in which the candle is made much shorter and stouter, and which gives a very similar output of filtered water. There is no doubt,

TABLE C.—*Average Quantity Filtered by Berkefeld Candle No. 14.*

No. of Candle.	1st Day.	2nd Day.	3rd Day.
No. 1. Time taken to filter 1 litre	128 seconds	428 seconds	750 seconds
Calculated quantity filtered in 24 hours	68 gals.	32 gals.	24 gals.
No. 2. Time taken to filter 1 litre	100 seconds	143 seconds	294 seconds
Calculated quantity filtered in 24 hours	157 gals.	87 gals.	41 gals.
No. 3. Time taken to filter 1 litre	77 seconds	130 seconds	461 seconds
Calculated quantity filtered in 24 hours	184 gals.	64 gals.	29 gals.

however, that the larger candles (No. 1), which are considered in our next table, offer greater advantages over the smaller forms both as regards output of filtered water and as regards risk of breakage.

TABLE CI.—*Average Quantity Filtered by Berkefeld Candles No. 1.*

Number of Candle.	1st Day.	2nd Day.	3rd Day.
No. 1. Time taken to filter 1 litre ...	56 seconds	160 seconds	285 seconds
Calculated quantity filtered in 24 hours	176 gals.	85 gals.	59 gals.
No. 2. Time taken to filter 1 litre ...	52 seconds	68 seconds	147 seconds
Calculated quantity filtered in 24 hours	316 gals.	178 gals.	90 gals.
No. 3. Time taken to filter 1 litre ...	43 seconds	55 seconds	94 seconds
Calculated quantity filtered in 24 hours	387 gals.	253 gals.	138 gals.

From this table it will be seen that very large quantities of water can be rapidly filtered by means of these candles. It need scarcely be pointed out that where, as in actual practice, the filter is used only intermittently, it will continue in operation for a much longer period before the output becomes so diminished that the candle requires cleansing. The water employed in these experiments was chiefly the New River Company's water, and this no doubt represents a very favourable water for these candles, other supplies which contain much matter in suspension, such as peaty waters will naturally rapidly block these filters.

METHODS FOR RESTORING OUTPUT.

The cleansing of the candles when the output becomes diminished is easily and quickly effected by rubbing the surface with a sponge, piece of loofah, or a brush, under a running tap. In this process a very thin surface layer of the filtering material is removed along with the sediment which has blocked up the pores of the filter and diminished its output. When cleaned in this way the original output is usually at once completely restored. Thus a filter containing candle No. 1 which had been in intermittent use for nine months, after cleansing, furnished a litre of filtered water in sixty seconds. In the case of a candle No. 14, which has been in domestic use for the last four years, the output after cleaning was still equal to that of a new candle. The surface of the candle was somewhat worn and irregular, but on testing its efficiency against test organisms it was found that it still completely prevented their passage.

Mechanical Cleansing.

The vendors of these filters employ a mechanical cleansin arrangement in the case of their large supply filters. This consists essentially in mixing a small quantity of prepared kieselguhr with the first water which is passed through the filter. A thin coating of kieselguhr is thus deposited over the cylinders upon which the suspended material in the water accumulates and as soon as the filter begins to get clogged the kieselguhr and the sediment which has collected can be completely thrown off and washed away without the filter being opened, by reversing the current of water and passing it backwards through the filter for a short time. We have experimented with this method on the filter shown in the block on p. 275, and although the output was not completely restored in the same way as was done by brushing the candle it would no doubt be very serviceable when used as they describe in their special filter. We observed when using the kieselguhr that when only a small quantity was mixed with the water, a distinct advantage might be obtained in the total quantity of water filtered during the course of three or four days. This will be seen by comparing the results obtained with the same candle with and without kieselguhr, as recorded in the following table:

Table CII.—*Filtration of a Berkefeld Candle (No. 1) with and w'thout Kieselguhr.*

Filter with and without Kieselguhr.	1st Day.	2nd Day.	3rd Day.
Without kieselguhr:			
Time taken to filter 1 litre	52 seconds	68 seconds	147 seconds
Calculated quantity filtered in 24 hrs.	316 gals.	178 gals.	90 gals.
With kieselguhr:			
Time taken to filter 1 litre	56 seconds	65 seconds	88 seconds
Calculated quantity filtered in 24 hrs.	314 gals.	248 gals.	192 gals.

In the course of the seventy-two hours the candle which had been treated with kieselguhr filtered 170 gallons more water than the other. This method would be especially serviceable in the case of turbid waters where the pores of the filters would otherwise become rapidly blocked, since, as our table shows, the chief advantage is gained on the second and third days, when the suspended matter present in the water has begun to collect on the cylinder.

We must accordingly conclude from the extensive series of experiments carried out with these Berkefeld filters that they afford complete protection against the communication of waterborne disease.

IX.

Aéri-Filtre-Mallié, Théories Pasteur, Porcelaine d'Amiante, Maison Mallié, *155, Faubourg Poissonniere, Paris.*—The Filtre Porcelaine d'Amiante is the only one of those sent out by this firm which we shall now consider. We have already given a brief description of it under the heading of table filters. It has been highly praised by many authorities, and has received an award from the French Academy. It is claimed for it by the vendors that it is the most perfect filter ever produced, and is "impenetrable." They state that only the porcelaine d'Amiante provides a continuous and perfect filtration of water. Miquel, in his experiments, found that this filter sterilised highly polluted stagnant water during twelve days' filtration, a result which he affirms could not have been obtained by any other filter. An examination of this filtering medium tends to confirm the assertion of the makers that it is the finest porcelain which has ever yet been put upon the market for this purpose ; it is composed, we believe, of an extremely fine porcelain, containing very finely powdered asbestos, and is of a reddish terra-cotta colour, which is probably due to the presence of iron. We have carried out experiments with candles of this material (figure A of catalogue), and also with the balloon-shaped filters (figure B of catalogue). This latter has a diameter of 2½ inches, and the walls are $\frac{3}{32}$ of an inch thick. Only the latter was used as a tap filter, the other candles being used for the purpose of testing the uniformity of the candles sent out by this firm.

In the course of our experiments with water we have repeated Miquel's experiment with stagnant water, in which he found that organisms were kept back for a period of twelve days. One of the large candles was allowed to rest in a vessel of Thames water taken at Waterloo Bridge from which the filtered water was drawn into an exhaust bottle by means of siphonage and the pressure of a water pump. The filter was retained at the temperature of the room, and samples of the filtrate were examined from day to day. The results are given in Table CIII.

