Dr Frank Seymour's report to the Local Government Board on the occurrence of lead poisoning in the Urban District of Guisborough, and its relation to the public water supply.

FOR OFFICIAL USE.

REPORTS

TO THE

LOCAL GOVERNMENT BOARD

ON

PUBLIC HEALTH AND MEDICAL MATTERS.

(NEW SERIES NO. 86.)

Dr. Frank Seymour's Report to the Local Government Board on the occurrence of Lead Poisoning in the Urban District of Guisborough, and its relation to the Public Water Supply.

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE
By DARLING AND SON, LTD., BACON STREET, E.

To be purchased, either directly or through any Bookseller, from
WYMAN AND SONS, LIMITED, 29, BREAMS BUILDINGS, FETTER LANE, E.C.,
and 54, ST. MARY STREET, CARDIFF; or
H.M. STATIONERY OFFICE (SCOTTISH BRANCH),
23, FORTH STREET, EDINBURGH; or
E. PONSONBY, LIMITED, 116, GRAFTON STREET, DUBLIN;
or from the Agencies in the British Colonies and Dependencies,
the United States of America, the Continent of Europe and Abroad of
T. FISHER UNWIN, LONDON, W.C.

1913.

Price Fivepence.

Dr. Frank Seymour's Report to the Local Government Board on the occurrence of Lead Poisoning in the Urban District of Guisborough, and its relation to the Public Water Supply.

ARTHUR NEWSHOLME,
Medical Officer,
9th December, 1913.

In August, 1913, Dr. W. W. Stainthorpe (senr., of Saltburn), medical officer of health for the combined sanitary districts of Guisborough Union, reported to the Board that a number of persons in the Urban District of Guisborough were suffering from illness, the symptoms of which suggested lead poisoning. Further, the cause of this illness was ascribed to the presence of lead in the water supplied to the town.

The Board desiring some further information on the matter, I was instructed to visit the district. This I did on August 25th and on subsequent dates.

The town of Guisborough is situated in the north-east portion of the North Riding of Yorkshire, in a hollow in the northern spurs of the Cleveland Hills. It lies on the shaley beds of the lower lias. The population has grown considerably in recent years, and at the 1911 census was 7,061.

It is estimated that half the male population of the town is engaged at ironstone mines in the neighbourhood. The remainder follow such occupations as are common in a small town in a semi-agricultural district.

OCCURRENCE OF CASES OF LEAD POISONING BEFORE 1913.

I was unable to obtain any history of prevalence of lead poisoning in the district before 1909. One of the practitioners in the town, Dr. W. W. Stainthorpe, junr., of Guisborough (referred to below as Dr. Stainthorpe), has, however, given me a list of cases of illness, attributed by him to lead poisoning, that have come under his observation since that year. The numbers are as follows :—

1909	...	...	...	4 cases
1910	...	...	...	2 „
1911	...	...	..	4 „
1912	...	...	...	8 „

Special reference may be made to two of the cases. The first, coming under observation in 1909, was that of a farmer W., aged 40 at the time. He first noticed pain in right arm and leg, he was badly constipated and suffered for a time from severe abdominal pain. Subsequently he suffered from right wrist-drop, and a blue line was discovered in the lower gum. This man (although not

(32527—21.) Wt. 29436—282. 500. 12/13. D & S

left-handed) is still considerably weaker in the right than in the left hand, and remains of a blue line are still visible. His wife suffered also from colicky pains, depression and weakness. She had no lead-line. In the man's case an examination of the urine showed traces of lead, in the woman's case no tests were made.

Up to this time the water used at the farmhouse where Mr. and Mrs. W. reside, and obtained from the public supply, was stored in a lead-lined tank. Water from this tank was found to contain lead. The water company replaced the tank by one of galvanised iron, and the symptoms indicative of lead poisoning in these cases have since gradually diminished.

The next case was that of a woman living in a new house also served by the public supply, where, it may be assumed, the new pipes would be especially susceptible to the plumbo-solvent action of the water if such existed. No tests appear to have been made at the time, but in the following year (November, 1910) on the occurrence of some further cases, water from a tap in this house was analysed and found to contain about $\frac{1}{20}$ grain lead per gallon. It cannot now be ascertained whether this sample represented the ordinary supply, or was that obtained on first turning the tap after allowing the water to remain in the pipes overnight.

Cases of Lead Poisoning or Suspected Lead Poisoning in 1913.

In 1913, cases of lead poisoning or of suspected lead poisoning, hitherto occurring only sporadically as indicated above, were noticed in considerable numbers, so much as to produce what may be termed an epidemic during May, June and July.

