Report on the purification of the Hoogley water for the supply of Calcutta / by Thomas Spencer.

REPORT

ON THE

PURIFICATION OF THE HOOGLEY WATER

FOR THE

SUPPLY OF CALCUTTA.

BY

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&c., &c., &c.,

CHEMICAL ENGINEER.

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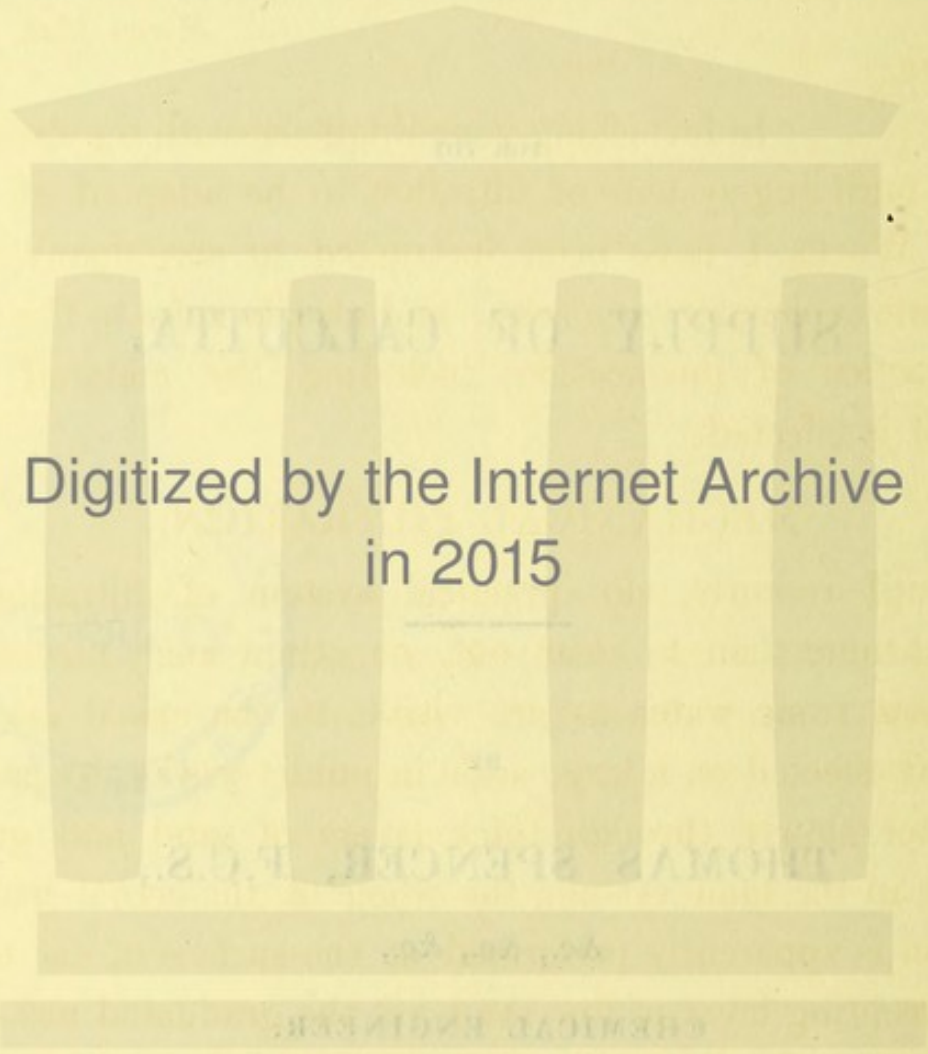

TO THE CHAIRMAN

OF THE

MUNICIPAL JUSTICES OF CALCUTTA.

Euston Square, London,

March 12*th*, 1866.

Sir,

In furnishing your Engineers with the drawings for my purifying system of filtration, to be adopted at your Water Works, I have been instructed to accompany them with some explanatory remarks; and also, to refer to the mode and practice of purification, including the material with which it is effected.

MECHANICAL FILTRATION.

