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### **Contributors**

Thorne, Richard Thorne.

London School of Hygiene and Tropical Medicine

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Wellcome Collection  
183 Euston Road  
London NW1 2BE UK  
T +44 (0)20 7611 8722  
E [library@wellcomecollection.org](mailto:library@wellcomecollection.org)  
<https://wellcomecollection.org>

**Dr. Thorne Thorne's Report to the Local Government Board on an Extensive Epidemic of Enteric Fever, affecting especially Red Hill, in the Urban Sanitary District of Reigate, and Caterham in the Rural Sanitary District of Godstone.**

GEORGE BUCHANAN,

Assistant Medical Officer,

7th April, 1879.

On February the 4th last the Local Government Board received a communication from Dr. H. C. Hilliard, of Caterham, to the effect that within the previous 10 days 25 cases of enteric fever had come under his notice in that place. The outbreak was explained to have been sudden in its occurrence, and, as the result of some inquiry which he had made, Dr. Hilliard stated his belief that the disease had been conveyed by means of the water supplied by the Caterham Waterworks Company. Under these circumstances I, on the same day, received instructions to make immediate inquiry into the causes of the outbreak. This inquiry was commenced on February 5th, and it was continued at intervals until early in the following month.

On reaching Caterham I found that the other medical practitioners in the place had also been called in to a considerable number of cases of the same disease. The first person attacked had sickened on January 19th; a second attack occurred on January 20th, two more on the 23rd, three on the 24th, and from then up to February 2nd, to which date information was at first limited, fresh attacks in fresh houses had occurred day by day, the total number of houses affected being 35, and the total number of sick being 47. The daily number of attacks which came under medical treatment had varied from one on January 19th, 20th, and 30th to ten on February 1st. This group of 47 cases, included as they were within a fortnight, was at once made the subject of inquiry.

Caterham is situated in the rural sanitary district of Godstone, and it has a population of about 5,800. One part of it, which will in this Report be called Lower Caterham, occupies a position near to the southern extremity or head of the Caterham Valley, a valley bounded by chalk hills, extending north and south for a distance of about 5 miles, and opening out at Caterham Junction about half way between Caterham and Croydon. The houses in Lower Caterham consist mainly of superior villa residences, many of which have been built within recent years. The other part, or Upper Caterham, lies at a higher altitude at the southern end of the range which bounds the valley on the west. Here also are a number of villas, the old village of Caterham, one of the asylums belonging to the Metropolitan District Asylums Board, and the barracks of H.M.'s Foot Guards.

The cases of enteric fever above referred to, and which had occurred in the fortnight ending February 2nd, were spread over a very wide area, some in Upper, some in Lower Caterham, extending to the extreme outskirts of those places. The houses attacked belonged to no special class, both rich and poor having suffered. It was at once apparent that the disease could not have been conveyed to the affected houses by means of any general system of sewers common to the district, for by far the majority of the houses were found to drain into separate cesspools excavated into the chalk; some of these cesspools, as also the house drains, being efficiently ventilated, others having no such ventilation. Some of the houses affected had no artificial means of drainage, the liquid refuse being thrown on to gardens adjoining them. There was also no possibility that there had been any common cause of infection in connexion with the prevailing means of excrement disposal, because there was nothing in common with regard to such disposal. Most of the houses in which the disease had appeared were provided with waterclosets, a considerable number of which were apparently well trapped and ventilated. Others had closets which were fitted with a trap and pan and emptied into cesspools, and though these closets were at times a source of nuisance owing to the absence of any flushing apparatus, yet they were all situated out of doors. Others again were provided with common privies and a few with earth-closets. The possibility of infection having been communicated by means of a milk-supply was next inquired into, and it was ascertained that 33 of the houses affected received their milk from at least five different and completely independent dairies, and that, at the remaining two, private cows were kept. It was also evident that personal infection could not in any way have led to the outbreak.

Further, there was no history of any recent prevalence of enteric fever in Caterham. It was stated that the locality for some years past had been remarkably free from the



disease, and during the twelve months preceding the outbreak only one isolated case could be heard of. This is believed to have been an imported case, and it terminated fatally on August 16th, 1878.

With regard to the water-supply, it was ascertained that out of a total of 558 houses in Caterham, 419 were provided with water from the mains of the Caterham Waterworks Company, the remaining 139 deriving their supply from local wells or from rain-water-tanks and barrels. Of the 47 persons attacked during the fortnight January 19th—February 2nd, 45 resided in houses where the water of the Caterham Waterworks Company was in use, a circumstance which, having regard to the other points already adverted to, indicated a likelihood that this water had been the means by which the infection had been conveyed. This view received confirmation when it was further ascertained that the two remaining patients, who resided on premises where private wells were in use, had, owing to the nature of their employment, not only been in the habit of spending the day at houses to which the Company's water was laid on, but had admittedly used this water.

I further ascertained from Dr. James Adam, Medical Superintendent of the Caterham Asylum, that no case had arisen in that establishment, where nearly 2,000 patients are under treatment; and also from Dr. James Magill, Coldstream Guards, that there had been a similar immunity from the disease amongst the 500 men under his charge in the Caterham Barracks. Both these establishments derive their entire water-supply from a well which belongs to the Metropolitan Asylums Board, and which is sunk to a depth of 462 feet into the chalk. The same has remained true up to the present time.

In the meantime, however, I received information from several sources, notably from Mr. E. L. Jacob, Medical Officer of Health for the combined sanitary districts of Surrey, to the effect that enteric fever was also epidemic in Red Hill.