Dr. Stainthorpe has given me a list of 87 cases applying to him for treatment between March and the beginning of September :—

—	Age 1–20.		Age 20–50.		Age 50 upwards.		Age not stated.		Total.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
March	—	—	1	—	—	—	—	—	1	—
April	—	—	—	—	—	—	—	1	—	1
May	—	2	5	2	1	—	2	8	8	12
June	2	—	7	8	2	1	4	13	15	22
July	1	2	3	9	—	—	1	4	5	15
August	—	1	—	3	—	—	—	—	—	4
September (to 5th)	—	—	1	2	—	—	—	1	1	3
Total	3	5	17	24	3	1	7	27	30	57
Total for both sexes...	8		41		4		34		87	

Since Dr. Stainthorpe has latterly ceased recording all the suspicious cases which he sees, it may well be that the numbers of these in his practice during July, and more especially August, are greater than those given above, but he is satisfied that the prevalence of the illness has distinctly diminished since July.

Having regard to the insidious onset of lead poisoning, the date of the commencement of illness has naturally been difficult to fix in many cases. In others it roughly corresponds with the date of calling in medical aid.

Reasons for considering the Cases due to Lead Poisoning.

Dr. Stainthorpe's attention was called to the matter this year in the following way. He had been himself ill for about a year with vague abdominal symptoms diagnosed by various clinicians as appendicitis or duodenal ulcer. Recollecting previous cases which he had diagnosed as plumbism, it occurred to Dr. Stainthorpe that possibly his own illness might be due to lead poisoning. Accordingly in May 1913 he caused a sample of urine to be tested by Messrs. Brady & Martin, of Newcastle-upon-Tyne. Lead was found to be present.

Dr. Stainthorpe then considered that it was quite possible that a number of cases of illness of a somewhat obscure nature which had come under his observation, characterised by neuralgic pains, headache, dyspepsia, or other indeterminate symptoms, might also be due to lead intoxication. He therefore caused a number of samples of urine to be examined, and of 24 samples sent to the same analysts as had been employed in his own case, 17 were found to contain lead.

Subsequently, the expense of having samples tested being beyond the means of many of the poorer patients, Dr. Stainthorpe obtained the use of a laboratory in Guisborough and made a large number of tests upon the urine of various persons in whom he suspected the presence of lead poisoning. He found lead to be present in 76 instances out of about 100.

In the case of three patients, samples of urine were also analysed in Newcastle for Sir T. Oliver, and lead was found in two of them, while in several other cases positive tests were made by more than one observer.

From Dr. Stainthorpe's list of cases from 1909 onward, it appears that the signs or symptoms of those attacked may be tabulated as follows :—

Colic	present in	77 cases.
Headache	„	72 „
Neuralgic pains	„	79 „
Anæmia	„	78 „
Blue line	„	11 „
Convulsions	„	1 „
Wrist drop	„	1 „
Ankle drop	„	1 „

I visited a large number of these cases, both those of recent occurrence and others of longer standing.

The more prominent and usual symptoms observed were :—

Abdominal pain, usually severe, extending across the lower part of the abdomen in some cases, in others across the epigastrium. This

pain was variously described as 'colicky,' 'gnawing,' or 'as if bowels were tied together.' Often it was found to be worse in bed or when hungry.

Constipation.—This was usually a pronounced symptom, although in some cases diarrhœa was found to exist. Notwithstanding the prevalence and severity of constipation, I do not think that as much weight should be attached to it as to certain other symptoms: for in a given number of persons, two thirds of whom are females, a considerable degree of constipation may exist without receiving much attention. On the occurrence, however, of other illness in the individual, constipation, till then disregarded, is likely to be brought forward as a noteworthy symptom.

In certain of the cases visited, indeed, I was informed by the patient that a state of costiveness was usual, but in others I was assured that it was a new symptom commencing at the time of the illness in question.

Headache was very common and usually of a severe character. Its site was either in the occipital region extending downwards into the neck; across the vertex; or, less frequently, in the frontal region.

Neuralgic pains were also of common occurrence among those visited. They appear more frequently to have affected the lower than the upper limb, and were often referred to the joints or to the long bones.

General weakness and inability to work were much complained of. That these are entirely subjective complaints, lending themselves readily to malingering of the crudest type, cannot be denied. On the other hand, I could hardly attribute malingering to such persons as widows who had to support themselves, or fathers of families for whom the loss of a number of days' work is serious and much felt, or women who, though accustomed to do their own house work, were unwillingly compelled to call in assistance for the performance of duties ordinarily readily carried out.

Anæmia.—The presence of anæmia alone is of little importance. It was, however, observed not only in the younger women in whom anæmia is common, but also in men, matrons and children, and I was struck, in walking through the town, by the large proportion of persons met with who appeared anæmic. This apparent prevalence, and the fact that it was often found in conjunction with other suspicious symptoms, give anæmia some diagnostic value.

Miscellaneous complaints, such as bad taste in the mouth, sweating, drowsiness and lassitude were also complained of in a number of the patients seen. Weakness of various muscles was met with, and generally many of the cases recalled the observation of the Medical Officer of the Board (Supplement to the 38th Annual Report, Appendix A., No. 10). "Apart from definite recognisable "symptoms" . . . "the frequent ingestion of minute doses of lead "into the system causes lassitude, inability to work, and anæmia; "and is probably the cause of much inefficiency and ill-health in "persons who themselves, and whose medical attendants, are "unaware of the cause of the chronic ill-health from which they "suffer."

