Telb on the Serpentine
Rangers Report on Supp[...]
Leicester
Clay on the Supply of
Board of Health Report
Homersham on Metrop[...]
Hassall's Microscopic [...]
of Water of Londo[...]
Robertson on the Buxton Water
Napier on the Soft Springs of
the Surrey Sands
Aitkin & Taylor — West Middlx Report
Rowlandson on Napier's Scheme
Ranger on Southampton Water Supply
Wicksteeds Reports on the
Leicester Supply & Sewage

Med. Leg. Tr.
Vol. 31

# SUGGESTIONS

FOR THE

## SUPPLY OF THE METROPOLIS

FROM THE

# SOFT WATER SPRINGS

OF

## THE SURREY SANDS,

ADDRESSED TO THE GENERAL BOARD OF HEALTH,

BY

THE HONBLE. WILLIAM NAPIER.

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*(Presented to both Houses of Parliament by the General Board of Health.)*

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# PREFACE.

I MAKE no apology for offering these few pages to the Public. At the present time, when on the eve of a severe struggle between Sanitary Reform and Water Monopoly, it behoves the humblest labourer to add his mite in aid of the great work.

It seems right also to explain the circumstances under which I undertook to coöperate in the investigation of this question. Deeply interested in the progress of Sanitary legislation for the poor, a perusal last spring of the Report on Water Supply, by the General Board of Health, gave me an anxious desire to develope in detail some of the broad principles so admirably laid down. I requested the Board to give me the assistance in such an undertaking of all the information already acquired on the subject by their officers, and which was most courteously and handsomely granted. Thus prepared, I proceeded in August, last year, to the Surrey Sands, and devoted ten weeks to the necessary local investigations. The results of my observations were offered to the General Board in the form of a Letter, which was also published in the *Times*.

An earnest conviction of the perfect practicability of the scheme of adopting the soft springs as the future source of water supply, determined me to accept the request then made that I would aid in the consideration of some of the many phases of the question. For eight months I have closely studied the whole subject, and on several occasions have addressed myself to the General Board.

It is a *résumé* of these labours that I offer to all who practically or in principle are warmly interested in the question, and may be anxious to form their own conclusions on the evidence collected or opinions advanced.

In confirmation of my practical examinations of the quality and available quantity of soft spring-water, I give, in Appendix A., a report and some analyses by Professor Taylor, of Middlesex Hospital, who kindly consented to give the subject his careful consideration, and in Appendix B. the report of Mr. Rammell, the gentleman deputed by the General Board to test my statements of quantity. In Appendix C. I offer a refutation of some assertions lately put forth by the New River Company.

In conclusion, I would congratulate the Public on the fair prospects of their cause. The real obstacles to the subversion of a powerful Water Monopoly have now been swept away in two decisions of the Government, supported by overwhelming majorities, in an impartial and discerning Legislature.

I allude, in the first instance, to the suppression last year of the Cemetery Monopolies; secondly, to the defeat of the Bill of the Corporation of the City of London for extending Smithfield Market, and to the decision that this service shall no longer be administered by the representatives of vested interests, but by the State in the form of a Government Board.

The field of battle is then clear. The Public hold the issue in their own hands, if they will but appeal for protection to the leading organs of the press—stedfast champions of their rights, to a First Minister who has declared it his duty to prefer the interests of a community to those of a class, and to a Parliament which has ever nobly advocated the cause of Sanitary Reform.

WILLIAM NAPIER.

2, GLOSTER TERRACE, LONDON,
*April* 11*th*, 1851.

## TO THE GENERAL BOARD OF HEALTH.

London, *January* 15*th*, 1851.

My Lords and Gentlemen,

Having on more than one occasion been permitted the privilege of submitting to your notice a few remarks upon some of the chief points involved in the consideration of the proposed Soft-water Supply to the Metropolis, I trust that, in requesting the further honour of presenting the whole in a more collected form, I do not trespass too far on the kind indulgence of the General Board. The subject is divided under the following heads:—

I. Examination of the Gathering Grounds.

II. Method of Collection, Conduction, and Delivery of the deep Spring-water, with an approximate estimate of the Expense of the Works.

III. Some evidence of the popular appreciation of Soft Water.

IV. Some evidence as to the comparative action of Hard and Soft Water upon lead.

V. Some remarks on Combined Works.

VI. Further consideration of the probable source of the deep Spring-water of the Gathering Grounds.

VII. Water supply in ancient, as compared with the present times, whether for the purposes of irrigation or house consumption.

I would only further remark, that if my observations are somewhat divested of the guise usually given to documents in public business, the Board will perhaps kindly remember, that facts do not always present themselves in preappointed official terms and forms.

I remain, my Lords and Gentlemen,

Your obedient Servant,

WILLIAM NAPIER.

THE GENERAL BOARD OF HEALTH,
WHITEHALL.

# SUGGESTIONS,

*&c.*

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I.

## Examination of the Gathering Grounds.

Having had the pleasure of receiving instructions in August last to visit the gathering grounds of the proposed water supply to the metropolis, in order to gauge the streams and make a careful re-examination of the general capabilities of the country for the purpose intended, I have the honour to submit the results of my observations, with a few remarks on the different bearings of the scheme.

On reading the Board's Report presented to the Houses of Parliament during the past Session, I perceived that from the very short time at the disposal of the Board, the calculation of the quantity of water available from the rain-fall on the district, an extent of nearly 150 square miles, was necessarily founded on the discharge of the streams at their outfall.

The Board was thus manifestly placed under great disadvantage when endeavouring to ascertain the character of these waters; for as such waters inevitably partake of the nature of the soils through which they have passed, and as the pure sands of the district, the limits of which are already defined in the Report on Water Supply, are not only bounded by clay on the north-east, east, and south-east, by chalk on the west, but are also intersected from east to west in the south by a high range of chalk hills, the *course and outfall* of these streams present certainly a widely misleading test of the quality of the water to be derived from pure sands.

Considering the purity and softness of the supply to have the first claim upon my attention, and bearing in mind the principle enunciated by the Board, "the nearer the source the better the quality," I made it my first object to examine the nature of the soils in which the rain-fall of the country makes its re-appearance after percolating through the upper crust, and next, the soils through which it passes to its outfall.

The water-supply of Farnham being derived from the hill, on the south side of which the village stands, I proceeded thither, not only to examine its source as likely to present indications for purity to be looked for elsewhere, but also to have a good bird's-eye view of the whole area under investigation. The position of the hill in the south-west, its elevation of nearly 700 feet above the level of the sea and 300 feet above the plains beneath, admirably adapted it to this purpose. I then observed that the Farnham water does not come from surface drainage, but is derived from 16 small springs, issuing at the south side, on a contour, so to say, about 50 feet below the highest level of the hill. From the contracted area out of which so large a supply is gained, I was induced to suspect that these springs are not exclusively due to the rain-fall on the ground above them. I was further led to this consideration by observing that in this instance at least, from the slope of the ground, and from the almost impenetrable hardness of the superficial covering of gravel, the rain-fall could scarcely find its way through the surface. A violent storm having most opportunely come on whilst speculating over this probability, I perceived that by far the greater portion of the water apparently ran rapidly down the hill-sides and was speedily out of sight, leaving the surface perfectly dry, except where irregularities retained a few pools, which subsequent observation proved to me were exhausted by evaporation rather than by percolation. I then examined the north side and found that on the same contour a still greater indication of springs existed. This satisfied me that these waters are in a great degree due to rain-fall *elsewhere;* for a rough calculation of the yield of the springs much exceeded the available rain-fall on the area within the contour; but as there will probably be much difference of opinion on this point, I propose hereafter to consider the subject more in detail, and trust that the many eminent geologists of the day will perhaps give the question their attention.

Having completed my observations at Farnham Hill, I naturally anticipated that if the other ranges of the district were of like geological formation, they would in all probability present similar appearances about the same level; a most desirable source for the streams of the country, the advantage of which, in addition to the proposed drainage supply, could hardly be over-estimated. The first week of my researches was confined therefore to the nature of the soil throughout the district, presenting generally a vast depth of pure sands, obscured in the higher levels by extensive patches of gravel from 2 to 20 feet in depth; in the lower, by a poor loam from 1 to 3 feet deep. Patches of peat, here and there in spots of some depth, exist principally in the lower levels. On the west and south-west the loam has a sub-soil of very stiff clay, apparently of the London formation, which also crops out on the north side of Farnham hill. On the north and north-west, in the valleys, there exists within a small area a considerable quantity of iron in some of the peaty bogs. All these are marked upon the plan which I shall hereafter have the honour to lay before the Board, and which I have prepared as accurately as the shortness of the time allowed.

The next object of my research was the quality and quantity of the water. The Board, in their Report, have given the quantity now brought into London by the different Water Companies as a stream 9 feet wide and 3 feet deep, flowing with a velocity of two miles an hour—a supply double the actual consumption. In the course of my exploration, I could not fail to observe that such a volume of water of desirable quality was nowhere to be seen, and those who look at these grounds, with the desire not to find the requisite quantity, may apparently satisfy themselves; but regarding the outfalls, I felt convinced that their many sources would give both the quality and quantity of the desired water. To discover these sources was then my task.

A most minute inspection of the gathering grounds has shown me that, generally speaking, their nature exactly adapts them for the means of collection proposed by the Board, namely, a system of thorough drainage. A more admirable plan of gathering rain-fall could not have been conceived; the sands, acting as a natural filter, deprive the water on its passage to the pipes of any impurity contracted either in the air or in percolating through the upper crust; as for instance, where the water might be discoloured by peat, experiments have proved that the sands restore its primitive colour and deprive it also of the flavour imparted by the peat. The heath which covers the entire area of the gathering grounds also stains the water, but the impurity is removed by this process of natural filtration. I would remark, that the discoloration visible in the stream called the Blackwater is not entirely caused by peat, but chiefly by the heath and loose black loamy nature of the soil through which it flows. This I have proved by following up its various sources, one of which only at Cove rises in and passes through peat. Samples of springs rising in peaty bogs show very slight discolouration.

Guided by what I had seen at Farnham Hill, I turned my attention to look for springs, and after much and close examination, to the conclusion that the origin of many little silver threads of water, silently stealing down the hill-sides under the grass, arose also from such sources. A diligent search showed me that the quantity of water to be derived in this manner within the original area of the gathering grounds is so great, that if the neighbouring ranges of mountains and hills on the south side, namely, Hindhead, Blackdown, Hascombe Hills, Leith Hill, &c., presented the same feature, I might probably hope to collect a stream, 9 feet wide and 3 feet deep, of the desired softness and purity.

I am now happy to inform the Board, that a month's researches into every hill and glen, every copse and crevice, has produced this result. Having tested the waters as they issue from their sources, I can announce that I have gauged a sufficient number of springs and rivulets to enable me to form an opinion both as to quantity and quality; the water being of its primitive purity; perfect as to aeration; brilliant in colour; soft almost as distilled water; of a grateful temperature, about 50°; and almost free from all mineral, animal, and vegetable impregnation. In a future section of this Report, I hope to be able to give the Board more extended information on these points, as also with reference to the levels of the springs above mean tide and a small plan of the whole area under investigation, showing the relative position of the springs. Thus, by gauging and testing the streams at their sources, instead of in their course and outfalls, we have the realization of the principle laid down by the Board, and this difference will go far to account for the variance of my results with those of Dr. Angus Smith.

The table of springs and rivulets (p. 6.) gives their hardness according to Dr. Clarke's soap test, their daily discharge and the number of houses they are equivalent to, at 75 gallons per house: an addition of one-half the average domestic consumption, as proved by an experiment instituted in the district of Earl-street, London, on a block of 1,200 houses of a fair average class; the gaugings of the sewer gave 44¼ gallons, and of the butts and cisterns, 51⅓ gallons per house.

Where the springs flow into ponds dammed up for the use of mills, I have taken the samples for test from the springs themselves, as the evaporation alone of large surfaces of water will often add two and upwards degrees of hardness, and the waters are also exposed to deterioration in colour and, as I have found, in taste. For instance, at Minley Pond, itself situated between sand-hills, the springs do not show half a degree of hardness, the pond one and a-half; at Sweetwater Pond the springs have half a degree of hardness, the pond two degrees; at Bushbridge the springs have one degree of hardness, the pond nearly six.

An erroneous opinion seems to prevail generally that large bodies of water should be examined for test of quality; but these, in proportion to their size alone, show a scale of hardness contracted in their passage through loamy or other soils; hitherto, the little springs rising in pure sands and scarcely seen under the herbage, have been almost entirely disregarded, although when gathered together they form a volume equal in extent to that collected on the lower levels, and of a purity and softness in no case to be found there.

TABLE of Springs and Rivulets, showing their Hardness, Daily Discharge, and the Number of Houses each is equivalent to, at the rate of 75 gallons per house.

| NAMES. | Degrees of Hardness | Gallons discharged per day. | Houses, at 75 gallons per House. | REMARKS. |
|---|---|---|---|---|
| Hind Head and Black Down :— | | | | |
| Holy Water . . . | 2 | 1,350,000 | 18,000 | Will be led away at one degree of hardness. |
| Bramshot . . . . | 1½ | 13,399,714 | 178,622 | One and a-half degrees under the mill wheel; but will probably be led away at half a degree of hardness. |
| Down Lands . . . | 1 | 540,000 | 7,200 | |
| Headley Down . . | 1 | 239,731 | 3,197 | |
| Barford Mills . . . | 1 | 3,880,000 | 38,400 | |
| Devil's Jumps . . . | 2 | 360,000 | 15,000 | |
| Punch Bowl . . . | 1 | 299,995 | 3,999 | |
| Cosford House . . | 1 | 674,928 | 8,999 | |
| Gray's Wood . . . | 1 | 84,240 | 1,123 | |
| Kotchet . . . . . | 1 | 32,568 | 434 | |
| Five other springs . | 1 | 127,562 | 1,700 | |
| Hascombe Hills :— | | | | |
| Sweet-water Pond . | 1 | 1,066,795 | 14,223 | Will be taken away at half a degree of hardness. |
| Bush Bridge . . . | 2 | 529,200 | 7,056 | |
| Chapel Copse . . . | 2 | 224,697 | 2,995 | |
| Hascombe . . . . | 2 | 229,116 | 3,988 | |
| Leith Hills :— | | | | |
| Totsford . . . . . | 2 | 1,799,798 | 23,997 | Will be led away at one degree of hardness. |
| Watton. . . . . . | 2 | 890,956 | 11,879 | |
| Rookery . . . . . | 2 | 1,436,400 | 19,532 | |
| Easthampstead Plain :— | | | | |
| Wishmoor . . . . | 1 | 388,308 | 5,177 | |
| Broad Moor. . . . | 1 | 176,840 | 2,347 | |
| Sandhurst . . . . | 1 | 54,000 | 720 | |
| Ambarrow Hill . . | 1 | 75,888 | 1,011 | |
| Barkham . . . . . | 1 | 101,088 | 1,347 | |
| Wokingham. . . . | 1 | 599,904 | 7,998 | |
| Bull Brook . . . . | 1 | 113,320 | 1,497 | |
| Chobham Ridges :— | | | | |
| Pirbright . . . . . | 1 | 810,000 | 10,800 | |
| Railway . . . . . | 1 | 460,000 | 6,134 | |
| Cow Moor . . . . | 1 | 90,435 | 1,285 | |
| Coldingley . . . . | 1 | 758,160 | 10,108 | |
| Folly . . . . . . | 1 | 256,492 | 3,419 | |
| Bagshot . . . . . | 1 | 630,000 | 8,400 | |
| Bristow Farm . . . | 1 | 14,999 | 199 | |
| Farnham :— | | | | |
| Aqueduct. . . . . | 1 | 45,848 | 584 | |
| Minley . . . . . . | 1 | 134,928 | 1,798 | |
| Northfleet . . . . | 1 | 6,426,000 | 85,650 | |
| Long Bottom . . . | 1 | 31,809 | 424 | |
| Bramshill . . . . . | 1 | 43,372 | 578 | |
| Eversley . . . . . | 1 | 74,779 | 997 | |
| Castle Bottom . . . | 1 | 270,000 | 3,600 | |
| North :— | | | | |
| Farnham Hill . . . | 1 | 685,454 | 8,739 | |
| Total gallons . . | .. | 39,407,324 | 523,156 | Total equivalent in houses. |

Giving altogether 39½ millions of gallons, which might be brought to London at a hardness certainly not exceeding one degree. I can answer for at least 10 millions more under two degrees of hardness. I must remark, that though these gaugings are only offered as an approximation, I consider they will eventually prove to be rather under than over stated.

As the gaugings of these springs have been taken at the end of a drought of nearly five weeks and at the close of an average dry summer, I conceive they are to be relied on with safety as indicating the flow of the springs at their usual summer ebb. Being a perfect stranger to the district and of course obliged to depend very much on the testimony of the residents as to the flow of the springs, I have addressed myself to persons of all classes, gentry, farmers, and labourers; many of whom have resided all their lives on the same spot and are therefore well able to offer an opinion. I received much valuable information from an herb doctor, who devotes his sole attention to wounds and sores, and finds his remedies in herbs and grasses, many of which grow in water, by which means he had come to the knowledge of these springs. The unanimous opinion of all observing persons is, that I gauged these springs at their lowest. I am convinced that in many instances these springs are, as has been proved at Farnham hill, not entirely due to the rainfall on their drainage areas, but perhaps to that on ranges of equal and higher levels, where the nature of the strata will not permit of the rainfall making its appearance again after percolation; the water then finds its level, and possibly an easy channel through accidental geological faults to the sands of the gathering grounds. I attribute the fact of the springs invariably coming out under the highest and steepest bank of the hills, to the circumstance that such is the only place where on that contour there is not the usual densely packed covering of gravel, through which they would scarcely penetrate when there is an easier outlet. The steepness of the bank itself is apparently caused by the undermining action of the springs.

My opinion of the unfailing yield of these springs is confirmed by the peasants. A curious circumstance was in several instances related, that at the close of autumn, generally in October, when there has been no rain in this district, the springs commence rising just after a high wind. No explanation of this apparently extraordinary circumstance is offered, which to me however admits of some explanation, the high wind being possibly a fortuitous circumstance, but probably indicating a storm of rain and wind in other places where the strata are of the formation alluded to.

Droughts of much longer duration than five weeks seldom occur, and should they do so, the yield of the springs is so far in excess of the present requirements of the metropolis, that there is little foundation for any apprehension of scarcity.

To detect the presence of these springs in combination with other waters, was in some cases very easy, as where the residents are acquainted with them, or where they are so large as to thrust themselves on one's view ; but often they have nearly eluded my most vigilant scrutiny. Situated in the hollows of the hills generally, collections of rain-water are to be found, girt sometimes by dense copses, with rushes and long-tangled grass ; the marshy appearance of the ground on the lower side might by a casual observer be taken for the soakage of the pond, but if a trench be dug to the outfall, the run is found to be constant, proving the presence of springs flowing into or rising in the ponds themselves. On one occasion, on questioning an intelligent labourer, he remarked, that when bathing in Minley Pond, he found the water at some parts much colder than others, and was at a loss to account for the circumstance, which however clearly indicated the position of the springs, as I invariably found the outfall to exceed the flow into the pond.

So secluded are some of these sources, that their existence on one occasion, at Chapel Copse, only became known to a *soi-disant* game-keeper, but I greatly fear a poacher occasionally, by the flight of game to drink there after dawn. This spring yields 224,697 gallons per day, equal to the supply of 2,995 houses, and forms one of the many threads contributing to the desired supply. I am further of opinion, in which I am confirmed by all the residents, that these springs will, when opened, that is given a free passage to the surface, often be much increased in volume ; indeed this has on several occasions been proved to be the case by paper manufacturers and others who have been anxious to increase their supply : as for instance, at Barford Mills, where some years ago the paper mill could only work for three or four hours a-day, but the spring having been opened now affords a sufficient supply for six hours' work. I have tested these waters, and all others in the district, including wells, and those from the surface, at different stages—as where joined by fresh tributaries, or entering a new soil—from their outfall to their sources, and the result has been very decisive in confirming the remark made by Professor Way, in his able paper on 'The Power of Soils to absorb Manure,' "that ordinary soils consist of three substances, sand, clay, and vegetable matter, but that very generally a fourth may be added, carbonate of lime." When these springs rise in any other than pure sands, the water almost at once becomes hard to five or six degrees. If in any case I believed a stream to have a very pure source, I proceeded up its course, examining it at the junction of each tributary, and have never failed in discovering at length and generally from the highest source, the thread of soft and sweet water to be added to the growing stream for water supply.

Let me point out, for example—

| | | |
|---|---|---|
| The Wey, at Guildford, which has a hardness of | 9 | degrees. |
| At Elstead . . . . . . . . . | 9 | ,, |
| Below the junction of the Bramshot river . . | 9 | ,, |
| Above the junction of the Farnham branch . | 6 | ,, |
| Above the junction of the Bramshot branch . | 14 | ,, |
| At Farnham . . . . . . . . . | 15 | ,, |
| But turning up the Bramshot river at Headly Wood . . . . . . . . . . | 5 | ,, |
| At Bramshot . . . . . . . . | 1½ | ,, |
| At Shotter Mill . . . . . . . . | ½ | ,, |

The above shows what different results two persons making the same investigations might arrive at. From Headly Wood to Bramshot is scarcely more than two miles; persons unintentionally, or for want of accurate investigation, might consider the water at Headly Wood the sample of greatest purity to be found, and go away with and disseminate a totally false impression. I have reason to believe it will be generally found that the opponents to the Board's proposition have from one cause or the other made this great mistake.

The power of soils in hardening water is particularly evident when comparing the water in a large pond to that in a well, which becomes hard almost in proportion to its depth. A notable instance occurs at Tomlin's Pond : a collection of rain-water with a few small springs in it has a hardness of only two degrees, whereas a well sunk close by for the convenience of some cottagers has a hardness of 5½ degrees. Again Minley Pond has a hardness of only 1½ degrees, while a well sunk through the loam into the pure sand has 3 degrees of hardness.

The following is a list of some of the well and surface waters in the district, with their degrees of hardness : —

*Wells.*

| | Degrees. |
|---|---|
| Hartford Bridge, Flats, 25 feet deep | 4½ |
| Ash Common, 80 feet deep | 6½ |
| Pirbight Common, 20 feet deep | 5 |
| Chobham Well | 5 |
| Swinley Cottage, Easthampstead Plain | 5½ |

*Surface Waters.*

| | Degrees. |
|---|---|
| Ash Common | 3½ |
| Holt Pond | 2½ |
| Dippenhalt | 3½ |
| Whitemoor | 3½ |
| Aldershot | 1½ |
| Canal Reading Road Bridge | 5½ |

Thus we see that waters stand for purity in this district in the following order :—

1. Spring issuing from pure sands.
2. Collections of rain water.
3. Water running through ordinary loamy soils.
4. Well waters.

How great is the loss of capital and labour expended on wells ! and when made what has been done ? A vast expense is incurred to dig a hole in the ground to allow water to soak into, impure from the mineral qualities of the soil : what water ? that which fell originally soft and pure, and which might have been collected on roofs, or by drainage of cultivated lands, led into a covered reservoir and thence to the highest room in the house. One gentleman with whom I am acquainted spent from 300*l.* to 400*l.* in sinking a well 300 feet deep, whence he obtained water of a hardness equal to that of London. 400*l.* would have drained from 40 to 50 acres of his land and paid for a covered reservoir, besides saving the labour of pumping and carrying, the waste of the latter in the case of using 75 gallons per day per house, amounting to a loss of three days' labour of one person in a week. The improvement of the land drained would alone have repaid the outlay.

I would proceed to point out the defects of storage reservoirs on gathering grounds as now existing in some parts of this country. They collect the crude surface waters, always liable to discoloration and thickening from dirt brought in by heavy rains, to deterioration in taste, to hardness from contact with the soil and also by evaporation, this last however being trifling as compared with the first, as has been already shown. Compare these results with the proposition of the Board. After the ground is once saturated, the rainfall passes immediately through a natural filter of sand into the drainage pipes which lead it away to storage reservoirs lined with tiles to prevent the water acquiring the mineral qualities of the soil, hence to a *covered* reservoir in the neighbourhood of its distribution, safe from the noxious influence of the impure atmosphere of a city. The importance of covered reservoirs cannot be overrated when the evidence given by several eminent professors of chemistry before the Board is considered, although little more than every day's experience is needed to show that what is disagreeable on a small scale must be very detrimental, often dangerous, in larger volumes of water. A tumbler of water cannot be exposed half an hour without becoming warm, vapid, and badly tasted—and from what cause?—simply because water has an extraordinary capacity for absorbing the impurities of the atmosphere.

Reverting again to the plan of collecting rainfall by draining the sandy heaths, I question whether it could in one case be carried out with advantage, namely, on the higher levels, as for instance, the crests of the Fox Hills and Chobham Ridges, where the strata of sand are of a very loose nature. I think that the surface once broken through, the water would pass by the pipes. The area on which this would happen is however not very large. It is very desirable to ascertain this point by trial works; a few acres drained would satisfactorily settle an important question. The same would occur in the lower levels were it not that nature has abundantly provided a subsoil in the form of a crust or pan about nine inches thick, composed of three inches of closely-packed pebbles and sand resting upon six inches of sandstone. This pan lies at a depth varying from one to three feet below the surface, in some cases it is found beneath a few inches of sandy loam. The pipes might be laid on the pebbles and sand encrusted together which would hold the water. The pan once broken through, the water would, I fear, be lost for ever. The cultivation of these heaths would eventually repay a large portion of the expense of collecting rainfall by drainage. Mr. Hewett, a most intelligent farmer and land-surveyor, from whom I have obtained much valuable information, assures me that where this pan comes near enough to the surface to be broken through, which is done at an expense of 8*l.* and 10*l.* per acre, and when properly manured, the cultivation pays handsomely.

The only disadvantage attending the Board's scheme, if in such an important matter it may be deemed so, is the expense of the large lined storage reservoirs necessary to contain a six weeks' or two months' supply for a city of the giant proportions of London; otherwise the system is unique in simplicity and perfect adaptation for the purpose required. So vivid was this impression on my mind, that on developing the idea of supply from springs, I conceived a method of adapting the principle to my own case. Where the springs are large, I propose to enclose them in brick or tiles, but when small and numerous, I would prefer to gather them together in one stream to be led away in earthenware pipes, but this must be effected on the pure sand, and great care must be taken to avoid the mixture of surface-washing. Where, when leading away a stream of springs, it would be liable to discoloration from heavy rains, I propose to provide a remedy by preparing at the point of diversion from the natural channel a new bed for a short distance at a less inclination; the bed to be a trench with a pipe at the bottom and filled up with small stones and sand, heather or heath being placed round the pipe joints. The stream being led on this new bed will percolate into the pipe beneath. When the extent of the ground above the springs would expose them to be choked up by rubbish and dirt after a storm, I would intercept the rainfall in contour trenches with pipes underneath them also, and lay a branch to lead the water away to the main. A large addition might thus be made to the flow of the springs if desirable.