In this experiment it will be seen that the filtrate remained sterile up to the eighth day, which is a period of time at least double that during which the Pasteur-Chamberland gives a sterile filtrate under similar conditions.

The experiments with this material as a tap filter were carried out during the colder season of the year, when undoubtedly

TABLE CIII.—*Thames Water taken at Waterloo Bridge.*

1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.	8th Day.	9th Day.	10th Day.	11th Day.	12th Day.
—	—	—	—	—	—	—	—	+	+	+	+

the temperature conditions are much less favourable for the growth of water organisms through the filter, and where, accordingly, the filtrate would tend to remain sterile during a longer period. The temperature of the water during the first experiment varied from 16° C. down to 12° C., but we may mention that during this period Chamberland and Berkefeld filters under precisely similar conditions failed to discharge continuously sterilised water. The results are set out in Table CIV.

These results with water are certainly very striking, and indicate that at any rate when exposed to a moderately low temperature this filter can apparently supply a sterile filtrate for at least a month. We have already pointed out that the growth of water organisms through the walls of the candle into the filtrate does not in any way indicate the incapacity of a filter to prevent the transmission of waterborne disease, so that the power possessed by this filter of offering greater resistance to the passage of water organisms does not necessarily indicate more perfect protection against cholera and typhoid, although it undoubtedly does show that in this material we have an extremely effective filtering medium. The very fine nature of the porcelain would no doubt manifest its influence most markedly in the case of the filtration of fluids containing toxic bacteria, but, as has already been discussed elsewhere, it is very doubtful whether such refinements in the action of a filter such as those which exist between the d'Amiante, Chamberland and Berkefeld filters would exert any perceptible influence in actual use.

We have carried out experiments with tap water and emulsions of cholera (Table CV) and typhoid bacilli (Table CVI) over prolonged periods, using the two forms as table filters. In no instance have we been able to demonstrate the presence of either of these organisms in the filtrate.

These experiments prove that this filter provides as perfect a protection against the transmission of waterborne disease as is afforded by any of the methods of filtration at present known to scientific workers.

I 2

Table CIV.—*Porcelaine d'Amiante on Tap.*

(Pressure 16 lbs. Temperature 16° to 12° C.)

Presence or Absence of Water Organisms in Filtered Water.

Days ...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
First experiment ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Second experiment ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Third experiment ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table CV.—*Tap Water + Cholera Bacilli.*

Description of Filter.	Days.								
	1	2	3	4	5	6	12	20	26
Balloon-shaped Form	—	—	—	—	—	—	—	—	—
Candle Form	—	—	—	—	—	—	—	—	—

Table CVI.—*Tap Water + Typhoid Bacilli.*

Description of Filter.	Days.								
	1	2	3	4	5	6	12	20	26
Balloon-shaped Form	—	—	—	—	—	—	—	—	—
Candle Form	—	—	—	—	—	—	—	—	—

We must now briefly consider the mechanical details which would affect its application in practice. The most important from the practical point of view is the rate of filtration, and the ease with which the filter can be cleaned. The rate of filtration in this filter (Fig. "B." of catalogue) is exceedingly slow, since with a pressure of 16 lbs., when the filter is still new, a period of two hours is required for the filtration of a single litre. Under continuous filtration the rate of output slowly declines. On cleaning the filter by brushing it with a nailbrush the original rate of filtration is at once completely restored. A filter in continuous use for five months, being brushed from time to time, at the end of that period, when cleaned still gave almost the original output. This is a result which we have never been able to obtain with any other of the porcelain filters, and is to be ascribed no doubt to the fineness of the porcelain retaining all the suspended material on the surface of the candle, whence it can be easily removed by the process of cleansing. In this respect the porcelain d'Amiante possesses advantages over many other forms of porcelain. The mechanical fittings of the filter are also all that can be desired. In conclusion, however, although we must regard this filter as affording a perfect protection against disease, the slow rate of filtration will prevent its ever coming into general use for the filtration of water.

X.

PUKALL FILTER, *Royal Porcelain Factory, Potsdam, Berlin.* —This is a filter of apparently only recent introduction and at present is not in extensive use; indeed, from the fact that we were unable to obtain a case or fittings with the filter, it may perhaps even be said not to be upon the general market. As we were unable to obtain either catalogues or pamphlets relating to this filter we are unable to compare the claims put forward on its behalf with the results obtained in our experiments. The filtering medium consists of a very fine form of unglazed porcelain which is moulded into a very peculiar-shaped filter, a lower tubular part, which expands above into a spheroidal portion, the dome of which is somewhat flattened. In our experiments the tubular portion was fitted with an indiarubber cork, through which passed a piece of glass tubing in order to facilitate the collection of filtered samples.

We obtained this filter in three sizes—small, medium, and large. As already stated, the texture of the porcelain seems to be very fine and the walls accordingly are correspondingly thin, about $\frac{3}{32}$ in. in thickness. The length of the smallest filter is $3\frac{3}{4}$ in., while the diameter of the globe is $2\frac{1}{4}$ in. The medium-sized filter is 6 in. in length, the globe-shaped portion being $3\frac{1}{2}$ in. in diameter. The large form is 10 in. in length and the globe-shaped portion $6\frac{1}{2}$ in. in diameter. The filters had to be fitted up in tin cases constructed in the laboratory and fastened down with solder; as these were unfortunately unfitted to withstand very high pressure owing to the flexibility of the metal, we were unable to estimate exactly the pressure to which the filter was exposed, as this had to be regulated only by the tap. The pressure under these conditions was usually considerably under 16 lbs., so that the rapidity of filtration is really somewhat understated in the figures which are given below. The rate of filtration of the three filters under pressure is as follows: The small-sized filter delivered a litre of water in fourteen minutes; the medium size a litre in nine minutes; and the large form the same quantity in four minutes. These results as regards output are certainly very favourable for a porcelain filter, but it must be pointed out that the quantity declines very rapidly under continued use as foreign matter collects on the surface of the filter. Brushing the surface almost completely restores the original output, but no doubt in course of time the pores in the interior of the porcelain would also become more or less blocked, and probably the only effectual method of renovating the filter would be by baking it at a red heat. The filters are no doubt quite well suited to undergo this process, as they consist entirely of unglazed porcelain, although their unusual shape placed certain difficulties in the way, in our hands, as we had, at the time when these experiments were carried out, only the ordinary laboratory combustion furnace at our disposal.