Until recently, no practical system of filtration attempted more than to clear out, or strain such mechanical impurities from water as are visible to the naked eye, and which is effected on a large scale in public works, by passing the water slowly through thick layers of sand and gravel. Though in the same system, the whole of the actual work of filtration is apparently performed at the surface of the upper or intercepting layer of fine sand, yet the graduated masses of coarser material, have always been found indispensable to operate below, as retarding or frictional media, to prevent the water from passing through the surface of the fine sand too quickly. Without the intervention of these retarding layers, to operate thus indirectly, the lighter particles of matter are invariably carried beneath the surface, by which the filtering operation is rendered valueless.

With a view to diminish the thickness of this lower mass of retarding media—which, apart from its cost, in-

volves considerable increase in that of the construction of the reservoirs to contain it—an upward system of filtration has frequently been tried, but as often abandoned, when found, to involve the removal of the whole of the filtering media, whenever the intercepting layer at the bottom requires cleansing. By the downward system on the other hand, cleansing is effected by the removal of a thin layer of the top sand only, and which ought to contain all the intercepted impurities, leaving the layers below unblemished. Notwithstanding its greater expense at the outset, the balance of convenience being found to predominate so much in favour of the downward system, it is now in general use in most water works where filtering is practised.

In order to combine the advantages of each system, and at the same time to diminish the larger mass of material required for the downward one, I have devised a mode in which both are made to operate together, and which in practice is found highly successful. This system is fully shown in the plans and sections with which I have furnished your engineers It has not only the advantage of considerable economy—as only half of the ordinary quantity of filtering media is required, and if need be, still less—but the operation of filtering is in itself much better performed.

Thus, the lesser thickness of material required for the shallow beds, involves, I need hardly say, considerable saving of excavation and brick-work, because the depth of the walls is so much less. I have calculated that the relative saving effected by this system in the eight filter-beds for your present Works, if estimated by the cost of labour and material in this country, will amount to a sum of not less than £21,000, and no doubt, considerably more in India. But this is exclusive of the saving of steam power, that would otherwise be required to lift eight million gallons of water, an additional four or five feet, daily. Besides, this mode of filtration is found to operate

best with a small head of water in the filter-bed—which must also be of peculiar advantage in the present works, where from the level character of the river, so little fall can be obtained for the water, without considerable expenditure of steam power. But its advantages will be even more evident, on reminding you, that the atmospheric oxygen necessary to purification, is more easily attracted by the magnetic material through a few inches of water, than if the power had to be exercised through a greater depth. By the ascending apparatus placed on the lateral drains at the bottom of the beds, the downward rush of the water is effectually regulated, and thus, allows of more complete interception of the suspended matters, which are therefore less likely to choke the interior. In a word, a lengthened practice of this system, under a variety of circumstances, has abundantly shown, that it renders the operation of straining water nearly perfect, whilst the economy of its construction is beyond question.

The mode I adopt of supplying the unfiltered water from a basin in the centre of the bed, instead of from an inlet at the side, has also several advantages. It allows the process to go on steadily, from centre to circumference, and on letting in the water after any temporary stoppage, such as cleansing the top sand—or allowing occasional access of air—the surface is not nearly so liable to be furrowed up as in the former mode.

In my system, the water descends through the sand, not in straight, but in a series of conoidal lines, intersecting each other, and which converge below at the regulating apparatus, where the water is bent upwards, as in a spring, before it reaches the lateral drains at the bottom of the bed. By these means no more than a certain quantity of water can pass through the regulating apparatus at any point, in a given time, which greatly contributes to keep the surface of the bed free from hollows, whilst it promotes the quiet interception of

the lighter particles of suspended matters, on the surface of the fine sand at the top.

To understand the, as yet, unwritten philosophy of filtration, it is necessary to bear in mind that what I term the "retarding layers" are placed in the beds for the *sole purpose* of acting in opposition to, or partially overcoming the downward gravitation of the water, in order that the lateral or capillary attraction, between the water and the media itself, may be allowed to operate. Consequently, any arrangements that shall bend or retard the flow of the water in its downward passage, necessarily promotes the attraction of the suspended matters to the sand at the surface, and thus prevents them from being carried down along with the water. In short, it is to the sand's attraction of the lighter matters in suspension, that mechanical filtration is due. Hence the necessity for the masses of filtering media which are placed in filter beds of the ordinary construction.

SUBSIDENCE.