At Redhill, inquiries similar to those which I had made in Caterham, had been undertaken by Mr. Jacob, and to him I am indebted for the greater part of the detailed information as to the cause of the epidemic in that locality.

Red Hill, including Earlswood village, the Earlswood Asylum for Idiots, and a district known as Mead Vale, forms the eastern ward of the borough of Reigate, and it has an estimated population of 9,500. It is situated about eight miles by road from Caterham, and it differs from that place in several material respects. It lies on a different geological formation, namely, on the lower green sand; it is nearly throughout provided with a modern system of sewers, which is believed to be efficiently constructed and efficiently ventilated, and many of the drains connecting the houses with the sewers are also ventilated. But, in regard of the epidemic of enteric fever, the two places presented certain remarkable points of similarity. In both the epidemic had commenced at about the same time. In Red Hill, the first two attacks were reported to have occurred on January 20th; these were followed by 3 others on the 21st, 5 more on the 22nd, 12 on the 23rd, and at the expiration of the first fortnight, viz., by February 2nd, fresh attacks in fresh houses had every day occurred until the total number of houses affected was 96, and the number of patients had reached 132. The sewers, it is true, were common to the greater part of the district affected, but in this respect there were some striking exceptions, to which reference will be made, and so far as prior cases were concerned from which the infection could have been communicated by means of the sewers, there was evidence to the effect that Red Hill had been for at least eighteen months past quite free from the disease. The milk-supply of the houses affected was also ascertained by Mr. Jacob to have been derived from many sources having nothing in common, either amongst themselves or with the Caterham dairies. The water-supply for the greater part of Redhill is, like that for Caterham, derived from the works of the Caterham Waterworks Company, and I found that, as the result of an early investigation of the epidemic, Mr. Jacob had, quite independently of either Dr. Hilliard or of myself, arrived at the conclusion that the spread of the disease was in all probability due to this water. Red Hill contains about 1,700 houses, and of these 924 had the Company's water laid on to them. Of the 96 houses affected during the first fortnight of the epidemic 91 habitually drew their water from the Company's mains, and the histories obtained with reference to the attacks in the remaining 5 were such as to confirm the impression that the Caterham Company's water had been the immediate cause of the epidemic.

Thus, at one of these houses, where ultimately three persons were attacked, the supply had, it was hitherto believed, been exclusively derived from a rain-water tank, but it was now ascertained that the Company's water was, in addition, procured surreptitiously; at another, for which there was apparently no water-supply, the Company's water was procured from a neighbour; and with regard to the remainder, the patients affected



were not only persons who were employed where the Company's water was in use, but several of them had partaken of the water at their meals.

The following evidence, all tending in the same direction, was also during an early stage of the investigation communicated to me by Mr. Jacob.

Mead Vale is a locality within the eastern ward of Reigate borough. It contains about 160 houses, of which 140 are connected with the Red Hill sewers and 20 drain into cesspools; all, however, have their water-supply from local wells. Two attacks in two different houses had occurred in Mead Vale, but both persons were employed at the Earlswood Asylum for Idiots, where the Company's water was at the time in use. Of these two houses one had cesspool drainage.

In Red Hill itself is a group of 30 houses which are supplied with water from a well at the South-Eastern Railway Station. These houses are in close proximity to and immediately surrounded by others to which the Company's water is laid on; both groups being connected with the public system of sewers. In the 30 houses referred to, not a case of enteric fever had occurred, whereas from the houses around them, numerous cases were reported.

Reigate town also, which forms the western ward of the borough, and has a population of about 8,500, but which has a different water-supply, entirely escaped, only two cases, which were undoubtedly imported from Red Hill, having occurred there.

Thus, all the facts ascertained in connexion with the course of this epidemic up to February 4th afforded very strong presumption that it had been caused by the use of the Caterham Company's water. All that has arisen since that date goes to strengthen this view.

The Caterham Waterworks Company, at the date when this inquiry was commenced, had two deep wells, both sunk in the summit of the high-lying ground which forms the western boundary of the Caterham Valley near its southern extremity. These two wells are situated about 30 feet from each other; they first pass through about 140 feet of gravelly soil, consisting of Oldhaven pebble beds with a little clay and flints. At this depth the chalk is reached; it consists partly of soft and partly of hard chalk, the formation being about 310 feet in thickness. Below this is the upper green sand, having a depth of about 55 feet. For about 490 feet, both wells are several feet in diameter, and they are connected by three adits in the chalk. From the bottom of the two wells and from the lowest adit a series of borings have been made through the upper green sand down to the gault; an experimental boring, which has since become silted up, passing through the gault into the lower green sand. From these wells the water is pumped into a series of tank reservoirs, in which it is submitted to Clark's softening process. These reservoirs, some of which are of recent construction, freely communicate with each other, and from them the supply is delivered by gravitation.

During the past twelve months a third well and boring has been made for the Waterworks Company by the Diamond Rock Boring Company. This well is situated within 90 feet of the others, but it extends through the gault, which is here 343 feet in thickness, into the lower green sand below; this latter formation having been reached on February 22nd last. Since 1861, and until the construction of the third boring was undertaken, the water supplied by the Caterham Company was held in high repute in the district to which it has been delivered, and the freedom from such diseases as enteric fever and diarrhoea which is stated to have been experienced in the district, has been to a great extent attributed, especially by Mr. Jacob, to the wholesome water-supply. Since the third well has been begun and prior to the epidemic under consideration, certain complaints were indeed made with regard to the water, but they were ascertained to be due, under circumstances to be hereafter explained, to conditions resulting from the recent boring operations, which had led to unavoidable turbidity in the supply and which had also prevented the process of softening from being regularly carried out. There is, however, no reason to believe that this unavoidable turbidity or temporary hardness of the water prejudicially affected those consuming it. In short, considering the deep sources of this water, and the previous history attaching to its use, it was by no means apparent how it could latterly have been the means of producing an extensive epidemic of enteric fever.