Cases of serious illness.

The foregoing are the more salient and common symptoms met with among the cases investigated. There were, however, some cases of a much more grave nature, and others in which the symptoms were very slight indeed.

Among the cases of serious illness, mention may be made of the following :—

G. H. T. Male, 41. Married. One child, aged 13. Began to be troubled with vomiting in autumn of 1912. Vomiting continued at intervals and ultimately occurred after nearly every meal during part of the spring of this year. Then followed abdominal pains ; nervous irritability and inability to settle to work ; severe pains in head, getting worse towards night ; numbness of feet ; pains in hands and feet ; sleeplessness ; aphasia of a week's duration. When examined walked with the help of a stick ; had marked right ankle drop ; was considerably wasted, having lost about 2 stone since beginning of illness ; grip weak ; ptosis of right eyelid ; lachrymose ; stated that he was barely able to do any work whatever. This man had no blue line. His symptoms were suggestive of early general paralysis. I made enquiries as to possible predisposing cause of this disease, but neither from the patient himself nor from other evidence could I find any reason for supposing that the disease was, in fact, general paralysis. The urine was tested by two independent observers ; both found lead present. The patient was a copious water drinker, often drinking a glass or two of water from the tap the first thing in the morning.

Another case was that of a woman, T., who had, for about a year, suffered from epileptiform convulsions. These seizures occurred without warning, but otherwise presented the usual features of an epileptic fit. They were attributed to chronic nephritis. Subsequently she complained of neuritic pains in forearms. The urine contained albumin and lead. On treatment she improved and was free from seizures for one month, a longer period than had elapsed between fits for some time.

A third case, A., had been ill about nine weeks at the time of my visit. She first complained of pain situated in the region of the left kidney, and also suffered severely from headache. Afterwards colic and vomiting took place. No blue line, but some suspicious discoloration along margin of lower gum. On the occasion of my first visit she was too ill to be seen. Afterwards, however, I saw her, and, although she was semi-conscious, I succeeded with some little difficulty in getting her to answer questions. I was informed that at times it was not possible to do so. Lead was found in the urine of this patient also.

On the other hand, numerous cases are included in the list furnished me, which presented only the slightest symptoms, such as localised neuritic pains. In other circumstances it is not improbable that the suspicion of lead being concerned in these cases would never have arisen ; their attribution to lead rests upon their similarity to the more pronounced cases and on the fact that many of them were found, after Dr. Stainthorpe had made a practice of testing urines in suspicious cases, to be excreting lead.

The opinion that lead poisoning was prevalent in Guisborough is thus based on the following considerations of facts brought to my notice, principally by Dr. Stainthorpe :—

(*a.*) A number of cases of illness amounting to 1 per cent. of the population, presenting in the main similar features, were noticed to occur in the town at about the same time. This pointed to some common cause.

(*b.*) These cases were not restricted to persons of any one age-period, sex, class or occupation.

(*c.*) Some few of these cases were typical clinical examples of somewhat mild lead poisoning.

(*d.*) In the majority of instances lead was found to be excreted by the urine.*

On the other hand, the following points required consideration :—

(*a.*) The presence of the Burtonian line ("blue line") was infrequent. This, however, is not altogether surprising in the absence of any suspicion of inhalation of lead dust.

(*b.*) The cases were of a comparatively mild nature as compared with cases of lead poisoning usually met with industrially.

(*c.*) The reported cases were confined to a single practice although there are two other medical practitioners in the town. I made inquiries of these practitioners and was informed that no case which they definitely regarded as lead poisoning had come under their notice. This was in spite of the fact that their attention had been drawn to the question by the reported prevalence of the disease in the practice of their colleague. On the other hand, neither of them had caused any tests to be made for the presence of lead in the urine, although the value of such tests in doubtful cases was not disputed.

With a view of ascertaining whether in point of fact the prevalence of symptoms such as observed by Dr. Stainthorpe was restricted to his practice, I made, in company with the medical officer of health, a house-to-house visitation which extended to nearly 150 houses.

The following is an analysis of observations made :—

Houses visited	147
No one at home	21
No suspicious symptoms heard of in any inmate of the house	87
Suspicious symptoms heard of or observed in one or more inmates	39

* The significance of lead in urine should be regarded in the following way :— Lead is not normally excreted in urine, nor is it a normal constituent of the human body. When it has gained access to the body, however, it may be excreted for considerable periods of time, the general health meanwhile remaining unaffected —in fact, so long as the excretion equals the ingestion symptoms often do not occur. As soon, however, as any adventitious circumstances, such as chill, feverish illness, &c., interfere with the excretory function, then lead becomes stored up in the body and is liable to produce prejudicial effects. In other words, though the health of a person who is excreting lead by the kidney may be unaffected, yet that person is liable to suffer from symptoms of lead intoxication at any time. There is a presumption that when symptoms not incompatible with lead intoxication occur in a given individual who is actually excreting lead, then lead is the cause of the symptoms; and when the symptoms alone are themselves sufficiently marked to suggest lead poisoning, then the presence of lead in the urine may be taken as conclusively establishing the diagnosis.