It is unnecessary to give the series of tests to which each of the three forms of this filter was subjected. It will be sufficient to record the experiments carried out with one or other forms as the results obtained with the other forms were precisely comparable. We give in the appended table the experiments carried on with the largest form:

Table CVII.—*Tap Water. Temperature 16° C.*

Description of Filter.	1st Day.	2nd Day.	3rd Day.	4th Day.
Large Pukall on tap	—	—	—	+

Here the filtrate remains sterile for three days, but in several other experiments in which the other forms were used, the organisms appeared in the filtrate considerably earlier, usually on the third day, and on one occasion even on the second. We were also able to observe that the organisms present in the filtrate did not appear to have been weakened in their passage through the porcelain; this was evidenced by their exhibiting their power of liquefying the gelatine at first to a much greater extent than is usually observed in the case of organisms that have run the gauntlet of the Pasteur-

Chamberland filter. One of the medium-sized filters was tested on a tap with staphylococcus pyogenes aureus; the results obtained are given in the accompanying table:

TABLE CVIII.—*Table Water + Staphylococcus Pyogenes Aureus.*

Description of Filter.	1st Day.	2nd Day.	3rd Day.	4th Day.
Medium Pukall	—	—	—	—

The negative result recorded on this occasion indicates that this filter is apparently impenetrable to the passage of the test organisms, but this point is much more definitely proved by the experiments with cholera and typhoid bacilli which were carried out with the filters fitted up as table filters. The results obtained are to be found in the appended tables.

TABLE CIX.—*Tap Water + Cholera Bacilli.*

Description of Filter.	1st Day.	2nd Day.	3rd Day.	4th Day.	7th Day.	12th Day.	18th Day.
Medium Pukall	—	—	—	—	—	—	—
Small Pukall...	—	—	—	—	—	—	—

TABLE CX.—*Tap Water + Typhoid Bacilli.*

Description of Filter.	1st Day.	2nd Day.	3rd Day.	4th Day.	7th Day.	12th Day.	18th Day.
Medium Pukall	—	—	—	—	—	—	—
Small Pukall...	—	—	—	—	—	—	—

These experiments indicate very definitely that this form of porcelain can be relied upon to arrest the passage of disease organisms. It must be concluded, accordingly, that this filter affords a perfect protection against the transmission of waterborne disease.

XI.

SLACK AND BROWNLOW, *Abbey Hey Works, Gorton, Manchester.*—We have already reported on the compressed charcoal filters supplied by this firm under the heading of non-pressure filters, so that we considered it unnecessary to test further this material when used as a tap filter. This firm has, however, recently placed upon the market a filter which, they claim, is germ-proof. Here the filtering medium consists of unglazed porcelain; we therefore considered it desirable to bring this form under examination. It is stated by the vendors, in their catalogue, that "the filtering tube or candle consists of a hollow cylinder of porous porcelain, which in specially prepared forms is recommended by Dr. Koch, Professor Pasteur, and other eminent scientists as being the only one which effectually sterilises water, and thus arresting all disease germs communicated by water, and preventing cholera, typhoid fever, dysentery, etc. Scientists and the highest medical experts acknowledge the system of filtration through porous porcelain tubes to be the best, and the marvellous power of our germ-proof tubes in sterilising water is the result of exhaustive experiments extending over several years: water literally teeming with germs and impurities is rendered bright, sparkling and absolutely sterile." They also quote a report on their filter by Mr. W. A. H Naylor, F.I.C., F.C.S., which is as follows: "I have tested several candles of unglazed porcelain manufactured by you, the experiments made having special reference to their capability of removing micro-organisms from drinking waters. On passing one of the London company's waters through the respective candles, the filtered water so obtained was in every case found to be free from bacteria and germs, that is,

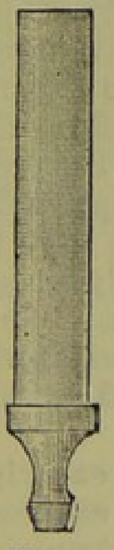

Fig. 11

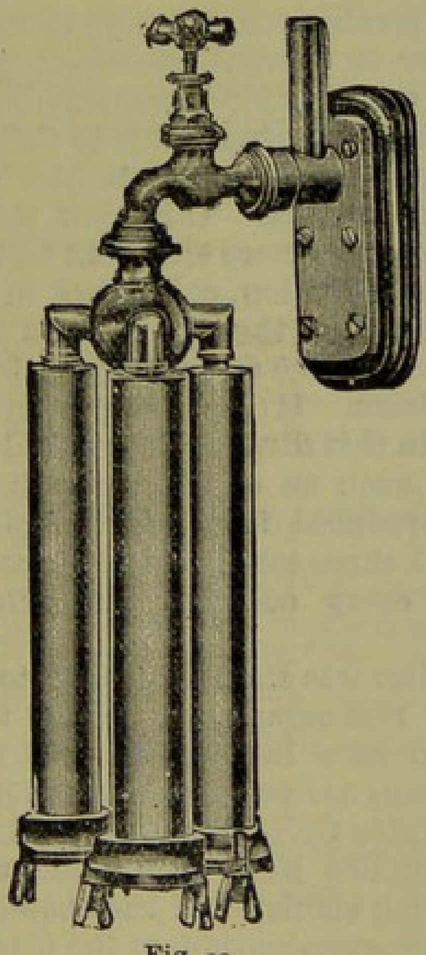

Fig. 12.

it was in a sterile condition. The same water before filtration through your candles gave evidence of the development of bacteria to a considerable degree."

The porcelain in this type of filter is used as a candle formed on a model similar to that of the Pasteur-Chamberland system, but differs slightly in dimensions, being about 6⅝ in. in length and 1⅛ to 1¼ in. in diameter, with a glazed porcelain nipple. In the accompanying illustrations can be seen this form of candle, along with a tap filter consisting of a group of three of these candles. We carried out our experiments on a tap filter containing one candle, which is described in the maker's catalogue as No. 115. The fittings of this filter are all that can be desired. The results of our experiments with this filter when fitted on the tap at 24 lbs. pressure appear in the appended table:

TABLE CXI.—*Slack and Brownlow Candle on Tap (Pressure 24 lbs., Temperatur 18° C.)*

Quantity of Filtrate Examined.	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.
1 c.cm. in gelatine plate ...	—	—	—	+	+	+	+
10 c.cm. in broth	—	—	—	+	+	+	+

These results would appear to indicate that this filter has the power to prevent the direct passage of water organisms, since of course their appearance on the third and following days would be probably due to their growth through the walls of the candles—a process to which even thoroughly reliable filters are subject. This view was confirmed by subjecting the filter to the more stringent test which we have described in the introduction, consisting in collecting 200 or 300 c.cm. of the filtrate on the first day in a sterile flask and incubating at 20° C. for three or four days before testing for the presence of organisms. If only 2 or 3 water organisms happened to be present in this filtrate, they would in this time have multiplied to such an extent as to have been easily recognised when introduced into gelatine plates or broth. We have subjected three candles of this make to this stringent test, and on every occasion the filtrate remained absolutely sterile.