However great the advantages of the new system are in themselves, they will be considerably lessened, if, previously to filtration, the water is not made to undergo a thorough system of subsidence. Indeed it is not too much to say that the success of the purifying process will greatly depend on the care with which the arrangements are made for this department.

I find that the amount of suspended matter in a cubic foot of the Hoogly water, is variously estimated by different experimentalists, which no doubt arises from the different states of weather prevailing at the time the experiments were made, though under any circumstances the amount is large. As in all questions of general engineering, it is deemed best to estimate strength by the weakest parts, so in the present case, the quantity of mud to be dealt with in the subsiding reservoirs, ought to be estimated by very nearly the maximum

quantity found, coupled with the longest period it takes to subside. Looking over the figures given by Dr. Macnamara, in that portion of Mr. Clark's Report which I have seen, I quite think it will not be safe to estimate the amount of this matter at less than a cubic inch in a cubic foot of the Hoogly water—which in relation to the quantity we have to deal with in the waters of this country, is very large.

I also fully agree with Mr. Clark where he says that :— "The only effectual means to be adopted for the first process "of cleansing is the simple one of allowing the muddy particles "to subside through the water, in preferenee to that of "straining, by which the water is drawn through the mud ; "as it is highly probable that while extracting the mechanical "impurities, those in solution may be increased by bringing "the water into more immediate contact with the sedimentary "matter."

That the effect he states would take place under the circumstances, there need be no doubt. The subsiding tanks ought therefore, to be unusually large—that is, comparing them with our experience here, where we have to deal with no water with so much sediment. As the salubrity of the water must mainly depend on the arrangements which are made to free it from chemical impurity, every effort ought to be directed towards giving the filter-beds as little mechanical work to perform previously as possible, in order to prevent the purifying material from any chance of becoming fouled. It therefore greatly depends on the subsiding arrangements, as to whether the layers below the surface of the beds, shall ever require to be cleansed within any reasonable period. At the same time, in none of the filter-beds which have hitherto been laid down on my system, do I find reason to anticipate any future disturbance of the purifying layer. And as the Carbide gives out no part of itself to the water, nor can combine chemically with anything in it, no limit

can be assigned to the time it is calculated to perform its purifying duty.

PURIFYING PROCESS.

I now arrive at the chemical, or, more properly speaking, the physical purification of the water, as it is effected by the magnetic material, now commercially known as Carbide. Though the purifying operation is performed by it in the filtering-beds, it must be viewed practically, as a distinctive process from that of mechanical filtration, or straining, to which the previous observations have been chiefly confined.

Before the discovery of this purifying material, no mode was known to Chemists or Engineers of depriving water of its organic impurities. It is true that new charcoal appeared to do so, to some slight extent, because it was observed that the domestic filters, in which it was used, deprived highly coloured water of a small proportion of colour, by a species of bleaching; though even this effect ceased after a few hours' of continued immersion. Charcoal was, therefore, always limited to small filters, used intermittently; though acting even to this extent, it soon becomes foul, and imparts taste and bad odour to the water it is intended to purify. In short, the purifying power of carbon or charcoal, in any shape, is feeble and temporary, and becomes so soon choked, that Engineers, and others connected with the supply of water, never employ it in filter-beds, though so readily and cheaply obtained. Previously to the introduction of the Magnetic Carbide, so little hope was there of any practical means of depriving water of soluble "organic matter" (which is only another term for deleterious impurity), that the Government Commission "on the supply of water to the Metropolis" said, at the termination of its Report, that :—"Whatever substances may be employed "for filtering, water cannot be deprived of matter held in "solution by any practical modification of the process of

"filtration." To which it added, as the result of numerous experiments, that :—though newly-made carbon or charcoal, slightly decolourises or bleaches water, yet this substance in any form, offers no exception to the general rule.

Although it is generally acknowledged that water will bear a considerable proportion of soluble *in*organic matters, without its salubrity being materially interfered with, yet, a relatively small proportion of organic impurity, gives to it entirely another character.