In the 39 houses the "suspicious" illness heard of or observed affected some 50 persons, among whom the following symptoms, singly or combined, were reported :—

Colic or marked abdominal pain	15
Anæmia	22
Headache	16
Neuritis or neuralgic pains	7
General weakness	5
Pain in back	3

In only one case did I observe a blue line, and that a very dubious one.

I would not be understood to imply that I found definite evidence that lead poisoning had occurred in these 39 houses,* but in view of the prevalence of plumbism I considered that in each of these houses there were persons with slight maladies of which the symptoms individually were not incompatible with lead poisoning, and that these symptoms became suspicious when aggregated in the same individual. I obtained urinary specimens from eight of the most pronounced cases. In this number were included persons in the *clientèle* of each practitioner in the town : some of the patients, however, had not called in medical aid.

Further, I examined 24 women and girls, principally the latter, at a steam laundry in the town. There was a history of headaches in three and of abdominal pain in two. Anæmia in many of these persons was very marked in degree, and at least two-thirds of the number were definitely anæmic. This may in large measure be attributed to the age of most of the workers, or to the nature of the work. In one case I obtained a urinary sample.

The nine samples of urine thus collected by me were examined for the presence of lead by my colleague, Dr. G. W. Monier Williams. Five of them were found to contain lead in amounts varying from 0·1 milligram to 0·4 milligram per litre. Lead was also found to the extent of 0·1 milligram per litre in a specimen furnished by a gentleman who had had a previous test made with positive result, but who was desirous of having the accuracy of that test put to further proof.

I also inspected 314 school-children with a view of ascertaining the presence, or otherwise, of a Burtonian line ; in no case did I find it present. About 15 per cent. of the children were of a pallor suggesting anæmia.

Possible Causes of the Outbreak.

Lead poisoning may be due to a variety of causes, as—

(*a.*) Employment in connection with the manufacture of lead compounds ; in Guisborough, however, there were no manufactures.

(*b.*) Constant use of lead or lead compounds, as in the case of painters, plumbers, gasfitters and others ; but the

* I met with some cases in the course of this house-to-house visitation which were already included in the list given me by Dr. Stainthorpe, but these are disregarded in the above analysis.

epidemic in question was not restricted to those using lead or its derivatives in their daily work. It included all ages from four weeks to sixty-eight years, and among the number were various persons between whom not the slightest community of occupation could be traced.

(*c*.) Ingestion of lead salts. This may be by means of medicine, but it is not conceivable that upwards of a hundred individuals should by any rational person be so dosed with lead salts as to produce widespread effects of the nature already described. Many of the affected, moreover, had not attended a doctor for some considerable time before the onset of the illness in question. The hypothesis is in fact so fantastic that I only refer to it because I was informed that it had been suggested in the locality. The explanation that the lead had been ingested quasi-medicinally in the form of diachylon pills may similarly be dismissed. Lead poisoning is met with in beer and cider drinkers, especially those accustomed to partake of a morning draught which may have lain overnight in lead pipes leading from cellar to counter. Aerated waters sometimes extract lead from the heads of syphons, but the distribution and history of the cases were here inconsistent with any such explanation. For the same reason the use of certain forms of cooking vessels, the eating of tinned fruit, &c., could be eliminated.

In short, no supposition other than the action of an agency such as the drinking water, common to the whole community, would meet the case. The water supply was already suspect, and its relation to the prevalence of lead poisoning may now be considered.

Water Supply.

Guisborough has a constant water supply provided by the Guisborough Water Company obtained under conditions regulated by Board of Trade Orders of 1871, 1880, and 1911, made under the Gas and Waterworks Facilities Act, 1870.

Not all the houses in the urban district are on the supply, but all the houses in the town are either individually connected to the mains or have access to standpipes common to two or more houses.

The houses, or standpipes, are connected with the mains by lead pipes. In the majority of instances these average about 30 feet in length, but it is noticeable that twelve of the individuals in whom evidences of lead poisoning were found, lived in three houses situated at the distal end of the mains and having lead service pipes up to 300 feet in length.

Sources of Supply.—There are two: from a gathering ground of about 600 acres of open peaty moorland, with a small wooded area in its central portion, and from springs. The latter are situated either in the gathering ground or just outside it. The proportion of the total supply obtained respectively from surface water and from the springs cannot be stated, but is obviously liable to considerable variations. Surface water from the gathering ground is conducted by three principal streams and their tribu-

taries, augmented by cuttings, to a reservoir on the western side of Westworth Plantation, about two miles south-east of Guisborough town. The capacity of this reservoir is stated to be about 11,000,000 gallons. It is some 725 feet above ordnance datum and about 400 feet above the town, and from it the water is piped to the town by a route which is somewhat circuitous to suit the contour of the ground. The main leading from the reservoir to the town is joined, about half a mile from the reservoir, by the two spring water mains. The water from springs on the west side is first collected in a "spring service reservoir;" that from the springs on the east is conducted to the main at the same point without entering any reservoir. In its further course to the town, the mixed water in this main passes first through an apparatus for lime treatment, and secondly through "Candy" filters, to both of which further reference is made below. The average daily consumption of water is estimated at 130,000 gallons, or a little over 18 gallons per head of the population, but the meter by which the amount used to be measured has not been in working order for some time.