This filter was then subjected to a series of experiments with our test organisms. Six of the porcelain candles were fitted up in a battery, and fed with a rich emulsion of staphylococcus pyogenes aureus for three days, but as will be seen in Table CXII none appeared in the filtrate.

Two candles were then fitted up as table filters, and fed with a rich emulsion of the cholera bacillus in sterilised tap water, the examination of the filtrate being carried out for a week. On each occasion 300 c.cm. of the filtrate was added to concentrated broth, and incubated for the detection of cholera bacilli, but, as will be seen from Table CXIII, the result on each occasion was negative.

Table CXII.—*Sterile Tap Water plus Staphylococcus Pyogenes Aureus. Temperature 22° C.*

Date of Sample.	Presence or Absence of Staphylococcus Pyogenes Aureus in the Filtrate.
First day...	—
Second day	—
Third day	—

Table CXIII.—*Sterile Tap Water + Cholera Bacilli.*

Number of Candle.	1st Day.	2n Day.	3rd Day.	4th Day.	5th Day.	6th Day.	7th Day.
Candle No. 1	—	—	—	—	—	—	—
Candle No. 2	—	—	—	—	—	—	—

Rate of Filtration.

Our experiments were carried out with twelve porcelain candles which we had obtained through our agents, and each of these was tested on at least two occasions, sometimes after having been cleaned by being subjected to a red heat, which did not appear to affect their efficacy, although no reference to this method of renewing their output is made by the vendors. We must accordingly conclude that these filters (at any rate those candles which we have subjected to examination) are able to prevent the transmission of disease germs into the filtrate. The manufacturers make no reference to their candles being submitted to any test before being sent out, and it is probable that unless some process of selection

Table CXIV.—*Filtering Capacity of Slack and Brownlow Candles at 24 lbs. Pressure.*

Number of Candle.	Average Filtrate in Five Minutes.	Average Time Required to Filter One Pint.
1	1,250 c.cm.	2 minutes 16 seconds.
2	1 425 ,,	2 minutes.
3	1,850 ,,	1 minute 33 seconds.
4	1 950 ,,	1 minute 32 seconds.
5	2,000 ,,	1 minute 25 seconds.
6	2,000 ,,	1 minute 25 seconds.

is exercised imperfect candles might from time to time be placed upon the market; but, as we have already stated, the few that we have been able to bring under examination all passed our tests.

We shall now consider very briefly the rate of filtration of these filters and the other conditions which would affect their use in actual practice. We give in Table CXIV the initial output obtained with six fresh candles, from which it will be seen that their rate of filtration is rather above that usually obtained with porcelain candles:

Under continuous filtration the output of these candles falls very rapidly—the output after twenty-four hours being only about one-third and after forty-eight hours one-sixth of the initial filtering capacity. This is probably to be ascribed to the porous nature of the porcelain used, which permits of an initial high rate of filtration, but is at the same time, owing to the comparatively large size of its pores, liable to have these blocked very rapidly. The vendors do not describe any method of cleansing the candles, but we have found that the process of brushing, at first at any rate, renews their output. In practice, however, no doubt the candles would have to be subjected to a red heat from time to time to remove the organic matter retained in the pores of the candle. We have found, however, that these candles when raised to a red heat in our Muffle furnace became so profoundly modified in their filtering capacity that their output of filtered water was reduced from one-half to one-third of that which they originally provided. It would appear accordingly that these candles are not suited to undergo this process of baking, and this fact must seriously interfere with their use for many purposes.

This filter is a recent addition to those on the market, and accordingly has not been been tested to the same extent in laboratories and in actual practice as in the case of some of the older forms, but so far as our experiments go they warrant us in concluding that this filter protects against the transmission of waterborne disease.

XII.

Duff's Patent Germ-Proof Filter. Agents: Witty and Wyatt, Limited, *88, Leadenhall Street, London.*—The vendors state that the filtering medium consists of a natural stone, which it is estimated contains 41 billions of granular particles to the cubic inch. They state that "water readily passes through this, leaving all the microbes, germs, and other impurities on the outer surface of the stone, from which they can be easily brushed off with a scrubbing brush. This filter will filter the muddiest and foulest water. All dirt, germs, etc., are left on the surface of the stone. . . . . . It is impossible to have impure water under any circumstances."

This filter, which is shown in the accompanying illustration, has a cast-iron case (A) covered by a lid (B), which is held in position by a hoop and thumb screw (C). To the lid is attached a hollow cylinder of stone (D), which is the filter ing medium. The water to be filtered passes in at the cock (F), surrounds the stone, and issues through it as filtered

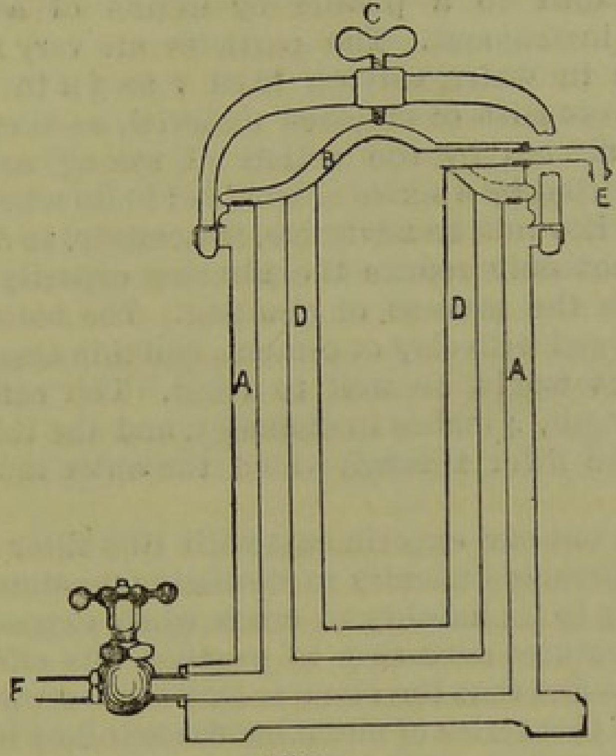

Fig. 13.