The annexed sketch is that of Farnham Hill, reduced from the Tithe Commission plan and tested as to accuracy. The blue contour line represents the level of the springs. I have caused them to be gathered together and gauged their flow as accurately as in my power. Their daily discharge is equal to 897,393 gallons.

The area within the contour line is 571 acres. The available rainfall from 22·65 inches per annum—(a mean of 30 years' register at the Military College, Sandhurst,) allowing the usual deduction of 14 inches for evaporation and absorption—is 279,858 gallons per day. The difference then, 611,160 gallons, is the least figure in favour of my assertion that the water in this hill is due to causes other than the local rainfall, for the rain on the hill does not all percolate but chiefly passes away.

I assure the Board, however, that a careful collection of these springs would almost double their volume and produce a daily discharge of 1,794,786 gallons. This then would leave a total of 1,514,928 gallons above the available rainfall on the hill, even supposing it all to penetrate.

In reference to my idea of the cause to which some of these springs are due, I would mention that a notable instance of the kind occurs in Hong Kong, an island mountain of not 25 miles in circumference at its base, and of 1,000 or 1,200 feet elevation above the level of the sea. The quantity of water supplied from springs on the *top* of this mountain is notoriously far beyond its rainfall, which latter, from the declivity of the ground is at once discharged into the sea, as all who have been there are well aware of. The shore of the mainland is not further than two miles and a-half, but the range of mountains of equal and higher elevation, and which furnish the supply, are at a distance of upwards of 10 miles. The rainfall cannot find its way again after percolation to the surface and is necessitated to find its level by crossing the sea and rising through the fissures of the granite formation of Hong Kong. The springs are rarely known to be affected in quantity even after a three months' drought in the island, the thermometer often at 88° and upwards in the shade.

The advantages I propose to derive from permanent springs, meaning those which always preserve an average flow, summer and winter, over surface drainage, are two-fold.

1. The continuous flow from springs gives water of better quality as to aeration and temperature.

2. An immense saving will be effected on the item of storage reservoirs, and I believe a considerable sum in the diminished quantity of excavation and pipeage. Assuming that the supplies from these springs do not materially alter, no necessity can exist for storage reservoirs. A small covered reservoir might be provided at Wimbledon Common to meet the greatest possible demand during the shortest time, otherwise, a main with a simple waste pipe into the Thames would suffice.

Too much importance cannot be attached to a constant flow of pure, cool and soft water, brought direct, without detention, from the Hindhead to the attic of the highest house in London. How grateful will be the daily use of cool soft water only 24 hours from a natural reservoir in the depth of the earth!

I consider I have realized in a remarkable manner, the Board's enunciation, "the nearer the source the purer the supply." The whole value of the scheme appears to me to depend on the accurate following up of this principle.

On consideration of the original proposal, there is only one more point I shall at present touch upon, namely, the great and scarcely estimable benefits of land drainage not only to the soil but to the inhabitants of the district. From the rainfall, a depth in the year of 22·65 inches (allowing seven to be absorbed), there remains nearly 15 inches, or 1,529 tons of water on every acre, impeding cultivation by diminishing the temperature of the soil, by not allowing a proper circulation of air in it, and by causing a perpetual evaporation, not only injurious to health in itself but excessively wasteful of the heat of the atmosphere, a loss which in our damp climate is a very serious consideration indeed, and it is only when the whole country shall have been perfectly drained, that this stigma of unnecessary and dangerous damp will be effaced from our registers of temperature.

Again, experience has satisfactorily shown that the low temperature of undrained land is the chief cause of scanty and poor crops and inferior growth of timber. In an economical point of view, it is most necessary then to remove this noxious agency.

Having given the results of my observations in detail, it may be now proper that I should state my opinion of their variance as compared with the conclusions enumerated in the report, which difference I attribute chiefly to the hitherto limited investigation of the subject.

Generally, in all points as applied to the quality of water, its advantages in economy, its beneficial influence on health, &c., my researches not only distinctly confirm the statements of the Board, but have also elicited further illustrations, in respect to which I hope shortly to have the honour of addressing them. This information I have collected from persons of all classes, medical men, manufacturers, farmers, tradesmen, peasants, &c., all of whom, in their different spheres, have given me valuable evidence on the subject in question.

The results of my experience are as follows:—

I. With respect to the quantity and quality of water to be derived from the gathering grounds, in whatever method of collection—

The report gives 28 millions of and under 3 degrees of hardness.

My results give 40 millions of and under 1 degree, and 10 millions of and under 2 degrees of hardness.

This improved quality is gained by my development of the principle of taking the water from its source (that is, where it issues from pure sands) and leading it away before it can be affected by contact with other soils. I beg to express my conviction that the purity will depend entirely on the careful execution of the work : it would give, to recapitulate its qualities, 40 millions of water—

Of primitive purity ;
Perfect as to aeration ;
Of a grateful temperature, about 50 degrees ;
Brilliant in colour ;
Soft almost as distilled water,

and almost free from all mineral, animal and vegetable impregnation, sufficing for the supply, at the estimate of 75 gallons per house, of 523,126 houses, nearly double the present number in the metropolis.

The 10 million gallons of and under 2 degrees of hardness are derivable from sources rising in sands not quite pure.

II. By the direct means of collection from springs, instead of the extensive system of land drainage originally contemplated, very considerable saving of expense would be effected.

*First.* In the less quantity of pipeage required, and consequently of labour expended.

*Second.* On the item of the large extent of storage reservoirs, originally required to provide for summer months, periods of drought and which by my plan would be unnecessary.

*Third.* On the reduced claims for compensation, especially as no breadth of land would be required to be taken up. A mere underground right of way, a pipe-laying easement would be required.

A résumé of the above then gives in favour of the plan proposed :—

I. Greater certainty of supply.
II. Superior quality.
III. Greater abundance.
IV. Greater speed of execution of work and application for service.
V. Greater economy.

Should the future exigencies of the metropolis require an increased supply, it may still be derived not only from land drainage of rainfall on the pure sands *beneath* the level of the sources now proposed, but also to a great extent *above* them.

I would remark that it might be considered desirable to allow the towns of Guildford, Richmond, &c., and the different villages on the line of water supply to London, to partake of the advantages proposed for that city. The first of these suffers severely from hard and expensive water. Of course they would have to pay their proportion of the rate to be levied to meet the expense of the works, which I am prepared to show will not, for an increased, continuous, pure supply of soft water, at high pressure, exceed a *fraction* of the sum now levied by the water companies, for an impure, hard, and defective one.

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## II.

### Method of Collection, Conduction, and Delivery of the Deep Spring-water, with an approximate Estimate of the Expense of the Execution of the Works.

Seeing the extreme importance of an accurate and detailed investigation of these subjects, I had hoped that the once contemplated assistance of the Commission of Sewers would have enabled me to have prepared an accurate plan of the proposed gathering-grounds of Farnham and Hindhead, by which means not only the actual and relative levels of the springs to one another and above mean tide would have been obtained, but also the inclinations of the collecting and conducting lines. With these data it would have been in my power to have determined accurately the lengths and diameters of the requisite pipeage for collection, also the amount, if any, of extra foundation necessary for the conducting culvert, and to have framed a complete estimate of the entire expenses of the proposed undertaking. Unhappily, the Hon. Commission of Sewers, though interested to the amount of at least one-fourth of the whole water supply, have not carried out the original order of the Court, which authorized the extension to the south of the metropolis of surveys already executed to the north, connected with the water-bearing power of certain districts at a sufficient elevation above mean tide.

Materially as this decision has impeded the investigation of the whole subject under consideration, I have endeavoured to complete, as far as my personal exertions could be made usefully available, an approximate view, based on the broad principles laid down by the Board in their Report on Water Supply, of all the details of the proposed scheme to gather spring water only, including what I conceive to be an outside estimate of the total expense of execution.

Feeling the heavy responsibility attached to my first communication to the Board, it was truly satisfactory to receive more than ample confirmation of my gaugings from Mr. Rammell, the ( gineer to whom the examination was assigned. Mr. Ramı ll's gaugings, amounting to 51,375,000 gallons, are 10 mı ons in excess of mine, thus verifying the opinion expressed, that I had rather under than over estimated the flow of the springs:

It is well known that a series of experiments of this nature should be conducted at different intervals of time and with great precision, but in this case it was very desirable to ascertain the minimum discharge of the springs after a period of long drought, which object I believe my approximate gaugings and Mr. Rammell's most accurate re-examination to have effected. It has come to my knowledge that one of the water companies' engineers has lately examined these sources, and realized a discharge of 60 millions a-day from 14 of the largest springs. This experiment was conducted during the late heavy rains, and is only of importance as showing that should the future necessities of the metropolis exhaust the deep spring water, a careful storage of surface water will afford an ample and pure supply, though not so pure as that from the springs, as being exposed to deterioration even in lined storage reservoirs.

Too strict attention cannot be afforded to the now indisputable fact, that the deep springs alone, after a protracted drought, yield 51,377,000 gallons per day, a discharge of 12,000,000 gallons in excess of the present requirements of the metropolis.

Plan No. 2 is reduced from the Ordnance maps and includes the whole area under investigation, which embraces, first, the sands of the Bagshot formation included between Wokingham, Farnham, Woking, and to within two miles of Chertsey; secondly, the part of the green sand formation extending south of the rivers Wey and Tillingbourne to Woolmar Forest, Hazlemere, and the Leith hills, including the low ranges of Hascombe and Hambledon. This sketch is submitted as explanatory of the position of the springs; the blue lines represent the probable directions of the pipes, and, as will be seen, are on the south side of the Hog's Back, gathered together at the pass in that range at Guildford where it is proposed to commence a conducting culvert, which will terminate in an adjusting reservoir on Wimbledon Common, as marked upon the plan. The springs from the Farnham Sands will enter the aqueduct in the direction of Woking. From the reservoir must radiate the lines of mains to connect with the existing street pipeage.

I have given as far and as accurately as in my power the levels of the spring-heads and of points on the lines of collection and conduction above mean tide. From these imperfect data are calculated approximately the diameters and lengths of the pipeage of collection as detailed hereafter.

In conclusion of the subject of the quantity of available water in this district, I wish to examine certain statements made to the New River Company by Mr. George Rennie, in a report on the supply of water to be obtained from the district of Bagshot.

As the copy of the Ordnance map which is appended to this Report comprises the whole area of sands, north and south of the Hog's Back, which have lately been the subject of further examination by me, and as Mr. Rennie's Report is confined solely to the sands north of that range, I would conclude that he considers the quantity and quality of the water derivable from the green sand formation unimpeachable, were it not that he makes a statement which, if borne out by fact, would condemn the source entirely; and my conclusion from his silence about the green sand formation, and from the nature of the statement alluded to, is that Mr. Rennie never visited this portion of the district at all.

I will now cursorily examine some of the statements made of areas available and waters gauged. 1. The total drainage area is given at 50,000 acres, and the discharge of water to be 12,142,852 gallons per day. On looking at the portion of Mr. Rennie's map coloured as an available source of water supply, I was surprised to observe that no notice whatever is taken of the portion of the Bagshot sand formation, including the Hertford Bridge Flats, Eversley Common, Minly, Northfleet, &c., although forming a part of the area mentioned and indicated by the Board as available, from Esher to Strathfieldsaye (*Vide* page 98, Report on Water Supply). This area comprises at least 5,000 acres, and the omission appears very strange when I remember that the discharge of the springs alone, having their outfall in this area, amounts to 9,130,000 gallons per day, one series at Baker's Bridge giving 8,251,000 gallons.

The total quantity of water derivable from the Bagshot sand formation will then be ; given by Mr. Rennie, 12,142,152 gallons, omitted by him 9,130,000 gallons; making a total of 20,393,152 gallons, a quantity larger by three-fourths than that reported by Mr. Rennie to be available. The discharge of the springs from this formation, as reported by Mr. Rammell, amounts to 19,138,000 gallons.

I will now remark upon a statement at page 11 of Mr. Rennie's report, where I find within six lines, two assertions, if true, so damaging to the Board's proposal, and yet from my knowledge so at variance with facts, that I deem it my duty in submitting them to the notice of the Board to analyze them carefully.

After asserting that the quantity of water really available would fall very far short of the Board's estimate, Mr. Rennie proceeds to say, alluding to the many requirements for water in London, besides house consumption—" If the deficiency for these latter purposes are to be taken from the River Wey, the hardness of which is established at sixteen degrees, it will go far to reduce the quality of the water for domestic use ; and in either case, whether taken from a tributary of the Thames, or from that river at Kew, the abstraction of so large a volume of water from the flow through the metropolis, during such seasons in particular, must prove injurious to the general scour and purity of this noble river." Of the springs from which it is now proposed to supply the metropolis, 31,237,000 gallons fall into the Wey, 18,138,000 gallons into the Backwater and Loddon, and 2,000,000 gallons into the Mole. The Loddon enters the Thames at Sonning, the Wey between Chertsey and Walton, and the Mole at Moulsey above Thames Ditton. In all, 51,375,000 gallons will necessarily be abstracted from the Thames. Let me examine to what extent the noble river will be reduced, for which purpose I will refer to Mr. Walker's report on the probable effect on the navigation of the River Thames, by the projected plans for the supply of London with water by the Henley and London Aqueduct Commission and the Metropolitan or Mapledurham Water Company.

The Henley scheme proposes to take its supply from the River Thames, near Mendenhead Abbey, or about 4 miles below Henley. We propose therefore to calculate on the extraction of 100,000,000 gallons per 24 hours, stated by the Henley project, which is exclusive of their taking an equal quantity (except in times of drought) for sewerage as has been stated. The effect on the tideway below Teddington lock comes to be considered separately. This lock, when built in 1810, had 6 feet upon its lower sill at low water, in times of drought. The removal of London Bridge, and the removal of shoals in the river, near London, have lowered the water so that there is only 3 feet 9 inches upon the Teddington sill. Mr. Leach has calculated that the effect of abstracting 100,000,000 gallons would be to lower the level of the water at the lock, and for a distance downwards, 7 inches, which would be a real and practical evil. It is proper to state that the above evil is not, in our opinion, without a remedy; for by the removal of Teddington lock and erecting a new lock near Kingston, or about 1 to 1½ miles above Teddington, with a sill of sufficient depth there, removing the shoals so as to allow the tide to flow more freely up to the proposed lock, and deepening the river up to it; the abstraction of water would be compensated for, and the navigation of the Thames improved by the greater quantity of tidal water which would flow and ebb at any tide.

Such was Mr. Walker's opinion. Mr. Rennie having predicted a great injury to the river at the metropolis, I will carry the investigation further. According to Mr. Leach's calculations the abstraction of 50,000,000 gallons would lower the water on the sill at Teddington lock 3½ inches; the probable reduction in depth therefore at Vauxhall bridge, would, from the increased width, be less than one-fifth of an inch. Such therefore would be the amount of injury to the general scour and purity of this noble river. I will argue further, and having proved that according to the newly proposed system of sewage by carrying away and discharging it into the river at Woolwich, the abstraction of 50,000,000 gallons would lower the depth of the river at the metropolis one-fifth of an inch, will show that if Mr. Rennie's suggestions on sewage were attended to, and the Thames were still used as the main sewer of the metropolis, as advocated in Mr. Rennie's letter to the "Times" of December 27, 1849, the one-fifth of an inch would of course be restored.

Now as regards Mr. Rennie's assertion concerning the River Wey, the hardness of which is established at sixteen degrees. If the word *sixteen* be not a mistake of the printer's, I am at a loss to understand how Mr. Rennie could arrive at such an erroneous conclusion; for after the junction of the Farnham river with the stream from Bramshot, the River Wey has not a hardness of more than nine degrees, according to Dr. Clarke's soap test.

Attached to Mr. Rennie's report I find several chemical analyses of waters from the New River and Farnham sources, by Professor Brande. To one of these I request the attention of the Board, viz. that from a lead cistern at the Lion Hotel, Farnham, given as follows:—

| | Grains. |
|---|---|
| Carbonate of lime, silica, and carbonate of lead | 3·00 |
| Chloride of sodium . . . . . . | 1·40 |
| Sulphate of lime . . . . . . | 0·70 |
| Organic matter . . . . . . . | 1·40 |
| Total grains per gallon . . . | 6·50 |

One item of this analysis certainly astonishes me. The object of the examination of the specimen can only have been to ascertain the action of the soft water on the lead cistern, and to see in how far the effect could be chemically detected in the water. How are the three ingredients, carbonate of lime, silica, and carbonate of lead, combined that they could not be separately weighed? Is it because the analyzer deems all three of so little importance that closer examination is useless? I fear not, for Professor Brande has so explicitly stated his opinion as to the action of pure water on lead that it will be necessary to look farther. Is it found convenient to leave to the imagination of the public what proportion each ingredient bears to the whole? My own opinion is decided, that the three ingredients could not easily be weighed together; at any rate, such an analysis would be considered slovenly and unprofessional, and I appeal to the whole honourable profession of chemistry, whether or not this analysis of an important question bears the stamp either of impartial truth or scientific accuracy.

Before proceeding to discuss the method of collecting, conducting, and distributing the springs, I would again refer to the great mistake made by those who informed the Board that the supply at Farnham was derived from under-drainage, a term implying a system of pipes, laid at a certain depth from the surface, to receive and convey away the rain-fall, but which is erroneously applied to the case in question, as the supply is obtained by leading away a few small but constant springs through an adjusting reservoir to the town.

The method of collection and material of the pipes should now be considered. The superiority of earthenware over metal pipes has already been so clearly represented and discussed in the Report of the Board on Water Supply, that it is in vain for those unfavourably disposed to reiterate their ordinary and groundless prejudices. History, ancient and modern, records the efficient and extensive application of earthenware pipes for the conveyance of water: and at the present moment they are rapidly replacing metal pipes for water and gas supply in France and Switzerland. I propose hereafter to give some instances of their application, meanwhile no one will deny the practicability and propriety of a recurrence to the ancient practice of using earthenware pipes even of considerable diameters, for the purposes of collection. The following is an approximate calculation of the lengths and diameters of the proposed pipeage, showing a total length of 816,640 yards of pipes of all diameters from 2 inch to 2 feet, of which—

| | | |
|---|---|---|
| ·35 or $\frac{35}{100}$ are | 2 | inch |
| ·20 or $\frac{20}{100}$ are | 3 | „ |
| ·11 or $\frac{11}{100}$ are | 6 | „ |
| ·05 or $\frac{5}{100}$ are | 9 | „ |
| ·04 or $\frac{4}{100}$ are | 12 | „ |
| ·06 or $\frac{6}{100}$ are | 15 | „ |
| ·02 or $\frac{2}{100}$ are | 18 | „ |
| ·01 or $\frac{1}{100}$ are | 21 | „ |
| ·16 or $\frac{16}{100}$ are | 24 | „ |

These pipes should be laid up to the very sources of the springs and should be arranged as only to receive their least flow, the surface water, during periods of rain, being allowed to pass away without contaminating the source of supply. They should be laid at a depth of 4 or 5 feet and carried to the outfall along the natural slope of the county, thus increasing to a trifling extent the distance, but avoiding works of masonry and interference with the surface.

Supposing then the springs collected and brought down to the pass in the range of the Hog's Back at Guildford, I now come to consider the nature of conduction to the adjusting reservoir. According to all experience, ancient and modern, water must be covered in from the atmosphere to preserve its native purity and softness. This is not only known to the Board but much insisted upon in their Report on the Water Supply. The double culvert of brick proposed will answer all the purposes required, combining, as it does, strength and efficiency of form with great economy of construction. The line of direction as indicated by the Board is an inclination from the contour at Guildford to that at Wimbledon Common, thus saving expensive foundations, by keeping under the surface, the deviation from the straight line not being considerable.

Having brought the spring-water to Wimbledon Common, the next point is, whether or not it be really imperative to have an adjusting reservoir; if so, the locale is admirably adapted for the purpose, as having a considerable elevation above mean tide, more than sufficient to give high pressure to one-half of the metropolis. The supply for the more elevated portion must be pumped, the expense of which will

*Note.*—A great advantage however will exist in having a surplus of water always disposable, in the event of extensive fires. We have every right to hope that the system of constant supply at high pressure from large pipes with plugs at short distances, and hose always and conveniently ready, as recommended by the Board, will with common vigilance on the part of the police render such occurrences as rare in London as they now are at Hamburgh; but as a little negligence and the accidental coincidence of high winds make such events possible, it will be well to have plenty of water available. I would remark, that while at Hamburgh the risk from fire amounts to nothing, it does not seem that the rates of insurance are diminished, and it is said that the insurance companies of London do not be very trifling when it is remembered that the cost of raising 90,000 gallons 50 feet high is only 1*s*. As regards reservoirs generally, where water is obtained from pure sources, and the supply is equal to the greatest possible demand within the shortest space of time, they are to be utterly condemned as possessing no advantage and involving possibly many serious evils. (*Vide* "Report on Water Supply.") As to the case in question, the sources of the proposed supply yield rather more than 51,000,000 gallons in 24 hours or 25½ million gallons in the time when the greatest demand is necessarily made. The supply is therefore 14½ million gallons short of the demand, estimated at 40,000,000 gallons a day for all purposes. A reservoir of small capacity is therefore in the present question imperative. The only other means suggested to me of making good the deficiency, is by increasing the section of the conducting culvert, but I consider the reservoir to be the cheapest and most desirable means of effecting the purpose of equalisation.

A covered reservoir as proposed by the Board might be constructed to contain 100,000,000 or 200,000,000 gallons, equal to from two to five days' consumption. The entering

contemplate any reduction when this city shall partake of the security now afforded to Hamburgh. How is this? The companies are not slow to charge enormously for what they term great risks, and why, therefore, are the public not to share in the saving from increased safety? Should this subject not hereafter receive the attention of imperial legislation, it will be well for persons to consider whether with jets of water, say 80 feet high, always at command, and hose conveniently disposed perhaps in the lamp-posts, or in receptacles under the pavement, it will not be more economical, by increased vigilance, to become our own insurers, and save 1*s*. 6*d*. in the 100*l*. for building, 3*s*. for property, and the tax of 3*s*. per thousand. The Board have given the rental of the houses of all London at 12,000,000*l*., which capitalized at 25 years' purchase, amounts to 300,000,000*l*. Say the property amounts to 300,000,000*l*., the present rate on the first would give, if all insured, 225,000*l*., on the second 450,000*l*., the duty 101,250*l*., in all 776,250*l*., which, divided among 280,000 houses, gives an average perpetual rate per house of 2*l*. 15*s*. 6*d*. I am told that insurance is beneficially affected by competition; but the arguments advanced, are not sufficiently supported by the facts of the case for me to admit their validity. Such needless extravagance neither can or will continue, and the administration of this branch of public affairs must eventually be combined with all the others.

water should be introduced in several places at the bottom and not opposite the channels of delivery; thus compelling a thorough mixture and avoiding all stagnation. It is wonderful to observe the confluence of streams, especially of those of very considerable and disproportionate velocity, apparently struggling long ere they amalgamate thoroughly. This circumstance is plainly visible at the junction of streams flowing from different formations, and an instance occurs in the district in question, for I find, first on the authority of Mr. Long, a resident, and subsequently on personal enquiry, that at Tilford, the point of junction of the hard water from Farnham with the soft from Headley, "the poor people who live in the cottages on the side where the Farnham water flows, do not dip their buckets from their own bank, but, crossing Tilford Bridge, obtain a supply of soft water for their washing, from the Headley portion of the current."

A fact which strongly corroborates the evil influence of open reservoirs in allowing the water to stagnate has been exemplified at Dublin, the north side of which city is partly supplied by the Portobello reservoir, about 100 yards long, 70 yards wide, and of a considerable depth; the reservoir is supplied from a canal close by, through which a current is constantly flowing. A few years ago this reservoir was exceedingly dirty, and while being cleaned the supply was drafted direct from the canal, when a considerable improvement was remarked in the quality of the water. The reservoir being cleaned, the water was again turned in, and, although passed through a new filter, there was an immediate change for the worse, being in fact little better than before the reservoir was cleaned, thus corroborating the assertion of Dr. Hassall, that water not kept thoroughly in mixture and motion must deteriorate. Let any one in London observe the reservoir in the Green Park, which, though cleaned out and of late whitewashed at the bottom once a month nearly, reminds one rather of a duck-pond than anything else. The same deterioration occurs also at Liverpool, where the spring-water from the new red sandstone is pumped into a reservoir, which became so foul in a few months that the water could not be used. This also occurs at Carlisle.

We need not, however, go farther than to the salt ocean for advice on this subject; all who have seen the sea after a long calm, will remember the filthy scum which dimmed its fair surface. I deem it right to draw attention to this deterioration of water, for I understand the New River Company propose to ask this Session for powers to construct enormous open reservoirs of upwards of 1200 acres in extent to contain a supply for the whole metropolis.

It now only remains to connect the reservoir with the existing system of street and house distribution. It is most desirable that earthenware pipes should be used; the water would then reach us as pure and cool as at its source. I am aware that some engineers state it as their opinion that pipes of large diameters cannot be made sufficiently strong to withstand the hydraulic shock at the required pressure. The desirable size varies from 18 inches to 24 inches, and the highest part of London is, I believe, 400 feet above mean tide.

That earthenware pipes of a certain diameter have been and are now in use at a considerable pressure is undoubted. It is urged, however, that they have had a fair trial in this country and have been found wanting. How and where was the trial, and what were the causes of failure? I find it stated in a valuable Report on Long Town, Stoke-upon-Trent, by Mr. Rawlinson, one of the Board's engineers, that "a Mr. Bradshaw laid tile pipes through this town with socket joints made with Roman cement, but they would not stand the pressure, which was 128 feet; they did not stand it one day. The pipes were made of blue marl, some of a superior material, but these even did not stand; they did not go in the joint, but in the middle of each pipe."

Mr. Badlon, plumber, stated "that in a general way the pipes broke at the socket collar, and when they were suddenly stopped."

Again, I am informed that Sunderland was laid with earthenware pipes, which are supposed to have been tested up to 300 feet of pressure, but they failed under an intermittent supply; the joints were secured by a ring of cast iron and stood. It is generally supposed the failure was owing to defective laying without proper foundations. Now what does this all go to prove? In the first instance, culpable recklessness in laying down pipes not tested as to strength to resist a known pressure; in the second case, an almost apparent determination to make the system fail. The pipes withstood the pressure, the joints were perfect, but the skill of the manufacturer and of the engineer were frustrated by the carelessness of those whose duty it was to lay the pipes. I confess, that if these statements have been accurately given to me, I see a fair prospect of earthenware pipes being made perfectly efficient. The points to be attended to in the elucidation of the system are, first, strength of material to withstand pressure and the smaller hydraulic shock that will still exist even on the constant system of supply. Second, a simple, efficient, and economical joint, that will admit of one length of pipe being removed and replaced when necessary. Lastly, a proper system of laying, as in cradles. I must add, that some experiments were instituted on this subject by Mr. Quick, the able engineer to the Vauxhall and Southwark Water Company, who states, I believe, that the pipes failed under the hydraulic shock.

Having described the means proposed for the conduction of the springs of Farnham and Hindhead into the existing system of street pipeage, I propose, before offering the Board an approximate view of the whole expense of the works detailed, to enumerate the injuries they would entail on property.