A water, for example, which may have dissolved in it, from 20 to 30 grains of earthy salts of lime, magnesia, or common salt in a gallon, is very far from being thereby unhealthy. On the contrary, from 10 to 14 grains of such matters are even more desirable than otherwise. But what is recognised as impurity is comprised in the term organic matter. That for example, which is derived from animal sources, is much more injurious in water, than even a less quantity, derived from the soakings of ordinary vegetation, because the former generates the deleterious gases of putrescent fermentation, much sooner than the other. At the same time, the difference in this respect is less, if the organic matter happens to have its source in nitrogenous vegetation; for then it is little less deleterious than if derived from animal matter. But under any circumstances, more than one grain, even of vegetable organic matter, in the gallon of water, is considered injurious as regards health, even in this country, whilst its putrescent effects are necessarily increased in a warmer climate, especially if combined, ever so slightly, with animal matter.

To devise some remedy for this state of things, which were beginning to be much felt in this country, I devoted to the subject several years of enquiry, which has resulted in the discovery of the material, now acknowledged to be so efficient in purifying water. Already it has been subjected to continued

operation, on every scale of magnitude, and in most climates, for the last seven years, without once exhibiting any diminution of power, or efficiency.

By its means, water is, not only deprived of organic matter, but the matter itself is destroyed in one and the same operation, by a physical process closely analogous to that of ordinary combustion. For this reason it is obvious, the purifying substance can never be permanently fouled by the matters held by the water in chemical solution. Moreover, I know of no instance in which it has been found necessary to add to, or renew it, since the system was first in operation. Nor is there reason to believe that this state of things will undergo any change; and when it is considered, that the purification is produced in virtue of the nature of the material itself, it is hardly possible to conceive any influences which are ever likely to affect it.

Already it is acknowledged to have conferred much benefit, especially on towns, where, without its aid, a supply of naturally pure water was either a physical, or a commercial impossibility. The former peculiarly applies to the case of Calcutta, where so much organic impurity of the worst character is inevitable to the water of the great river, on whose banks the city is situated.

Formerly, while having to refer to the relative capabilities of my modes of treating impure waters, I often felt apprehensive, lest I should appear to speak of them too favourably—and consequently left unsaid, what ought perhaps to have been known. Now however, I venture to think, that after nearly seven years' practical experience in every variety of circumstance, I am entitled to refer to them with as little reserve as I should of any other admitted improvements, which have come within my experience, and which have been found uniformly successful.

NATURE OF THE PURIFYING MATERIAL.

In Mr. Clark's report, I observe that he says, in referring to this point, that he believes that the ferruginous material—used for purification—is "similar to the scales which fall from blacksmiths' anvils during the process of forging iron." This is not exactly so, except that both are iron, and that to some extent they equally obey the magnet; but the difference between them is, that one purifies water, whilst the other not only fails to do so, but on the contrary, imparts to it an iron flavour. Further on he states, that as magnetic oxide of iron abounds in India, it may not be difficult to effect its conversion into the requisite substance for purification.

Many besides Mr. Clark, have thought that natural magnetic oxide might be applied to this purpose. Some were even led to suppose that it would be available without any preparation. Indeed, the Directors of the first large water works where Carbide was about to be used, advertised for samples of it for trial. Though at the time I had good reasons for believing that no species of natural magnetic ore—as such—would answer, yet it became my duty, in connection with another chemist, to test the samples we received from most places where this ore is found. The results were, that amongst all forwarded, none were found that answered the purpose. Nor was this confined to the ores in their natural state, for on subjecting them to the mode of preparation applicable to non-magnetic ores in preparing Carbide, the results were in no way different.

It thus became evident that natural magnetic oxide was in no way calculated for the purification of water, a fact that will be more obvious on explaining the natural causes which prevent it being so. For example:—Natural magnetic ore is always found either in perfectly solid non-porous masses, or in crystals, which are equally non-porous

This absence of pores or cells, wherewith to *secrete and ozonize the purifying oxygen*, is the cause of its inactivity as a purifying agent. On the other hand, the artificial oxide prepared from the non-magnetic ores, *becomes porous in the process of preparation*, by which it is made to lose a portion of its oxygen, the space previously occupied by this gas being left open as pores. Hence, the important difference between the natural oxide and the prepared body—the latter being necessarily porous or cellular, whilst the other can never be made so.

Moreover, in subjecting the natural magnetic oxide to heat, as in converting hematite into ordinary carbide, less than nothing is gained, because it is not only impossible for the crystalline body to become porous, but on the contrary, its density is slightly increased, which renders it, if possible, still less fitted for the purpose than before.