water at the cock (E). The mechanical arrangements of this filter are good. We may also state here that the rate of

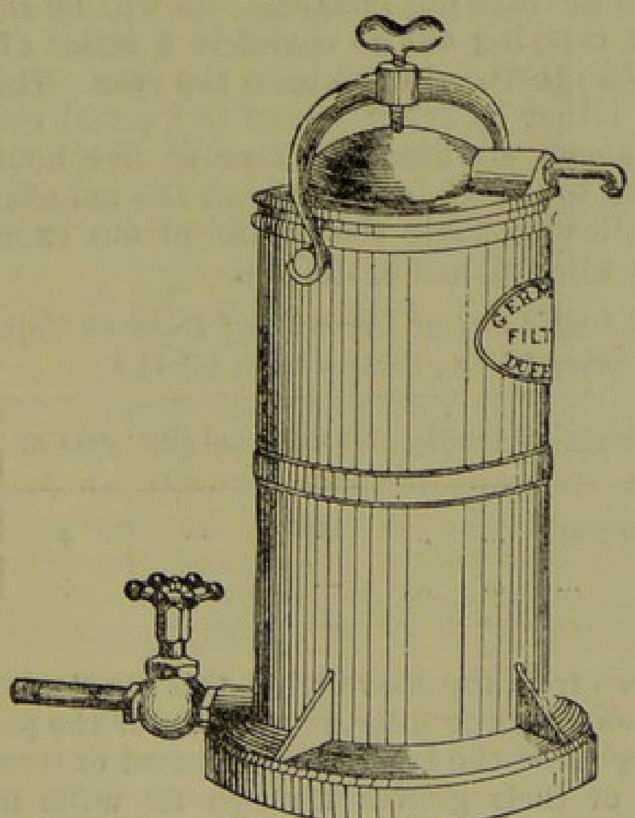

Fig. 14.

filtration is extremely rapid, and that so far as regards removal of suspended material from a water it functions

The filtering medium appears to consist of a natural sandstone, so soft in its consistence that it is easily rubbed down or scraped to a powder by means of a knife or other metal instrument. The particles are very fine when broken down in water, varying from 1 to 3 μ in diameter, and appear to consist of silicious material, as they were apparently unaffected by the action of strong acids. The stone is supported by a series of bands of brass wire, which it appears to us it would be advisable, if possible, to discard, as these must not only reduce the filtering capacity, but also interfere with the process of cleaning. The bottom of the candle is plugged with clay or cement, and this also is a weak point which it would be well to avoid. The candle is 11 inches in length, 4 inches in diameter, and the thickness of the wall of the filter through which the water must pass is 1 inch.

In carrying out our experiments with this filter we experienced considerable difficulty in sterilising the stone filtering medium owing to its liability to crack when exposed to the higher temperatures necessary to produce this effect. This was due to the fact that the stone is first of all cemented to a metal top and to a series of metal bands encircling its circumference, and that these metal fittings would probably expand much more rapidly when heated than the stone cylinder, which would naturally tend to a rupture at the junction of the metal with the filtering medium. As will be seen, this prevented our carrying out as complete a series of experiments as would otherwise have been the case. The candle was sterilised either by being placed in a vessel containing water in the steam steriliser for four or five hours, or by being heated up to 120° C. for an hour in the autoclave. We give in the following table the results of our experiments with this filter when affixed to the tap.

TABLE CXV.—*Duff's Patent Germ-Proof Filter on Tap. (Pressure 24 lbs., Temperature 18° C.)*

Quantity of Filtrate Examined.	1st Day.	2nd Day.	3rd Day.	4th Day.
1 c.cm. in gelatine plate	—	—	+	+
10 c.cm. in broth	—	—	+	+

As will be seen from the above table, this candle appears to conduct itself as a perfect filter, permitting of the passage of organisms only after the lapse of an interval of time which would permit of their growth through its walls into the filtrate.

The filter was then again sterilised, and after being fed with a rich emulsion of staphylococcus pyogenes aureus, was again affixed to the tap and allowed to run continuously.

Four samples were taken during the first day, the first immediately after starting, the second after the lapse of an hour, the third after two hours, and the fourth after six hours. On the second day two other samples were taken. We carried out these experiments with the filter attached to the tap, as we considered it possible that the germs might be washed through the filter only after the lapse of a certain time, owing to the thickness of its walls, but as will be seen from the table which follows we were unable to demonstrate the presence of the test organism in any of the samples examined.

TABLE CXVI.—*Tap Water + Staphylococcus Pyogenes Aureus.*

Number of Sample and Time of Taking.	Presence or Absence of Staphylococcus Pyogenes Aureus in the Filtrate.
First day, Sample 1 (immediately)	—
" " 2 (1 hour)... ...	—
" " 3 (2 hours) ...	—
" " 4 (6 hours) ...	—
Second day, Sample 1 (24 hours) ...	—
" " 2 (30 hours) ...	—

We intended then to test this filter with cholera bacilli, but during the process of sterilisation the candle cracked and was rendered useless for our purpose. Another candle was, however, obtained from the agents, and after sterilisation the experiment was proceeded with. The filter was fed with a rich emulsion of cholera bacilli in sterilised tap water, the filter being fed again and again with the filtrate which had passed through its walls. Large quantities of the filtrate were then taken and added to concentrated broth, to be incubated, so that we might detect cholera bacilli even if only a very small number should happen to be present in the filtrate. In this way more than two litres were brought under examination on the first day, and one litre on the second. The filtrates with one exception, however, remained absolutely sterile, and the growth on that one occasion was traced to the entrance of an accidental impurity acquired during the process of manipulation. The results obtained appear in Table CXVII.

This experiment demonstrates very clearly that this material furnishes a germ-free filtrate when tested under the most strict conditions that we could devise. We were proceeding to test this candle further with staphylococcus pyogenes aureus when our candle again met with an accident during the process of preparation. On applying to the agents we were unable to procure another candle, as it appears that only a few have yet been manufactured, the inventor apparently waiting to ascertain how far this filter subserved its functions before going further in the matter. We have accordingly been unable to proceed further in this direction.