The damages to property involved in the collection of the springs, and requiring compensation, are:—

1. Loss of water to millers and manufacturers, brewers, &c., if any.
2. For the purpose of irrigation.
3. For ornamental water.

Referring to the paragraph, page 115 of the Report on Water Supply, commencing "For the facilitation of the required works, &c.," I would express my opinion, that where the existing supplies of water to villages and isolated dwellings for house and farm-yard consumption are in question, which is a subject of considerable anxiety to the inhabitants of the district, special provision for their security might be provided in the Bill.

APPROXIMATE ESTIMATE of Profits and Va

| No. | Name of Mill. | Name of Proprietor. | Residence of Proprietor. | Description of Mill. | Nature of Right to Water. | Situation of Mill. | N Y esta |
|---|---|---|---|---|---|---|---|
| 1 | Abinger. . . . | W. J. Evelyn, Esq. | Wootton. . . . | Flour and grist | Absolute . . | Abinger. . . . | An |
| 2 | Bagshot. . . . | J. Cozner, Esq. . | Bagshot. . . | ,, | ,, . . | Bagshot. . . . | 33 |
| 3 | Barford . . . . | W. Waren . . . | Bramshot . . . | Paper . . . . . | Subject to Barford corn-mill. | Headley . . . | 60 |
| 4 | Barford . . . . | N. J. Fuller, Esq. | Frensham. . . | Flour and grist | Absolute . . | Frensham. . . | 100 |
| 5 | Bramshot . . . | C. J. Ellis, Esq. . | Essex-street, London. | Paper . . . . . | Absolute . . | Bramshot . . . | , |
| 6 | Bramshot . . . | W. Calcraft . . . | Bramshot . . . | Flour and grist | ,, | ,, | Anc |
| 7 | Bramley . . . | Colonel Wyndham | Bramley. . . . | ,, | Not absolute . | Bramley. . . . | , |
| 8 | Chobham . . . | J. Lipscomb . . . | Chobham . . . | ,, | ,, | Chobham . . . | , |
| 9 | Cosford . . . . | Lord Middleton . | Pepperharrow . | ,, | Absolute . . | Thursley . . . | , |
| 10 | Dunford . . . | T. Weding, Esq. | London . . . . | Flour, grist, saw | Not absolute. | Chertsey . . . | 50 y |
| 11 | Embrook . . . | J. Hayward . . . | Wokingham . . | Flour and grist | Absolute . . | Wokingham. . | 70 y |
| 12 | Easthampstead | Marquis of Downshire. | Easthampstead | ,, | ,, . . | Easthampstead | Anc |
| 13 | Emmett's . . | J. Mumford . . . | Chobham . . . | ,, | Not absolute. | Chobham . . . | ,, |
| 14 | Enton . . . . | Rich. Whitburn . | Enton. . . . . | ,, | Absolute . . | Godalming . . | ,, |
| 15 | Fleet. . . . . | H. P. Collett, Esq. | Yately . . . . | ,, | ,, . . | Hawly . . . . | ,, |
| 16 | Headley, Park | W. Langridge . . | Headley. . . . | ,, | Not absolute | Headley. . . . | 20 ye |
| 17 | Headley . . . | Sir A. Macdonald | Woolmer Lodge Hants. | ,, | ,, | ,, | Ancie |
| 18 | Hascomb . . . | T. Durrant. . . . | Witley . . . . | ,, | Absolute . . | Hascombe. . . | ,, |
| 19 | Heath. . . . . | J. Honer. . . . . | Pirbright . . . | ,, | Not absolute | Pirbright . . . | ,, |
| 20 | Lowder . . . . | J. Lucas. . . . . | Lowder . . . . | ,, | Absolute . . | Steep . . . . . | ,, |
| 21 | Pirbright . . . | H. Halsey, Esq. . | Henly Park . . | Flour, grist, saw | Absolute. . . | Pirbright . . . | ,, |
| 22 | Paddington . . | W. J. Evelyn, Esq. | Wotton . . . . | Flour and grist | Not absolute. | Abinger . . . . | ,, |
| 23 | Rake . . . . . | T. Durrant . . . | Witley . . . . | ,, | Not absolute. | Witley . . . . | ,, |
| 24 | Rookery. . . . | R. Fuller, Esq. . | Dorking. . . . | ,, | Absolute . . | Dorking. . . . | ,, |
| 25 | ,, . . . . | ,, . | Dorking. . . . | ,, | ,, . . | ,, . . . | ,, |
| 26 | Ruses . . . . . | Marquis of Downshire. | Easthampstead | Flour, grist, bone | ,, . . | Wokingham . . | 16 yea |
| 27 | Siccle . . . . | James Simmons | Cherimans, Haslemere. | Paper. . . . . | ,, . . | Haslemere. . . | 150 yea |
| 28 | New . . . . | James Simmons | Cherimans, Haslemere. | ,, . . . . . | ,, . . | Lynchmere . . | 70 yea |
| 29 | Pitfold . . . | James Simmons | Cherimans, Haslemere. | Bleaching . . . | ,, . . | Frensham . . . | 100 yea |
| 30 | Stanford. . . . | Sarah Walker . . | Headley. . . . | Flour and grist | Not absolute | Headley. . . . | 50 yea |
| 31 | ,, . . . . | Richard Knight . | Chawton, Hants | Paper. . . . . | ,, | ,, . . . | 42 yea |
| 32 | Snowdenham . | W. L. Henning . | Dorchester. . . | Flour and grist | ,, | Bramley. . . . | Ancien |
| 33 | Shotter . . . . | G. Oliver . . . . | Shotter Mill . . | ,, | ,, | Lynchmere . . | ,, |
| 34 | Westcott. . . . | R. Fuller, Esq.. . | Rookery Dale . | ,, | ,, | Dorking. . . . | ,, |
| 35 | Windlesham. . | J. Humphries . . | Bagshot . . . . | Flour, grist, saw | Absolute . . | Windlesham. . | ,, |

…in Mills in Berks, Hants, Surrey, and Sussex.

| …nber of: Benches. | …nber of: Paper Engines. | Average Daily Number of Hours' Work throughout the Year. | Weekly average Amount of Work capable of being Produced: Flour Mill. Sk. | Weekly average Amount of Work capable of being Produced: Paper Mill. Cwt. | Weekly average Amount of Work capable of being Produced: Saw Mill. Ft. | Price charged for Grinding: Flour, Sack. s. d. | Price charged for Grinding: Grist, Sack. s. d. | Price charged for Sawing: Hard Wood, 100 Ft. s. d. | Price charged for Sawing: Soft Wood, 100 Ft. s. d. | Average Annual Value of Work. £. s. d. | Rateable Value according to Poor-rate Assessment. £. s. d. | Value of Mill and Machinery. £. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .. | .. | 9 | 40 | .. | .. | 2 0 | 1 4 | .. | .. | 251 6 8 | 192 0 0 with farm. | 798 | Rated with farm. |
| .. | .. | 8 | 25 | .. | .. | 2 0 | 1 4 | .. | .. | 143 0 0 | 40 0 0 | 777 | Machinery good, with 25 acres of land. |
| .. | 2 | 9 | .. | 8 | .. | .. | .. | .. | .. | .. | 43 4 0 with house | 1,060 | Foolscap paper. Rated with house. |
| .. | .. | 10 | 40 | .. | .. | 2 0 | 1 6 | .. | .. | 236 12 0 | 19 8 0 | 798 | |
| .. | 3 | 20 | .. | 20 | .. | .. | .. | .. | .. | .. | 54 13 4 | 1,995 | Fine white paper. |
| .. | .. | 10 | 50 | .. | .. | 2 0 | 1 6 | .. | .. | 390 0 0 | .. | 870 | Rated with farm. |
| .. | .. | 12 | 55 | .. | .. | 2 0 | 1 6 | .. | .. | 364 0 0 | 32 14 0 | 956 | Machinery good. |
| .. | .. | 12 | 55 | .. | .. | 2 0 | 1 6 | .. | .. | 416 0 0 | 41 10 0 | 1,030 | ,, ,, |
| .. | .. | 9 | 40 | .. | .. | 1 6 | 1 0 | .. | .. | 175 6 0 | 30 0 0 | 725 | Not good. |
| 2 | .. | 12 | 30 | .. | 6000 | 2 0 | 1 6 | 3 6 | 2 6 | 361 10 0 | 40 0 0 | 945 | |
| .. | .. | 5 | 20 | .. | .. | 1 8 | 1 0 | .. | .. | 91 16 8 | 28 0 0 | 525 | Rated with house and meadow. Machinery in good repair. |
| .. | .. | 12 | 45 | .. | .. | 2 0 | 1 2 | .. | .. | 297 5 4 | 23 3 6 | 905 | Rated with 8½ acres of land; steam-power not included in valuation. |
| .. | .. | 10 | 40 | .. | .. | 2 0 | 1 6 | .. | .. | 260 0 0 | 57 0 0 | 756 | |
| .. | .. | 12 | 50 | .. | .. | 2 0 | 1 6 | .. | .. | 390 0 0 | 40 0 0 | 924 | Rated with house. |
| .. | .. | 12 | 55 | .. | .. | 2 0 | 1 6 | .. | .. | 286 0 0 | 50 0 0 | 998 | Rated with house, and 40 acres of land; also saw machine, and thrashing machine not included in valuation. |
| .. | .. | 11 | 45 | .. | .. | 1 6 | 1 0 | .. | .. | 240 10 0 | 181 16 4½ | 810 | Rated with house and 200 acres of land. |
| .. | .. | 12 | 45 | .. | .. | 2 0 | 1 6 | .. | .. | 286 0 0 | 32 0 0 | 825 | |
| .. | .. | 5 | 25 | .. | .. | 2 0 | 1 6 | .. | .. | 137 16 0 | 21 0 0 | 735 | |
| .. | .. | 10 | 50 | .. | .. | 1 6 | 1 0 | .. | .. | 351 0 0 | 53 10 0 | 1,045 | Machinery excellent. |
| .. | .. | 10 | 40 | .. | .. | 2 0 | 1 4 | .. | .. | 251 6 8 | .. | 840 | |
| 2 | .. | 10 | 45 | .. | 5000 | 2 0 | 1 0 | 3 6 | 2 6 | 312 0 0 | .. | 840 | |
| .. | .. | 8 | 40 | .. | .. | 2 0 | 1 4 | .. | .. | 266 18 8 | .. | 830 | This mill will probably not be affected. |
| .. | .. | 12 | 55 | .. | .. | 2 0 | 1 6 | .. | .. | 416 0 0 | 83 2 6 | 966 | Machinery good; rated with house and 32½ acres of land. |
| } .. | .. | 12 | 40 | .. | .. | 2 0 | 1 6 | .. | .. | 260 0 0 | 50 0 0 | 1,008 | Statute mills, work alternately. |
| .. | .. | 5 | 16 | .. | .. | 1 8 | 1 0 | .. | .. | 82 16 0 | 23 0 0 | 485 | Machinery and mill in bad repair. |
| ..<br>..<br>.. | 4<br>2<br>1 | 11<br>11<br>11 } | .. | 40 | .. | .. | .. | .. | .. | .. | 130 10 0 | 4,200 | Rated all together, at present unlet; valuable drying machine. |
| .. | .. | 9 | 35 | .. | .. | 2 0 | 1 6 | .. | .. | 195 0 0 | 71 7 10 | 693 | Rated with house and 66 acres of land; machinery indifferent. |
| .. | 2 | 10 | .. | 30 | .. | .. | .. | .. | .. | .. | 38 8 0 | 1,370 | Coarse paper. |
| .. | .. | 12 | 50 | .. | .. | 2 0 | 1 6 | . | .. | 351 0 0 | 70 0 0 | 1,050 | Rated with house and land. |
| .. | .. | 10 | 50 | .. | .. | 2 0 | 1 4 | .. | .. | 381 6 8 | 22 15 0 | 1,050 | |
| .. | .. | 12 | 55 | .. | .. | 2 0 | 1 6 | .. | .. | 416 0 0 | 70 0 0 | 1,092 | Rated with house and 2 acres of land; machinery new. |
| 1 | .. | 6 | 30 | .. | Staves 4000 | 2 0 | 1 4 | .. | Staves 6 6 pr 100 | 209 18 8 | 55 0 0 | 620 | Rated with 11 acres of land; machinery bad. |
| | | | | | | | | | | | Total Value . . | 32,521 | |

The table (p. 30) gives the whole number of mills in the district which can possibly be affected in any way, in value amounting in all to 32,000*l.*, but I believe this to be above the market value. This table is the result of considerable investigation, and may be relied upon. It gives the name and description of the mills, the average hours of work per day, nature and quantity of work, the annual income, valuation to poor-rate, and total estimated value of the mill and machinery. As regards the flour-mills, I know that foreign or other corn is ground by steam in London and sent into the markets of Guildford and Farnham, where it undersells the flour ground by the water mills, which cannot compete against steam power with the advantages of proximity to market and the saving in labour, time, and expense of cartage.

I am convinced that the millers will, if left to themselves, readily come to terms and be glad to be rid of their unprofitable calling and unsaleable stock.

I shall now offer the Board an approximate view of the expenses of the whole undertaking. The prices estimated for the earthenware pipes are lower than such are now sold for, but the reduction is based upon a careful calculation by the engineers of the Trial Works as to what might be done by contract. The same, in a less degree, applies to the construction of the double brick culvert and of the covered reservoir.

The whole, it will be seen, amounts to 646,800*l.*, including compensation, and 10 per cent for contingencies.

*Total Expenditure.—Items.*

| | £. | *s.* | *d.* |
|---|---|---|---|
| Collection . . . . . . . . | 40,000 | 0 | 0 |
| Conduction to Service Reservoir on Wimbledon Common, in a double brick Culvert, 24 miles, at 7,000*l.* per mile . . . . | 168,000 | 0 | 0 |
| Covered Service Reservoir to contain four days' supply, at 50,000,000 gallons per day . . | 80,000 | 0 | 0 |
| Estimate of expense of Mains to connect the Reservoir with the present Street-pipeage . | 200,000 | 0 | 0 |
| Probable amount of Compensation for Mill-owners, Irrigation, &c. . . . . | 100,000 | 0 | 0 |
| | 588,000 | 0 | 0 |
| 10 per Cent. for contingencies | 38,800 | 0 | 0 |
| | £646,800 | 0 | 0 |

Supposing, however, that the total expenses of the scheme, including pumping-engines, amounted to three-quarters of a million sterling, the interest of this money, at 6 per cent., paid off in 21 years, will only amount to a rate, on the average of 280,000 houses, of *3s. 2d.* per house per annum. Let me now examine what is the average perpetual rate of the water companies. Referring to their evidence before the Board, it appears that the total number of houses they supply is 270,581, and their total receipts, according to their own calculations, 431,868*l.*, which will give an average rate per annum of 1*l.* 12*s.* nearly.

I think it will be allowed I have shown that an improved supply of pure soft water at high pressure may be brought into the present street-pipeage for a fraction, or one-tenth, of the sum now exacted by the Companies for a defective, intermittent, and impure one, laid down by the Board in the Report on Water Supply, as follows: defective, in that an average of 6 per cent. of the houses in the metropolis are unsupplied with water; intermittent, as the water is only laid on from every other day to twice a-week; impure, in the large quantity of bicarbonate of lime held in solution, rendering the use of such water alike wasteful of material and prejudicial to health.

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## III.

### Some Evidence of the Popular appreciation of Soft-water.

*Soap and Tea.*

In confirmation of the evidence of the Board, as expressed in the Report on Water Supply, pages 64 to 80, I will submit some further popular appreciation of the economy of soft water for domestic purposes, as extracting a greater strength of tea and requiring less soap for washing. Every one has heard of this fact; many have observed it; yet none almost but the poor ever dream of taking advantage of the economy offered by soft water, even where such is within their reach. It is thus most difficult to obtain a record of actual saving of expense effected in these necessaries of life by the use of soft water, but as the importance in the present time of clearly establishing a practical means of economy is very great, I have exerted myself to procure further testimony and thus to obtain the means of establishing something like a scale of comparison of the relative economical values of hard and soft waters, from actual popular experience, which will completely defeat the endeavours of adverse interests to throw discredit upon the statements made by the Board on this subject. The result of my researches is a confirmation of these statements and of popular evidence generally, and the importance of the economy being accurately made known to the public, and more especially to the poor, cannot be sufficiently estimated.

I am aware that it is said, "Oh, a little more or less tea and soap, what does it matter?" or, perhaps, "Boiling the hard water throws down the lime, and a little soda settles any difference as to soap." Let me now test these objections by facts and figures, for the sake at least of the very poor who form so large a proportion of the consumers of the metropolis.

In Farnham, I find, that at one of the largest washing establishments it is stated, in one case, by Mrs. Corps, "We now do with the soft spring water the same amount of washing with 4 lbs. of soap, that formerly took 6½ lbs. of soap and 6½ lbs. of soda with the hard well-water or the river water." Putting soap at 6*d.* and soda at 1½*d.* per lb., this gives the respective expense of soft and hard water as 2*s.* to 4*s.* 0¾*d.*, or as 1 to 2.

Again, in the second case, Mrs. Hayes of Farnham says, "With soft water, 6 lbs. of soap does now the same washing that was done by 9 lbs. of soap and 9 lbs. of soda formerly." Here the expense of soft water is to hard water as 1 to 1·9.

Take a third case; Mr. Edwards, plumber, of Farnham, says, "For upwards of 35 years I have employed a brazier and assistants, for whom I find soap to wash when leaving their work. As long as the hard water was in the house, the expense of soap per week was 3*d.*, having now soft water, the same washing is done for 1*d.*" Soft water is here as 1 to 3. This is an outside case, from the dirty nature of the brazier's work, but affords valuable proof of the comparative solvent powers of the two waters with soap.

I will now quote one of the many striking cases of evidence obtained from the very poorest classes of peasantry. Mrs. Barfell says, "I am a very poor woman with a large family, and am obliged to reckon closely how far my earnings will go. I have lived 20 years here on Farnham-hill and 10 years previously at Richmond, where the water was very hard. My soap goes twice as far, and my tea one-third farther with the soft water than it did with the hard. I wash for my 10 children here in soft water with the same amount of soap that I formerly used for less than half the number of children. Two ounces of tea goes now as far as three at Richmond."

The relative expense of soft to hard water, is therefore shown to be by Mrs. Corps, 1 to 2; by Mrs. Hayes, 1 to 1·9; by Mr. Edwards 1 to 3; by Mrs. Barfell 1 to 2. The universal testimony of the inhabitants at Farnham gives the economical value of soft to hard water with soap as 2 to 1. The well waters in Farnham have only 10 degrees of hardness according to Dr. Clarke's test, and the hardness of the Thames water is, I believe, 13 degrees of the same scale, but as boiling would probably reduce both to the same degree, I may say the above instances establish practically that at Farnham with soft water, soap will go twice as far as with hard.

Apply this to the case of a poor family in London, using 1 lb. of soap and 1 lb. of soda per week, an expense of 7½*d.* will with soft water be reduced to 3¾*d.*

Again at Whitehaven, where a water of 5½ degrees of hardness was formerly used and was four months since replaced by water of 1 degree of hardness, a Mrs. Curlett, washerwoman, says, "When washing formerly with hard water from the town fountain I used for a certain quantity of clothes 3 lbs. of soap and 2 packets of washing-powder. With the new soft water I use only 1½ lbs. of soap and no washing-powder for the same quantity of washing. This is the experience of all the washerwomen of the town. My washing cost me a-week formerly 3 lbs. of soap at 6*d.*, 1*s.* 6*d.*; two packets of washing-powder, 1½*d.*, 3*d.*; in all 1*s.* 9*d.* At present the washing costs me 1½ lbs. of soap at 6*d.*, 9*d.*; a saving of 1*s.* a-week and 2*l.* 12*s.* a year, which will nearly pay my rent."

Mr. Musgrove the secretary to the Water Works Company, Whitehaven, states that the expression of the poor of this town is, "The soft water is the greatest blessing ever came to Whitehaven; we never had such tea in our lives, and we save a great quantity of soap." Mr. Musgrove says, when the soft water was first introduced the only complaint was that it took all the strength out of the tea on the first infusion.

As regards tea it is more difficult to obtain exact proof of actual quantities saved by the use of soft water, because there are many teas varying in strength and doubtless many dilutions which defy precise measurement, and therefore it is only at such places where the two waters are available for comparison that accurate testimony can be obtained. The evidence of all at Farnham is, that with soft water the same quantity of tea will go one-third farther than with hard water. This fully confirms the testimony of M. Soyer, Mr. Philip Holland, and Professor Way, as given in the Report on Water Supply. The relative extractive powers of soft and hard water in respect to tea are given by M. Soyer, at 5 to 3, by Mr. Holland at 18 to 8, by Professor Clarke, as a most material difference even in waters varying from 4 to 16 degrees of hardness.

At several towns in Lancashire, Bolton, Bury, and Stockport, which have soft water supplies, the evidence is all to the same purport; I will give the result of an experiment made at Bolton by the manager of the workhouse, on tea with the two waters available there, the one of 2 degrees, and the other of 6½ degrees of hardness. The following letter was received by me on the 14th January.

SIR, *Bolton Workhouse, January* 12, 1851.

IN accordance with your request I have tested the advantage to be derived from soft water over that of hard water in the use of tea in this establishment. For the number of old women we have at present whom we indulge in allowing them tea, we are using 4 ounces of black and green tea mixed, for a meal. The day after our visit here, I ordered 6 ounces of tea to be used with the hard water we formerly made use of instead of 4 ounces with soft water; after the tea was made with 6 ounces and hard water, both the matron and myself were of opinion the infusion of tea was weaker than had it been made from 4 ounces with soft water; without saying anything on the subject, we repeated the experiment for three days, and at the close of the third day, a deputation was appointed from amongst the old people and waited upon me, and "complained that the tea had not been so strong as it had been formerly; the person making it must have made a mistake, and forgot to put the usual quantity of tea to the same quantity of water." This is the result, as far as I have proved it with tea.

I am, Sir,

Your obedient servant,

J. HARRISON.

At Bolton, then, the saving of soft water of 2 degrees of hardness is proved with tea to be one-third the quantity consumed with water of 6½ degrees of hardness, or a little harder than the Thames water boiled.

Assuming, then, the saving in soap to be one half and in tea one-third, let me apply these data to the case of any family in London who use per week 1 lb. soap, 1 lb. soda, value 7½*d.*; 3 oz. tea, value 9*d.*: the saving by the use of soft water will be in the soap, $3\frac{3}{4}d.$, in the tea, $3d.$, making a total saving per week of $6\frac{3}{4}d.$, or $1l.$ $9s.$ $3d.$ per annum. What a blessing soft water will then be to the poor labourer and the wretched needle-woman whose weekly earnings may average $15s.$ and $5s.$ a-week respectively ! $1l.$ $9s.$ $3d.$ to them a treasure unknown and untold. This sum will pay for the education in the year of three children.

I will now remark on the evidence before the Select Committee on the River Lea Trent Bill, by Professors Taylor and Brande, on the subject just treated. It will be well to give extracts from the evidence published. First we have Professor Taylor examined, who in answer to question 117, says—

Having taken equal weights of green and black tea, and having poured equal measures of boiling, distilled, or pure water and river water into two basins, I did not let Mr. Cooper know into which basin I had put the river water. When cold he tasted them, and he at once pronounced as of equal strength or stronger than the other, the one in which I had used the ordinary river water.

Again, in answer to question 119, Have you tried the two kinds of water in making tea, soft and hard water ?

We have; I tried with pure distilled water and River Lea water ; we applied a test of the infusion of tea, and we both considered that the Lea river water made the tea, if anything, rather stronger than the same amount of distilled water; at any rate there was no difference in favour of the pure water.

Professor Brande, examined, says, in answer to question 176 —What is the difference you have found in soft and hard-waters in the infusion of tea ?—

In regard to Thames water and I believe also in regard to New River water, inasmuch as they are very much alike, they appear to make tea in the same manner as distilled water, excepting that the colour is darker a little in regard to the river waters, so that tea made with the river water looks much stronger than the other ; the taste seems to me to be very nearly the same.

The pith of Messrs. Taylor and Brande's evidence is, that distilled water is rather inferior than otherwise to Thames, River Lea, and New River waters in power of extracting the strength of tea.

I confess that the opinions of these two professors of chemistry astonish me; the charitable conclusion would be that these gentlemen do not possess the usual fineness of the organs of taste and sight accorded to men generally, for their opinions are found to be in opposition to the entire popular evidence of all who have ever had the means of comparing soft and hard waters. I must really be excused if I prefer the discernment (in the matter of tea) of the old women in the Bolton workhouse to the testimony of Professors Taylor and Brande. These gentlemen do not even mention to the Committee, they were aware that their opinions were at variance with the experience of every old wife in Great Britain or indeed in the civilized world; such is nevertheless the case.

*Beer.*

Nearly all treatises on the art of brewing beer mention the superiority of soft over hard water for this purpose; but I am not aware that any one has yet demonstrated the actual economy of soft water in extracting a greater weight of wort from a certain weight of malt, than could have been effected by hard water. Having heard that such was the case, I made inquiry when at Farnham whether there were not some brewer who made it his business to wander from house to house round the country in practice of his vocation. Such a person must have more experience of the comparative values of soft and hard water for brewing than any one who, residing always in one place, would probably only be acquainted with the qualities of one description of water. Very fortunately I made the acquaintance of a certain Wilkinson, famous for his beer-making talents, whose evidence I will now impart. He says—

For 25 years I have brewed for all the country 14 miles round Farnham, and consequently have great experience of the value of the different waters of the country for brewing; these vary very much, from the soft spring water at Farnham to hard waters from the wells in the sand, clay, and chalk, or to the waters of the rivers Wey and Blackwater. My observation gives, the softer the water the better the beer, and the greater the power of extracting the strength of the malt.

I have proved it often, and am ready to make the experiment before any one.

I mean that soft water will give a stronger wort than hard water. Soft water extracts above one pound more wort to the quarter of malt, of whatever quality, than hard water will.

A 36-gallon barrel of the best beer is now made from 28½lbs. of wort, by hard water, but the soft spring water of Farnham will extract 30 lbs. of wort from the same quantity of malt.

The beer made from soft water is better tasted, softer, and keeps longer, as it does not turn acid so soon as that made with hard water.

From the data given by Mr. Wilkinson, it is seen that with water of about 15 degrees of hardness a hogshead of the best beer would have been made from 42¾ lbs. of wort; but that by using soft water the same quantity of beer would contain 45 lbs. of wort—a gain of 2¼ lbs. of wort to the hogshead, not calculated by rule of thumb, but measured by the saccharometer in the hands of an experienced workman. By using soft water, therefore, one hogshead may be saved in nineteen—an economy of 5¼ per cent. On reading this calculation to Mr. Wilkinson, he quite concurred with me in the result.

Let me now examine what may be the economy of a very soft water of one degree over that of a moderately hard water.

On making inquiry at Whitehaven, as to the value for brewing purposes of the new supply of 1 degree over the old one of 5½ degrees of hardness, Mr. Colbeck, brewer, states,

With the hard water from the town fountain I made 10 barrels of ale from 30 Winchester bushels of malt; with the new soft water, only four months in use, I obtain 10¼ barrels of ale from the same weight of malt, a saving of 2½ per cent.