I need hardly repeat that these results necessarily arise from the fact already stated, viz.:—that as magnetic ores possess no superabundant oxygen, they can never become porous; and that heat can only reduce them to the state of metallic iron. As non-magnetic ores, on the contrary contain an extra atom of oxygen, or carbonic acid, either of which may be driven off by the judicious application of heat, a porous body results, which, after being impregnated with carbon to increase its hardness, constitutes the required purifying material.

Much misapprehension formerly arose on this score, before the difference was properly understood. However, so little purifying power is practically manifested by natural magnetic oxide in its crystalline state, that it is hardly too much to say, that even a chemist, residing on a stratification of it for years, would be little likely to discover, even by accident, that it possessed any powers of purification over ordinary sand.

It is therefore not sufficient that the oxide should be magnetic, but it is absolutely necessary that it should also

be porous or cellular. Moreover, even in this country where hematite ores abound, those which are considered the best for making iron, are far from being equally so for conversion into Carbide. I do not positively say however, that an available hematite may not be found somewhere in India, but only, that according to my experience, it is exceedingly improbable that any natural magnetic ore—properly so called—will ever be discovered, which shall be convertible into Carbide. In short, such a substance would imply a physical impossibility. It is true, on the other hand, paradoxical as it may appear, that this oxide, if existing in combination with primitive or transition rocks, such as trap or chloritic slate, slowly effects the purification of the spring water which we see flowing from them, but the state of the oxide in these conditions widely differs from that referred to above. Such rocks for example, sometimes contain from 15 to 18 per cent. of this oxide, but then it does not exist in a crystalline or vitreous state, as in the impervious crystals of magnetic ore. It is, on the contrary, in mixture with the substance of the rocks themselves, which are to a considerable extent, pervious to atmospheric influences and moisture, and hence the difference we observe in their purifying effects, as compared with those of magnetic ore; which is as little pervious to such influences as ordinary glass. Rocks, on the other hand, which may contain an equal quantity of non-magnetic oxide of iron, such as those of sandstone, exercise no purifying effect whatever on water. Indeed, where this oxide abounds in excess, the spring waters are often chalybeate.

Notwithstanding the principles of purifying water are so often manifested in the operations of Nature, yet so sparingly are they exercised, that a few pounds of the magnetic Carbide, operate as perfectly, as several hundred times as much of the natural rocks, even were they in other respects available for the operations of the filter bed.

APPLICATION TO THE HOOGLY WATER.

In the remarks I have to make on this concluding head of the Report, it will be unnecessary to enter into the theoretical explanation of the purifying action, further than to state, as much as is requisite to be known, in order to maintain the filter-beds in vigorous operation. As already intimated, they are planned to perform the double function, of intercepting the lighter particles of suspended matters at their surface, and also to purify the water on its reaching the layer of Carbide some fifteen inches below.

I must again repeat, that this magnetic body is not to be reckoned on to filter or strain, but that its function is simply to purify. Great care ought therefore to be taken, that this most important part of the operation is not interfered with, by imperfect filtration in the layer above. As the magnetic material is meant to operate only on those impurities which are held in chemical solution, all that come under the denomination of mechanical or suspended matters, ought therefore, to be previously disposed of, either in the subsiding tanks, or on the surface of the beds above.

For these operations, oxygen is the main agent of chemical purification. Though a considerable proportion of this gas, in mixture with atmospheric air, is found in most river waters, yet the sample of the Hoogly water which was forwarded to me, did not contain quite so much of this gas as it probably did when it was first taken. At the same time, some decrease of oxygen is not unusually found in water collected so long previous to analysis. Most river water however, contains as much of it as is found necessary to effect its purification, when passed through a sufficiently thick layer of magnetic Carbide. The purifying operation which takes place in contact with the Carbide, may be explained by stating, that the atmospheric oxygen in the water, is attracted into the pores or cells of this