With a view to the elucidation of this point, it was first sought to ascertain whether any pollution of the water had taken place in the mains after it had left the Company's works, owing to intermissions in the service. This appeared at first to be possible,



for not only was the occurrence of such intermissions reported to me, but during the course of this part of the investigation two waterclosets were found in Caterham, the water-supply for which was derived from service-pipes which passed direct from the main into the closet pans without the intervention of cisterns, and were fitted with screw-down taps. The reported intermissions were, however, on investigation ascertained to have been temporary stoppages in the supply, caused by the freezing of the water in service-pipes, and I was assured by the Secretary to the Company that for at least many months past the Company's pipes had remained always full and under pressure. No intermissions, it was added, had occurred even during repairs, the service not only being a constant one, but the fixing of new service-pipes being in addition always effected under pressure whilst the mains are fully charged. Moreover the physical circumstances of the two closets, improper as they were, did not appear such as would in fact have permitted entrance of any foulness from them into the water pipes. No such dangerous services to waterclosets were found in any other portion of the district supplied by the Company, and in the two cases above referred to they have since been done away with.

I next made inquiry with a view of ascertaining whether any accidental contamination of water in the reservoirs, or in the mains, could have resulted from any irregularities in the supply during the recent boring operations or otherwise. I found that during the course of these works, and owing to the turbidity which has been referred to, the Caterham Waterworks Company had on several occasions procured an additional supply, which was pumped into their mains from two sources; the one, the deep chalk well belonging to the Caterham Asylum, the other, a well at Kenley, a place situated in the Caterham Valley between 3 and 4 miles to the north of Caterham. This latter well, which is also sunk in the chalk to a depth of 150 feet, belongs to the Kenley Waterworks Company, and it supplies the rapidly increasing groups of villa residences at Kenley and in the immediate neighbourhood.

With regard to the water derived from the well at the Caterham Asylum, it must be noted that it ceased on December 30th, 1878, and was not resumed until January 30th and 31st last, when a further supply was delivered into the Company's mains. Now if the water delivered by means of the Caterham Company's mains was the vehicle by which infection was conveyed, that infection must have been first distributed through them about 10 or 14 days prior to the occurrence of the first cases on January 19th and 20th, that is to say, between January 5th and 9th; and since no water from the asylum well was for many days prior to or subsequent to that period being delivered to the Company, it cannot have been concerned in the distribution of the infection. The evidence, too, already quoted as to the immunity of the asylum and the barracks from the disease, renders any further consideration of this water as a possible source of the infection quite unnecessary.

The supply from the Kenley Waterworks Company was delivered continuously every night into the Caterham Company's mains from November 26th, 1878, to January 3rd, 1879; it was resumed again from January 5th to the 10th, after which it was discontinued until the nights of January 14th and 15th; this supply finally ceasing on the morning of January 16th. This water was therefore pumped into the Caterham Company's mains for the period (January 5th to 9th) above referred to as that during which the distribution of infection must have commenced. Though the Kenley water, if it had had mischievous quality, would thus have had opportunity of doing mischief, there is absolutely nothing to suggest that it possessed such quality. On the contrary Kenley itself, which never ceased to be supplied from its own well, remained quite free from enteric fever during the whole course of the epidemic. Further, I was informed that there are good engineering grounds for believing that little or none of the Kenley water ever could have reached Red Hill, and it can therefore have had no concern in the fever there.

Many other points relating to the method of distribution of the Caterham Company's water were inquired into, but none led to any explanation of the circumstances of the epidemic.

As the Board are aware, suggestions of danger to the water in the deep wells of this chalk district, due to the prevalence of a system of cesspool drainage, have from time to time been made, and owing to this, as also to local representations, special inquiry was made as to the possibility of the soakage of filth from the surface soil around either of the Caterham Company's wells. Both the wells which were in use prior to the epidemic are steined with brickwork down to the level of the chalk. Not only is this brickwork not absolutely water-tight, but there was ascertained to be a somewhat free communication of water between the new boring and the other wells, and hence both the Company's premises and some neighbouring ones were examined, with a view of ascertaining whether any means existed favouring the



pollution of the water in the method indicated. On the Company's premises a cesspool was found, but it was cemented and evidently water-tight. This cesspool has since been done away with. A similar one is stated to have been found some ten months earlier, and this was also at the time abolished, the soil for a considerable distance around being at the same time cut away. The only other cesspools in the vicinity of the wells, are the following: 1st, One situated at a house about 1,100 feet to the south of the wells. This is a cemented tank, the contents of which are pumped on to the land. 2nd, One which is situated at some stables about 360 feet to the north of the two older wells, and about 270 feet in the same direction from the new bore: but this was originally constructed as a rain-water tank, and it is known to be water-tight. 3rd, Another on the same premises, and situated about 570 feet from the older wells, and about 480 feet from the new bore. This cesspool is about 6 feet in diameter and 15 feet in depth; it is stated to be dug in a clayey soil, and its contents overflow on to some meadow land. It is not cemented and it is believed to be "nearly" water-tight. Danger of soakage into the Company's wells from this cesspool is probably very remote, if at all possible.