The great value of the economy thus shown to be effected at Whitehaven lies in the fact of that saving of 2½ per cent. being the superior measure of economy of water of 1 degree of hardness over water of 5 degrees of hardness formerly supplied. This being about the degree of hardness to which the Thames or chalk waters are reduced by boiling, or by Professor Clerke's process.

Looking then to the examples of Farnham and Whitehaven, where the merits of the two waters, hard and soft, have been weighed, it may be assumed, without fear of error, that the use of Farnham soft spring water in London would make 5 per cent. more beer or ale from the same weight of malt, as now used. Such waters would indeed be valuable to the London brewers.

Is it now for the first time only that the comparative values of hard and soft water for domestic purposes are investigated? Hardly; for what says that great philosopher, Lord Bacon, on this subject?—

It is a thing of very good use to discover the goodness of waters. The taste, to those who drink water only, doth somewhat; but other experiments are more sure.

1. Try waters by weight, wherein you may find some differences, though not much, and the lighter you may account the better.

2. Try them by boiling upon an equal fire, that which consumeth away fastest you may account the best.

3. Try them in several bottles or open vessels, matches in everything else, and see which of them lasts longest without stench or corruption, and that which holdeth unputrefied longest you may likewise account the best.

4. Try them by making drinks stronger or smaller with the same quantity of malt, and you may conclude the water which maketh the stronger drink is the more concocted and nourishing, though perhaps not so good for medicinal use. And such water (commonly) is the water of large and navigable rivers, and likewise in large clean ponds of standing water, for upon both of them the sun has more power than upon fountains or small rivers; and I conceive that chalk-water is next to them the best for going furthest in drink, for that also helpeth concoction, so it be out of a deep well, for then it cureth the rawness of the water; but chalky water towards the top of the earth is too fretting, as it appeareth in the laundry of clothes, which wear out apace if you use such waters.

5. The housewives do find a difference in waters for the bearing or the not bearing of soap, and it is likely that the more fat waters will bear soap best, for the hungry water doth kill the unctuous nature of the soap.

6. You make a judgment of waters according to the place whence they spring or come. The rain-water is by the physicians esteemed the best, but yet it is said to putrefy soonest, which is likely, because of the fineness of the spirit; and in conservatories of rain-water (such as they have in Venice) they are found not so choice waters, the worst perhaps because they are covered aloft and kept from the sun.

Snow-water is held unwholesome, in so much that as the people that dwell at the foot of snow mountains, or otherwise upon the ascent (especially the women), by drinking snow-water have great bags hanging under their throats. Well-water, except it be upon chalk or a very plentiful spring, maketh meat red, which is an ill sign. Springs on the top of high hills are the best for both; they seem to have a lightness and appetite for mounting, and besides they are more percolated through a great space of earth. For waters in valleys join in effect with all waters of the same level, whereas springs on the tops of hills pass through a great deal of pure earth with less admixture of other waters.

7. Judgment may be made of waters by the soil whereupon the water runneth, as pebble is the cleanest and best tasted, and next to that clay-water, and thirdly, water upon chalk; fourthly, that upon sand, and, worst of all, that upon mud. Neither may you trust waters that taste sweet, for they are commonly found in rising grounds of great cities, which must take in great filth.

Measuring then Farnham soft-water by Lord Bacon's tests, as well as by all the popular evidence of the day, its economical superiority to the hard chalk-waters now supplied in London for domestic consumption is certainly beyond contradiction.

### *Medicinal value of Soft Water.*

The Board in their Report on Water Supply, pages 50 to 60, have quoted much evidence, ancient and modern, which would prove the superiority of soft over hard water for drinking, in being more grateful to the constitution of man, and show that the habitual use of hard chalk waters impairs the digestive functions, and predisposes to urinary and calculous disease. Having visited nearly all the hard and soft water districts in England and Scotland, and made much inquiry on this subject, the almost universal testimony of the medical profession goes to corroborate these conclusions. In those towns where soft water has superseded the use of hard, the most decided evidence is obtained.

There is much difficulty in forming an opinion from comparison of the per-centage of the complaints indicated in districts where the different waters occur; for the health of the human system depends upon so many various circumstances, and is affected by so much external influence, that it is hard to fix exactly upon the one, from many known causes of improvement, which shall have caused a certain marked decrease in disease or have given increased vigour of body; nevertheless, diligent inquiry and research prove, that disorders of the stomach do prevail excessively in the chalk districts, while, on the other hand, these complaints are found materially lessened, both in number and vigour, where soft water is used. Persons of delicate digestion soon feel the benefit of a change from hard to soft water.

One disease particularly seems to prevail in the chalk and limestone districts, that of inflamed and relaxed sore throat and goitre. Several provincial surgeons testify to the fact, that habitual soft water drinkers are speedily attacked on the change to hard water, and that no cure is so rapid and certain as that of a return to their accustomed drink; where such has not been possible, the use of distilled water has had the same effect.

This tendency in hard waters thus to irritate and disease the throat is not peculiar to Britain, for I find on the authority of John McClelland, Calcutta, that in the province of Kemaon, on the southern border of the Himalayas, and consisting of mountains of the second rank, from 4,000 to 8,000 feet high, with numerous deep rugged valleys, goitre is very common. It occurs chiefly in those valleys or parts of valleys which abound in limestone, and is comparatively very rare where slate and clay predominate.

In the district of Barabree, the eastern part is clay-slate; and in five villages there, with a population of 155 inhabitants, there is not a single case of goitre.

In the western portion, where limestone abounds, out of a population of 192 persons, occupying six villages, 70 are goitrous, but in one village of this district where clay-slate is alone found, there is not a single case, although in another village half a mile off, where the water abounds in carbonate of lime and soda, 40 out of a population of 50 are affected with goitre. Mr. McClelland infers, that water abounding in carbonate of lime is the cause of goitre, and he says, that he did not meet in his travels with a single exception to this theory.—

(*Some Inquiries in the Province of Kemaon, &c., by John McClelland*, Calcutta, 1843.)

With reference to the tendency of lime water to produce or predispose to calculous disease, the evidence of Dr. Shier, the Agricultural Chemist to the Colony of Demerara, is remarkable. He states :—

I have paid much attention to the sorts of waters derived from particular geological formations, and have examined many waters from streams and wells on the spot. The water of Demerara is so disagreeable that the storage and use of the rain-water is universal; it is collected on the roofs, which from the nature of the fuel used, viz., wood and charcoal, are cleaner than in England.

Local circumstances favour us, for we are enabled to build our kitchens to leeward and collect our water to windward. The first fall of rain after a long drought is allowed to pass away in a waste-pipe, and the tanks are covered.

The Demerarians, on visiting other countries, feel the change from soft to hard water keenly; those who visit Barbadoes, where the hard water from the coralline formation is very disagreeable, are wont to suffer so much from the change, that the proprietor of one of the hotels there has been necessitated to construct a tank to receive the rain-water. I consider the purity of water to have a most important effect on health.

I can state one fact as indisputable, that calcareous disorders do not originate in Demerara. Where cases of stone and gravel occur in our hospitals they are found in patients who have come from colonies where the water is hard. This is corroborated by several of the leading medical men. Since leaving the island, I have experienced the effects of the change from soft to hard water. At the Tavistock Hotel, where I reside, I find the result of washing with hard water and soap to be a sort of anointing of myself with an insoluble lime-soap. I consider the use of hard lime-water to be most prejudicial to the health of animals.

Dr. Shier's evidence appears to me to be most valuable; for if rain-water, comparatively inferior in aëration and coolness, is so grateful, how superior in every respect must be the soft spring water well aërated by oxygen, and of a delicious coolness! His evidence as to calcareous disorders would render more accurate investigation of this subject very desirable.

I think I may here transcribe with advantage some remarks on water by Mr. Dod, a civil engineer, who published a report on Metropolitan Water Supply in 1805. He says :—

Observations and experience confirm the statement, that the nearer all waters approach to that of pure or distilled water, they are the best and most proper for man to take as an element, being also the best solvents for digestion, antidotes for raging thirst, and a regale to the weary, as well as most useful for all culinary purposes. The greater part of the spontaneous springs and wells in the metropolis and its environs produce hard and chalybeate waters. A few are of a calcareous nature. The too frequent use of chalybeate waters has been stated by Dr. Ruttey, and other medical gentlemen, to be seriously injurious to some persons, particularly those who are old and infirm, and have not sufficient health for activity; also to persons of gross habits of body, or those afflicted with scorbutic humours, although, on the other hand, they possess medical virtues when used as remedies. The too frequent use of water highly charged with calcareous matters has also ill effects on some persons in the habit of drinking them, but not to that degree as the former.

It is strange indeed, that in the 45 years that have passed since the publication of Mr. Dod's remarks, science has done so little towards the investigation of this important matter. Great as has been the improvement in the last few years of chemical knowledge, there yet remains a large field to the inquiring mind, for we can neither detect in water the presence of matters we know to exist therein, or in the air the presence of the poison which we feel in our systems.

Dr. Kilien, of Bonn, is of decided opinion that where the skin of the body is broken, the application of hard lime-water is most prejudicial, and that the healing virtue of soft water is very remarkable.

Reflecting on the difficulty of any comparison of the effect of the two waters as even where they may both be available, or where the hard has been replaced by the soft supply, it is very satisfactory to find that throughout the country generally a conviction of the great superiority of soft water is fast gaining ground in the opinions of the medical profession, while in London, on mature consideration of the question, Mr. Simon, the Medical Officer to the City, has given, in his Annual

Report for 1850-51, the following verdict: "Believing that water is eligible for human consumption in proportion as it is free from the admixture of any material foreign to its simple elementary constitution, exception being made only of so much dissolved air as will render it sparkling and palatable, I entertain no doubt, that a water devoid of considerable hardness would (*cæteris paribus*), for the purpose of cookery and beverage, be far preferable to that which the Companies now distribute through the City of London."

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## IV.

### Some Evidence as to the Comparative Action of Hard and Soft Water upon Lead.

Having been requested by the Board to investigate at Farnham the comparative action of the different waters in use upon lead, I submit:

I. The results of my observations in a tabular form.

II. Some evidence from the two principal plumbers in that town as to their experience of the erosive action of hard and soft waters.

III. A comparison of the erosive action upon lead of the soft spring water at Farnham, and that by the hard waters supplied to the metropolis from the rivers Thames, &c.

When my attention was first turned to the new source proposed by the Board for Metropolitan Water Supply, and when aware of the extreme purity of the deep spring waters of the Farnham and Hindhead district, their probable action upon lead became a subject of considerable anxiety; for although fully convinced that earthenware would some day be matured for house distribution, I feared lest any delay in perfecting the new distributory apparatus might retard the execution of this most important branch of the entire scheme of sanitary regeneration for the metropolis, as proposed by the Board.

Would or would not these pure waters act upon leaden pipes fully charged, was then the question.

Aware of the prevailing opinion in the profession of chemistry, that all waters contained (though not necessarily) more or less carbonic acid gas, which would erode lead pipes, unless protected by the deposit of salts of one kind or another, I devoted my attention to form an approximate idea of the probable action on lead of the water from the new sources. Assuming it to be correct that a deposit would afford protection to the lead from the action of carbonic acid gas (but which assumption does not appear to me to be at all warranted by experience), I felt convinced that the trifling quantity of salts of lime and common salt contained in these waters would not afford any such safeguard, and proposed to investigate in what proportion this gas existed in them, as compared with the quantity contained in the hard chalk waters of the Thames, Lea, &c.

That the soft sources contained at any rate a less quantity, appeared highly probable, from the fact that the waters from the deep springs, though brilliant and well aërated, did not sparkle as much as those from the chalk formation, known to contain a large quantity of carbonic acid.

On making the experiment roughly, I was indeed surprised to find that the presence of this gas was not to be detected in any of the specimens from the deep springs. My next step was to make some inquiries at Farnham as to the action upon lead of the spring and shallow well waters of the town, when I was informed that whatever in course of time might be the erosion of that metal by the soft water, the hard waters from the wells in the sand and in the clay or chalk acted far more quickly and seriously.

Being much engaged upon the chief object of my presence in the gathering grounds, I did not at that time pursue the investigation of this subject any further, only remarking to others on the absence of carbonic acid gas in the deep spring water, and reserving the question for further examination by some professional chemist.

In October last, having been informed that Mr. Simon, the officer of health to the City of London, and Mr. Taylor, professor of chemistry at the Middlesex Hospital, were about to examine and report on the new sources, I requested permission to accompany these gentlemen on their tour of inspection. The first spring visited was that at Valewood, near Hazlemere. Professor Taylor, having tested the water for the different salts and acids, said he would ascertain the proportion of carbonic acid gas contained as in comparison with that in the East London and New River sources. On finding no trace of this gas, Mr. Taylor expressed great astonishment, and even doubted that an accident might not have happened to his test, the accuracy of which he had ascertained before leaving London. Subsequent examination however proved that neither the water at Valewood, or any of the other specimens collected from the gathering grounds, gave even an indication of carbonic acid, and I would now request the attention of the Board to a most important statement by Professor Taylor, as contained in Mr. Simon's Annual Report on the Health of the City of London, just now published, where, in reporting on the quality of the proposed soft sources, Mr. Taylor says that, from the absence of carbonic acid gas in these waters, it is probable there would be no action upon leaden pipes fully charged.

Having been requested to consider this subject as developed at Farnham, I resolved to examine carefully the well-pumps and soft-water cisterns, and laid down the following points for observation in each house visited :—

1st. To examine the pumps, the house cisterns, and distributing pipes.

2nd. To note in each case the source of the supply, whether spring water from the hill, or local well water.

3rd. To note the hardness of each source according to Dr. Clarke's test.

4th. To test for carbonic acid gas and sulphuric acid.

5th. To ascertain the depth of each well and the nature of the formation of soil.

6th. To remark as accurately as possible the action in each specimen examined—the action of the water upon the lead.

From these data I conceived a decisive result might be obtained as to the action of the soft water on a fully charged leaden pipe; this point settled at Farnham must also decide upon the action of the new sources in London, for all the deep spring waters of the gathering grounds are of a similar character.

I now submit the following Table to the Board's notice.

TABLE of WATERS examined at FARNHAM, showing their Comparative Action on Sand.

| No. | Names of Proprietors. | House Cisterns, or Pumps. | Nature of Source. | Hardness of Water. | Quantity of Carbonic Acid. | Sulphuric Acid. | Depth of Well. | Nature of Soil. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ° | | | Feet. | | |
| 1 | William Lindsay. | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | This cistern has been in use for 10 years, and there is no trace of erosion perceptible. |
| 2 | Mrs. Barlinge . | Pump cistern | Well water . | 15 | Considerable . | . . . | 25 | Gravel into sand. | This cistern, 9 years ago, was quite eaten up by erosion; the new one will soon be in holes. |
| 3 | ,, | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | 12 years in use, and shows no trace of erosion. |
| 4 | Mr. Brook . . | ,, | ,, | 1 | ,, | Traces . . . . . . . . | . . | . . | Ditto ditto. |
| 5 | Mr. Newell . . | ,, | ,, | 1 | ,, | Traces . . . . . . . . | . . | . . | 6 years in use, and shows no trace of erosion. |
| 6 | Mr. Betts. . . | Pump cistern | Well water . | 11 | Considerable . | Considerable . . . . . | 25 | In sand . | Erosion visible in white spots, which can be scraped out into holes. |
| 7 | ,, | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | 7 years in use; no erosion visible. |
| 8 | Mr. Bartholomew | ,, | ,, | 1 | ,, | . . . | . . | . . | 2 years in use; no erosion perceptible. |
| 9 | N. Williams, Esq. | Cistern . . | Rain water . | . . | Not examined . | Very considerable . . . | . . | . . | This cistern has been in use 50 years; outside is worn out; inside, no trace of erosion; as good as new. |
| 10 | ,, | Pump cistern | Well water . | 23 | Considerable . | . . . | 25 | In sand . | Not of very old date; erosion perceptible in black spots. |
| 11 | Mr. Johnston . . | Copper boiler | ,, | 9 | ,, | . . . | 25 | ,, | Sides and bottom much furred up. |
| 12 | ,, | Pump cistern | ,, | 9 | ,, | . . . | 25 | ,, | Sides and bottom much eroded; holes nearly eaten through. |
| 13 | Mr. Grey . . . | ,, | ,, | 6 | Scarcely perceptible. | Great quantity . . . . | 27 | ,, | In use since 1743; no erosion visible. |
| 14 | Mr. Stewart . . | ,, | ,, | 8 | Very little . . | Considerable . . . . . | . . | . . | In use since 1785; no erosion visible. |
| 15 | N. Sloman, Esq. . | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | 2¼ years in use, and shows no trace of erosion. |
| 16 | ,, | Pump cistern | Well water . | 6 | Considerable . | Little . . . . . . . . | 26 | In sand . | 2¼ years in use; much erosion visible, in black and white spots. |
| 17 | Rev. Mr. Tankey | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | 12 years in use; shows no trace of erosion; as good as new. |
| 18 | Mrs. Marryatt . | Pump cistern | Well water . | 6 | ,, | . . . | 26 | In sand . | No erosion visible whatsoever. |
| 19 | W. Newnham, Esq. | House cistern | ,, | 15 | Great quantity | . . . | 27 | ,, | Very much eroded in white spots, which can be picked out. |
| 20 | ,, | ,, | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | 13 years in use; no erosion whatsoever visible; as smooth as when new. |
| 21 | W. Knight, Esq. . | ,, | ,, | 1 | ,, | . . . | . . | . . | 7 years in use; no trace of erosion. |
| 22 | Mr. Hunter . . | Pump . . | Well water . | 17 | Very little . . | . . . | 27 | In sand . | Nozzle of pump had a trace of erosion in one black spot. |

Table of Waters examined at Farnham, &c.—*continued.*

| No. | Names of Proprietors. | House Cisterns, or Pumps. | Nature of Source. | Hardness of Water. | Quantity of Carbonic Acid. | Sulphuric Acid. | Depth of Well. | Nature of Soil. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ° | | | Feet. | | |
| 23 | W. Payne, Esq. | House cistern | Spring water | 1 | None | Traces | . . | . . | 2 years in use; no trace of action whatsoever. |
| 24 | ,, | Pump cistern | Well water | 3 | Traces | . . . | 20 | In sand | 2 years in use; no erosion perceptible. |
| 25 | Mr. Stewart | ,, | ,, | 13 | None | . . . | 27 | ,, | 20 years in use; no erosion visible. |
| 26 | Mr. Alexander | ,, | ,, | 7 | Traces | Very little | 27 | ,, | In use since 1789; no erosion visible. |
| 27 | Miss Ward | ,, | ,, | 16 | Small quantity | . . . | 28 | ,, | 20 years in use; very slight erosion perceptible in spots. |
| 28 | Miss Deadman | ,, | ,, | 16 | Great quantity | Considerable | 28 | ,, | The erosion has always been so great, that copper was substituted for lead. |
| 29 | Mr. Allfield | ,, | ,, | 20 | Scarcely perceptible. | ,, | 25 | ,, | In use since 1808; no erosion visible. |
| 30 | "Lion and Lamb" | House cistern | Spring water | 1 | None | Traces | . . | . . | This is a very old cistern; well-water was formerly pumped in, when there was considerable and constant erosion; 11 years ago the spring-water was pumped in, when the erosion ceased. |
| 31 | ,, | Pump cistern | Well water | 4 | Not much | . . . | 26 | In sand. | Very slight erosion, but in progress. |
| 32 | Mr. Coutar | House cistern | Spring water | 1 | None | Traces | . . | . . | This cistern is 40 years old; well-water was formerly pumped in; the erosion was so great that it was constantly being repaired: 2 years ago spring-water was turned in, when the erosion ceased. |
| 33 | "Queen's Head" | Pump cistern | Well water | 12 | Considerable | Considerable | 25 | In sand. | 7 years in use; great erosion in progress. |
| 34 | Mr. Lockerby | ,, | ,, | 11 | Great quantity. | Very considerable | 25 | ,, | The erosion is so great that the bottom has been once eaten through; erosion in progress. |
| 35 | Mr. Birch. | House cistern | Spring water | 1 | None | Traces | . . | . . | No erosion whatsoever visible. |
| 36 | ,, | Pump cistern | Well water | 5 | Traces | Great quantity | 25 | In sand. | No erosion visible. |
| 37 | Captain Talbot | House cistern | ,, | 8 | Great quantity | Considerable | 40 | ,, | Great erosion in progress; holes will soon be eaten through. |
| 38 | John Andrews | Cistern | Spring water | 1 | None | Very little | . . | . . | This tank is in the open air, and was put up 50 years ago when well water, 12° hardness, and containing much carbonic acid, was pumped in. The bottom has twice been eaten up by erosion. Twelve years ago, when again repaired, the spring water was turned in, and erosion has ceased. |

## Table of Waters examined at Farnham, &c.—*continued.*

| No. | Names of Proprietors. | House Cisterns, or Pumps. | Nature of Source. | Hardness of Water. | Quantity of Carbonic Acid. | Sulphuric Acid. | Depth of Well. | Nature of Soil. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ° | | | Feet. | | |
| 39 | Goat's Head inn. | House cistern | Well water . | 16 | Great quantity | Little . . . . . . . . | 25 | In sand. | 6 years in use; great erosion visible in black and white spots; the hose much eaten up. |
| 40 | Farnham . . . | Pump. . . | Spring water | 1 | None . . . | Traces . . . . . . . . | . . | . . | Erected in 1803; shows traces of action, but very slight. |
| 41 | Richard Smith . | House cistern | ,, | 1 | ,, | . . . | . . | . . | No erosion whatsoever visible; 7 years in use. |
| 42 | ,, | Pump cistern | Well water . | . . | Considerable . | . . . | 12 | In sand. | Trifling erosion. |
| 43 | Mr. Mayhew. . | ,, | ,, | 6 | ,, | Very considerable . . . | 20 | ,, | 20 years in use; considerable erosion in white spots. |
| 44 | Mr. Lamport. . | ,, | ,, | 8 | ,, | Considerable . . . . . | 12 | ,, | 7 years in use; erosion but trifling in dark spots. |
| 45 | "Unicorn" . . | ,, | ,, | 6 | Traces . . . | Very considerable . . . | 12 | ,, | Scarcely perceptible; erosion in dark appearance. |
| 46 | "Green Man" . | ,, | ,, | 13 | Considerable . | ,, | 12 | ,, | 2 years in use; slight erosion. |
| 47 | Wm. Partrick . | ,, | ,, | 2 | ,, | Great quantity . . . . | 12 | ,, | 10 years in use; very considerable erosion in progress. |
| 48 | Mr. Peskett . . | ,, | ,, | . . | Small quantity | Very considerable . . . | 12 | ,, | 10 years in use; considerable erosion. |
| 49 | Mr. Martin . . | ,, | ,, | . . | . . | . . . | . . | . . | 18 years in use; great erosion in progress. |
| 50 | Mr. Harris . . | ,, | ,, | 7 | Great quantity. | Very considerable . . . | 12 | In sand. | 18 years in use; considerable erosion in progress. |
| 51 | Mr. Smithers . | ,, | ,, | 7 | Considerable . | ,, | 12 | ,, | 40 years in use; much eroded in spots. |
| 52 | Mr. Whiley . . | ,, | ,, | 5 | . . | ,, | . . | . . | No erosion. |
| 53 | Mr. Sturt . . . | ,, | ,, | 8 | Great quantity | Considerable . . . . . | 12 | In sand. | Much eroded in white spots. |
| 54 | Mr. Keen . . | ,, | ,, | 6 | ,, | ,, | 12 | ,, | Great erosion; 4 years in use. |
| 55 | Five cottages. . | ,, | ,, | . . | . . | . . . | . . | . . | 17 years in use; trifling erosion. |
| 56 | Mrs. Nash . . | ,, | ,, | 17 | Great quantity | Very considerable . . . | 12 | In sand. | Great erosion; much eaten up. |
| 57 | Mr. Nash. . . | ,, | ,, | . . | ,, | ,, | 12 | ,, | Ditto. ditto. |
| 58 | Miss Stevens. . | ,, | ,, | 6 | ,, | ,, | 12 | ,, | 30 years in use; much eaten up and destroyed. |
| 59 | ,, | House cistern | Spring water | 1 | None . . . | Traces . . . . . . . . | 12 | ,, | 1½ years in use; no erosion visible. |
| 60 | Mr. Mason . . | Pump cistern | Well water . | 20 | Considerable . | Very considerable . . . | 20 | ,, | 12 years in use; slight erosion in dark spots. |
| 61 | Mr. Piercy . . | ,, | ,, | 3 | Very small quantity. | Great quantity . . . . | 20 | ,, | 70 years in use; trifling erosion. |
| 62 | Miss Stratford . | ,, | ,, | 1 | Large quantity | . . . | 20 | ,, | 40 years in use; great erosion. |
| 63 | Miss Hackman . | ,, | ,, | . . | . . | . . . | . . | . . | 30 years in use; much eaten through. |
| 64 | Bush Hotel . . | ,, | ,, | . . | Considerable . | . . . | . . | . | 5 years in use; trifling erosion in progress. |

From the data afforded by the Table, it will be seen,—

I. That 13 house-cisterns were examined, which had contained for periods varying from 1½ to 12 years the pure soft spring water of Farnham Hill, 1 degree in hardness, and that in no case was any action whatsoever visible on the lead.

II. That one pump erected in 1808 over the soft-water tank at the market-place showed slight traces of erosion after 42 years.

III. That 50 cisterns of leaden pumps over shallow wells of old and modern date were examined.

IV. That 10 of these showed scarcely perceptible, or total absence of, erosion.

V. That the remaining 40 bore evidence of varied action, from trifling to very extensive erosion and eating up of the lead.

VI. That in the case of the 13 house-cisterns containing soft spring-water no trace of carbonic acid is detected.

VII. That in the case of the 10 pump-cisterns which exhibited no erosion, no carbonic acid gas, or mere traces, were detected in the water.

VIII. That in the other 40 which bore marks, in most cases, of a violent action—the existence of carbonic acid was ascertained almost in proportion to the extent of the ravages on the lead.

IX. That the hardness or softness of the well waters does not seem to follow in any proportion as to erosive action.

Having thus enumerated the conclusions, warranted by facts ascertained by my investigations, I propose, before commenting upon them, to offer some evidence from the two principal plumbers of Farnham; which town, I would remark, affords an unusual field for observation in this matter, as within a circuit of three square miles round the town, water is yielded from three formations—sand, clay, and chalk.