substance, in virtue of its magnetic nature—and because, oxygen itself is also a magnetic body. The consequence is, that this purifying gas, like all other magnetic bodies, becomes polarised in the presence of a similar body, by which a complete change of property ensues. In a word, from a state of comparative inertness, which does not allow it to combine very readily with organic matter, this gaseous body suddenly becomes a most active agent of natural purification—viz., Ozone. This transformation—for it is nothing less—of ordinary inactive atmospheric oxygen, into this highly active purifying agent, takes place only *within* the cells of the magnetic body. Hence arises the necessity for care that its surface shall be kept free from any accession of mechanical impurity on the one hand, and that the water shall be well oxygenated on the other. When these two conditions are fairly provided for, and the layer of Carbide is of commensurate thickness, no river water, however chemically impure it may be at its entrance to the filter-beds, will be found with any deleterious impurity, on arriving at the drains below. This, I may add, is no matter of chance, for, when the conditions are fulfilled, the result is one of calculable certainty. Considerable practice has abundantly shown, that, with the regulating apparatus, and their connecting air-pipes; and with ordinary care of the surface of the filter-bed, this state of things cannot fail to be permanent.

There are certain periods of the year when all river water is more impure than it is at others. At such times, should the thickness of the layer of Carbide be found hardly adequate to perform its work of purification, it is well to throw the beds out of operation, for about an hour, twice in the 24. That is to say, they should be permitted to work only 22 hours out of the 24; the intervals of rest being an hour each. Short periods of this duration are amply sufficient to fill the cells of the Carbide with ozonized oxygen, for,

the magnetic body elects this gas, in preference to the other constituents of the atmosphere.

In considering the average quantity of the material necessary to purify the Hoogly water, at all seasons, I shall be guided less by my own experiments and analysis (which is subjoined below) than by the series of analyses made by Dr. Macnamara, of samples taken throughout the year. Mine being limited to one sample, and this not a very large one, which, though quite sufficient for analytical purposes, was hardly so for purifying experiments, still the one affords a guide for the other. However, with these elements before me, it will not be difficult to estimate with considerable accuracy the quantity of Carbide required.

Before proceeding farther, let me again state, that to effect the *perfect* purification of river water with Carbide, all depends on the quantity of this material which shall be used in the filter beds. In a word, however impure such water may be, the circumstances can always be met by a sufficiency of the purifying material. However, on the excellent engineering principle of having all things "a little stronger than strong enough," and if a relatively small increase of expenditure is not an object, (and where purification is concerned it ought not), I should in all cases recommend at least, one-third more Carbide to be put into filter beds, than would be sufficient to meet the average state of impurity. It is at the same time well to remember, that no strong necessity exists that water should be rendered absolutely free from all trace of vegetable matter. Indeed any quantity, not exceeding half a grain in a gallon, is harmless, because the minuter portions are found to be held so intimately in chemical solution with the water, as to be beyond the reach of those influences which, with larger quantities, give rise to the putrefactive decompositions, which generate the deleterious gases, that are so prejudicial to health. Indeed, one function of the Carbide, hardly second in importance

to destroying organic matter, is that of oxidizing, and therefore neutralising the evil effects of these gases.

I now arrive at the consideration of the quantity of this material necessary for the purification of the Hoogly water. At the close of 1863, when I forwarded a Report to your municipality on the subject, I was unacquainted with the quality of the water as resulting from analysis, and therefore could only judge from the known character of the river, and the influx of impure matter from the numerous population on its banks. I based my estimation however, on the quantity of Carbide which I found to be necessary in dealing with the most impure river waters in England, and I stated, that a ton of the purifying material was usually required here—in not very extreme cases—for every four yards of filtering area. At the time the estimate was made, this quantity (taking the specific gravity of the Carbide I then used into account,) implied a layer of over $6\frac{1}{2}$ inches in thickness. But I likewise added, that, as putrefactive decomposition ensues so much more rapidly in warm climates, the quantity I named would be, in my opinion, the minimum one likely to be required.

Since then I have been furnished by Mr. Smith with a sample for analysis of the Hoogly Water, taken at Pultah Ghaut, and also with a tabulated report of the results of seventeen analyses of the same by Dr. Macnamara, the samples for which were taken at nearly monthly intervals from the river, at the same place, from December, 1861, till January, 1863. I have thus before me the elements of more precise data than I had when I made my former statement.