In estimating the risk, regard has been had to several points which I propose to note here, not so much because of any danger believed to have resulted from this cesspool up to the present date, but mainly by way of caution as to the construction of cesspools in this locality in the future.

In the first place the clayey nature of the soil is relied on to prevent soakage. From a description of the soil in this neighbourhood which I have received from Mr. W. Whitaker of Her Majesty's Geological Survey, it appears that the hill in which the waterworks and the above-named premises are situated is an outlier of pebble-gravel (belonging to the Oldhaven Beds), resting irregularly on the chalk, and flanked on the north-west and north by an irregular deposit of pebbly loam, of much later date, which masks the junction of the Oldhaven Beds and the Chalk. The Oldhaven Beds at this point consist to a great extent of a deposit of well-rounded flint pebbles in a sandy matrix, but in places are irregular masses of angular flints in a loamy matrix, and it is highly probable that the cesspool in question has by a fortunate accident been sunk in one of the latter places. Not only can such a soil not be relied on elsewhere in this vicinity, but there is no security that the chalk itself may not be met with, so irregular is its surface. Indeed, according to Mr. Whitaker, it appears that on one side of one of the Company's wells it is met with at a depth of 90 feet, on the other at 140 feet, and that it may elsewhere come much nearer to the surface.—Again, the dip of the strata at this point is northwards at an angle of about five degrees, and both the surface-slope and the flow of underground water are stated to be in the same direction. Hence it has been assumed by some, that the danger of soakage from a cesspool situated at a reasonable distance to the north of the wells need not receive serious consideration. This northward flow of the underground water is however only one of the elements to be considered. Within the cones from which these wells are supplied the flow of the water is, owing to the existence of fissures in the chalk, if not, also to other causes, at times in other directions. Thus, during the boring operations which have been carried on by the Diamond Rock Boring Co., it was found necessary to pump into the bore itself about 3,000 gallons of water every hour, to facilitate the process of boring, and special arrangements had been made to receive the water as it rose from the bore into tanks, from whence after subsidence it might again be utilised for the same purpose. Shortly after these arrangements had been carried out, however, it was found that although this bore is situated to the north of the other wells the whole of this water escaped through a fissure which had been reached in the chalk, and which is believed to be about 14 feet in length, and through this fissure the water found its way in a southerly direction through the intervening 90 feet into the other wells. This it was that led to the turbidity in the supply which had been complained of. Somewhat similar occurrences have been observed with regard to water which has been allowed to run to waste on the surface. On one occasion the waste water was pumped into a hollow spot, about 170 feet to the east of the wells; here it disappeared, but it was soon ascertained to be returning into the wells at a depth of 420 feet, that is about the level of the "upper spring" supplying them, and it was found necessary to discontinue the process. On another occasion the waste water was led by means of a trench to a spot on the slope of the hill to the east of the works, and about 320 feet from the wells. From this point also it found its way back to the wells. Under the circumstances narrated it is clear that, although there are no grounds for believing that danger has actually arisen from the existence of any cesspools near the Company's wells, yet a system which allows, within the drainage area of a well, of soakage from cesspools, is obviously one calling for immediate remedy on the part of the Sanitary Authority.

Circumstances had, however, in the meantime come to my notice which had led to the inquiry with reference to any possible contamination of this water-supply being extended in another direction.

During the latter part of 1878 and the beginning of 1879 the Caterham Waterworks Company constructed an adit from one of their old wells up to the new bore which was then being sunk. This adit is situated in the chalk at a depth of 455 feet, it measures 6 feet by 4 feet, and is 90 feet in length. A number of men were employed in this work, some of them being in the well below, others on the surface.

Inquiry was made as to whether any of these men had ailed whilst at their work, and it was ascertained that one of them who left work some time in January was believed to have been ill, although no inquiries had been made concerning him since he quitted the works. This man I sought out, Mr. Jacob accompanying me on the occasion. At first his wife only could be found, but subsequently an interview was had with the man himself, and from the statement of the two the following history was obtained:—



J. K., aged 32 years, the man in question, resides in Caterham, and he entered the service of the Caterham Waterworks Company on October 25th, 1878, being employed as a labourer in the construction of the new adit referred to. The position assigned to him was that of "loading man," he being employed in the adit below in attaching to a rope, let down from above, the buckets by which the excavated chalk was raised to the surface, and in again receiving those buckets when lowered full of bricks and cement, required for the work in progress. Owing to a temporary inability of the pumps to keep down the water below the level of the adit, work was discontinued on December 14th, when J. K. was discharged, and it was not until December 29th that he was again sent for to resume the place he had formerly occupied. When he returned he was in perfect health, but "in about a week," *i.e.*, about January 5th, 1879, he felt himself ailing. His symptoms, which, according to his statement, steadily increased, were at first loss of appetite, recurring attacks of shivering alternating with a feeling of heat, great pains in the limbs, which he attributed to rheumatism, but which instead of being confined to any of the joints, were described both by himself and his wife, as an "aching all over," and diarrhoea. As the symptoms became aggravated, he was so exhausted during his work and became so "giddified" that he was more than once drawn to the surface, and immediately on his return home he was compelled to go to bed. More than once his wife noticed that he was "light-headed" in his sleep. All this while the diarrhoea continued, the man making a great effort to remain at his work, because, as he explained, he had had no employment between the 14th and 29th of the previous month.