I shall commence with Mr. Edwards, the chief plumber of Farnham, who, when asked to give his experience and opinion as to the relative action of the soft spring and hard waters upon lead, states—

I have been in the plumbing trade in this town 39 years, and am well acquainted with the action of the different waters in this neighbourhood on lead. I believe that all waters will in course of time have some action. The hard waters from the chalk act most violently and immediately, as will often the clay waters. The soft spring-water from the hill will also act in long course of time upon lead, violently in open cisterns, but to a much less extent in pipes. I have taken up, in the course of my life, a number of the lead-pipes in Farnham Park, which bring down the Bishop of Winchester's supply from the springs on the hill. Many of these pipes, which have been laid from 50 to 170 years, show very little trace of action from the water. (These pipes are not fully charged.) Some have shown a good deal. The lead tank at the Castle, new in 1818, was worn out and replaced this year. (This tank is roofed over, but quite open to the air.) I do not think that the soft water will act upon a leaden cistern under 10 or 12 years; in fact, I know it does not, and in a pipe for far longer. I have never seen soft water in a lead pipe without air, except at Hill's-place, near Farnham, where the lead pipe leads into the brick cistern; the lead is not acted upon or eaten by the soft water. Whatever the action upon the lead by the soft water may be, it is nothing to the action of the waters from the town wells, and the wells in the chalk and clay. They eat up the lead—some in less time, some in longer—but all quickly and violently. They eat the bottom out of a cistern very soon. At Colderey, near Froyle, I have known the water from a well 70 or 80 feet deep in the chalk, when run into a new cistern, to bite the lead so as to become white, like lime-water, in little more than a week. I repaired and painted this cistern. In four years the bottom of a cistern there is eaten up.

At Berry-court, Bently, near Alton, water is pumped from a well 70 or 80 feet deep in the chalk, into a cistern put up by me 15 years ago; in 7 years it was full of holes. The water from the clay is very bad upon lead. A cistern at Mr. Knight's was quite eaten in holes by the hard water coming off the clay. I have seen the water from the chalk eat up copper pipes. These sparkling waters are the worst upon lead.

William Lindsey, the second plumber in Farnham, states—

I was apprenticed in 1814 to Mr. Falkner, plumber, Farnham, and have resided here ever since (27 years) as master plumber, and know all the well-waters in and round the town, and the spring-water from the hill. My experience of the action of the hard-water on lead is, that it is always most serious. The two worst cases I remember, were the cisterns at the 'Lion and Lamb,' and at Mr. Andrews. (See 30 and 38 of the Table.) At the 'Lion and Lamb' the water was always eating holes in the lead-pipe, so that the air got in and the pump was useless. The proprietor was going to give up the well, when I put in copper pipes tinned. A very bad case was at Mr. Lambert's. This was a cistern in a stable-yard for watering the waggon-horses. The water was pumped in from a well. Thirty years ago I was called to put a new bottom in the cistern. When taken out, a rap from a hammer made holes through it like as many pea-holes. I put in a new bottom, 7lbs. to the foot, and in 10 years it was eaten up again. I renewed the cistern with a copper bottom. The case at Mr. Coutan's was also bad, the water was pumped in from a well: this cistern was always being repaired; three years ago I was called in to see it, when I repaired it, and Mr. Coutan had in the soft water; it never wants repair now. The action of the hard waters upon the lead has always been remarkable. It has been the custom to make the bottoms of the cisterns to hold hard water half an inch thick, on purpose to withstand the action of the water, and then they are always wanting repair. The lead for cisterns to hold hard well-waters is always 7 lbs. to the foot; if to contain soft water, 4 lbs. to the foot. I don't remember seeing a single bad case of soft water acting upon a lead-pipe.

In 1821 I was working at Squire Halsey's, Henley Park; in the garden there was a lead cistern to catch rain-water, date 1500 and odd years; it was said to be 300 years old. Not being wanted any more I took it away to melt up; it was half an inch thick. I can swear there was no action upon it, it was as smooth inside as the day it was made.

The evidence of the two Farnham plumbers may be resolved into the following heads :—

I. That the action of hard waters from the shallow wells in Farnham, and the clay and chalk in the neighbourhood, is immediate, very violent, and most dangerous.

II. That the action of the deep spring-water from Farnham-hills is even in cisterns very slow in comparison with that by the hard waters, being, to produce great erosion, as 35 to 4 and 5.

III. That the action of soft-water in a fully charged leaden pipe is very slow, probably not visible for 40 or 50 years, and sometimes not seen in a pipe 170 years old.

Believing it to be most important to be able to produce a specimen of this leaden pipe 170 years old, I requested permission from the Bishop of Winchester to cut out a piece, at a place where I considered the least air could get into the pipe. His Lordship having most courteously granted this favour, a piece two feet long was cut out of an ancient moulded pipe, the ends burned together, as was then the custom, the art of soldering being unknown. This specimen, laid down in 1677, and taken up in December 1850, shows no trace whatsoever of action from the soft spring-water.

Recurring now to the evidence adduced by my own observations and the experience of the two plumbers, I would deduce as follows :—

I. That the action of waters upon lead will be much in proportion to the quantity of carbonic acid gas they contain.

II. That the use of hard chalk-water, which contains a large quantity of carbonic acid gas, is, both in leaden cisterns and pipes, excessively dangerous.

III. That although the pure soft spring-water rises at its source perfectly free from carbonic acid gas, and experience has proved that very many years' contact with the atmosphere, from 10 to 20 probably, are necessary to give it enough of that gas to become erosive in contact with lead, yet, as shown by the Board, on the principle of high pressure, cisterns for ordinary domestic purposes are unnecessary and had better be avoided.

IV. That from the entire absence of carbonic acid gas, the pure soft waters of the deep springs in the gathering-grounds of Farnham and Hindhead may be conveyed in fully-charged leaden pipes without any risk whatsoever of erosive action taking place.

Having shown the comparative action on lead at Farnham of the hard waters from wells in the chalk, sand, and clay, and of the soft spring-water; the former in numerous instances producing violent erosion in leaden cisterns in four and six years, while only one case of bad action of the soft water occurred at the Bishop's Palace in 35 years, it remains only for me now to ascertain the comparative action on lead of the soft spring-water with that by the hard waters of the rivers Thames, Lea, &c. For this purpose I will call Mr. Eastwick, master plumber, Haymarket, who has long experience of the action of the water supplied by the Grand Junction Works on lead in cisterns and pipes. He says—

There is always a considerable deposit from the water, which, if not regularly swept out of the cistern, will sooner or later destroy the bottom; that always goes first, and before the sides; the sides of the cisterns are generally made 4 lbs., and the bottom 6 lbs. to the foot. The bottom of a cistern filled with Grand Junction water will be eaten through in about ten years. I have seen many rain-water lead cisterns from 15 to 20 years old, and never remember any action whatsoever upon them.

Again:—

William Millard is head plumber to Mr. Worley, of Highgate, principally supplied by water from the New River Company during the last five or six years. The water is hard, but not so hard as from the wells, which would eat away the bottom of a cistern in three or four years. The cisterns containing the New River water would last twice as long (from six to ten years). In one house in Highgate there are two cisterns supplied, one by hard well-water, the other by rain-waters; the first is full of holes, though not quite through; the rain-water cistern is no worse for use; when last cleaned out was as good as new.

Again:—

William Hawkins, plumber to Mr. Short of Kentish Town, has worked there for 14 years. The town is supplied from the Hampstead ponds three times a week, during three-fourths of an hour to an hour. The action of this water on the leaden cisterns is to corrode them very much, making holes in them, rendering them leaky, and of no service without constant repair. The corrosion is effected by a white substance left at the bottom, which eats its way completely through the lead; such a cistern must be constantly cleaned out; if done so regularly it may last six or seven years. The bottoms of these cisterns are made 6 lbs. to the foot. Such a cistern, if not taken care of and regularly swept out, would be eaten through in two years. Has seen many rain-water cisterns; they might be affected somewhat in twenty years, but, as far as his observations went, no sensible effect was produced. Has cleaned out many rain-water cisterns with much sediment at the bottom, but has always found them perfectly sound and free from corrosion. Has taken down leaden pipes for conveying rain-water 40 years old; the lead appeared perfectly sound, presenting no appearance of action whatsoever.

The evidence of these plumbers may be distinctly resolved into three facts :—

I. That the hard waters of the Thames, New River, Grand Junction, &c., will eat up the bottom of a cistern, 6 lbs. to the foot, in time varying from six to ten years. The water from the Hampstead Water-works much sooner.

II. That the deposit of carbonate of lime from the waters of the rivers Thames, Lea, &c., does not afford any protection to the lead.

III. That the evidence of these plumbers does not give within their experience one decided case of corrosion on rain-water cisterns.

Observing these three results, and remembering the small action upon lead of the Farnham soft spring-water, we find the comparative erosion of the hard river-waters supplied in London and the soft spring-water at Farnham to be to produce bad corrosion in cisterns, as six and ten years to thirty-five years.

As regards the action of the Thames and Lea waters upon iron, no further evidence is required than may be obtained by any one who has sufficient curiosity to see the operation performed of blowing off that which has lain in a " dead end," being thick and coloured with oxide of iron. That this occurs to a great extent is allowed by several of the engineers of the Water Companies.

From the whole of the evidence obtained at Farnham and in London I deduce—

I. That the comparative erosion of hard river-waters in London and soft spring-water at Farnham is in the proportion of 5 to 1.

II. That the deposit from the hard river-waters affords no protection to the lead in cisterns and pipes.

III. That from the pure nature of the Farnham and Hindhead soft spring-waters, and from the total absence of carbonic acid gas, there is no hazard whatsoever of erosion in fully charged leaden pipes.

I will now refer to the evidence of the different actions of hard and soft waters upon lead, by Professors Taylor and Brande, as given before the Select Committee on the River

Lea Trust Bill. I will first give certain portions of their evidence in full, and then, having condensed it, proceed to analyze their statements, as compared with the above facts.

On the question being put to Dr. Taylor, whether the qualities of pure water, as detailed by the Board, in page 81 of their Report, would be represented in distilled water, he said :—

It would perhaps, with one limitation ; that distilled water, as it commonly exists, does not contain much air ; it is not much aërated ; and I think that the suggestion of having the water entirely free from mineral and other matter, and at the same time well aërated, is an impossible thing. I believe that to get water thoroughly well aërated, we must have some of these materials in it to combine with carbonic acid.

Again, question put :—

And that perfect aëration, according to you, is incompatible with the other qualities prescribed here ?—I think it is. We might give distilled water air by passing carbonic acid into it ; but I think that would be a very expensive process to supply 2,000,000 people.

Again questioned :—

It seems that the question between hard and soft water comes to be a question between people's clothes and their health ?—I should think so, certainly. We cannot have a water which we should call wholesome without being what is sometimes called impure, if by impurity we consider the mixture of chemical ingredients with it.

Committee :—

76. Is it your opinion that this water, as described in this Report, coming through a leaden pipe, would in fact be poisonous ?—I have not the least doubt of it ; nothing on earth should induce me to drink such water.

Answer :—

I must profess my astonishment that, with a knowledge of a fact that anybody can ascertain in five minutes by trial, such a recommendation may be given ; it would be most fatal to the whole population.

77. What do you mean by the recommendation given ?—The recommendation that these should be the qualities of the water

selected. I do not hesitate to say that it would poison thousands if water were brought to London in that state.

Again, answer to question 86 :—

As aëration is laid down as an essential condition, I beg to say, the more you impregnate this water with air, the greater the danger; of itself it will not act unless there be air; so that we say, chemically, the cause of the poisoning is this—that it is nothing in the water, but that the water forms a vehicle for dissolving out of the atmosphere the oxygen and carbonic acid, which it conveys to the lead, and as far as the lead takes it, the lead loses its substance; and so it goes on until the whole lead is destroyed or the water evaporates.

Page 18 :—

As a general rule, in proportion as water is soft from deficiency of saline matters, its tendency to become poisoned by lead is increased, and a soft or pure water is therefore dangerous in proportion to its degree of softness or purity. The water which would be most economical for soap would therefore, *cæteris paribus*, be the most liable to be impregnated with a poisonous salt of lead, and be therefore quite unfit for dietetic use. The employment of such water for drinking would give rise to the general diffusion of paralysis and colic.

Question 80, speaking of river Lea water :—

We say this water is excellent in this respect, that if supplied through leaden pipes or cisterns it would be entirely free from any risk of poisoning those who drink it. It is this powder (the saline residue obtained by evaporation), in fact, which is the protection.

Professor Brande, in answer to question 193 :—

I should be extremely apprehensive of the consequences of bringing anything in the shape of very pure water, that is, water not containing certain ingredients in certain proportions, into London through leaden pipes or even through iron pipes.

I have given the evidence in Professor Taylor's and Brande's own words, that every one may judge for themselves as to the value of the professional opinions of these gentlemen in the question of corrosion of lead by hard and soft pure waters. I will now condense the evidence, as its meaning would be impressed upon my mind :—

That Professor Taylor declares "that pure soft water well aërated is an impossible thing. That water, to be well aërated, must have some of the materials "to combine with carbonic acid;" in fact, "that aëration of water is not complete without the presence of carbonic acid." "That water cannot be wholesome without being injured in the mixture of chemical ingredients in it." "That the Farnham water, proposed to be brought to London by the General Board of Health through leaden pipes would poison thousands, particularly if its qualities are such as related by the Board:—

"1. Free from all animal and vegetable matter, especially matter in a state of decomposition.

"2. Pure aëration.

"3. Softness.

"4. Freedom from earthy, or mineral, or other foreign matters.

"5. Coolness in drinking.

"6. Limpidity or clearness.

"That drinking such a water as described above from leaden pipes would give rise to the general diffusion of paralysis and colic." "That the deposit of salts of lime in the hard water of the rivers Thames, Lea, &c., is necessary to afford protection to the leaden pipes." "That no action upon lead can result from the use of such hard water as the rivers Lea, Thames, &c."

Now having given first my own evidence of experience as to the comparative erosive powers of hard river-waters and soft spring Farnham water, free from carbonic acid gas, and subsequently records of the professional opinions of Professors Taylor and Brande, before drawing my conclusions upon this subject, I must congratulate the public—

I. On the fact that fortunately there are gentlemen of chemical science who differ with Professors Taylor, Cooper, and Brande, whose opinions give the most one-sided view of the question I have ever read from men of professional reputation and research.

II. That their opinion as to the necessity of deposit to afford protection to lead is refuted by the experience of every plumber in London.

III. That the excellent health of the whole population of Farnham, in successive generations from the year 1677, when the soft water was first led from the bishop's palace through a lead pipe to the town, utterly refutes the slightest foundation for the anticipated poisoning of thousands in London as predicted by Mr. Taylor.

It would almost seem that Messrs. Taylor and Brande have never heard of and certainly not seen the opinions on the Farnham spring-water by some of the most eminent chemists in this country in the Board's Report on Water Supply expressed by Professors Lyon Playfair and Way, and Dr. Angus Smith, gentlemen who devoted weeks of careful investigation to the subject, and subsequently by Professor Taylor, of Middlesex Hospital, who is now thoroughly analyzing several specimens of the deep springs, and whose report I shall hereafter lay before the Board.

Before submitting my deductions from the evidence adduced on both sides, I would refer to the opinions of Professors Cooper and Brande on this subject prior to those expressed before the Committee on the River Lea Trust Bill.

I extract the following paragraphs from the evidence of Mr. Cooper before the General Board of Health, where, in giving his desideratum of water for domestic use, he states:—

> I am free to confess that I take the Artesian-well water, such as that of Trafalgar-square (which I have very carefully analyzed), and that also of Her Majesty's Mint, as the beau ideal of what a water ought to be for the supply of a city or town; but as there are places in great number out of the reach of such a supply, I can only then say, to take the water of Trafalgar-square as the standard of comparison and select that which approximates to it the nearest in all its qualities.

Again:—

> It is nevertheless true that, in an economical point of view, as regards the saving of soap or extracting a better infusion from malt, as in brewing, or for the purposes of the tea-table, in obtaining a

better infusion in the tea-pot from an equal quantity of tea, a water containing the smallest amount of calcareous salts is to be preferred.

Professor Brande, in his account of his analysis of waters proposed for the use of Liverpool, varying in hardness from 1, 2½, 3, 4½, to 9 degrees, according to Dr. Clarke's test, states :—

In common language they are all very pure, and quite fit for domestic purposes.

Referring now, I., to the analysis of the Royal Mint water by Professor Brande, and alluded to above by Mr. Taylor, we find that one gallon, on being evaporated, gave—

1·5 grains carbonate of lime,
12· grains carbonate of soda,
18·1 grains sulphate of soda,
8·3 grains muriate of soda;

in all 39·9 grains of solid matter to the gallon, this water being probably 2 degrees in hardness.

II. To the waters proposed for the supply of Liverpool and shown to be 1, 2½, 3, 4½, and 9 degrees in hardness, it is seen that Mr. Cooper speaks of the Mint water as his beau ideal of water for domestic use and economical in the consumption of tea, soap, &c.; that Professor Brande considered the waters for Liverpool to be very pure and quite fit for domestic purposes.

How is it then that both these gentlemen have so suddenly changed their opinion as to the desirable nature of water for domestic purposes? The spring-water from the gathering grounds does not contain more or less calcareous salts than the Mint water, and yet Professors Brande and Cooper stated before the Committee on the River Lea Trust Bill that, in making tea, the hard river-water makes if anything a stronger infusion than distilled or perfectly pure water. Professor Brande also must have remembered, when he decided on the fitness of water of 1 degree for domestic use at Liverpool, that this water must necessarily be drunk from the iron mains and leaden distributing apparatus existing there.

That Professor Brande's opinion as to the fitness of the water for Liverpool was understood to be as I have quoted, is evident, for reference is made to his opinion on these waters by Mr. Simpson, one of the engineers of the Chelsea and Lambeth Companies, in a Report with Mr. Newlands, where he refers to the analysis and testimony of Professor Brande in favour of the superior softness of the waters proposed to be supplied to Liverpool, contrasting its advantages with the Thames water, varying from 14 to 17 degrees of hardness. It remains for Mr. Cooper and Professor Brande to reconcile these different opinions on the same subject to the public, who are at a loss to understand them.

I now beg leave to submit the following deductions from the different statements adduced by the opinions of Professors Lyon Playfair, Way, Dr. Angus Smith, and subsequently of Professor Taylor of Middlesex Hospital; and on the authority of Mr. Simon, medical officer of the City of London; also by my own researches in confirmation:—

I. I submit that the action of water upon lead is to a great extent due to the proportion of carbonic acid gas it may contain.

II. That the pure soft spring-water of the Farnham and Hindhead district is well aërated by atmospheric air, not by carbonic acid gas, which gas merely gives a more sparkling appearance to water but is not at all necessary for aëration.

III. That the soft spring-water of the Farnham and Hindhead gathering grounds may, if considered desirable for a short time, while the system of earthenware is being matured, be drunk from fully-charged leaden pipes without the slightest risk of injury whatsoever from erosive action on the lead.

IV. That whatever may in course of time be the action of the soft spring-water of Farnham on leaden cisterns exposed to the air, the same erosion is produced by the hard waters of the rivers Thames, Lea, &c., in one-fifth of the time.

Much having been said about the action upon lead of some soft water at Claremont, I would point out that this water contains an excess of carbonic acid gas, and then proceed to relate a case of nearly fatal poisoning of a lady who drank much water from the lead cistern of her house in Essex-street, supplied, I believe, by the hard Thames water. I give the words of the medical gentleman who attended this lady, and whose skill saved her life.

Mr. George Williams, surgeon, Hampstead, says,

The following are the facts of the case, to the best of my remembrance; but I will shortly furnish a statement corroborated by the patient herself.

I remember Mrs. William Cox, who consulted me on 28th of November 1848, as to the nature of the sickness she was then suffering from. I found her in bed, with the hands dropped, legs and arms attenuated and perfectly useless, suffering from obstinate constipation and severe colic. On examining her mouth I saw the blue line on the margin of the gums, which is distinctive of poisoning by lead. She had been treated by medical men in London for rheumatism and other imaginary disorders, and only became worse when she removed to Hampstead, when I was consulted. I immediately pronounced her case to be poisoning by lead, and having prescribed accordingly, she recovered nearly perfectly, though very slowly. Her husband attributed the attack to the water from a lead cistern in their residence in Essex-street, where they had resided. Had Mrs. William Cox continued to drink this water she would have died shortly. I think I remember that Mr. Cox, now dead, stated he had himself suffered much from the same cause.

Having satisfied my mind as to the probable action of the Farnham soft water upon the leaden distributory apparatus of the metropolis, I deemed it advisable to see in how far my convictions would be borne out on inspection of the towns which naturally or by preference have soft water supplies. Very many of the principal towns in Scotland and a few in England, principally in Lancashire, and already enumerated in the Report on Water Supply, partake of this advantage to health and purse. In no one instance did I find any other feeling to exist, than that of the warmest self-congratulation and thankfulness for the blessing they enjoyed.

As to any inconvenience from the action of the pure soft water upon the leaden distributory apparatus, while I say that by the application of very fine chemical tests the presence of lead in a few instances was perceived, where water had been long standing in cisterns, yet in no case did it occur, or was there a single complaint, when the same water was drawn from service pipes on the constant system.

Aware that a mass of evidence on this subject has been collected by the Board of Health, I do not offer such as I myself gathered in my tour of inspection, but will only quote the testimony of the very experienced foreman of the extensive firm of plumbers, Messrs. Blaikie, in Aberdeen, and whose evidence is a fair sample of the whole :—

John Allan is foreman to Messrs. Blaikie, plumbers, Aberdeen; has been in the trade 36 years in this town and neighbourhood; Messrs. Blaikie have nearly all the plumbing work of Aberdeen and the surrounding country. The greater part of the town has been supplied with soft water from the river Dee for 25 years; has of course often taken up and repaired the leaden service pipes, but never remembers to have seen any corrosion or eating up by the water.

Old Aberdeen has been supplied for 20 years from a soft spring. The water is brought in a 1½ inch lead pipe, from the spring head to the town, a distance of half a mile. The spring head is 2 feet square, 3 feet deep, and the conducting pipe is laid to the bottom of the water, so that no air can enter; this pipe is as good as the day it was laid. The hard well waters of this town act very much upon lead; so much so that the cisterns are made of lead 7 lbs. to the foot. Cisterns to contain the soft water are made of lead 4 lbs. to the foot. Has observed, that rainwater cisterns were not corroded unless allowed to be dirty.

In corroboration of this witness's testimony were produced pieces of the leaden pipes 20 years in use, which internally were as good as when first laid down. I may further add, that on application to the physician of the Infirmary at Aberdeen, as to the existence of the lead colic from drinking poisonous water, his experience was given as follows :—

In answer to your note of Monday last, I beg to state that in my experience of nearly a quarter of a century, as a Dispensary or Hospital physician, I have never seen a case of colic or poisoning from drinking water from the lead pipes. Such a disease was not known here even when our mains as well as the service pipes were of lead.

Here then is a case of the use for a quarter of a century, of perfectly pure soft water of under 2 degrees in hardness, conducted at first in leaden mains, and to the present day drunk from leaden service pipes, and yet in all that time no case of colic has occurred.

It is very satisfactory to know that a Government Commission of Inquiry has been appointed to investigate and elucidate this much vexed question. That the verdict will be favourable to the soft water cause I do not hesitate to assert, even although in opposition to the recorded opinions of Professors Brande, Taylor, and Cooper.

I would congratulate the Board that the question is not whether the water of the gathering-grounds is or is not pure enough, but that the only ground of objection is that it is too pure; on this the chemists are arrayed, the gist of the argument being that it is too pure to be conveyed through the present leaden distributory apparatus; in other words, that according to the present Water Company's witnesses, the existing distributory apparatus is decidedly unfit for the conveyance of water of the purest quality. The procuring a suitable apparatus for the conveyance of the purest water is then the real question at issue. It is no longer a question for chemists or physicians, but for mechanics, whether we cannot get a new distributory apparatus equally cheap, which shall be fitted for the conveyance of pure water. I am informed of instances already in which tradesmen have taken down lead cisterns, and put up slate cisterns in exchange. Under the system of constant supply, the cisterns themselves will be entirely superseded. I am further informed that tradesmen will be ready to take away the existing lead and put down glass service-pipes in exchange for the lead of the existing cisterns and service-pipes; but I rely upon Roman and other experience that earthenware may be substituted with great economy and advantage. With respect to the iron mains, the pipes in Manchester are protected by Dr. Angus Smith's enamel, and cost from one-half to one-third of the price which the Water Companies in London paid for their early iron pipeage, which the evidence of Professors

Taylor, Cooper, and Brande, would tend to show now to be quite unnecessary.

In conclusion, I would remark that, whereas it is for many reasons desirable to change the lead pipes for earthenware as early as practicable, experience of facts justifies me in asserting as undeniable, that, meanwhile, any danger to the inhabitants of the metropolis arising from the action of water upon lead will, by changing the source of the supply from the present hard waters of the rivers Thames, Lea, &c., to the soft spring water of the Farnham and Hindhead gathering grounds, proposed by the General Board of Health, be protracted from complete destruction of the bottom of a leaden cistern from a period of 6 years to 35 years.

## V.

### Some Remarks on Combined Works.

Having considered the subject of soft water, as the most desirable for the metropolis, in its intrinsic economical value and superior quality for health, as compared with hard water; also the probable expense of its delivery into the existing street-mains and distributory apparatus; the task I originally allotted myself might seem to be concluded. Were the efficiency of a scheme of water-supply alone dependent on its perfect execution —were such a work complete in its own isolation—I might look forward with nothing more than natural anxiety to practical success of the most important branch of sanitary regeneration for this vast city. But as water-supply cannot be considered, much less executed, without the nicest calculation of the necessary means for carrying away the water that has been introduced when its end shall have been accomplished, I trust to be pardoned for trespassing longer on the attention of the General Board, while shortly reviewing the circumstances under which water-supply should be combined with its sister work, viz., the drainage of the metropolis, now in trust of the Commission of Sewers. In the first instance, the principle which should guide not only the selection of the instrument whereby these inseparable works should be carried out, but also that which should determine their method of execution and their future administration. Secondly, the expense at which these elements of health may be afforded, remembering, while framing such estimates on the one hand, the necessity of perfection in construction of works, and, on the other, the pecuniary interests of the public.

*The Principles involved.*

When a necessity is occasioned—when a want exists—there is but one source of supply—viz., the public market; and if the article of demand be of too great value to be there found, it must be sought from the hands of the monopolist, who, in right of the outlay of invention or capital, has obtained protection of the law from competition. That such security should be given to science and enterprise is undoubtedly proper; but certainly it should be continued for no longer time than shall have afforded fair interest and remuneration for the expenditure.

When consumers cannot supply themselves in the market, and refuse to submit to the terms of the alternative, they have no remedy but to acquire such monopoly for themselves, or seek the protection of the State.

To become the purchasers will not answer the desired ends, for the new proprietary must almost necessarily include the seeds of the late evils, which cannot fail to exercise the most deleterious influence to the public interest, whether expressed in awarding exorbitant compensation to themselves, or in the corrupt administration of the services. Experience has ever shown that the government of such affairs by the representatives of the different vested interests, has almost invariably resulted in the most shameful abuse of power and privilege.

If the State be appealed to, protection may be afforded either in the shape of restriction imposed, or by Government itself becoming the fountain of supply. The first is but the palliation of an evil. The latter, under the circumstances of an impossibility of competition, which, I believe, alone justifies such a remedy, is the last and the only effectual resource against the oppression of a monopoly.