To arrive at the necessary quantity of Carbide, I consider that the quantities of organic impurity shown in the water by the analyses of Dr. Macnamara are sufficient for all purposes. On looking over his table, I find that the two largest amounts there given, are in December and January, being 4.2 grains

to the gallon of water in each case; whilst in three cases (July, September, and October) it amounts to only 1.5 grains to the same quantity. In one of the columns I find no results are entered against organic matter, and in another only 0.6, but as I have no doubt they are omissions in each case, I leave them out of the present calculation. Computing therefore, the amount of organic matter as derived from the results of fifteen analyses of filtered water, I find the average to be 3.1 grains to the gallon of 70,000 grains. This amount will, I have no doubt, represent with sufficient accuracy, the quantity of organic impurity to be dealt with throughout the year. Though I do not find that Dr. Macnamara estimates how much of this impure matter appears to be of vegetable, and how much of animal origin—yet judging from my own analysis of the one sample, I should say that if better than a fourth is estimated as being due to animal sources, it will not be far from correct.

As my own analysis of a single sample, is necessarily of less relative value than the series of Dr. Macnamara, made so close to the spot, and before time was allowed for the water to undergo any material change, I am disposed to base my calculations on his observations in preference to my own; especially on finding my details to agree so closely with his. My analysis, however, which is appended, has been so far useful, in furnishing me with the character of the organic matter in the water, and its sediment, with both of which I was previously unacquainted.

Recurring to my Report of 1863, where I estimate the quantity of Carbide likely to be required for your works, I say, that "a ton of this material in every four yards of filtering area is found sufficient for impure river-water in England," At the time, I took it for granted that the impurity of the Hoogly water did not greatly exceed "that of the Thames at Westminster Bridge," but I add, that by "transmitting

the analysis of a competent chemist, or, on furnishing me with samples for analysis, taken in different states of weather, the quantity of magnetic Carbide necessary for its purification may be more exactly determined."

These data are now before me, from which I find the organic impurity of the Hoogly water considerably exceeds that of the Thames at the period referred to. Consequently, an increased bulk of Carbide will be necessary to meet this extra degree of impurity, though fortunately the circumstance will not add proportionately to its weight. The quantity then estimated, viz., a ton for every four yards, would have made, of that used at the time, a layer of about $6\frac{1}{2}$ inches in thickness, but which—with the impurity I now find must be dealt with—would have been insufficient. Since then however, I have secured a lighter and more efficient ore from which to prepare this material, thereby rendering it, in effect, less expensive, because a given weight is of greater bulk, whilst it acts more efficiently than the denser material. As the larger quantity will consequently, weigh little more than the smaller one formerly estimated; its cost will be little if any increased.

After maturely weighing all the circumstances, I have concluded, that to deal with the impurity in this water, as shown by the analyses, a layer of not less than 9 inches of magnetic Carbide will be required. Therefore, to cover the eight filter beds to this depth, 5,000 tons of the lighter material will be sufficient, but for a similar layer of the heavier material, about 6,300 tons would have been required; whilst the superior porosity of the lighter one renders its purifying powers greatly superior. I may add that in practice, I recommend a 9 inch layer of Carbide to be mixed with 3 inches of well washed coarse sand, so as to bring it up in the filter bed to 12 inches.

I have already stated that thorough purification depends on the quantity of magnetic material used; I therefore speak

advisedly when I say, that a layer of less than 9 inches will not satisfactorily purify the Hoogly water. In short, the deleterious matter it contains is not to be "burned out" with a smaller quantity—"burning out" being the correct term in relation to the action of the Carbide.*

In dealing with water of this impure character, any attempt to save two or three inches in the purifying material will be false economy. For example, at Wakefield, in Yorkshire, where I have constructed large purifying works, it was considered that 6 inches would be sufficient. But during a dry season, finding the river water had become very impure from the influx of sewage, I strongly recommended the layer to be increased to 9 inches—which was done. The consequence is, that the rental has already increased sufficiently, to pay for the alterations, and whilst writing this Report, the Manager informs me, that the Company have purchased land on which to erect additional filter beds—the demand for the water having increased so largely. Had a less quantity of purifying material been used, I am convinced I should not have had to record similar results.

ANALYSIS OF THE HOOGLY WATER.

I have now only to add a few words regarding the results of my analysis of the sample of this water which was furnished to me, on his arrival, by Mr. Smith.