Ability of the untreated water to act on lead.

As regards the spring water, the analyses available, including one made for the district council by Mr. Fairley, County Analyst, in September, 1913,* do not show any reason for suspecting it of plumbo-active tendencies. It is a pure water with a comparatively high degree of alkalinity. The reservoir water, however, is by no means free from suspicion. In January, 1909, a sample of reservoir water analysed by Dr. J. C. Thresh for the water company was acid in reaction and dissolved "an appreciable quantity of lead." In February, 1911, the same analyst found the water still acid and with a slight action on lead. When tested, however, by Mr. Fairley, in September, 1913, for the purposes of the present inquiry, the reservoir water was found to be slightly alkaline and to have only a very slight plumbo-solvent action (0·70 grains lead dissolved by one gallon of the water in 72 hours).

Variations in acidity and in plumbo-solvency are to be expected in such a water on account of variations in the amount of rainfall which have occurred in the period preceding the time of analysis. I have no records of the rainfall about the time of the two first analyses referred to; but in regard to that of September last a record of the rainfall at the Cleveland Water Company's reservoir, which is about two miles distant from the Guisborough reservoir, and at a similar altitude, shows that during the summer of this year the rainfall has been below the average of the preceding 38 years. The drought was especially marked in July and August, the rainfall for these months being as little as 3·35 inches, while the average for the same months in the preceding 38 years is 6·607 inches. Indeed, records are unnecessary to demonstrate the dryness of the season, for at the time of my visit the water in the reservoir was 10 to 12 feet below the overflow weir, and the feeders were reduced to the merest trickle or to complete stagnation. The water in the reservoir was discoloured and turbid: the neck of a bottle was barely visible at a depth of 18 inches.

---

* *See* Addendum B, p. 18.

I examined such water as was to be found flowing in these feeders and found that in some cases it was acid in reaction to methyl orange. Judging from a series of four samples kindly taken for me from feeders by the medical officer of health, however, the water in them at the time did not possess any strongly marked power to dissolve lead. It is well known that in gathering grounds of this nature the first flow of the feeders after a drought is markedly acid in reaction and has considerable plumbo-solvent action, whereas at the end of a period of drought such water as remains flowing in feeders is often free from any acidity or plumbo-solvency. February of the present year was unusually dry (48½ per cent. below the average of the preceding 39 years), while in March and April the rainfall was 27½ per cent. above the average. In December, 1912, the rainfall had been 58½ per cent. below, while in January, 1913, it was 45½ per cent. above the average. It is therefore probable that while in August the reservoir was receiving little or no acid water, in January and March of this year an unusually large amount of acid water had flowed into the reservoir from the gathering ground.

The above refers to the reservoir water alone ; as already stated the Guisborough supply also contains spring water, which has a neutralising effect, but it should be remembered that if heavy rain followed drought at a period of the year when the springs were much reduced, the counteracting effect of the spring water would be relatively less.

As regards " erosive " as distinct from " solvent " action of the raw water upon lead, little information can be given : the matter had not been investigated previous to my visit. During my inquiry samples from the reservoir, and also of spring water taken from the spring service reservoir, were tested by Mr. Fairley. These showed no erosive action in one and in three days. Subsequently Dr. Monier-Williams examined for erosive action the samples from the feeders taken by the medical officer of health : all of these were found to have some erosive action, varying from 3 parts of lead per million in 24 hours to 34 parts per million in 72 hours.*

Treatment of the water in relation to ability to act on lead.

That, before 1912, the possibility of some action of the water on lead was recognised is made clear by the following considerations :—

1. The company then adopted treatment with a view to preventing such action.

2. Analyses had shown that the water as supplied to the consumers either contained lead or was capable of acting on that metal. Thus, towards the end of 1910, five analyses of water from house taps, made at the instance of the medical officer of health by Messrs. Pattinson and Stead, of Middlesbrough, showed the presence of dissolved lead in amounts varying from ·007 to ·049 grains per gallon. Two samples (representing respectively the mixed water from three taps in different houses, and water from the main) analysed for the water company in the early part of 1911

* *See* Addendum B. (C) p. 20.

by Dr. J. C. Thresh, showed no lead in solution, but the samples were reported to be "capable of acting on lead to a slight extent." Reporting on two samples taken from town mains on 28th December, 1911, Dr. Thresh said :—"The waters contain an infinitesimal and quite negligible quantity of lead, but both are capable of taking up a considerable quantity of that metal, fully ½ grain per gallon in 24 hours."