With reference to this man's diarrhoea it is necessary to make the following explanation:—Both from his own statement, and from that of others, it appears that all the men who worked in the adit were expected to make such preparation before descending the well, that no occasion should exist for relieving themselves below; but should such necessity ever arise, and should there be at such a time any difficulty or delay in their being drawn to the surface, the buckets which were regularly being raised to the surface were to be used for that purpose. J. K. states that he strictly complied with these regulations before descending, but that notwithstanding all his efforts, the purging under which he was labouring was such that he was compelled to evacuate whilst in the adit "at least two or three times" during each shift, the shifts lasting apparently from 8 to 12 hours each according to circumstances. Indeed, as time went on, the man's diarrhoea must have been considerable, for besides the attacks which came on whilst in the adit, he almost invariably suffered from it, before descending, immediately after ascending, and also at his own house. So matters continued until January 20th, when work was again suspended for two days on account of a rise in the water level. But during the night of the 21st he was so much worse that he was unable to rise next morning. According to his wife's statement he found he could not stand when he got up, and returning to his bed suffered from "shivering down the back," "aching and exhaustion," and later on severe abdominal pain came on, which compelled him to lie with his knees drawn up: he was also "burning hot." This pain was looked upon as "cramp," and was alleviated by linseed-meal poultices which were applied by his wife. The more severe symptoms, including the diarrhoea, having subsided, he was two days afterwards able to get up for a while, and from this time convalescence appears to have set in. No medical advice was sought, mainly, as he explained to me, owing to his straitened circumstances. When I saw him, on February the 8th, he had the aspect of a man who had recently suffered from some acute disease; he was still very weak, and it was obvious that he had greatly lost flesh.

As the successive points in this history were learned, more and more resemblance appeared to a mild case of enteric fever, until, after the whole of the above story had been learned and after the man himself had been seen, the diagnosis of this fever could be made with a considerable degree of certainty. Then inquiry as to the man's movements at the period when the cause of his own fever must have been operative, brought out the fact that he had spent December 25th and 26th at Croydon, so that he had had opportunity beyond what Caterham then afforded for getting the fever.

On the morning following my interview with J. K., I proceeded to Croydon, with a view of ascertaining whether any clue could then be obtained with regard to the possibility of the man having in any way been exposed to the poison of enteric fever on December 25th or 26th; the only accurate history of his movements during those two days relating to that part of them actually spent in Croydon. It appears that on the days in question there had been a gathering of his friends at the house of a relation. The information which I obtained there was, however, entirely negative; at the same time it was evidently incomplete and otherwise unsatisfactory. For, after the lengthened examination to which J. K. had been subjected on the



previous day, he apparently apprehended the object I had in view, and during the same evening, some one had gone over from Caterham, and had evidently informed the relative at Croydon of my intended visit. As the result of this, certain information relating to the residence and antecedents of some of the visitors at the gathering, and desirable for the completeness of my investigation, was practically refused me. In making inquiry as to the possibility of any local source of infection, I received the assistance of Dr. Philpot, Medical Officer of Health for Croydon. The only sanitary defect, with regard to the premises themselves, was the existence out of doors of a pan-closet, trapped and connected with the public sewer, but not provided with proper means of flushing. It is, however, noteworthy, that at one of the small group of cottages in the side street in which the house in question was situated, it was learnt that during the previous October and November there had been a case of "low fever" in a child, and that shortly before Christmas the child's father had suffered from "acute diarrhoea."

I have now no hesitation in taking it as a fact that a man ill of enteric fever from January 5th to the end of the month was occupied during the first fortnight of that period at work in the well of the Caterham Waterworks Company. The fact, it will be observed, is not inferred from any consequences of it, but simply from what was seen and heard of the particular individual.

But now let us see what those consequences would have been. If this man's stools could by any means have found their way into the water of the well in which he had been working, and being enteric fever stools could thus have led to the development of the poison of that disease in the well, the effect on the water consumers ought to have been noticed within from about 10 to 14 days after the date when the diarrhoea first came on. And this, in effect, is precisely what did take place, the epidemic having commenced on January 19th and 20th in Caterham and Red Hill respectively. This remarkable concurrence of dates led to a more detailed inquiry as to the course of the man's diarrhoea whilst working in the adit. He admitted that the purging was very copious, in short that it "ran from" him; indeed, when at home, he was, because of the suddenness of its onset, unable to resort to the closet. He further admitted that owing to his frequent use of the bucket whilst at work, complaints were made by his fellow workmen on the surface; but he stoutly denied that he had ever been so pressed by necessity, or so influenced by those complaints, as to relieve himself in the adit without waiting for a bucket. But even accepting his denial, there were undoubted means by which his evacuations could have found their way into the water. According to his statement, the bucket was used as a closet when it was empty, when half full, and when full; he added, however, that when it was full he first took some of the chalk out and subsequently replaced it. During an earlier stage of my inquiry I had occasion to descend one of these wells, and I noticed that any article let down by a rope, by its oscillations to and fro, came into constant and somewhat violent contact with the walls of the wells, and on inquiry of J. K., whether the same did not take place with the bucket, he admitted not only that this was so, but that some of its contents frequently fell over a stage into the water below. On further inquiry, he added that some portions of his evacuations probably did so also. And he further stated that the looseness of his bowels was such that the bucket itself must almost of necessity have been stained with them. This bucket, which was merely emptied out above, then received, as already explained, materials which were used in the construction of the works below. Here then were the stools of an enteric-fever patient, from about January 5th onwards getting into the Caterham Company's water and distributed with that water to the district served by the Company.