The fallacious opinion of the practicability of competition in water-supply has been abandoned. No one longer asserts that water can be considered in the same light as bread and meat, or the other necessaries of life; but were there even many sources of supply available in this article, unlimited competition would still be illegal, as an invasion of the rights of public and private order and security. Such wants as can be gratified without inconvenience or injury to a neighbour, may be legally and profitably sought in any favourite market; but the cumbrous machinery of water-supply and drainage involve, if left to individual will, an extent of confusion as much to be feared as the inevitable loss of capital would be deplored. Let any one who has witnessed the strife and rivalry of the existing water and gas companies only picture the results, if either sources were more accessible to private caprice than at present.

I shall then assume that the government of these affairs is a legitimate function of the State. On what principle shall the works be executed and administered? Undoubtedly, the best is that asserted by the General Board of Health, who propose that such works should be offered, in gross or detail, to competition by public tender—a principle of competition *for* instead of *in* the field. This method will assure to the ratepayers all the advantages and protection of competition, without its drawbacks. The bonds and penalties which will accompany the contract will ensure its faithful execution, and form as efficient a check to the contractor as the fear of rivalry in ordinary trade.

Such a good means and principle of government being then open, what is the present position of the interests at issue, and what the difficulties that are said to be so insuperable to the desired reform?

The water supply is in possession of nine companies, whose avarice and constant breach of faith with the public have caused the present appeal to Government for interference, that Parliament shall recall the powers so shamefully abused.

It is generally understood that a Bill will shortly be brought into the Lower House empowering the consolidation of the companies, and authorising the execution of the soft-water scheme. Grateful as the public will doubtless be for the last boon, I would protest against the idea that such a half-measure will find acceptance at their hands. Further, no project should be entertained that does not include combination of water with drainage-works, for, if their respective machinery be not carefully proportioned and adapted, the efficiency of the whole must inevitably suffer.

Of what avail will be the Act of Consolidation, if cheap water—the right of all, but more especially of the poor—be not added?—cheap water, not in the sense of the present monopolists, but as provided in the Public Health Act for provincial towns, at a rate of twopence a house per week. An unlimited supply of pure soft water, at something very nearly approaching this price, for a period of thirty years, is attainable by the inhabitants of London, who now pay 7½*d.* per week per house, which sum, I am prepared to show, is more than ample to pay for—

I. The purchase of the present companies' plant.

II. The introduction of soft water.

III. The main drainage of the metropolis, even at the apparently large estimate of the Commission of Sewers.

IV. The house drainage, not included in the present estimate of the Commission of Sewers.

What are the difficulties opposed to the desired reform?

This question is usually answered by an assertion of the jealousy of Government interference with private enterprise, and of the difficulty in determining and providing the amount of compensation to the companies.

It has already been seen that water-supply is not a field for competition. The compensation question is strictly as easy of solution. The right on the part of the public to choose their own source of water-supply without indemnity for loss of profits to the existing monopolists being conceded, the real value of their machinery alone remains for consideration. Now, as it is vain for the companies to expect compensation for unnecessary works, rival lines, and parliamentary expenses, the worth of the stock would be represented by what it would fetch in the market, and, even taking the most favourable view of the whole case, to which the companies have no claim, by the price of works *de novo* to effect the same purpose, calculated on the most liberal scale.

The proposition of a giant company is monstrous. Surely divided is less noxious than concentrated evil. It is not so humiliating to be the victim of nine less powerful than one giant monopoly. Although in combination against the public, mutual fear and distrust were some restraint.

If any reform is to be attempted, let the whole case be met.

Buy up the companies' stock; consolidate the administration of water-supply and drainage; put up the works to public tender, giving the preference to the existing companies under circumstances of equal offers ;—and it is yet in the power of this city to have a copious supply of pure, soft, and cheap water.

*Calculation of the future Rate for Combined Works of Water Supply and Drainage, on the existing arrangements.*

| | |
|---|---|
| Present perpetual water-rate, per house (270,795) per week | 7½*d.* |
| Expense of proposed main drainage, as estimated by the Commission of Sewers, at 1¼ million sterling, equal to a rate for 30 years, of, per house (284,000), per week, about . | 1¼*d.* |
| Estimated cost of house drainage, as calculated by the General Board, per house, per week . . . | 2*d.* |
| Total rate for combined works for 30 years, per house, per week . . . . . . | 10¾*d.* |
| Perpetual rate . . . . . | 7½*d.* |

*Comparative Estimate.*

| | |
|---|---|
| Compensation of the companies, calculated at the expense of new and effectual works to be 2,000,000*l.* sterling, equal to a rate of, per house (280,000), per week, nearly | 2*d.* |
| Estimated cost of soft water, ¾ million sterling, equal to, per house (280,000), per week . . . | 2/3$^{d.}$ |
| Estimated cost of main drainage by Commission of Sewers, as before, per house, per week . . . | 1¼*d.* |
| House drainage, as before, per house, per week . | 2*d.* |

Total rate for combined works, soft-water supply, and compensation to companies, to be distributed over 30 years, on 280,000 houses, per house, per week, 5$\frac{1}{12}$*d.* or 6*d.*, less by 1½*d.* than the perpetual rate of the present companies, on 271,795 houses, for water alone.

I have now given the figures, which are the strongest advocates in an argument. The great fight is about to commence. Not so much between the claims of hard or soft water, but a struggle whether the unrighteous powers of vested interests shall prevail over and trample under foot the cause of sanitary reform. Of one thing I am assured, that, whether it be this session or next, or five years hence, the victory will, under Providence, be to the side of justice.

## VI.

### Further Consideration of the probable Source of the Deep Spring Water of the Gathering Grounds.

The waters derivable from the Farnham and Hindhead district are three in number, viz., deep spring water, shallow land springs, and surface-drainage. The ancient precedents of water-supply justify me in adhering to the plan I have proposed, and in accordance with the principle enunciated "the nearer the source the purer the supply."

1. To lead away the deep springs only.
2. To protect the spring heads from surface washing, by the methods proposed, should the Board deem them efficient.
3. To calculate only on the flow of the deep springs found to be available at the end of past drought, and thus to measure the capacity of the adjusting reservoir.

In corroboration of my opinions as to the probable effect of opening up the spring heads, I will quote a fact from Colonel Chesney, who says,—

> In the province of J'Haluman, in Affghanistan, there is nothing worthy of the name of a river, yet abundance of water can be found even for irrigation by digging a few feet into the beds of the streams, which cease with the rains.

However this may be, I do not propose to carry the system so far, but would rely only upon the least natural flow of the springs at the driest season of the year. Such will more than meet the exigencies of London at the present time, and indeed for many years to come.

I will now offer a few remarks on the probable sources of the large quantities of water found to be available on the Farnham and Hindhead gathering-grounds. It will be remembered, while deeming it necessary to draw attention to the fact that in many instances the flow of the springs much exceeded the rainfall on these drainage areas, I respectfully submitted the investigation of the question to the eminent geologists of the day as well worthy of their attention. On mentioning the subject to the distinguished president of the Geological Society, I was informed by Sir Henry de la Bèche, that though unaware of any faults in the Bagshot and green sand formations, such might nevertheless possibly exist and give an undue proportion of water, even at the rather considerable height above mean tide at which the springs chiefly take their rise.

In addition to the view offered on this subject there is another means of accounting for the presence of more water on one spot than its rainfall would give, especially on high elevations, viz., by dews and vapours, or mists, as noticed by several authors.

What is dew? and whence derived? I cannot, in explanation, do better than quote the words of the scientific author of the treatise on Meteorology, in Chambers' Educational Course, where he says, p. 40 :—

Where moisture is precipitated at night in the form of wetness and drops on the surface of the ground, and on the leaves of plants, it receives the name of dew. This precipitation arises when the surface of any body is cooled below the dew point temperature. The dew point being the lowest point to which the air can be cooled down without giving out visible moisture. Thus, if the dew point were at 45°, and if by any means a glass tumbler were cooled down to 40°, it would, therefore, have to give out all the vapour it could not hold at that temperature; but the precipitated surplus in this case would not appear as mist in the air, but would adhere to the surface of the glass.

Having thus clearly seen what is dew, and whence derived, it remains to consider whether the heat of the day does not extract, in the form of evaporation, the quantity of moisture thus deposited during the night. This I believe to be the case with the local moisture, as it were, but not with that brought from a distance.

That the elevated district of the green sand formation, embracing the greater portion of the area from which flow the springs proposed to be diverted to the metropolis, attracts by condensation a great proportion of the clouds and vapour, borne thither from the ocean by the prevailing south-westerly winds, is undoubted.

We learn from the author of that most interesting and able paper on Metropolitan Water Supply, published in the last Quarterly Review, that the quantity of water ambient (as aptly expressed by him) in the atmosphere is enormous, and that the sea evaporates at the rate of 16 tons per acre per day.

Let me compare this calculation with an experiment by Dr. Halley, who took a vessel of water and made it the same degree of saltness as the sea by means of the hydrometer, and, having placed a thermometer under it, he brought it, by means of a pan of coals, to the same degree of heat with that of the air in the hottest summer. He then placed the vessel in one scale and counterpoised it with weight on the other. After two hours he found that one-twelfth of a cubic inch was gone off in vapour from a surface of 10 square inches. This would give an evaporation of half a cubic inch from the same surface in a day, or rather more than five tons per acre in the same time.

Dr. Halley's experiment assigns, therefore, only one-third of the evaporation given by the author just quoted; taking even the smaller figure as the truth, what a mass of water is thus held in suspension in the air, and possibly may be deposited on the earth's surface in the form of moisture.

Next as to the affinity of different soils for attraction of such moisture, Sir Humphry Davy, in his Elements of Agricultural Chemistry, says,—

The power of soils to absorb water by cohesive attraction depends, in great measure, on the state of division of the parts; the more divided they are, the greater is their absorbent power. The different constituent parts of soils appear likewise to act, even by cohesive attraction, with different degrees of energy. Thus vegetable substances seem to be more absorbent than animal, animal substances more so than compounds of silica and alumina, and the latter more absorbent than carbonates of lime and magnesia; these differences, however, may possibly depend upon the differences in their division, and upon the surface exposed.

Thus it will be seen, that, though the great division of parts of the Bagshot and green sand formations may somewhat increase the proportion, yet the formation in itself only ranks in the third class, as to capacity for attracting moisture; but though absorbing less from the atmosphere, these sands yield a greater proportion of what they do assimilate than other soils, for Schübler has defined by experiment that the hygroscopicity of elementary soils, or the quantity of water they retain between their particles without allowing it to run off after saturation, is as follows:—

| | Parts of water in 100 of soil. |
|---|---|
| Silicious sand | 25 |
| Gypsum | 27 |
| Calcareous sand | 29 |
| Poor clay | 40 |
| Rich clay | 50 |
| Argillaceous earth | 60 |
| Fine clay | 70 |
| Fine calcareous earth | 83 |
| Garden earth | 89 |

Assuming it to be correct, that much vapour is attracted by condensation to these elevated districts, a large proportion of the moisture is evidently available as an additional water-source.

The power of soils to absorb moisture ought to be much greater in warm or dry countries, than in cold and moist ones. This statement is confirmed by the experience of those who have travelled in the sandy deserts of Asia and Africa, and have slept on the ground; they will remember how soon their clothes were saturated with the heavy dews. I have some reason, therefore, for stating that a part of the unusually large quantity of water shown to be available in this district, is very possibly caused as well by rainfall elsewhere, as by the condensation of mists and vapours.

The capacity of water to assimilate water to itself is well known, and dews are thus the probable means by which ponds on high elevations, into which there is no drainage, retain their level despite the heavy demands many of them are known to sustain.

White, in his "Natural History of Selborne," alludes to this subject,—

To a thinking mind few phenomena are more strange than the state of little ponds on the summit of chalk hills, many of which are never dry in the most trying droughts of summer. In chalk hills I say, because in many rocky and gravelly soils, springs usually break out pretty high on the sides of elevated grounds and mountains. Now we have many such little round ponds in this district, and one in particular, 300 feet above my house, which, though never above 3 feet deep in the middle and not more than 30 feet in diameter, and containing, perhaps, not more than 300 hogsheads of water, yet never is known to fail, though it affords drink for 300 or 400 sheep, and at least 20 head of large cattle. This pond, it is true, is overhung with two moderate beeches, that doubtless at times afford it much supply; but then we have others so small, that without the aid of trees, and in spite of evaporation from sun and wind, and perpetual consumption by cattle, yet constantly maintain a moderate share of water without overflowing in the wettest seasons, as they would do if supplied by springs. By my journal of May, 1785, it appears "that the small and even considerable pools are now dried up, while the small ponds on the very tops of the hills are but little affected." Dr. Hales, in his 'Vegetable Statistics,' advances from experiment that, "the moister the earth is, the more dew falls upon it in the night; and more than a double quantity of dew falls on a surface of water than there does on an equal surface of most earth." Hence we see that water, by its coolness, is enabled to assimilate to itself a larger quantity of moisture nightly by condensation, and even with copious dews can alone advance a considerable and never-failing resource.

In this manner, also, are replenished the almost inexhaustible pools called vleys, in the sandy deserts of Africa. During many months of drought in that country, it is wonderful to observe these shallow lakes sustain the enormous demands made upon them by cattle. Without such replenishing by the dew they would be dried up in a very short time.

The amount of rainfall is taken from a register kept at the Royal Military College, Sandhurst, from the year 1818 to 1846.

The average fall of the last 15 years, during which time the register appears to have been correctly kept, is 22·64 inches. I consider this to be a very low estimate, however, of the average rainfall over the whole district. The fall on the ranges of the Hindhead must considerably exceed this amount; for I find in White's 'Selborne' a register for ten years at that place; the greatest fall being, in 1782, 50·26 inches, the lowest, in 1788, 22·50 inches, and the average of all 37·58 inches. The elevation of the Hindhead is about 800 feet above mean tide. Let me compare the mean 37·58 inches with the fall on equal elevations. On referring to a statement of rainfall at Glencare in the Pentland Hills, 734 feet, and at Gilmourton in the Avondale Hills, 600 feet above mean tide, I find the average of the former (as recorded by Mr. Beardmore) to be during 15 years, from 1831 to 1846, 41·7 inches; and of the latter, during three years from 1845 to 1847, inclusive, to be 66·3 inches; so that, taking the average elevation of the springs in the Hindhead above mean tide to be 550 feet, I consider that 22·64 inches is the least quantity likely to be available over the whole district, except indeed in a season of unusual drought. In such a case, the flow of the springs being ten millions at least beyond the present demand, I have every right to suppose that their discharge would not be reduced by more than the excess, viz., one-fifth of the whole.

With reference to the measurement of rainfall, it is difficult indeed to obtain more than a very approximate idea for a given district of not very great extent. The method of measurement is so uncertain, as liable to be affected by currents of air and evaporation. It is well known that elevated regions attract by condensation more rain than low lands, and yet a rain-gauge, placed on the ground, will register a greater fall than one placed immediately and even at a small height above it.

M. Arago has shown, from 12 years' observations at Paris, that the average depth of rain on the terrace of the Observatory was 19·88 inches, while 30 yards lower it was 22·21 inches. Dr. Heberden has shown the rainfall on the top of Westminster

Cathedral during a certain period to be only 12·02 inches, and at a lower level on the top of a house in the neighbourhood to be 22·608 inches. This fact has been observed all over the world, and I can only account for it as partly by the greater amount of condensation the nearer the earth's surface, but probably also from currents of air depriving a rain-gauge at a high elevation of its fair share. Referring to the proportion the available water bears to its drainage area, I find that the discharge of the springs amounts to four-sevenths of the rainfall, and this it must be remembered after a protracted drought.

The very porous nature of these deep sandy formations must certainly give a larger available proportion of the moisture deposited than more retentive rock; the evaporation being necessarily much less.

While this question is being investigated, and remembering the objection advanced against my opinion offered thereon, it being said that the stated purity of the water militates against the probability of an increase from foreign sources, it will be worthy of consideration in how far this very purity may or not verify the important principle lately discovered by Professor Way, that waters containing carbonate of lime are purified by their being passed through clay and loamy soils. It is strange indeed that for the first time in the middle of the nineteenth century, science is really applied to the discovery of a means of more effective purification of bad water than the ordinary processes of filtration afford. Too great value cannot be attached to Mr. Way's researches, and it is earnestly to be hoped they may be successfully completed, as independently of the advantage and economy of soft and pure water to manufacturers, bleachers, dyers, brewers, &c., the importance to health of being enabled to purify large quantities for drinking is inestimable, as on board ships and in such places where the local water only is available, as in military posts also, but of this I shall treat more largely on another occasion.

In South Africa I have seen farmers and soldiers obliged to to drink water that a dog in this country would turn from with disgust.

The only process of this nature at all applicable to the purposes of manufacture is the invention of Dr. Clark, who softens water containing dissolved bi-carbonate of lime by adding the quantity of lime necessary to turn the soluble bi-carbonate into insoluble carbonate of lime, which is precipitated. I understand that Dr. Clark's latest experiments show that he can thus reduce the hardness of chalk waters to 4°, and that in the progress of subsidence, a large portion of the organic matter goes down, which is very satisfactory, but at the best this is more a palliative than cure of a serious evil.

## VII.

### Water Supply, in ancient as compared with the present times, whether for the purpose of irrigation or home consumption.

I shall proceed to extract from some authorities, ancient and modern, a few remarks on the subject of water supply, whether from springs, rivers, or by collection of surface water in reservoirs, and to show what immense value was attached to this subject by them :—

Referring to Mr. Eubanke's Hydraulics, we read that Molina, in his 'Natural and Civil History of Chili,' observes,—

That previous to the invasion of the Spaniards, the natives practised artificial irrigation by conveying water from the high grounds to the fields in canals. The Peruvians carried this system to a great extent. These people had laws for the protection of water similar to those of Rome, Greece, and Egypt, and all older nations. The seventh Inca constructed some water-works which in their beneficial effects equalled any similar undertakings in any part of the world. He made an aqueduct 12 feet in depth and 120 leagues in length: the source, or head of it arose from certain springs in the top of a high mountain between Parcu and Picuy, which were so plentiful that at the head of the fountains they seemed rivers. This current of water had its course through all the country of the Rucanas, and served to water the pasturage of their lands, which are 18 leagues in breadth, watering almost the whole country of Peru.

There is another aqueduct, much like this, which traverses the whole province of Cantisugu, running about 150 leagues from south to north. The ancient Peruvians were well acquainted with the management and distribution of water through pipes, and what is singular, both the sources of the water and the direction of the tubes underground were kept a secret, as in Asia.

In Spain, reservoirs of rain-water for drinking, and the diversion of streams for irrigation—nearly all works of very old date —are common, and I shall quote the words of the author of the most interesting 'Handbook of Spain :'—

At Valencia the Moors have bequeathed their hydraulic science, by which they exercised a magic control over water, wielding it at their bidding. They could do all but call down the gentle rains from heaven, that best of all irrigation. The network of artificial canals is admirable.

In the Huerta of Valencia, a main trunk artery or principal canal supplies all the smaller veins of the circulation; this is managed by a reticulated network of ramifications and drains. The Toledan Moors were first-rate hydraulists, their king Almamum had a lake in his palace, and in the middle a kiosk, from whence water descended on each side, thus enclosing him in the coolest of summer-houses. Toledo, built on a lofty rock, was badly supplied with water, whereupon the Romans stemmed the defile with a gigantic viaduct and aqueduct, which ran from the Puerte de Vevenes, distant seven leagues. Some remains may be traced near the convents Santa Siste and Santiago, and the line is still called El Camino de Plata—the Road of Silver.

At Segovia, the steep-banked rivers below are difficult of access, and the waters not very wholesome. The pure stream of the Rio Tório was thus brought from the Sierra Fonfria, distant three leagues.

At Meuda, the mighty pool or reservoirs, "El Lago de Proserpina," which lies about one league north, the grand wall which dams up the water is gigantic. There are towers by which staircases lead down into the huge tanks called "Los Bocines." There is another Roman reservoir near Truxillanos, two miles distant, called "Albuera de Cornalvo;" it is smaller than the Charca, but equally colossal in style of execution. On the route from Alicante to Xativa, we have the Pantano de Tibi, a magnificent dike which dams up the torrents of the mountain gorge. Walk on the top of this vast wall or breakwater, which is 150 feet high and 66 feet thick; above is the lake-like reservoir, below bold masses of rock with here and there elegant stone pines.

Granada is a city of fountains. The Darro and Keuil are drawn off by canals from high up between the sources, and thus the waters retain the original elevation above the town; columns of water are thrown up in great body and height. Under the Plaza de los Algibes, an open place, are the cisterns which are filled by Darro. There also exists a modern aqueduct built by the Maestre Esquival, under Philip II. It conveys water from El Barbillon, a spring which rises about two leagues from Merida near the village Truscillanos.

Now, it is curious to trace the same veneration for water—according to the ancients the "origin of all things"—to the faithful followers of Mahomed who lured them by promises of "springs of living waters," "security in shades;" amidst gardens and fountains pouring forth plenty of water. The refractory and unbelieving he threatened with "no cessation of the torments of thirst;" they would be obliged to take "copious draughts of filthy and boiling water." I shall give an extract from that extraordinary book, Sale's Koran.

In Arabia, the province of Jaman was governed by princes of the tribe of Hamgar. The first great calamity that befel the tribes settled in Jaman, was the inundation of Aram, which happened soon after the time of Alexander the Great, and is famous in Arabian history. No less than eight tribes were forced to abandon their dwellings on this occasion. Abdshem, surnamed Sabee, having built the city from him called Jaba and afterwards Maub, made a vast mound or dam to serve as a basin or reservoir to receive the water which came down from the mountains, not only for the use of the inhabitants and watering their lands, but also to keep the country they had subjected in greater awe, by being masters of the water. This building stood like a mountain above their city, and was by them esteemed so strong, that they were in no apprehension of its ever falling. The water rose to the height of almost 20 fathoms, and was kept in on every side by a work so solid, that many of the inhabitants had their houses built upon it. Every family had a certain portion of this water distributed by aqueducts; but at length God being highly displeased at their great pride and insolence, and resolving to humble and disperse them, sent a mighty flood which broke down the mound by night, while the inhabitants were asleep, and carried away the whole city with the neighbouring towns and people.

Again, in referring to Colonel Chesney, I find that

In Assyria and Mesopotamia, great water-courses intersected Susiana; crossing the latter territory from side to side at different places, they formed as many lines of intercommunication between the great rivers Tigris and Euphrates. By these means supplies of water were obtained in almost every direction, not only for the towns and irrigation, but for navigation.

The distances which water was thus brought is wonderful.

The canal of Samos is cut to a distance of seven stadia under a mountain 900 feet high in order to supply the city with water. The subterranean aqueducts, or kanats, are very numerous ; such are those near Shuster. In some instances lateral galleries have been added to the main shaft to open the springs indicated by the water travelling into the main channel. These kanats are frequently carried 12 or 15 miles, and sometimes much more. The karavanserai on the march between Dagau and Mushed draws the supply of water from a distance of about 20 miles, and in the plain of Jultanigul water is in one instance carried 40 miles. At Palmyra the supply of water was brought by aqueduct 3 miles to the city from the Grotto of Ephea, and near the spring is an altar devoted to Jupiter.

At Mecca is the well which, according to tradition, was that found by Hagar when Ishmael was perishing from thirst ; this spring is so abundant that it supplies a large portion of the consumption of the city.

I think I have quoted sufficient to show that the ancients evinced their appreciation of the value of pure water, not only by taking it from its source, from the spring-heads, but also by the care which they took to preserve it from the atmosphere by leading it to their cities in pipes of earthenware or metal or in aqueducts ; and yet with all these bright examples before us, we have, except in the case of the Chadwell spring, drawn our supplies from bodies of water which by their size alone show a scale of impurity. The Chadwell spring, even by the faulty method of conducting in an open canal now degenerated into a dirty ditch, for I call that a ditch which has mud at the bottom deep enough to plunge a stick into several feet in depth, and which receiving much sewage and drainage, arrives at its destination fearfully deteriorated as to purity.

I will now submit a few instances of the method of supply from springs, and of the use of earthenware pipes in ancient times, by the inhabitants of Mexico, Chili, Peru, Egypt, Arabia, Persia, Turkey, and Italy. Chili, Mexico, and Peru—these countries present at the present day many relics of splendid public works which rival in magnitude those of Egypt and India ; remains of aqueducts of great magnitude, skilful workmanship, and beautiful simplicity, still attest the industry, wealth, and science of the inhabitants of these countries before the Spanish invasion. I find Mr. Eubanke, in his description of hydraulic works in ancient Mexico, quotes Herrera's authority, that at the time of the Spanish invasion of these countries in 1518, "the inhabitants of Tlascala, a populous city, had bowers, baths, and fountains." Cortez wrote to Charles V. of Spain of the environs of the city of Cholula, containing 20,000 inhabitants, that almost all the fields were well watered. Herrera says, "the streets were very regular, and that fresh water was brought in pipes from the mountains to every house." Cortez mentions the spring of Amilco, near Cherubusco, of which the waters were conveyed to the city in two large pipes, well moulded and as hard as stone. The following extracts from Colonel Chesney's expedition to the Euphrates and Tigris will give some idea of the value assigned to water by the Egyptians, Persians, Arabians, Moors, and Turks, as seen in their laws, and by the enormous labour expended and science applied to enable them to attain their desired purpose :—

In Persia we know that such is the value of water at the present time, that those who bring a stream into a place where none existed previously have free inheritance of the ground for five generations. Neither labour or expense was spared to convey water through subterranean channels to places where it was wanted. These subterranean water-courses have been common through Susiana, Persia, and the rest of the land of Cuch, from the time of Houshung, to whom the invention is attributed. The extreme dryness of the climate, together with the scarcity of running water, obliges the people of Persia to turn their anxious attention to the discovery of springs; this being accomplished, and a promising head of water obtained, the subterranean tunnel is executed.

Colonel Chesney then describes the formation of the tunnel, about 3½ feet in diameter, by sinking shafts to the proper depths and connecting these points by galleries :—

These water-courses yielded a considerable resource to the Shah, who in many cases received rent amounting to 20 per cent. for a flowing stream, 15 per cent. for kanats, or subterranean aqueducts, 5 per cent. for wells or reservoirs. The day of bringing the water to its ultimate destination is made one of rejoicing among the peasants, who, having patiently awaited the fortunate hour, receive the gushing forth of the stream with shouts of joy accompanied by songs, music, and loud expressions of the anxious desire that prosperity may attend it.

The aqueducts just described being only adapted for ground that is tolerably even, the Eastern people have overcome the difficulties of a hilly and irregular surface by means of another description of canal, met with in Barbary and Turkey, a system of earthenware pipes, called souterari. Water is conducted in this manner from the well known reservoir near Belgrade, to Constantinople (between five and six miles), by such pipes, 4½ inches in diameter, having a number of inverted syphons connected together and opening at the superior parts into small cisterns, placed at the top of towers of a particular description, whence the water was distributed.