TABLE CXVII.—*Sterile Tap Water + Cholera Bacilli.*

Number of Sample.	Presence or Absence of Cholera Bacilli in the Filtrate.
First day, Sample 1	—
" Sample 2	—
" Sample 3	—
" Sample 4	—
Second day, Sample 1	—
" Sample 2	—
" Sample 3	—

As we have already stated, the rate of filtration of this filter is very rapid. This will be seen from the following table:

TABLE CXVIII.—*Filtering Capacity of Duff's Patent Germ-Proof Filter.*

No. of Candle.	Day.	Average Filtrate in 5 minutes.	Average Time required to Filter 1 pint.
Candle 1	First day	9 litres	19 seconds.
"	Second day	3 "	57 "
Candle 2	First day	14 "	13 "
"	Second day	5 "	34 "

As will be seen from this table, this filter, like all others, would in course of time rapidly diminish in its output from the deposition of suspended materials on its surface. We have found that when cleaned, as recommended by the makers, by a brush, the output was renewed, but we have been unable to carry out a sufficiently extensive series of experiments to warrant us in concluding how far this output would be permanently maintained. If the metal bands were removed no doubt the candle might be subjected to a much more effective process of cleansing.

As has been already mentioned, we have unfortunately been unable to continue our investigations on this very interesting filter, but so far as our experiments go they warrant us in concluding that this filter affords protection against the communication of waterborne disease.

CONCLUDING REMARKS ON TAP FILTERS.

In this part of the report we have given the results of the examination of the filters of twelve manufacturers, and have had to report unfavourably on six of these; the six other types of filters appear to afford protection against the communication of waterborne disease.

It will be observed that in this pressure filter report we have not thought it necessary to test so many types of filter or of varieties of filtering material as was the case in the report on table filters. We have been guided in our selection of filters for examination by (1) the possibility of their conferring protection against the communication of waterborne disease and (2) by the fact of their having been in extensive general use. Thus, a filtering material such as silicated carbon, which was not found efficient in its action when used as a table filter, might possibly, when used as a pressure filter in a more compressed form or with a greater thickness of filtering material, exert a more perfect filtering action. The results obtained with these different materials, however, were found to be absolutely comparable with those described in the previous report when used for table filters.

The following list contains the names of those firms whose filters, so far as appeared from our experiments, did not appear to be calculated to confer protection against the communication of waterborne disease:

MANUFACTURERS WHOSE FILTERS PERMIT OF THE DIRECT PASSAGE OF DISEASE GERMS.

THE SILICATED CARBON FILTER COMPANY, *Battersea, London.*

MAIGNEN'S "FILTRE RAPIDE" AND "ANTI-CALCAIRE" CO., LIMITED, *255, Regent Street, London, W.*

WILLIAM DALTON, *9, Dickson Road, Blackpool.*

JACOB BARSTOW AND SON'S PATENT COMBINATION NATURAL STONE AND CARBON FILTERS, *Filter Works, Pontefract, England.*

PIEFKE FILTER: ARNOLD UND SCHIRMER, *Gr. Frankfürter Str. 123, Berlin, N.O.*

FILTRE UNIVERSEL: CHABRIER JEUNE ET CIE., *63, Rue de Maubeuge, Paris.*

The following list contains the names of those firms whose filters in our experiments appeared to afford protection against the communication of waterborne disease:

MANUFACTURERS WHOSE FILTERS DO NOT PERMIT OF THE PASSAGE OF DISEASE GERMS.

FILTRE CHAMBERLAND, SYSTÈME PASTEUR. SOLE LICENSEES AND MAKERS IN THIS COUNTRY, J. DEFRIES AND SONS, *147, Houndsditch, London, E.C.*

THE BERKEFELD FILTER COMPANY, LIMITED, *121, Oxford Street, London, W.*

AËRI-FILTRE-MALLIÉ THÉORIES PASTEUR, PORCELAINE

D'Amiante, Maison Mallié, *155, Faubourg Poissonnière, Paris.*

Pukall Filter, Royal Porcelain Factory, *Potsdam, Berlin.*

Slack and Brownlow, *Abbey Hey Works, Gorton, Manchester.*

Duff's Patent Germ Proof Filter. Agents: Witty and Wyatt, Limited, *88, Leadenhall Street, London.*

GENERAL CONCLUSIONS ON FILTER REPORT.

In the course of our examination of the different filters above detailed, we have, we believe, tested all the materials and combinations of materials which have been used to any extent in the construction of filters, which, to recapitulate, are as follows:

1. Carbon in its various forms, either pure or compounded with some other chemical substance—for example, the silicated or manganous varieties:
   - (*a*) As blocks, or in the powdered or granular form, used either separately or in combination—for example, *Doulton's Manganous Carbons; Morris's Patent "Circulating" Filter.*
   - (*b*) Charcoal as fine powder deposited on asbestos cloth, or placed in the interior of a stone block—for example, *Maignen's Filtre Rapide; Barstow's Filter.*
2. Iron in the form known as *spongy iron* or as *magnetic oxide*, either:
   - (*a*) Alone—for example, *Spencer's Magnetic Filter;*

     Or:
   - (*b*) Along with asbestos cloth—for example, *Spongy Iron Company's Filter.*
3. Asbestos in various forms, either:
   - (*a*) As a film of compressed asbestos pulp—for example, *Nibestos Filter;*
   - (*b*) As asbestos cloth on which fine charcoal or magnetic oxide is deposited—for example, *Lipscombe's New Patent Cylinder Filter; Spongy Iron Company's Filter.*
   - (*c*) As a fine deposit on cellulose discs—for example, *Piefke Filter;*

     Or:
   - (*d*) As porcelain manufactured from finely-powdered asbestos—for example, *Porcelaine d'Amiante Filter.*
4. Cellulose, either:
   - (*a*) As discs of compressed cellulose—for example, *Piefke Filters;*

     Or:
   - (*b*) As compressed cellulose, with a fine deposit of asbestos pulp—for example, *Piefke Filter.*
5. Porous stone (artificial or natural), either:

(*a*) Alone—for example, *Doulton's Stone Bottle Filter*, *Duff's Patent Germ-proof Filter*;

Or:

(*b*) With other substances, such as powdered carbon—for example, *Barstow's Tap Filter*.