Apart from the amount of sediment and the character of its organic matter, it is in other respects an excellent water. Compared with the supply to London it contains only half the quantity of earthy salts in solution, and is softer in the same

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* At the time the above report was written, I calculated on each square yard of area to filter 650 gallons daily, which is the quantity usually calculated on for our water in this country. From the immense quantity of fine suspended matter in the Hoogly water however, Mr. Clark intends—very properly in my opinion—that the quantity filtered in your beds shall be 500 gallons to each square yard daily. But as this necessarily enlarges the whole area of the beds, it also considerably increases the quantity of Carbide required for them.

proportion. Whatever the character of its sediment might have been at the time it was collected, I am unable to say, but on its arrival here, the water became colourless and bright after standing in a glass vessel for a few hours ; but of course this affords no information as to the period it would have originally required to have deposited this sediment. On uncorking the bottles the odour emitted by the water was most offensive. It was not the ordinary one of sulphureted hydrogen (rotten eggs), which, though highly offensive, is seldom found in sufficient quantity to be unwholesome, but it was that peculiar odour which unmistakeably betokens those gases which are generated by decomposing animal matters. Immediately after being opened, the water contained in one of the bottles, was passed through ordinary filtering paper, to clear it of sediment, and then through a small Carbide filter, from which it came perfectly odourless, and as bright and tasteless, and to all appearance as pure, as spring water. Subsequent analysis showed that it contained (0.60) a very little over half a grain of organic matter to the gallon—a quantity which is practically harmless, if composed of vegetable matter.

If a larger sample had been operated on, I should have considered the result more satisfactory, as the Carbide filter, through which the water passed, was necessarily small (a larger one would have absorbed the whole sample), and as it had to be previously cleared of water, its pores were charged with more ozonized oxygen than if the operation had been continued longer with more water. Still I have no doubt that, with careful subsidence, a 9 inch layer of light porous Carbide, will render the water of the Hoogly in all respects most desirable for a town supply.

Before concluding allow me to say, that in making the drawings for the filtering beds, I am greatly indebted for several valuable suggestions to your Engineer, Mr. Smith. His knowledge of the locality, and climate, and practical

acquaintance with materials, and construction in India, have enabled me to perform my share in planning these works with more confidence than I could have otherwise had.

I have the honour to be,

Sir,

Your very obedient Servant,

THOMAS SPENCER, F.C.S., &c.,

Chemical Engineer.

POSTSCRIPT.

I have omitted to say in the body of the Report that should the layer of Carbide at any time get fouled with suspended organic matters, as may possibly happen, it is only necessary to run the water off, and allow the Filter Bed to rest or "lay fallow" for a few days, when all such impurities will be burned off by the action of the atmospheric oxygen on the Carbide. The presence of such matters are known by the sluggish action of the filter. This is a much better course to follow than washing.

ADDENDUM.

Analysis of a sample of Water from the River Hoogly, taken at Phultah Ghaut July 29th, 1865 (as per label on bottles).

To the Chairman of the Municipal Justices, Calcutta.

Sir,—On subjecting this water to analysis it was found to contain the following substances, in grains to a gallon :—

Carbonate of Lime	5.50
Do. Magnesia	2.70
Sulphate of Soda	0.11
Chloride of Sodium	0.15
Silica	0.37
Organic Matter and Loss . . .	1.96
Total grains of Solid contents in a Gallon .	10.79

Hardness by Clark's scale, 7.4 degrees.

REMARKS.—Traces of Phosphoric and Nitric Acids were unequivocally indicated in concentrated portions of the water, but by reason of the very small sample on which I had to operate (about a third of a gallon) the quantities were too minute to bear quantitative estimation. They are therefore included in the item set down to organic matter, as no doubt they belong to its animal portions. At the same time the peculiarly bad odour emitted by the water before analysis strongly indicated the presence of phosphureted hydrogen gas. As a rule, both Phosphoric and Nitric acids, are due to animal matters.

Sedimentary Matter.—The sedimentary matter found in the sample on being thoroughly dried and weighed, yielded at the rate of 84 grains to the gallon — which is large. After incineration it was again weighed, when the loss which accrued indicated the above quantity to contain 6.56 grains of suspended organic matter. The inorganic portion is chiefly composed of silicate of alumina, and is remarkable for containing no carbonates.

Yours very obediently,

THOMAS SPENCER, F.C.S.

London, *March*, 1866.

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