Near Jerusalem, Kalatelbruah has within it a pool which possibly may be the sealed fountain (Canticles, iv. 12), and is apparently the principal feeder of the three adjoining reservoirs. Being on the slope of the hill, they descend in succession, the bottom of the first being on the same level as the surface of the second, which carries the water into the third and lowermost. An aqueduct carries a supply of water along the side of the hills to Bethlehem, and Jerusalem is, to this day, supplied by a ten-inch earthenware pipe.

That the Romans used earthenware pipes for street and home distribution is well known. Frontinus, who had the direction of the aqueducts under the Emperor Nerva, mentions that Rome was supplied from nine, that emptied themselves through 13,594 pipes of earthenware, of one inch in diameter; and Veginus has observed, that they discharged 500,000 hogsheads of water (equal to 26,000,000 gallons) in the day.

The palace erected by the Emperor Trajan, in the middle of the lake of Nemi, was supplied by means of earthenware pipes with an abundance of pure water from the fountain of Egeria, not only sufficient for drinking-purposes, but as an ornament through the courts and apartments. Several of the smaller pipes, 16 inches long and 4 inches in diameter at the upper end, 2½ at the lower, still remain in the walls of the fountain of Egeria, and elsewhere. Thucydides, lib. xxxi., observes, that the best method of conducting water from a spring is to use earthenware pipes 2 fingers thick, one jointed within the other, and the joint made secure with quick-lime and oil. Water was conducted to a height of 100 feet by this means.

Earthenware pipes have come into extensive use of late years in France and Switzerland, for gas and water supply. For this latter purpose the manufacturers, Messrs. Reichnecher alone, have, since 1840, supplied towns in the departments of Haut-Rhin, Bas-Rhin, Moselle, Côte d'Or, Haute Seine, &c., and some places in Switzerland, with no less than 37¾ millions yards of these pipes; moreover, Messrs. Reichnecher announce a daily increasing demand, and yet we in England have utterly repudiated the use of the earthenware pipe, the very name of which, in connexion with water, is refreshing.

From the evidence thus given, I conceive I am justified in assuming that skill and perseverance will overcome the difficulties at present existing; at all events, experience justifies a fair trial, and should the hydraulic shock prove insuperable, which I cannot conceive, we can but fall back on the iron pipes coated with one of the numerous preparations of the day, of which that in use at Manchester, the invention of Dr. Angus Smith, seems to bear away the palm. The iron pipes, when heated to 300 degrees, are dipped into a pan of gas-pitch, and kept there for a short time. When taken out they are found to be covered with a fine black varnish, said by the patentee to be very durable. There is another experiment in progress, and which I understand promises well, to give iron pipes an internal coating of porcelain. If this can be economically effected, it will be the best material to use after earthenware.

# APPENDIX.

## (A.)

*To the Honourable William Napier.*

Dear Sir,—Shortly after the publication of the letter which I had the honour of addressing to Mr. Simon, the Officer of Health to the City of London, and which is contained in that gentleman's Report on the Sanitary condition of the City, you requested me to make a more extended investigation as to the chemical composition of the water found in the sandy district around Farnham and Bagshot, to examine into the action of those waters upon lead, and to give a general opinion as to their fitness for domestic purposes.

The following Report contains the result of my inquiries. It is, I regret to say, somewhat less complete than I could have desired. This has arisen from a variety of causes, with some of which you are already acquainted; but the principal difficulty has been caused by the extreme purity of the waters to be analyzed, which rendered a rigid quantitative estimation of their constituents a matter of considerable difficulty, unless a quantity of water were used, larger than it was in our power at the time to collect. It is on this account that I have given only general statements as to the composition of many of these waters, for with whatever care the process may be conducted, I have but little confidence in the accuracy of numbers derived from the analysis of one or two gallons of a water containing several solid constituents, the total amount of which does not exceed three or four grains. In conducting these experiments, I have been assisted by my friend and colleague Mr. C. Heisch, the analysis of the Wishmoor Bottom water, and most of the qualitative examinations, having been made by that gentleman.

The general features and the geological characters of the area in Surrey, from which it is proposed to draw the supply of water for the Metropolis, have been so frequently described as to require no remarks from me. For facility of reference it may be divided into a northern and a southern portion, according as it lies north or south of a long range of chalk hills, called the Hogsback, the general direction of which is nearly due east and west.

Commencing with the springs south of the Hogsback, which afford the bulk of the proposed supply, I have examined the water from the following places,—Witley, Haslemere, Downlands, Critchmere, and Headly Down.

1st. *Witley.*—In the village of this name there are several large ponds called Sweetwater Ponds. These ponds are supplied by springs rising from their bottom, and also from several small springs adjacent to them. From one of the latter, the water of which has been carefully collected in a small bricked well by the Rector of the parish, in whose ground it rises, the present sample was taken.

If a perfectly clear and transparent water, with a total absence of flavour, but leaving a cool refreshing impression on the tongue, may be called sweet water, this water deserves its name.

An imperial gallon of the water when evaporated to dryness, left a residue which dried at 230° Fahrenheit, weighed 4·40 grains. The residue was of a faint yellow colour, attracted moisture from the air, and when calcined, gave but slight indications of organic matter. Another portion of the water, mixed with carbonate of soda, evaporated to dryness, and the residue heated red hot, gave 3·32 grs.

The following tables illustrate the composition of an imperial gallon of this water. The first table expresses the quantity of each constituent actually found in the water, without reference to its mode of combination, while the second shows the manner in which the constituents are possibly combined :—

1.

| | |
|---|---|
| Chlorine | 0·53 |
| Sulphuric acid | 0·31 |
| Lime | 0·48 |
| Magnesia | 0·15 |
| Potass | 0·14 |
| Soda | 0·67 |
| Silicic acid | 0·61 |
| Nitric acid | undetermined. |
| Organic matter | trace. |

2.

| | |
|---|---|
| Cloride of calcium | 0·50 |
| Chloride of magnesium | 0·28 |
| Sulphate of lime | 0·53 |
| Nitrate of magnesia | 0·12 |
| Nitrate of potass | 0·30 |
| Nitrate of soda | 0·19 |
| Silicate of soda | 1·21 |
| Organic matter | trace. |
| | 3.13 |

The quantity of water in my possession was not sufficient to enable me to determine the amount of nitric acid. I have therefore combined as much of the soda with the silicic acid as is requisite to form a neutral silicate, and the rest of the soda and other bases with nitric acid. This analysis is therefore probably not quite correct in its details, but time did not permit me to make any further examination of the water.

The hardness of this water as determined by the soap test, distilled water being taken as unity, = 3·2.

2nd. *Haslemere.*—The spring from which this water was taken issues from the foot of a low sand-hill, and is received into a natural basin about four or five feet in diameter, from which it flows into a moderate-sized shallow pond. The water is perfectly clear and brilliant; it has no appreciable taste, but leaves a soft, agreeable impression upon the tongue. When mixed with a solution of chloride of calcium, to which ammonia has been added, there is not only no turbidity produced, but, even after the mixture has stood for many weeks in a closed bottle, not the slightest deposition of carbonate of lime can be perceived. Consequently, this water is very nearly, if not absolutely, free from uncombined carbonic acid, a rather remarkable fact, and one which I have since found to be the case in other waters, from the same district. As far as I am aware, the non-existence of carbonic acid in mineral waters has not been remarked by chemists. Hardness, distilled water being taken as unity, = 2·6.

An imperial gallon, evaporated to dryness, left a residue which dried at 230° Fahr.,=5·58 grs. This residue was nearly white, when heated red hot it charred slightly, but quickly resumed its original whiteness. The quantity of organic matter is therefore very small.

Another portion of the water evaporated along with carbonate of soda, and the residue calcined gave 4·22 of solid matter in the imperial gallon.

By analysis an imperial gallon of this water was found to contain:—

| 1. | | 2. | |
|---|---|---|---|
| Chlorine | 0·84 | Chloride of calcium | 0·71 |
| Sulphuric acid | 0·47 | Chloride of magnesium | 0·37 |
| Lime | 0·69 | Sulphate of lime | 0·79 |
| Magnesia | 0·15 | Chloride of sodium | 0·16 |
| Potass | 0·12 | Silicates of soda and potass | 2·22 |
| Soda | 0·94 | Nitrate of potass | trace. |
| Silicic acid | 1·25 | Organic matter | do. |
| Nitric acid | trace. | | |
| Organic matter | do. | | 4·25 |

An analysis of this water was published by me in Mr. Simon's report, already alluded to. With the accuracy of that analysis I never felt quite satisfied, partly on account of the small quantity of water on which I had operated, and partly, because I suspected that the German glass vessels employed by me, yielded up a portion of their substance, when water as pure as this was evaporated in them, a fact which I have since ascertained beyond all doubt. I determined, therefore, on the first opportunity, to re-analyze this water, especially as I had also some doubts whether the lime really existed in the water, in the state of carbonate of lime, as it is usually stated in the published analyses of Farnham waters.

The experiments I have recently made induce me to think that such is not the case; or, at all events, I cannot obtain experimental evidence of the presence of carbonic acid in combination with the earthy bases. For the following reasons I have therefore arranged the constituents of the water in the manner expressed in the second table, although, of course, other modes of combination might be suggested.

1, The residue left by the evaporation of the water is deliquescent, and the addition of a small quantity of water extracts nearly the whole of the earthy salts.

2, The insoluble matter left after the residue has been washed with water, does not effervesce on the addition of an acid.

3, That the potass and soda are in combination with silicic acid is, I think, rendered probable by the fact that the quantity of earthy and alkaline bases is more than sufficient to combine with the whole of the chlorine and sulphuric acid present; and also, that, when the water is evaporated to a small bulk, it manifests an alkaline reagency.

3rd. *Downlands.*—This sample of water was taken from a small spring called Wagner's Well. It is situated close to the road at the foot of a wooded hill about a mile from the "Seven Thorns" inn, on the Portsmouth Road. The well itself is a shallow basin, of about five feet in diameter, and about two feet in depth. From the whole surface of the bottom of the well the water rises, and, although the apparent quantity is not large, it is constantly flowing, and has never been known to dry up, even in the hottest summer..

The water is perfectly clear and transparent, inodorous, has no perceptible taste, and does not deposit any solid matter on standing. As a drinking water it is much admired by the people in the neighbourhood, and its sensible and chemical characters fully justify its reputation.

An imperial gallon, on evaporation to dryness, left a solid white residue, which dried at 230° Fahr.=4·76 grs. When heated red hot the residue became slightly charred, quickly resumed its white colour, and weighed 3·8 grs. Of this 0·18 gr. consisted of silica, the remainder of the chlorides of sodium, potassium, and calcium, with a small quantity of sulphuric acid magnesia, and a trace of oxide of iron. Hardness, as compared with distilled water taken as unity, 3·8.

4th. *Critchmere.*—Owing to an accident which occurred during the examination of this water I am unable to do more than give a general statement of its sensible qualities. To the eye it is bright, free from floating matter, and deposits nothing on standing. To the taste it is agreeably soft and flavourless, without being vapid. It contains less than 5 grs. of solid matter in the imperial gallon, and the residue left by evaporation contains but a very trifling quantity of organic matter. Hardness, distilled water being unity, =2·6.

The spot from which this water is derived is the shoulder of a small hill, or rather ridge of meadow land; the surface of which, for a considerable extent, is rendered quite soft and spongy by numberless small streams of water issuing from it. From this source a very considerable quantity of water might be obtained of a most unexceptionable quality.

5th. *Headly Down.*—This water was taken from one of a series of springs which arise at the bottom of a small valley that runs along a range of low sandhills.

It is a remarkably pure water, being perfectly free from dissolved organic matter. It is bright, almost brilliant, without the least perceptible taste, but agreeably soft and refreshing.

An imperial gallon left, on evaporation, a residue of 3·21 grs., which was perfectly white, and did not become at all charred when heated red hot. In its general chemical characters the water resembles that from Wagner's Well, but no trace of iron could be detected in it. Hardness, distilled water being unity, = 2.

Of the waters north of the Hogsback I have examined samples from Wishmoor Cross, Bagshot; also from the springs at Minley, and from Baker's Bridge.

*Wishmoor Bottom, Wishmoor Cross.*—This specimen of water was taken from a small swift running stream which runs through East Hampstead Heath. It was perfectly clear and transparent, but when concentrated by evaporation to about half its former bulk acquired a distinct yellow colour, and had a slight taste of vegetable matter.

The following analysis was made by Mr. Heisch. An imperial gallon evaporated to dryness left a residue, which dried at 300° Fahr., = 3·93. The residue from another imperial gallon when heated red-hot = 2·985 grs. The residue became very black when heated burnt with flame, and evidently contained organic matter:—

By Analysis an Imperial Gallon gave—

| | | | |
|---|---|---|---|
| Chlorine | 0·917 | Chloride of calcium | 0·66 |
| Lime | 0·39 | Chloride of magnesium | 0·07 |
| Magnesia | 0·06 | Chloride of potassium | 0·60 |
| Potass | 0·38 | Chloride of sodium | 0·27 |
| Soda | 0·91 | Carbonate of lime | 0·09 |
| Alumina | 0·04 | Carbonate of magnesia | 0·06 |
| Oxide of iron | 0·20 | Oxide of iron | 0·20 |
| Silica | 0·03 | Alumina | 0·04 |
| | | Silicate of soda | 1·75 |
| | | | 3·74 |

*Minley.*—This water was collected from one of the numerous shallow streams which intersect an extensive marsh containing several large ponds.

The water was slightly opalescent, and had a faint yellow tint, which became very distinct when concentrated by evaporation. On standing, small ochreous flocculi of organic matter and oxide of iron were deposited. It had a weedy taste.

Hardness, distilled water being unity, = 1·9. An imperial gallon, on evaporation, left a residue of 5·43 grs. when dried at 300° Fahr., which by ignition became black, and burnt into a white residue slightly coloured by oxide of iron. The residue weighed 4·56 grs. Of this residue 2·74 were soluble in water, 0·48 in muriatic acid, and 1·31 remained insoluble. The aqueous solution contained the chlorides of sodium, potassium, calcium, and magnesium, with the sulphates of those bases. The acid solution contained sulphate of lime, alumina, oxide of iron, and a trace of phosphoric acid.

Although the quantity of organic matter in this water is not numerically greater than is stated to be contained in some samples of Thames water, yet the colour and the taste of vegetable matter which this water possesses would preclude its being used for economical purposes, unless it could be obtained free from those impurities. Its opalescent appearance was perhaps accidental, as a large quantity of rain had fallen during the night previous to the morning on which the water was collected.

*Baker's Bridge.*—The water you sent me thus labelled is most remarkable on account of its extreme purity. An imperial gallon, when evaporated, left a residue of a slight yellow colour, which, dried at 230° Fahr., amounted only to 1·40 grs. Although 3 gallons of the water had been received for the purpose of making a quantitative analysis, I was obliged, on account of the small quantity of its solid constituents, to abandon the attempt. The solid residue consisted of the chlorides of calcium and sodium, the sulphates of those bases, and a small quantity of organic matter. The presence of iron could not be detected.

Hardness, distilled water being taken as unity, = 1.2.

Table exhibiting the relative hardness, and also the amount of solid matter, in an imperial gallon of water from the following places :—

| | Degree of Hardness—Distilled Water = 1. | Solid Matter in the Gallon when dried at 230° Fahr. |
|---|---|---|
| Whitley . . . . | 3·2 | 4·40 |
| Haslemere . . . | 2·6 | 5·58 |
| Downlands . . . | 3·7 | 4·76 |
| Critchmere . . . | 2·5 | .. |
| Headly Down . . . | 2·0 | 3·21 |
| Wishmoor Bottom . . | .. | 3·93 |
| Baker's Bridge . . . | 1·2 | 1·40 |
| Minley . . . . | 1·9 | 5·43 |

It will be, I think, sufficiently evident, from the above analyses, that the water from Haslemere, Whitley, Critchmere, Headly Down, Baker's Bridge, and Downlands, although slightly differing from each other in their chemical composition, are possessed of one common character, that of extreme purity.

The average quantity of solid matter in an imperial gallon of these waters does not exceed 3 or 4 grains, while the very best of the water at present supplied to the metropolis contains at least 17, and frequently rises to 21, grains in the gallon.

Taking the analyses by Messrs. Playfair, R. and J. A. Phillips, Clark and Ashley, of Thames water from Henley to London Bridge, I find the mean quantity of solid constituents in the gallon is 21·75 grains.

If freedom from any excess of saline or earthy constituents, oxide of iron, or organic matter, perfect transparency, with a total absence of any perceptible flavour, but leaving a soft, cool, and refreshing impression on the tongue, indicative of sufficient aëration, are to be considered the desirable characteristics of a good drinking water, these waters possess those qualities in an eminent degree, while their not giving any deposit upon being boiled, together with their increased solvent power, renders them peculiarly fitted for all culinary and manufacturing purposes.

To railway proprietors and others employing the motive power of steam, water like this would be most valuable, as it is more than probable that the boiler of a locomotive engine, supplied with such water, would not require cleaning as long as the engine itself lasted.

With regard to the water from Minley and Wishmoor Bottom, I cannot think that either of them is fit to be used. Its milky appearance gives an unsightly look to the former, while the quantity of organic matter both contain, together with the presence of $\frac{1}{350000}$

part of oxide of iron in the water from Wishmoor Cross, renders the use of these waters objectionable.

It is, however, to be observed, that both these waters were taken from brooks some miles from their source, and that the vegetable matter is evidently derived from the moor through which they have flowed.

This, among many other facts, clearly shows the necessity of strictly attending to the plan proposed, of collecting the waters at their *very source*, before they have had time to become contaminated with the various saline and mineral ingredients of the soil; and it is on this account that you have, in my mind, very wisely rejected from your plan the streams, pools, and other large collections of water so profusely scattered over the district.

But even were it shown that the water from Minley or Wishmoor could be obtained sufficiently pure, these sources of supply might be safely set aside, since it has been satisfactorily proved in the Report of Mr. Rammell, that the entire ascertained supply is very far above the requirements of the metropolis.

While upon the subject of supply, I cannot help remarking that the quantity of water at present issuing from many of the springs, might, in all probability, be much increased were the ground excavated, so as to form a shallow well from 10 to 20 feet in diameter, carefully steyned round with stones or well vitrified bricks. In this manner I believe that much of the water would be collected which, from not finding a ready vent, now steals insensibly away through hidden channels. The experiment might be tried at a very trifling cost, and Wagner's Well at Downlands appears to me an eligible spot for the trial.

We have been so long accustomed to the use of a comparatively hard, impure, and frequently a dirty water, that many persons cannot immediately perceive the great difference that exists between the present hard and the proposed soft water supply. Such persons are disposed to exclaim, when the subject is brought before their notice, that although it may be quite true that the Surrey waters are the best, yet that the other is sufficiently good for all purposes, and has served them for a very long time. But let these persons have placed before them, for the sake of comparison, a glass filled with water from both sources, and I will venture to assert that the most prejudiced will at once admit that, even supposing they are equally salubrious (a matter which admits of much doubt), it is worth a very considerable expense of time and money to make the exchange of a water which, if unfiltered, as is frequently the case, is either turbid or opalescent, and the taste of which, if not positively unpleasant, is flat and unrefreshing, for one that is bright to the eye, cool, soft, and refreshing to the palate.

When also told that the cool bright water contains but 3 or 4 grains of solid matter in the imperial gallon, and may be boiled down to a few ounces without depositing any sediment, while the other water cannot be heated without becoming milky, and if boiled for an hour or two deposits 10 or 12 grains of earthy matter from each gallon; and if to this be added, that the average hardness of one does not exceed 2·5°, while that of the other varies from 12° to 15°, I think they must admit that there are great and cogent reasons for no longer permitting the largest, wealthiest, and most densely populated spot on the face of the globe to be far inferior in its supply of that most necessary element of life—pure and undefiled water—not only to some of our own towns, but even to that of many continental cities, both of ancient and modern times.

With regard to the action of these waters upon lead, I have made the following experiments, which I will first briefly describe, and afterwards draw such conclusions as their result appears to warrant.

Pieces of sheet lead, exposing about twenty-one square inches of surface, were scraped bright, and placed in bottles completely filled with water from Witley, Haslemere, Baker's Bridge, and Wishmoor Bottom. The bottles were secured by good-fitting stoppers, firmly tied down, so that access of atmospheric air was wholly excluded.

Similar pieces of lead were likewise placed in bottles, the mouth of the bottle being left open, and the lead only partially immersed in the water. These experiments were made in order to illustrate the difference of action that takes place in leaden pipes supplied with water on the constant and on the intermittent system. The lead was placed in the bottles on the 7th January, and the water examined on the 19th April.

*Witley.*—Lead *wholly immersed, and air excluded.*—After the lapse of five days the lead became uniformly coated with a thin white uncrystalline film. At the termination of the experiment the film had not apparently increased in quantity, and no deposit of carbonate or oxide of lead was to be perceived at the bottom of the vessel. The water, on being carefully tested with sulphuretted hydrogen, in the presence of Mr. Heisch, and with every advantage of light, &c., did not exhibit the slightest trace of lead.

Lead *partially immersed, with access of air.*—After the lapse of four days the immersed portion of the lead became coated in the manner just described. At the expiration of a week a slight uncrystalline deposit was observed at the bottom of the vessel, and when finally examined the bottom of the vessel was sprinkled over with minute crystals of carbonate of lead. Sulphuretted hydrogen produced a very slight discolorization of the water.

*Haslemere.*—The action of this water upon lead is nearly similar to that from Witley.

*Baker's Bridge.*—Lead *wholly immersed, and air excluded.*—After having been immersed a week the lead was of a dark colour, no deposit was to be perceived on the bottom of the vessel or upon the lead itself, but, after the expiration of another week, crystals of carbonate of lead partially coated the surface of the lead. At the expiration of the experiment the whole of these crystals did not probably exceed 1-10th of a grain in weight. With sulphuretted hydrogen the water became so faintly discoloured as to be just perceptible.

Lead *partially immersed, with access of air.*—In two days the water became milky, and rapid formation of carbonate of lead took place, so that, when finally examined, the entire bottom of the vessel was covered with a deposit 1-10th of an inch in thickness. The supernatant water, when carefully decanted but not filtered, gave not the slightest indication of lead when tested by sulphuretted hydrogen.

*Wishmoor Bottom.—Lead wholly immersed, and air excluded.* Lead coated in spots with a white film—no deposit. Sulphuretted hydrogen produced a slight discolorization.

*Lead partially immersed, with access of air.—Very* slight deposit of carbonate and oxide of lead. Sulphuretted hydrogen produced a slight discolorization. The presence of iron in this water renders it doubtful whether the discolorization might not be owing to that metal.

*Downlands.—Lead wholly immersed, and air excluded.* After the lapse of twelve weeks, not the least sign of lead produced by sulphuretted hydrogen. The lead coated with a white uncrystalline film.

*Action of the water upon old leaden pipes.*—To ascertain whether these waters would, if transmitted through pipes already in use, dissolve any portion of the white crust of earthy matter and carbonate of lead which lines the interior of such pipes, a certain quantity of each water was kept for a week closely corked up in short lengths of an old pipe that had served for many years as the exhaust-pipe of a hard-water well, and had become much corroded. The same experiment was also tried with pipes which had served for the transmission of hard river water. In no instance could I detect the presence of lead in solution.

The result of these experiments tends to show that the above-mentioned waters, with the exception of the water from Baker's Bridge, exert but a very moderate action upon lead, even when placed under circumstances best adapted to favour that action. Also, that this action is materially diminished, though not absolutely prevented, by shutting out the access of atmospheric air.

The latter fact is strikingly shown in the case of the water from Baker's Bridge, which, when free to the air, oxidizes lead nearly as rapidly as distilled water; but when the air is excluded the formation of carbonate of lead is exceedingly small, as will be seen by reference to the experiment just related. These facts prove satisfactorily the necessity of keeping the pipes always charged with water, or, in other words, it forms an additional argument in favour of the advantages to be derived from a constant over an intermittent supply.

It is also to be observed that the lead is rarely dissolved in the water, but exists diffused through it in the form of thin shining scales or of a dense white powder. This is a general fact, and I have repeatedly convinced myself that the presence of lead cannot be detected by sulphuretted hydrogen in water that has been carefully decanted from a very copious deposit of carbonate of lead, even when pure distilled water has been the subject of trial.

Filtration of the water, prior to use, would therefore absolutely deprive it of every particle of lead; and if the filtering material were animal charcoal, or burnt bones, the whole of the lead would be abstracted, even if that lead were present in a state of actual solution.

Although desirous of expressing myself guardedly as to the possible effect that might be produced on the health of the community by the use of these soft waters when conveyed through leaden pipes, I cannot come to any other conclusion but that the formation of carbonate and of hydrated oxide of lead takes place so slowly in pipes kept constantly charged that no danger would arise. Every observation I have made confirms this view; and if we turn from the experiments of the laboratory and appeal to those practically made on the large scale in the towns of Aberdeen, Farnham, and in many of the towns in Lancashire and Cheshire, whose inhabitants have been for many years supplied with soft water conveyed by leaden pipes, we find from the evidence of competent and impartial observers, that not the slightest detriment to the health of the inhabitants has been experienced. This to my mind forms the most unobjectionable test to which the matter can be subjected, and if the statement be correct, must be conclusive. Dr. J. Smith, in a paper recently read before the Chemical Society of London, has stated that in many instances he could not detect lead in the soft water supplied to the town of Aberdeen, while in other cases lead was detected in quantities varying from $\frac{1}{100}$ of a grain to $\frac{1}{20}$ of a grain in the gallon; and he concludes, that water containing less than $\frac{1}{20}$ of a grain of lead in the gallon exerts no deleterious influence upon the animal economy.

It must not, however, be supposed that Thames and other hard river waters have no action upon the leaden pipes and cisterns in which they are contained. Contrary to all preconceived notions upon the subject, I have constantly found carbonate of lead in the sludge deposited by these waters. Hard well-waters exert a still greater action upon lead, as is shown by the rapidity with which cisterns containing such water are frequently eat into holes or otherwise eroded.

Upon these and some other points connected with the action of water upon lead, I am at present engaged in a strict investigation. I have arrived at the general fact that, under ordinary circumstances, all natural waters act upon lead with formation of oxide and carbonate of lead; but that the amount of action varies considerably, and depends upon extraneous and accidental circumstances.

Such being the case, it is much to be desired that even the possibility of danger should be averted, by abandoning lead altogether as a material for storing or conveying water. For cisterns (if cisterns are necessary) slate forms an excellent substitute, while for pipes, iron lined with a vitrifiable crust, or with the hard and very durable varnish which that metal acquires, when it is brushed over, while heated red-hot, with linseed oil, would furnish a material which, as regards economy, strength, cleanliness, and salubrity, would fulfil every desideratum required.

I have the honour to remain,
Dear Sir,
Your very obedient Servant,
THOMAS TAYLOR,
Lecturer on Chemistry at the Medical School of the Middlesex Hospital.

4, *Vere-street*, *Cavendish-square*,
*April 24th*, 1851.

( B. )

Gwydyr House, Whitehall,
Nov. 5, 1850.