6. Forms of prepared porcelains from clays or pastes—for example, *Pasteur-Chamberland Filter*; *Pukall Filter*.

7. Compressed silicious or diatomaceous earths—for example, *Berkefeld Filter*.

As will be seen from the report, the only filtering media which were found on examination to be efficient were forms of porcelain, compressed silicious earth and natural stone, and we may now consider briefly the probability of the other media being rendered efficient. It has been already stated that we examined as tap filters a number of filtering media which had previously been found not to be efficient as table filters, since these media might be used in a denser form, or in larger quantity when used under pressure. We were unable to demonstrate in any case that either of these factors exerted any influence other than merely to diminish the number of organisms appearing in the filtrate, and in some cases to spread their distribution in the filtrate over a longer period.

MOLAR AND MOLECULAR ACTION IN FILTRATION.

The pores in a perfect filter are never smaller than the diameter of a bacillus, as is demonstrated by the fact that all the filters at present known to scientific workers permit, under favourable conditions, of the growth of water organisms through their walls into the filtrate. It is assumed that the microbes are arrested in the fine pores of the material by a species of molecular or surface attraction, and remain there unless the conditions are such that the organism is able to grow in the fluid as a long filament in contact with the surface of the pore till it arrives on the inner wall of the filter. It is assumed, accordingly, that the pores of such a filter are so fine, that when an organism enters its lumen it comes into such close relation with the walls, that molecular attraction comes into play and its further progress is arrested.[10] The difference in the action of different species of the efficient filters is probably to be attributed to the varying fineness of the pores occurring in their walls. Where the organism is brought into very close relations with the walls of the pores the porcelain appears to exert a distinct devitalising influence on

[10] In confirmation of this view that molecular action comes into play we may refer to the interesting results obtained by C. J Martin (*Journal of Physiology*, vol. xx. p. 364, 1896) with a Chamberland candle when used for the filtration of blood serum under a pressure of fifty atmospheres He found that after a time the pores appeared to become obstructed and probably filled with concentrated serum, so that the porcelain wall became apparently converted into a dialysing membrane, and in consequence the filtrate consisted merely of the salts and diffusible extracts, while the non-diffusible proteids were all retained on the surface of the filter.

the water organisms, which either prevents their further growth, or weakens them to such an extent that they appear in the filtrate only in an attenuated form. The Berkefeld filter appears to have the largest pores among the efficient filters, as is evidenced by the fact that the water organisms were not apparently weakened, that more species of organisms appeared in its filtrate, and that lowering the temperature to 11° C. did not prevent their appearance. The Pasteur-Chamberland filter, on the other hand, at 11° C., was able to give an apparently sterile filtrate for a prolonged period.[11] The Porcelain d'Amiante filter appeared to possess still finer pores, and to offer an even greater resistance to the growth of water organisms through its walls. These facts indicate clearly that the efficiency of the filtration depends on the character of the pores in the filtering medium, which naturally depend on the nature of the substance employed for this purpose. It is of course evident that no material can be expected to supply a series of pores of similar calibre within a narrow range, but that a certain proportion of larger pores, the effect of which will be probably annulled by increasing the thickness of the walls beyond that which would have been otherwise necessary, must be reckoned on. We have, for example, frequently observed air bells in the walls of Pasteur-Chamberland candles, which reduced the effective filtering capacity of the porcelain layer to one-third of that existing elsewhere, and yet these candles furnished a sterile filtrate. This indicates clearly that a very much thinner layer of this material might be used to furnish a sterile filtrate, if we could depend upon a wall of this thickness being homogeneous throughout and free from flaws. We cannot, however, as we have already stated, expect the channels in any medium to be quite uniform, and in all probability many of these at some part of their course would be so large as to allow of the direct passage of organisms, if this were not prevented by the channels opening into or leading from such larger pores being of a smaller diameter, corresponding to the channels prepondering in the filtering medium. The thickness of the layer of filtering material employed will be not merely that which is theoretically required to furnish a sterile filtrate, but that which gives the candle sufficient rigidity to withstand the process of cleansing, and, if necessary, sterilising, without being subject to the risk of breaking. The point, however, to which we wish particularly to draw attention is that the efficiency of the filtration depends entirely on the nature of the filtering material employed, that is to say, on the average size of the pores traversing its substance, and not on the mere thickness of the filtering material.

As we already stated in Part I of this report, the amount of

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11 *Vide* Footnote 8, p. 81.

filtering medium, when this is inefficient, present in a filter in all probability affects merely the period over which the disease germs would continue to be distributed in the filtrate, as the greater proportion of these will ultimately be washed through more or less rapidly, according to the depth of the medium which they have to traverse. An inefficient filter which received on one occasion water charged with disease germs would probably merely distribute these disease germs in the filtrate for a greater or less period of time, instead of the consumer receiving the disease germs all at one time where filtration was dispensed with. We have already suggested that in our opinion the effect of such a filter would be to materially increase the risk of infection without decreasing the severity of the disease, since the chances of the micro-organism passing unharmed into the small intestine and finding there suitable conditions would be greatly increased by its distribution over a more prolonged period.

Water an Unsuitable Medium for Disease Germs.

We are, however, unable to support the view that either cholera or typhoid fever germs can find a suitable breeding ground in any of the ordinary filtering media, and that from this cause the filter may continue to infect the water supplied. We have been unable to find any evidence that either of these organisms can multiply in water, even when highly polluted with sewage, and are accordingly strongly of opinion that the presence of disease germs in the filtrate from an infected filter is not to be ascribed to their multiplication, but to the germs originally introduced being gradually washed through into the receiver. We regard the experiments with perfect filters fed with raw sewage, where disease germs were unable to grow through into the filtrate, as strongly supporting this view. The history of epidemics spread by means of drinking water are also against the assumption that the germs multiply in this medium, since it has been observed that where a supply has been accidentally contaminated, but where the contamination has afterwards been cut off, the epidemic which originates through the drinking water does not continue to spread as one might legitimately expect if the germs were undergoing multiplication. It may be suggested, however, that the organic matter which has been retained in the pores of the filter may afford them sufficient nutritive pabulum; but the experiments which we have described with filters which had been in prolonged use, sterilised and unsterilised, give no support to this hypothesis. We do not indeed deny that these germs can multiply outside the living body; indeed, we believe that both are capable, under favourable conditions, of undergoing a saprophytic stage, but we believe that the necessary conditions are wanting under the circumstances we are at present considering.

Comparison of Filtering Media.