3. A few cases of lead poisoning had occurred before 1912 which were referable to the water.* Definite complaints of the activity of the water in regard to lead were made to the Company in 1910.

4. The ability of the water to act on lead was recognised in connection with the issue of the Board of Trade Order of 1911, which contained a clause requiring treatment to prevent action on lead to be undertaken after January 1, 1914.

Treatment of the water before 1912.

According to the information supplied to me by the water company, the sole method of treatment of the water up to 1904 was by means of sand filtration, adopted for the purpose of removing organic impurities, and without reference to the question of action on lead. About that time difficulty in obtaining suitable sand was experienced, and the filters gradually fell into disuse. Two mechanical filters were then supplied by the Candy Filter Company, Limited. These filters, which were supplied for the same purpose as the sand filters, are situated close to the town, and filtration in them is carried out by means of polarite and sand. Their size is such that the total superficies of filtering surface is about 56½ square feet. Since the average daily consumption of water is 130,000 gallons, the water must pass through the filters at an average speed of about 3 inches per minute ; since the filters are 8 feet deep the water is only in contact with the filtering material for 32 minutes. In practice the water will sometimes pass through the filters much more rapidly, the demand being greater at certain times of the day than at others.

The filters are washed periodically twice a week. In order to do this the filter which is undergoing washing is necessarily thrown out of action, while a considerable proportion of the water passing through the second filter is employed to produce a back flow in the first, so that for filtering purposes about half the capacity of a single filter is all that is available at such times. The result of this is either that water drawn off immediately after the filters have been washed has been "rushed" through the filters, or that the distributing mains get partially emptied, and when refilled, any incrustation or deposit in the pipes is disturbed, rendering the water turbid.†

Treatment in 1912 *and subsequently.*

Two samples taken from town mains on 22 January, 1912, were found by Dr. Thresh to contain no lead in solution, but one of them was capable of dissolving about ·07 grains of lead per gallon.

* *See* p. 2.

† This was pointed out by the Candy Filter Company in 1910. An effort has been made to counteract this tendency by washing the filters at a time when little water is likely to be drawn off in the town.

These samples were taken from the same mains as those of December 28th, which, as already stated, were strongly plumbo-active. During the interval no treatment appears to have been carried out to inhibit the action of the water on lead. In the December samples the free carbonic acid was respectively 4·62 and 3·52 parts per 100,000, and in the January samples it had fallen to 2·2 and 3·5 respectively.

Unfortunately no analysis of the reservoir water, or of the mixed but unfiltered water partly derived from the springs, was made at this time or useful information would have been obtained as to the effect of the Candy filters on the plumbo-solvent properties of the water. Unless we assume, however, that filtration actually increased the plumbo solvency,* it is clear that the reservoir water must have been in a dangerous state at the time. It is interesting to note that the rainfall in November and December, 1911, had been excessive.

In reporting on the samples taken in December, 1911, Dr. Thresh advised the Company to treat the water by the addition of lime, and acting on this suggestion the water company instituted a system of lime treatment controlled by a method of titration suggested by Dr. Thresh.

The lime treatment is applied to the mixture of spring and reservoir water at a point about half way between the reservoir and the filter house. Ground quicklime (containing 80 to 85 per cent. of caustic lime) is added by means of a hopper fixed in a small wooden tank. The amount of lime required each day is placed in this hopper. Water which enters by means of a small pipe from the main through the bottom of the hopper, percolates upward through the lime and leaves through a small hole near the top, thus filling the wooden tank which surrounds the hopper. Thence the lime-charged water is conducted back to the main and mixes with the water therein.

The tests by which the lime addition is checked and adjusted are carried out at intervals, usually weekly, and are as follows :—

A. 100 cubic centimetres of tap water are titrated with decinormal sodium carbonate solution using phenolphthalein as an indicator.

B. Another 100 cubic centimetres of tap water are titrated with decinormal sulphuric acid, methyl orange being the indicator.

If it is found that not more than one cubic centimetre of the decinormal alkali in A, nor more than 0·5 cubic centimetres of decinormal acid in B respectively are required to turn the indicator, then it is considered that the amount of lime added has been sufficient in amount. These determinations are carried out by the foreman of the water company who, although unskilled in chemical manipulations, appears to have become accustomed to this procedure, and to carry it out in a comparable manner. But the tests, however valuable they may be otherwise, are carried out solely on the treated water, and at best only show that something is wrong after the event, and some time must elapse before the error, if such exists, can be corrected.

* Such an assumption is not untenable according to some of Dr. Houston's experiments. Filtration alone may indeed increase plumbo-activity by removing from the water the vegetable slime which tends to coat the interior of the lead pipes.

I found it very difficult to trace any relation between the amounts of lime added and the reaction of the water as shown by tests. Had tests been made on the water both before and after treatment the results would have been much more valuable.