Now we know from ample experience that enteric fever is produced, and produced with the maximum of certainty, when the specific evacuations of that disease are consumed by a population. Again, it is a matter of experience that where enteric fever has been conveyed through water, some fortnight has to elapse between the distribution of the water and the occurrence of the disease among the community served by it. But a fortnight after January 5th is the very day when the first case of fever occurred, and during the fortnight following upon the period January 5th to 20th, *i.e.*, from January 19th to February 3rd, the disease became widely spread throughout Caterham and Red Hill; the distribution of the fever being limited, as we have already seen, to houses supplied with the water of the Caterham Company. There can, I think be no doubt but that we have in the man J. K. the cause of the disease which followed.

Hitherto, however, I have only dealt with the course of the epidemic up to February 2nd, namely, during the first fortnight of its progress, and I have only referred to it in so far as it related to Caterham and to the town of Redhill. With regard to these



two places no diminution in the epidemic was apparent until about the 11th and 12th of February. Up to about the 20th February, the disease continued exclusively to attack persons residing in houses to which the Caterham Company's water was laid on, or it selected from amongst those who habitually used another supply, those who had partaken of the Company's water occasionally, either whilst at their work or during a visit to houses to which it was laid on. After this time, however, the disease became, as might have been predicted, somewhat more diffused, and several of the later cases occurred in houses where there had been previous ones. Up to the end of February the total number of attacks concerning which information had been obtained, and including 13 cases in which the dates of attack could not with any accuracy be ascertained, was 305; of these 224, of which 9 terminated fatally, occurred in the town of Redhill, and 81, including 5 fatal cases, at Caterham.

The area of the Caterham Company's water service, however, includes other places than those hitherto named, and inquiry has been made in these places as to circumstances that should confirm or disprove the conclusions thus far arrived at. The information thus obtained, though not all as intelligible as that relating to Caterham and Red Hill, was, however, found to be in harmony with it when all the facts were ascertained.

This water was, together with another supply, used at the Earlswood Asylum for Idiots, this establishment standing in an isolated part of the eastern ward of the borough of Reigate. In this establishment the first case appeared on January 28th, and between this date and February 18th, 38\* persons in all were attacked, 33 being patients and 5 servants. Five fatal cases occurred amongst the patients. Dr. Graham, the medical superintendent, informs me that having noticed that the attacks were limited to those who were somewhat habitual water consumers, and apparently influenced by the turbidity which the Caterham Company's water had presented for some time past, he cut off that supply on February 8th, and limited the establishment entirely to a supply derived from local springs. The last attack in the asylum took place on February 21st, that is within a fortnight after the use of the Company's water was discontinued.

Between Caterham and Redhill, and in the course of the main leading from the former to the latter place, the same water is supplied to a few houses in Godstone and Betchingley, both in the rural sanitary district of Godstone, and to a few in Nutfield, within the rural sanitary district of Reigate.

Out of 622 houses in those three villages, 96 were provided with the Company's water, and in 9† out of the 96, fever prevailed. Of these 9, six were in Nutfield. No cases occurred in Godstone.

One more locality is supplied with this Company's water, namely, Warlingham, which lies about 3 miles to the north of Caterham, between that place and Kenley. One part of Warlingham, which is known as Whiteleaf, is a hamlet situated at the foot of the chalk hills, bounding the eastern side of the Caterham Valley; the other part lies on the hills, and is known as Warlingham village. The population of Warlingham was 773 in 1871, and the Caterham water is laid on to 156 houses, viz., 102 in Warlingham village, and 54 in Whiteleaf. Throughout the course of the epidemic only one person is believed to have suffered from enteric fever in Warlingham, the attack occurring in a child 9 years of age. It is known that the Caterham Company's water was regularly drunk by this child at his home, but since he attended a day school in Caterham to which the Company's water was also laid on, it becomes impossible to speak with authority as to where he contracted the disease.

In view of recent investigations into the intimate pathology of the infectious fevers, the contagion of enteric fever itself must probably be regarded as particulate, and when contained in water it must probably be viewed as held in mechanical suspension, rather than distributed throughout it after the manner of a chemical solution. Under these circumstances its distribution throughout a large body of water would probably be not wholly regular, and its passage into and through mains receiving the water might not be uniform, either in point of time or in the direction taken.

So far, however, there is nothing in the case of the Earlswood Asylum, or of the intermediary villages, but what is confirmatory of the experience of Caterham and Red Hill. The actual rates of houses attacked are not identical in the several places; but it could hardly be expected that they should be, for incidence of disease on any particular house

\* Two of the cases amongst the servants are, in the Table appended, included in the attacks at Red Hill. The persons attacked had their houses in that place and were attended there.

† This number does not include several houses in which imported cases sickened with the disease.



must have been determined by a multitude of minor circumstances; and any small group of houses, whether in Caterham or Red Hill, or in some outlying village, had a chance of being attacked to a greater or less degree than the average of houses supplied with the Company's water. As one of the many circumstances to which I refer, I may mention frost as affecting the water-services of houses. During the time that the Caterham water was mischievous there were many frosts, so much so that the notion of intermission arose. At Godstone this was specially noticed. The inequality of incidence, more at Nutfield, less at Godstone, then, is only what might have been anticipated.

But there remains the case of Warlingham, which has appeared at a first view more difficult of explanation. This is a village somewhat largely served by the Caterham Waterworks Company, no less than 156 houses being supplied from that Company's mains. Amongst 156 houses, we should expect at the Caterham and Red Hill rate to find some 12 houses attacked. But beyond the single case referred to, nothing was heard of the disease in the village. Why was this?