My Lords and Gentlemen,

The Hon. William Napier having shown in a Report to your Honourable Board, upon an extended examination of the proposed gathering-grounds for the supply of water to the metropolis, that the natural deep springs of the district yield water of exceedingly pure and soft quality, and in quantity beyond the estimated requirements; and from the importance of the subject it being expedient that further inquiry should be made, in order that the statements in that paper, and more particularly as to the quantities to be obtained from these sources, might be verified, you were pleased to direct me, by Minute dated the 18th ult., to visit the parts, and to make such examinations and gaugings as would enable me to report to you upon the case.

I accordingly immediately proceeded to Farnham, where Mr. Napier then was, and having placed myself in communication with that gentleman, received from him every information that could facilitate the attainment of the object in view, besides much personal assistance. Mr. Napier undertook to accompany me over the district, and to point out the various streams included in his calculations, and the precise spots where he had gauged them.

I determined to carry my examination over the whole of the proposed area of supply; conceiving that if it were limited to a part only, the results would be of comparatively little value; and was employed in this way, and in gauging the various sources, from the 19th to the 29th ult. inclusive.

As the weather may be supposed to have had some influence upon the gaugings, it will be proper to give a few particulars concerning it. Up to the time of my leaving town, for many months the weather had been almost uninterruptedly fine; indeed the spring, summer, and autumn were all unusually dry seasons. On the 19th, 20th, 21st, and 22nd no rain fell; the morning of the 23rd was wet; on the 24th a light rain commenced about 11 o'clock, and continued, with little intermission, during the rest of the day; the 25th, 26th, 27th, 28th, and 29th were perfectly fine, excepting the night of the 27th, when it rained rather heavily. Altogether the quantity of rain that fell was of small amount, and, I am satisfied, had no effect whatever upon the gaugings.

The porous soil of the district, under the influence of a long drought, quickly absorbed the rainfall, and prevented any inconvenience from surface-water. With regard to the springs themselves, they appear to be much too deep-seated to be affected in the least degree by the daily rain.

The testimony of old inhabitants whom I questioned about their permanency and equability of discharge, went to prove that the springs are quite insensible, even to the heaviest and longest continued rains, or at least until after a considerable lapse of time. It appears that their flow, though somewhat greater in the spring, and less in the autumn, remains very constant throughout the year. No one was prepared to assert that in March, when the winter rains have taken full effect, the volume of the springs is greater by one-half than in October and November, when the same may be said of the summer-droughts; while all concurred in stating that they had never been known lower than at that time. Upon this point I was most careful to obtain complete evidence, as the whole structure of the spring-water scheme of supply rests upon it; and the table of quantities which I have prepared may be confidently regarded as exhibiting the minimum yield of the springs at any period of the year.

A few words should be given in explanation of the mode of gauging adopted.

It was at first my intention actually to measure every stream, not too large to be so dealt with, into a vessel of known capacity, as in this way the results arrived at would have been reduced to absolute certainty and placed beyond dispute. With this view I caused to be prepared an open box or tank, 5 feet long by 2 feet wide, and 1 foot deep, containing 10 cubic feet, a capacity which, it appeared to me, the majority of the smaller streams would be sufficiently long in filling to admit of the seconds of time being accurately counted. The box, with proper troughs, was to be fixed at the side of the stream to be gauged, in such manner that the flow of water could be, on a given signal, instantly and wholly diverted into it. On putting the plan into operation, however, I found an insuperable obstacle to its success, in the porous nature of the beds of the streams, which rendered all attempts to intercept or divert the whole of the flow hopeless. From this cause it was quite impracticable either to dam up the water effectually, or to lead it along an artificial channel, laid at a less inclination, for discharge into the box. Most of the smaller streams have beds of perfectly clean gravel, through which, on the current being arrested, escape immediately takes place. It appeared, indeed, on close examination, that even the ordinary run of these streams is not wholly over or above the surface, but partly within the bed of the channel itself, much of the water thus passing away insensibly between the pebbles.

Any attempt to dam up these streams, with a view to gauging over a weir, must have failed from the same cause. Under these circumstances I had no option but to abandon my idea of measurement into vessels.

I then determined, as the best remaining means of arriving at certain results, to proceed as follows; selecting in all cases for measurement the most even part of the channel of the stream, so that the nearest uniform sectional area might be obtained throughout.

To obtain the velocity of flow on the surface by floating light substances, not only down the centre of the current, but along the sides of the stream; and also beneath the surface as far as possible, by observing the motion of any small particles of solid matter in the body of the water; thus in fact studying the movement of the stream throughout its whole section in order to make allowance on the spot for an average velocity.

In this way I am confident that far more accurate results have been obtained, than by the application of any of the many better known formulæ; all of which not only differ from each other, but have been shown to give results widely at variance with actual experiment.

The varied conditions of the streams,—some spread out in a thin sheet, others confined within a narrow and deep channel; some passing over a smooth bed, others over pebbles or inequalities, which, if the water was shallow, appeared in indentations or ripples on its surface; some creeping slowly along, others running at a high velocity; some having the current most rapid in the centre, others towards one of the sides, or in two or more parts of the section; some moving unevenly, others with a steady and uniform flow,—would have rendered any such arbitrary mode of measurement highly erroneous.

Before submitting the table of quantities it will be proper to give a short description of the parts which came under the more extended examination of Mr. Napier; and as this would be rendered more clearly in combination with the remainder of the district, I shall endeavour to sketch the whole, trusting that the Board will pardon the repetition of facts already within their knowledge.

The total area included is of very considerable extent. Taking Farnham as a point of departure, the district stretches northward beyond Sandhurst and Bagshot to Wokingham, Sunning Hill, and Virginia Water; and southward to the distant villages of Bramshot and Haslemere. On the western side its limits would be defined by a nearly straight line passing through Barkham, Eversley, Crondall, and Kingsley; while its eastern and south-eastern boundary, which is extremely irregular, would be marked by Chobham, Pirbright, Guildford, and Dorking, and the high watershed line stretching from the Leith Hill to the Hindhead. The length, from north to south, is about 25 miles, and the extreme breadth, from east to west, about 24 miles; the whole area included exceeding 300 square miles.

Of the three geological formations of which the district consists, the chalk appears in a high and straight ridge running westward from Dorking, through Guildford and Farnham. This rock, however, occupies only a very narrow strip of the area, and serves merely to divide the Bagshot sands on the north, from the greensand on the south, which latter formations—whose beds consisting almost entirely of pure silicious sand, in fact, constitute two enormous filtering reservoirs many miles in extent—form the only available portions of the district. The Board already possesses, in the evidence of Mr. R. Austen and Professor Ramsay, ample information as to the composition of these beds.

Parts of four distinct drainage areas are included within the limits. The valley of the Wey runs along the eastern side of the northern section, and across nearly the whole of the southern section. The Blackwater and other tributaries of the Loddon drain the large remainder of the northern section, except the upper part of its eastern side, which draws towards the Bourne Brook. The extreme western end of the southern section falls into the Mole.

The Wey drains about 310 square miles (230 of which are south of Guildford), the Loddon 250 square miles, the Mole 210 square miles, and the Bourne Brook 35 square miles; so that together these rivers carry off the drainage-waters of about 700 square miles of country. They all receive accessions of water from various formations. The Wey rises in the chalk, and has branches from the greensand, the Wealden, the Bagshots, and the London clay. The Loddon also rises in the chalk, while its principal tributary, the Blackwater, proceeds from the Bagshots. The Bourne Brook is chiefly fed from the Bagshots. The Mole rises in the Wealden, and passes successively through the greensand, the chalk, and the tertiaries.

Mr. Napier found that the variations of hardness which had been detected at different points of the streams in the lower levels, also existed in the small rivulets, falling down the hill sides, or occupying the bottom lines of the more elevated valleys, and still continued, but always with less indications of hardness, as these were traced up to their parent springs, where, in every case, the application of the tests showed a remarkable degree of purity in the water.

After a lengthened and minute examination chiefly of the more elevated parts of the district, he succeeded in discovering numerous springs, whose hardness did not exceed 1 degree, by Dr. Clark's test, and which, together with others previously known, made up a very considerable volume of water.

It then occurred to him to ascertain whether a sufficient quantity of water might not be obtained from the pure springs themselves to serve for the supply of the whole metropolis.

These springs all proceed either from the Bagshots, or the greensand, which formations, as before stated, are separated from each other by a high chalk-ridge, into a northern and a southern section. They occur in several distinct groups. The principal group issues from the greensand, and lies in the southern section of the district, between Godalming and the western limits. Here the spring-waters, even after they have run together into considerable streams, have lost little of their original purity and softness. Thus the Bramshot stream, where 13 feet wide by 9½ inches deep; the Sweet-water Pond stream, where 6 feet wide by 1 foot deep; the Cosford House stream, where 4 feet 6 inches wide by 7½ inches deep, show only from 1 to 1½ degrees of hardness. Another group on the greensand lies between Guildford and Dorking, where the springs are collected together into three main streams. The most important group in the northern section, which consists entirely of the Bagshots, issues at that part extending from near Frimley westward through Sandhurst to Eversley, and southward to near Fleet Pond. One stream here measures 18 feet wide by 1 foot deep. A second group occurs on the extreme upper edge of the northern section, extending from Barkham through Wokingham, to near Virginia Water; a third in the neighbourhood of Bagshot, its produce falling into the Bourne Brook; and a fourth near Pirbright, falling into the lower course of the Wey.

Mr. Napier's gaugings of the several groups gave the large quantity of 39½ millions of gallons daily; and his general examination led him to the conclusion that 10 millions more under two degrees of hardness might be obtained from other sources.

It was to test the accuracy of these calculations that I was directed to visit the district.

With regard to the first quantity of 39½ millions, the following table, which contains the results of my gaugings of 45 spring-water streams pointed out by Mr. Napier as not exceeding 1 degree of hardness, being with one or two insignificant exceptions the whole of those included in his list, will show that it has not only been realized by me, but that a considerable excess has been obtained above it.

TABLE of SPRING-WATER STREAMS in the Farnham and Hind Head District, showing the Sectional Area, and estimated Daily Discharge of each stream.

| | DESIGNATION. | SECTIONAL AREA. | | DISCHARGE PER 24 HOURS. | |
|---|---|---|---|---|---|
| | | Dimensions. | Area. | Individual Streams. | Totals. |
| | | Ft. In. Ft. In. | Ft. In. | Gallons. | Gallons. |
| | SPRING-WATER STREAMS FALLING INTO THE WEY (*above Guildford*). | | | | |
| 1 | Holy Water . . . . | 9 0 × 0 7 | = 5 3 | 2,703,000 | . . |
| 2 | Bramshot . . . . | 13 0 × 0 9½ | = 10 3½ | 7,953,000 | . . |
| 3 | Downlands (*a*) . . . | 2 6 × 0 5 | = 1 0½ | 803,000 | . |
| 4 | Downlands (*b*) . . . | 2 0 × 0 4 | = 0 8 | 600,000 | . . |
| 5 | Headley Down . . . | 1 3 × 0 4 | = 0 5 | 313,000 | . . |
| 6 | Barford Mills (*a*) . . | 2 3 × 0 4 | = 0 9 | 810,000 | . . |
| 7 | Barford Mills (*b*) . . | 3 0 × 0 7 | = 1 9 | 630,000 | . . |
| 8 | Devil's Jumps (*a*) . . | 1 3 × 0 2 | = 0 2½ | 58,000 | . . |
| 9 | Devil's Jumps (*b*) . . | 1 6 × 0 4½ | = 0 6¾ | 885,000 | . . |
| 10 | Devil's Punch Bowl (*a*) | 1 6 × 0 3 | = 0 4½ | 305,000 | . . |
| 11 | Devil's Punch Bowl (*b*) | 4 0 × 0 4 | = 1 4 | 544,000 | . . |
| 12 | Cosford House . . . | 4 6 × 0 7½ | = 2 9¾ | 3,417,000 | . . |
| 13 | Lea . . . . . . . | 2 3 × 0 2½ | = 0 5½ | 632,000 | . . |
| 14 | Sweetwater Pond . . | 6 0 × 1 0 | = 6 0 | 3,780,000 | . . |
| 15 | Chapel Copse . . . | 2 6 × 0 1½ | = 0 3¾ | 210,000 | . . |
| 16 | Bush Bridge . . . . | 2 6 × 0 4½ | = 0 11¼ | 632,000 | . . |
| 17 | Potsford . . . . . | 6 6 × 0 6 | = 3 3 | 3,510,000 | . . |
| 18 | Wotton . . . . . . | 3 8 × 0 2½ | = 0 9 | 1,316,000 | . . |
| | (*Below Guildford.*) | | | | |
| 19 | Pirbright (*a*) . . . | 5 0 × 0 4½ | = 1 10½ | 1,265,000 | . . |
| 20 | Pirbright (*b*) . . . | 5 0 × 0 5 | = 2 1 | 703,000 | . |
| 21 | Cow Moor . . . . | 2 3 × 0 1½ | = 0 3¼ | 168,000 | . . |
| | | | | | 31,237,000 |
| | SPRING-WATER STREAMS FALLING INTO THE LODDON (*Blackwater branch*). | | | | |
| 22 | Aqueduct . . . . | 1 0 × 0 1½ | = 0 1½ | 135,000 | . . |
| 23 | Northfleet . . . . | 18 0 × 1 0 | = 18 0 | 8,251,000 | . . |
| 24 | Minley . . . . . . | 4 0 × 0 4 | = 1 4 | 480,000 | . . |
| 25 | Bristow Farm . . . | 1 3 × 0 3 | = 0 3¾ | 281,000 | . . |
| 26 | Wish Moor . . . . | 3 5 × 0 3½ | = 0 11¾ | 806,000 | . . |
| 27 | Sandhurst (*a*) . . . | 1 6 × 0 1½ | = 0 2¼ | 63,000 | . . |
| 28 | Sandhurst (*b*) . . . | 3 0 × 0 3 | = 0 9 | 506,000 | . . |
| 29 | Broad Moor . . . . | 2 6 × 0 4½ | = 0 11¼ | 723,000 | . . |
| 30 | Ambarrow Hill . . . | 1 6 × 0 1½ | = 0 2¼ | 112,000 | . . |
| 31 | Yateley (*a*) . . . . | 1 2 × 0 2 | = 0 2¼ | 116,000 | . . |
| 32 | Yateley (*b*) . . . . | 1 2 × 0 1½ | = 0 1¾ | 49,000 | . . |
| 33 | Upgreen . . . . . | 1 3 × 0 1 | = 0 1¼ | 48,000 | . . |
| 34 | Eversley . . . . . | 1 2 × 0 2½ | = 0 3 | 186,000 | . . |
| | Carried forward . . | . . | 64 10¾ | 11,756,000 | 31,237,000 |

| | Designation. | Sectional Area. Dimensions. | Sectional Area. Area. | Discharge per 24 Hours. Individual Streams. | Discharge per 24 Hours. Totals. |
|---|---|---|---|---|---|
| | | Ft. In. Ft. In. | Ft. In. | Gallons. | Gallons. |
| | Brought forward . . | . . | 64 10¾ | 11,756,000 | 31,237,000 |
| | (*Other tributaries.*) | | | | |
| 35 | Barkham . . . . . | 5 0×0 6½ = | 2 8½ | 487,000 | . . |
| 36 | Wokingham . . . . | 6 0×0 5 = | 2 6 | 1,687,000 | . . |
| 37 | Ham Hall . . . . . | 4 0×0 8 = | 2 8 | 880,000 | . . |
| 38 | Bull Brook . . . . | 2 3×1 0 = | 2 3 | 759,000 | . . |
| | | | | | 15,569,000 |
| | Spring-water streams falling into the Bourne Brook. | | | | |
| 39 | Coldingly Moor . . . | 6 0×0 3½ = | 1 9 | 1,181,000 | . . |
| 40 | The Folly . . . . . | 1 9×0 3½ = | 0 6 | 344,000 | . . |
| 41 | Bagshot (*a*) . . . . | 0 9×0 2 = | 0 1½ | 112,000 | . . |
| 42 | Bagshot (*b*) . . . . | 0 8×0 1½ = | 0 1 | 32,000 | . . |
| 43 | Bagshot (*c*) . . . . | 3 0×0 2 = | 0 6 | 450,000 | . . |
| 44 | Bagshot (*d*) . . . . | 1 3×0 4 = | 0 5 | 450,000 | . . |
| | | | | | 2,569,000 |
| | Spring-water stream falling into the Mole. | | | | |
| 45 | The Rookery . . . | 4 0×1 0 = | 3 4 | 2,000,000 | 2,000,000 |
| | Total sectional area of the 45 streams gauged . . . . | . . . . . | 81 8¾ Square Ft. | . . | . . |
| | Total estimated daily discharge . . . | . . . . . | . . | . . . . . | 51,375,000 Gallons. |

From the above table it appears that 21 spring-water streams falling into the valley of the Wey, yield together a daily supply of 31,237,000 gallons, of which quantity the Bramshot stream alone produces nearly 8,000,000, and three others average 3½ millions each; that 17 spring-water streams falling into the Blackwater and other tributaries of the Loddon yield 15,569,000 gallons daily, the Northfleet stream alone giving more than half the quantity; that six streams falling into the Bourne Brook yield 2,569,000 gallons daily; that one stream falling into the Mole yields 2,000,000 gallons daily; and that the entire number of streams yield 51,375,000 gallons daily, being 11,875,000 in excess of the quantity of 39½ millions calculated by Mr. Napier.

It also appears that the aggregate sectional area of the 45 spring-water streams measured amounts to more than 81 square feet, from which it follows, that their mean rate of flow to produce the quantity of 51 millions of gallons is equal to 1·16 foot per second, or 0·80 mile per hour.

The gross daily quantity of water pumped into London by the various Companies has been shown to be upwards of 44 millions of gallons daily, which supply would be delivered in 24 hours by a brook 9 feet wide and 3 feet deep, running at the rate of 3 feet per second, or little more than two miles per hour.

To deliver the body of water discharged by the 45 springs at the same rate of flow, a brook 10 feet 3 inches wide, and 3 feet deep, would be requisite; while to deliver it at the actual mean rate of flow of the springs, the channel with a depth of 3 feet must be 27 feet wide.

With regard to the additional quantity of 10 millions of gallons, under 2 degrees of hardness, calculated upon by Mr. Napier, I beg to state that, after a careful consideration, I am of opinion that he has not over-estimated the further capabilities of the district. The numerous little threads of water which trickle, almost unperceived, into the larger streams, below the points where they were gauged, and sources existing in other parts of the district, but not included in the table, if collected together, would make up a very considerable quantity, and I think quite justify this further estimate.

It follows, then, as the result of my examination and gaugings, that the minimum available yield of the deep springs of the district may be estimated in round numbers at 61 millions of gallons daily, of which quantity 51 millions have been ascertained by Mr. Napier not to exceed 1 degree of hardness, and the remaining 10 is considered by him to be under 2 degrees of hardness.

In the Report of the Board upon the Supply of Water to the Metropolis, the present daily requirements of the population are estimated at 40 millions of gallons, being less than 2-3rds of the above quantity.

In conclusion, I propose to calculate the proportion which this quantity of 40 millions of gallons daily bears to an assumed whole quantity brought down by the main streams occupying the several drainage areas, and having their outfalls into the Thames.

The average annual rainfall of the district is about 24 inches. Assuming that 2-3rds of this quantity falls, either directly, as surface-water, or indirectly, in the shape of springs, into the river channels; the remainder, with the deposits from dew and mist, being returned again to the atmosphere by evaporation, or consumed in other ways, a total annual depth of 16 inches over the whole area will pass down the respective streams.

A basin, 63 square miles in extent, and 16 inches deep, would contain the whole annual quantity required for the supply of the metropolis, at the rate of 40 millions of gallons daily.

Supposing this supply to be drawn in nearly equal proportions from the whole of the 45 spring-water streams named in the table, we shall have, in round numbers, the yield of 38 square miles abstracted from the Wey, being that of about 1-8th part of its whole drainage area; the yield of 19 square miles abstracted from the Loddon, being that of about 1-13th part of its whole drainage area; the yield of 3 square miles abstracted from the Bourne Brook, being less than that of 1-11th part of its whole drainage area; and the yield of 3 square miles abstracted from the Mole, being that of 1-70th part of its whole drainage area.

I have the honour to be,

My Lords and Gentlemen,

Your very obedient Servant,

THOMAS WEBSTER RAMMELL.

*The General Board of Health,*
*&c. &c.*

( C. )

The New River Company have issued a report on the soft water sources, by Mr. Rowlandson, an engineer, employed, as he states, "to examine the district, and report generally on the nature of the scheme."

Having carefully read this paper, I think it right to answer those of the objections advanced, as appear sufficiently plausible to cause doubt to be thrown on the practicability of the proposal to adopt the soft spring waters of Farnham and Hindhead for the future source of supply of the metropolis.

The points of local investigation in this question, that strictly concern an engineer, are twofold, and may be thus expressed.

1st. Is the water of the quality intimated in my first paper?
2nd. Do the springs yield the quantity stated?

To such statements in the New River Report, as would appear to answer these questions in the negative, I would request the attention of the General Board.

Mr. Rowlandson's method of analysis of the quality of the spring-water is strange indeed, and not very indicative of any wish to obtain a knowledge of its chemical character.

I will now give extracts from pages 15 to 19, which are devoted to the consideration of quality.

Alluding to Bagshot Heath district:—

"The springs on this district are sometimes faintly coloured with decaying vegetable matter."

"The springs which issue at the margin of these sands, owing to the water coming in contact with the London clay, frequently possess a chalybeate taste."

Alluding to the water from the greensand:—

"The general character of the water procurable from the greensand district, is of much better quality in appearance than that which can be obtained from the Bagshot sand. On the green sands, the peaty surface is generally intermixed with a slight amount of clay, which tends to permit the water to flow off clearer than it is usually found from peaty surfaces."

"Sweet-water Pond is the most unfavourable specimen which I saw in this district."

"The fine stream at Bramshot is objectionable on account of its being so much used as an irrigant, which gives it the character of ordinary surface washings."

"I believe it will be found, that the average water from the greensand district will be about 5° to 6° of hardness, which will be increased, in dry seasons, to from 10° to 12°. It will, perhaps, be a fair estimate to set the waters from the greensand at one-half the hardness of the Thames water; if the water is obtained much softer in any particular spot on the greensand, it will be found to arise from an admixture of peat, or being largely diluted with rain water; in other words, surface washings, not springs."

Mr. Rowlandson's condensed analysis appears then to be a simple record of his own opinion, that the Bagshot spring water is peaty, and possesses a chalybeate taste; while that from the greensand, though better in quality, is, at a fair estimate, one-half of the hardness of Thames water.

I might answer, that mere assertions are no evidence, and could adduce, in opposition, my own chemical examinations and quantitative analysis of the water; but, fortunately, the public have it in their power to test the value of such statements by referring to the published decision on this point of the City medical officer, in his report for 1849—50. Turning to page 68, I find the following testimony:—

"I have spent three days on the site of the proposed sources, and many other days in informing myself on all the bearings of the subject. I have likewise collected water from a proposed tributary of the future supply, which has been analysed, and which shows (as my Appendix will illustrate to you) a remarkable and rare excellence. On one occasion of visiting the country, I was accompanied by Mr. T. Taylor, and we made on the spot a sufficient number of extemporaneous examinations to assure us that the essential features shown in the more elaborate analysis are (as geological considerations would lead us to believe) the general character of water throughout the district."

Such is Mr. Simon's opinion.

In the Appendix quoted, Mr. Taylor, the Professor of Chemistry at Middlesex Hospital, gives the hardness of the waters examined (taking distilled water at unity) at Haslemere 2·4°, at Boorley 1·5°, and at Barford 2·4°. Reducing this scale to that of Dr. Clarke, viz., taking distilled water at 0, the worst specimen is 1·4°, and the best half a degree of hardness, thus verifying my own experiments. I therefore re-assert, with undiminished confidence, that the average hardness of the soft spring water, if taken from the source, will prove to be one degree, or 1-15th, instead of half that of the Thames. The prophecy of the hardness being doubled during the dry weather will not be realized; for my own and Mr. Taylor's examinations were both conducted during the autumn, after an unusually hot and rainless summer.

Mr. Rowlandson's remarks and observations show that he did not examine the springs, indicated and selected, at their sources, for in no one instance are they to be found either peaty or chalybeate. It does seem unaccountable that Sweet-water Pond, itself a dammed-up stream of springs, should have been examined for quality when the feeding springs are situated just at the head and tail of the pond, and whose clear and sparkling waters, the admiration of the whole country round, could scarcely have escaped the eye of any but the wilfully blind.

Mr. Rowlandson's knowledge, however, of the character of this water unconsciously slips out at page 8, where he says, "there are some very fine springs which fall into this stream adjoining Mr. Chandler's residence." That gentleman's house may be about two or three hundred yards distant from the pond.

The statement that any softer water than 5° or 6° will be found to arise from an admixture of peat is incomprehensible. That peat possesses such a softening power is certainly a new discovery in chemical science.

Mr. Rowlandson's observation, that the "fine stream at Bramshot is objectionable on account of its being so much used as an irrigant," is extraordinary, when made in the face of the leading principle of the proposed soft water scheme, which establishes that no water shall be used but that of the springs led away from their sources, whether from boiling springs or oozing springs, drained on Mr. Elkington's plan. I think the subject of quality may now be dismissed.

The question of the quantity of available spring water now remains to be considered.

My original gaugings of the separate springs gave an aggregate discharge per day of 40 million gallons.

Mr. Rammell's more professional examination of the same sources, with a few additional springs, produced 51 million gallons.

Mr. Rowlandson estimates the whole quantity of water available in the district to be 53,490,000 gallons, of which he states 11,750,000 gallons only are spring water; the remainder, 41,640,000 gallons, are set down as surface washings.

As no list of springs, with their discharge, is given in the report, it is impossible to compare the separate items producing the three above-mentioned results; but Mr. Rammell's and Mr. Rowlandson's estimates are not much at variance. I confess, however, I am at a loss to understand by what means the quantity attributed to springs by Mr. Rowlandson, was separated from that of so-called surface washings; and on what principle is founded the assertion, that 4-5ths of the total daily discharge of the springs is surface washings.

Let me ask, that if the upper outfalls of the springs, rising in the vast and deep sands of this district, when gauged after a very dry spring and summer, and a drought of nearly two months' duration, gave, at the lowest estimate, a discharge of 40,000,000 gallons per day, how could any one drop of that quantity be surface washings? At such a time, the flow of the brooks was pure spring water, every gallon of which may be led away from its source, in earthenware pipes, uncontaminated by the flow over the surface of summer storms, or periodical winter rains.

It does appear to me, that Mr. Rowlandson, while acknowledging the fact of a daily discharge of upwards of 53,000,000 gallons from the springs, has endeavoured to throw discredit upon my assertion of the available quantity of pure spring water, by assuming that it was contemplated to use the water after it served the purposes of irrigation.

The most cursory reading of the nature of the proposal, as published in the 'Times' newspaper, will show how gratuitous is this assumption; and I repeat, once more, that both classes of springs, as already referred to, may be collected under the conditions proposed, in the quantity and of the quality originally set forth; the quantity having been confirmed by Mr. Rammell, and the quality by the medical officer of the City of London.

William Napier.

*London, April* 10, 1851.

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TIGHT GUTTER.