Although the quantity of lime added was supposed to be regulated by the tests suggested by Dr. Thresh, the company do not appear altogether to have depended on this method as a working basis. Thus in April of this year the acidity to phenolphthalein of 100 c.c. of the sample tap water equalled from 0·5 to 0·9 cubic centimetres of decinormal sulphuric acid, 22 pounds of lime being added daily; in July, with an acidity of 0·1 or 0·2, 50 pounds of lime were added; and in August, the acidity being still 0·2, the lime was suddenly reduced to 22 pounds.

The increase in July was no doubt made on account of the allegation that lead poisoning was prevalent; the abrupt return from 50 pounds to 22 pounds followed a suggestion made by Sir Thomas Oliver that the addition of lime had been too generous.*

As regards the amounts of lime added I compared the record of the amounts stated to have been added daily, with the amounts shown by the invoices to have been purchased. There was a discrepancy of over 25 per cent. between the totals arrived at. This may be due to occasional omission of lime treatment, or to incorrectness in taring the vessels in which the lime is measured. Moreover, I did not find any obvious relation between the amount of lime recorded as having been added, and the state of the treated water revealed by the tests made. These circumstances make it doubtful whether the addition of lime has been such as to constitute a uniform method of treatment.

If therefore, both the water and the treatment are subject to independent variations it is not unlikely that, at times, water having in a relative sense a considerable power of acting on lead may have been admitted to the town mains. It is not inconsistent with this

---

* Sir Thomas Oliver, who had received samples of water in July, 1913, informed the water company that he considered the untreated water was "obviously extremely dangerous," and that the treated water was considerably better but seemed somewhat beyond the margin of safety. His experiments consisted in immersing lengths of lead piping in samples of the treated and untreated water. The untreated water absorbed a comparatively large amount of lead. On adding a known amount of lime to each sample, the amount of lead absorbed by the sample of untreated water was reduced to little more than a tenth of what had been absorbed in the first experiment, while that absorbed by the sample of treated water was slightly increased. A third experiment was made by adding to the untreated water an amount of lime smaller than had been added to portion of the same sample in the second experiment, with the result that the action on lead was less than with the larger amount of lime. It is not stated what quantities of lead per gallon the figures represent, but this does not lessen the comparative value of the experiments. I have been unable to find a reference to similar experimental results. Sir Thomas Oliver also suggested that experiments should be made with a view of ascertaining whether some substance other than lime would be more beneficial. It should be added that the condition of the water supplied to the town about this time was considered satisfactory by the water company, who had received a report from Dr. Thresh on a sample of tap water sent to him on July 11th. This sample was reported to be "free from lead, and neither to erode nor dissolve the bright metal."

view that six samples of the treated water taken in the late summer, under the conditions above referred to, and analysed by Mr. Fairley, had no solvent action on lead, although as will subsequently be seen, three of them had relatively considerable "erosive" actions.

The effect of lime treatment on the lead-dissolving properties of the water.

The lime treatment is carried out to counteract an important, and usually the main cause of a water of peaty origin acting upon lead, namely plumbo-solvency due to acidity; and while the addition of lime may have been at times incomplete, it must be assumed that since the treatment was adopted the water supplied to the town was, as a general rule, distinctly less acid than in previous years, and on many or most occasions was not acid at all. But a salient point in the present inquiry is that more cases of lead poisoning have been discovered in the town since lime treatment was commenced, than had occurred during the years preceding this treatment, and probably more cases have in fact occurred.

It is difficult to account for this merely by the supposition that acid water was sometimes admitted to the town mains in spite of the treatment, and the facts suggest that during at least part of the period from February, 1912, until the date of the present inquiry, some circumstances hitherto unconsidered must have been at work which tended to increase the plumbo-active power of the water.

In this connection reference must be made to the "erosive" ability of the water in regard to lead; a property which requires particular consideration in a place like Guisborough, where great lengths of lead pipe are commonly found.

Erosive ability of the Treated Water.

As regards this property, Dr. Houston in his report to the Local Government Board on Lead Poisoning and Water Supplies (Supplement to 38th Annual Report, p. 422, Vol. II), says that lime treatment is seldom quite satisfactory except, of course, as regards removal of acidity and consequent plumbo-solvency, and sometimes "seems actually to render the water more prone to erode lead."

That the treatment to which the Guisborough water has been submitted will prevent erosion is by no means certain. As already mentioned, no experiments on this point appear to have been made prior to the present inquiry. It will be seen from the analyses reported in Addendum B.,* that of three samples of tap water taken on the 29th August, 1913, none eroded lead in 24 or in 72 hours; whereas of three similar samples taken from a tap in Bow Street on 1st September and examined by the same analyst the erosive ability was as follows:—

	Lead eroded in grains per gallon.	
	24 hours.	72 hours.
No. 6:— 8.15 a.m.	1·40	2·31
7:— 9.15 a.m.	1·75	3·40
8:—12.30 p.m.	1·05	1·22

The second of these samples was taken during the washing of the filters.

---

* *See* page 18.