In proceeding to consider the answer to this question, let the special situation of Warlingham, in regard to its water mains, be first observed. The village of Warlingham lies about three miles from the Caterham Water Company's works, and for the greater part of that distance it has a special three-inch main to itself and to a few houses between Caterham and Warlingham. The capacity of this main and of its branches is somewhat over 12,200 gallons. What if this main can have been charged with a different water and not with the water from the Caterham Company's wells?

Now, in a former part of this Report, I have told of the Kenley water being used to supplement the Caterham Water Company's supply during certain portions of the time when the Caterham wells were, for reasons named, furnishing a diminished and—as the result showed—an injurious supply. The Kenley water was, however, not mixed equably with the Caterham water. It was pumped into the Caterham Company's mains at one particular point. *And that point was at the extreme further end of the Warlingham branch of the system.* Before the Kenley water could get to the Caterham Company's reservoirs, it had to fill the whole of the three-inch Warlingham main and its branches, besides one other larger main near to Caterham. Every night an amount of Kenley water, which is variously estimated, but which at the lowest estimate averaged between 13,000 and 14,000 gallons, was pumped into this Warlingham system towards Caterham, and every day some 12,000 gallons of this Kenley water would have to be consumed at Warlingham before Warlingham could obtain a drop of water derived from the wells at Caterham. While this was going on there was for each house at Warlingham a supply of some 70 gallons and more of Kenley water to be got rid of before any of the Caterham water could be procured.

It is true that on particular nights, and those during the time that the Caterham well water had dangerous properties, this pumping of Kenley water was not going on. From January 11th to January 14th, more or less of Caterham water must have found its way in the direction of Warlingham. Whether it actually got there before it was met and driven back again by the Kenley supply, which on the 14th was again introduced into the end of the Warlingham main, or whether the Kenley water pumped in before the 11th was all that the village ever received during that interval, is more than can be decided with any degree of certainty.

For my own part I am quite prepared to believe the latter of these alternatives, the more so as I ascertained that the consumption of water in Warlingham was, at the special period referred to, as also during the greater part of January, at its minimum. For, owing to the exposed position of the service-pipes and taps, and to the hard frosts which then prevailed, hardly any water at all had in several parts of the village been obtained from the mains for several days; the inhabitants resorting to rain-water which is largely stored in the village. And even when the Company's supply was procurable it was, owing to the same cause, a mere "dribble."\* This however, is abundantly clear: the delivery of the harmless Kenley water to the village of Warlingham was so special and was continued during so large a part of the time when other places were being injuriously affected by the Caterham water, that the chances of suffering from any injurious influence carried by the latter water must have been out of all proportion less in the case of Warlingham, than in the case of places that got the bulk of their supply from the Caterham wells. And I am inclined to believe that, in the single case of enteric fever reported from Warlingham, the opportunity for infection did not occur in that place, but that the disease was contracted in Caterham.

\* The mean temperature on the grass as registered by Dr. Adam at the Caterham Asylum from January 8th to January 31st inclusive was 21·6° Fahr., it having varied from 12·0° Fahr. on the 11th to 31·5° Fahr. on the 15th; and the experience both at the Caterham Asylum and at the Guards Barracks is to the effect that during the late severe weather in January last the consumption of water was reduced nearly one half.



Rightly looked at, I judge that the almost complete, if not the complete, exemption of Warlingham, is a very considerable confirmation of the view I have expressed with regard to the origin of this epidemic.

In the Table appended to this Report I have shown the daily distribution of the cases of enteric fever in all the places supplied with the Caterham Company's water. The total number of cases up to the end of February is 352. The total number of deaths is 21. Since that date only a few scattered cases have occurred.

Throughout, the disease was typical enteric fever, the patients exhibiting the characteristic rose spots and diarrhoea, and some of them suffering from severe pulmonary and intestinal complications, the latter including perforation of the bowels, which in four cases was the immediate cause of death. Notwithstanding this, however, by far the majority of the cases were of an exceptionally mild character, and although, when subjected to examination, they were ascertained to be cases of genuine enteric fever, it is certain that, had it not been for the prevailing epidemic, no medical advice would in many cases have been sought, and some of the patients would not even have taken to their beds. By far the majority of those attacked were children; and amongst adults, women were more frequently attacked than men. This distribution of the disease is by no means uncommon in epidemics in which water is the vehicle by which the infection is conveyed, for children drink much more water than adults, and amongst the latter, men as a rule drink less than women.

#### *Remedial Measures.*

Immediately on ascertaining the circumstances under which it was evident that the water supplied by the Caterham Waterworks Company had become polluted, I took steps which led the Sanitary Authorities of the various districts concerned to issue notices informing the public that there were grounds for believing that the water in question had become accidentally contaminated, and cautioning them as far as possible, until further notice, not to use the water, or if no other supply could be procured, to have it thoroughly boiled before use. This notice was circulated on February 10th. I also advised the Waterworks Company to adopt the following measures:—1st, to pump their wells dry, if possible; 2nd, to scrape the walls of the wells and adits, afterwards scouring them thoroughly with a strong disinfecting fluid; 3rd, thoroughly to cleanse the reservoirs and wash them with disinfectants; and 4th, to saturate with a similar fluid all the soil in the vicinity of their works where the chalk from the adits had been deposited.