The efficiency of a filtering medium, as we have already stated, depends on the size of the channels by which it is traversed, and, of course, on their regularity. In our examination of the different filters at present in use we found only three substances which have supplied an efficient filtering medium—porcelain or paste, compressed diatomaceous earth and natural stone. It must be noted, however, that all porcelains do not arrest the direct passage of organisms, and that those which are capable of furnishing a sterile filtrate vary greatly as regards their output and the obstruction which they offer to the growth through their walls of water organisms. The most perfect filter, from the scientific point of view, which we have seen is undoubtedly the Porcelaine d'Amiante, in which the clay is mixed with finely-powdered asbestos; but, unfortunately, the rate of filtration is so slow that the use of this filter for domestic purposes appears to be out of the question. Inasmuch as the more pervious porcelains can be relied on to arrest the passage of infective disease germs, they are naturally much more suitable for all practical purposes. The compressed diatomaceous earths as used by the Berkefeld Filter Company furnish a much less perfect filter from the strictly bacteriological point of view than the porcelain; they are nevertheless capable of arresting the passage of disease organisms, and have the great advantage of affording a larger output. We regard this rapidity of filtration as an all-important point in discussing the applicability of any filter for domestic purposes. For this reason we are of opinion that experiments carried out with the more porous materials such as diatomaceous earths or natural stone, rather than with denser media such as porcelain, are more likely to lead to the production of the filter of the future. The same amount of output as from the Berkefeld filter may no doubt be obtained by combining a number of porcelain candles of slower filtering capacity, but we have already insisted upon the risk of a leak, and the whole object of filtration being frustrated from the multiplicity of fittings thus involved, and we are accordingly unable to recommend any such arrangement. In addition, the time and labour involved in cleaning a number of candles constituting such a battery to restore their output, would, we believe, prevent this arrangement ever coming into general use. Natural stone, as found in Duff's patent filter, affords an abundant supply of filtered water, but, as we have already stated, we have not had an opportunity of submitting this substance to as searching and prolonged an investigation as we could have desired. We do not know for example whether under more prolonged use the output would not become so seriously diminished by the collection of organic matter in the pores that its filtering efficiency could not be restored by the process of brushing. We must now, however, regard natural porous stone as one of those substances which can be used for the construction of an efficient filter. The only other substance which has been said to yield a sterile filtrate in scientific experiments is asbestos. The experiments which we have carried out with various forms of this material have not yet yielded satisfactory results, but they have indicated the possibility of sterile filtrates being occasionally obtained under special conditions in a laboratory experiment. In our opinion, however, this material must at present be regarded as absolutely unreliable, inasmuch as its want of rigidity must always render it liable to the organisms being washed through, in course of time, into the filtrate. It has in addition the great disadvantage that in most cases it has to be replaced from time to time with fresh asbestos wool, when the efficiency of the filter will vary, so that the filtering mechanism cannot be sent out by the makers as tested and warranted to be efficient in its filtering capacity. It is quite possible, however, that this material may come into use when combined with some rigid supporting material, when it might present certain advantages over the other materials at present in use.

We have described in detail, as regards each filter, the relative ease and rapidity with which it can be cleansed, and have pointed out that porcelain is not so easily nor so perfectly cleansed as the Berkefeld material; the latter filter, however, is much more fragile, and unless carefully handled a large amount of breakage may result.

Filtered Water to be Sufficient to Supply All Domestic Requirements.

We should like again to insist upon the necessity of all the water required for domestic purposes being filtered where it is considered necessary that the water to be used for drinking purposes should be subjected to this process, and that this should be effected with as little trouble as possible, other wise the person or persons to whom this duty is relegated may be tempted to neglect the filtration of the water to be used for household purposes. If the water supply is considered open to pollution, and accordingly recognised as a source of danger, all the water consumed must be subjected to the process if any reliance is to be placed on the filtration. We ourselves have had occasion to observe that where a filter has been attached to a pipe the servants soon learn how to disconnect the filtering mechanism so as to obtain quickly the water which they require, and thus obviate the necessity for waiting during the time occupied by its passage through the filter. If the process of filtration is to be relied upon, as in the case of waters which are known to be subject to contamination, the filter should be fixed either in the cistern, or, if attached to the tap, should be arranged in such a manner as not to allow of its being tampered with by those making use of it.

Use of Filters in Epidemics.

We have in this report kept specially in view the suitability of any filter to be used continuously for the filtration of water for domestic use, but we may here refer to the special use of filters in cases of emergency, such as an outbreak of epidemic typhoid. We have seen recently in the cases of Maidstone and Lynn that householders, although warned to boil their water, are either unable or unwilling to take the trouble to carry out this process in the thorough and complete fashion which is necessary to prevent infection. We believe that in such cases perfect filters, such as some of those we have described, have for this purpose an important sphere of usefulness.

Army Field Service Filters.

Through the kindness of the late Director-General of the Army Medical Department, Sir William Mackinnon, K.C.B., we were able to examine, for the first part of this report, the portable service filters which at that time were in use. It will be seen on reference to Part I that none of these portable service filters afforded any protection against waterborne disease; indeed, in our opinion, they would tend to increase rather than to diminish the risk incurred by those making use of them, since when such filters had once been charged with contaminated water they would continue for some time afterwards to discharge the disease germs into the "filtered" water. That this view, founded upon laboratory experiments, was not without justification has since, we believe, been indicated by the history of an epidemic of cholera which occurred in one of the regiments of our army in India.

To come down to more recent events, it is probable that the use of an efficient filter would have greatly reduced the number of cases of dysentery in the troops at present engaged on the Indian frontier. In this connection is it too much to suggest, considering how great are our interests in tropical climates, and the risk of acquiring waterborne disease run by so many of our race in these regions, that it is desirable that some effort should be made by those in authority to investigate and, if possible, recommend some practical method of meeting this ever-present danger?

Application of Results Obtained.

In this report we have given in detail the results of experiments with different filters as regards their power of preventing the passage of disease organisms, and have also, so far as possible, indicated the rapidity of filtration and the ease or difficulty with which they can be cleansed and their output renewed in the case of the respective filters. The reliability of the latter points may no doubt vary under different conditions, and we have no doubt that one filter may be better adapted for some conditions than for others. We have not, however, attempted to do more than to supply the data upon which water engineers and those interested in this question of water filtration may determine the form of filter best suited for their purpose. The conditions which obtain in actual practice are no doubt in many respects different from those which have come into operation in our experiments. Only experience can determine which of the filters reported upon are best adapted for domestic purposes; and should none of those at present on the market meet these requirements we have no doubt that the demand for such an article will in due course lead to the want being supplied.