Owing to the force which the springs supplying the wells exhibited at this time of the year, the Company after long continued efforts in this direction, found it impossible to pump their wells dry. They, however, pumped to waste an amount of water considerably exceeding one hundred times the total contents of the wells and adits, and having materially lowered the water level, the walls of the wells and adits were thoroughly cleansed and scoured with a disinfecting fluid; large quantities of disinfectants being also thrown into the wells themselves. The reservoirs were thoroughly cleansed and disinfected, and the soil in the vicinity of the wells and reservoirs was again and again saturated with disinfecting fluid.\* Measures were also taken so to flush the mains as to thoroughly clear them of all deposit. In short, the Company acted with considerable energy and promptitude in adopting all measures which were found possible to do away with the results of the accidental contamination to which their water had been subjected; and in view of the manner in which these measures had been carried out, I on March 5th communicated to the several Sanitary Authorities my opinion that, although in the absence of any test capable of showing the safety of the water it was difficult to speak on the point with authority, yet I thought the time had arrived when it might again be distributed by the Company without danger to the public health. I am glad now to add that nothing has since occurred which leads me to believe that the expression of this opinion was premature.

In all the sanitary districts concerned, the officers of the Sanitary Authorities visited every house where enteric fever was known to exist; disinfectants, with advice as to their proper use, were distributed, and besides other precautionary measures, immediate steps were in many cases taken to sever any direct connexions existing between the houses and either sewers or cesspools. To these steps, and as regards Red Hill to the efficiency of the system of sewerage, must probably be attributed the few secondary cases which arose. At Red Hill considerable energy was displayed in temporarily providing the public with another water-supply, water carts being used to convey it from house to house. In some parts of the district an alternative supply was not procurable. But everywhere people having private wells opened them freely to the general public. Some

\* Having regard to the stratum in which the wells and adits were constructed, chloride of lime was the disinfectant recommended for these several purposes. Permanganate of potash was in addition also mixed with the water itself.



old wells, the contents of which were, to say the least, of a questionable character, and the use of which had very properly been abandoned for some time past, were re-opened, and the authorities should now endeavour to have them again closed.

During the course of the lengthened inquiry on which this Report is founded, I received the most ready co-operation from all whose assistance I found it necessary to seek. Throughout the district all the medical men regularly supplied either Mr. Jacob or myself with lists of their cases; the Chairman and Secretary of the Caterham Water Company placed all the information they possessed and the personal assistance of their staff at my disposal, and from the officers of the Sanitary Authorities I received similar help. To Mr. Jacob my thanks are especially due. The detailed inquiry, in so far as it related to the districts under his medical surveillance, was mainly conducted by him. The advice tendered to the Sanitary Authorities in those districts was the joint advice of us both, and the investigation was in several respects materially facilitated by the valuable suggestions which he made.

Local Government Board,  
April 7th, 1879.

R. THORNE THORNE.

TABLE showing DATES of ATTACKS from ENTERIC FEVER in under-mentioned Places,  
supplied with the CATERHAM WATER.

Date.	At Caterham.	At Red Hill.	At Earlswood Asylum.	At Godstone.	At Bletchingly.	At Nutfield.	At Warling- ham.	Total.
Number of houses supplied with the Company's water -	419	924	1	39	23	34	156	—
1879.								
January 19 -	1	—	—	—	—	—	—	1
" 20 -	1	2	—	—	—	—	—	3
" 21 -	—	3	—	—	—	—	—	3
" 22 -	—	5	—	—	—	—	—	5
" 23 -	2	12	—	—	—	—	—	14
" 24 -	3	6	—	—	—	—	—	9
" 25 -	3	16	—	—	—	2	—	21
" 26 -	8	7	—	—	—	1	—	16
" 27 -	3	13	—	—	—	—	—	16
" 28 -	3	11	1	—	—	1	—	16
" 29 -	4	6	—	—	—	2	—	12
" 30 -	1	2	3	—	—	—	—	6
" 31 -	2	17	3	—	—	1	—	23
February 1 -	10	23	—	—	—	—	—	33
" 2 -	6	9	1	—	2	—	—	18
" 3 -	4	13	1	—	—	1	—	19
" 4 -	6	7	2	—	—	—	1	16
" 5 -	3	4	3	—	—	—	—	10
" 6 -	4	5	—	—	—	—	—	9
" 7 -	2	9	1	—	—	—	—	12
" 8 -	—	5	5	—	—	—	—	10
" 9 -	2	1	5	—	—	—	—	8
" 10 -	2	4	6	—	—	—	—	12
" 11 -	1	7	1	—	—	—	—	9
" 12 -	1	3	1	—	—	—	—	5
" 13 -	2	2	—	—	—	—	—	18
" 14 -		4	—	—	—	—	—	
" 15 -		5	—	—	—	—	—	
" 16 -		2	—	—	—	—	—	
" 17 -	1	3	—	—	—	—	—	3
" 18 -		1	1	—	—	—	—	
" 19 -	—	1	—	—	—	—	—	1
" 20 -	2	3	1	—	—	—	—	6
" 21 -	1	—	1	—	—	—	—	2
" 22 -	1	—	—	—	—	—	—	1
" 23 -	1	—	—	—	—	—	—	1
" 24 -	—	—	—	—	—	—	—	—
" 25 -	—	—	—	—	—	—	—	—
" 26 -	—	—	—	—	—	—	—	—
" 27 -	—	—	—	—	—	—	—	—
" 28 -	1	—	—	—	—	—	—	1
Date of attacks un- known -	—	13	—	—	—	—	—	13
Totals -	81	224	36	—	2	8	1	352