Now the only known factor which had undergone alteration between the time of taking the first three samples, and the earliest sample (No. 6) of the second series was that about half an inch of rain had fallen. The lime treatment was the same in amount, yet the alkalinity of the first three samples, calculated as calcium carbonate, was 1·33, 1·30 and 1·20, while in the second three it was 0·42, 0·49 and 0·49.

If, then, in three days, during which half an inch of rain fell, the degrees of alkalinity of the water could undergo a conspicuous reduction and the erosive power could rise from *nil* to 1·40 grains per gallon, it is clear that the treatment is not at present adequate to deal with all the variations which may occur in the water and affect its action upon lead. It should, however, be noted that the degree of alkalinity and of erosive ability of moorland waters is not actually great, and the methods for their estimation may not be so perfect as to allow of undue stress being laid on apparent quantitative fluctuations.

Moreover, while it is convenient to classify the action of water on lead into "plumbo-solvent" and "erosive" action, the distinction is to some extent arbitrary and both actions may occur simultaneously. In the ordinary use of the terms the former signifies the formation of a soluble lead compound, and the latter, disintegration of the surface of the lead (particularly when bright) with the formation of a relatively insoluble lead compound which tends to fall away from the surface of the metal, leaving a fresh exposed surface ready for further action. But it must be recognised that the circumstances in which the inner surfaces of lead pipes may be disintegrated are complex, while the chemical and physical conditions which favour it do not yet appear to be fully understood. Stress is laid by some writers on the importance of the presence of free carbon dioxide in the water, which results in lead compounds which would otherwise go into solution being converted into insoluble carbonates of lead. The lime treatment may thus in this instance have exercised a prejudicial effect by removing free carbon dioxide. In the treatment of plumbo-solvent water Dr. Houston has referred to the advantage of adding a proportion of sodium carbonate as well as lime.

Examination of lead pipes.

I was able to obtain portions of lead service-pipes that had been in use in the town. These were found to contain a brown, readily-detachable deposit. Using a small circular brush such as is employed for cleaning lamp chimneys, I brushed off a considerable quantity of this deposit from the interior of pieces of the lead piping.

The piping then showed marked eating away of the lead, chiefly along the bottom of the pipe. In some cases this was very marked and had caused bursting of the pipes.

Mr. Fairley kindly analysed this powder and found it to contain about 42 per cent. of metallic lead. (The full analysis will be found on page 20.)

The piping from which this powder was obtained had been in use for many years, and it is not possible to say when the formation of the lead compounds began to take place or ceased to do so, if, indeed, it had ceased. Yet the presence of a large amount of readily-

detachable lead compound on the inside of a water pipe shows that the water has at some time, if not continuously, had marked action on the pipe. It is conceivable that the amount of this deposit, or the ease with which it is detached, may have been affected by the treatment begun in 1912, but this can merely be a matter of conjecture.

Conclusions as to the effect of the treatment begun in 1912.

Consideration of the facts set out in the foregoing pages lead to the following conjectures :—

(*a*) That the treatment, though it appears usually to have been regularly applied, is not sufficiently regulated and governed by tests to constitute a treatment of uniform adequacy, and that, in consequence, water which has been insufficiently neutralised and remains plumbo-solvent may at times have found its way into the service pipes, notwithstanding the treatment.

(*b*) That although the treatment may have been ordinarily sufficient, or more than sufficient to counteract any acidity or plumbo-solvent property of the water under normal or average conditions, yet it may have failed on occasions when the water attained an abnormally high degree of activity (for example, after rain-storms following prolonged drought).

(*c*) That the lime treatment cannot be regarded as necessarily removing properties of the water, other than acidity, which enable it to act on lead ; in particular its "erosive" properties. Indeed it is conceivable that as a result of treatment, destruction of plumbo-solvency may be more than counterbalanced by increased ability to erode lead.

General Considerations on the Inquiry.

It has been shown that a large number of cases of illness have recently come to notice in this district, which, though usually mild and in some cases obscure in their symptoms, may be referred to lead poisoning, the occurrence and distribution of which can only be satisfactorily accounted for by assuming that the water supply was the agent by means of which the lead had been ingested.

Inquiry as to the nature and origin of the water places it under serious suspicion of having had plumbo-active properties during the period in question, but the evidence is in many respects unsatisfactory. On the one hand analyses made of samples taken at the time of my visit showed that the water then possessed little action on lead, and did not reveal the presence of lead in the water from taps served by lead pipes. On the other hand evidence was obtained of great variability in the character of the water in respect of its ability to act on lead, both before and after the supply was subjected to lime treatment. As a result, it is not possible to say with any confidence that the water will remain in the comparatively satisfactory state in which it was found at the time of the inquiry.

In order to safeguard the future and to arrive at more definite conclusions as to the best method of treatment to adopt it would be

advisable that the water company should employ a competent analyst for a period sufficient to enable him to devise and carry out a series of differential experiments. These should be made in reference both to plumbo-solvency and to plumbo-erosive ability, and extend over some considerable time, so that the nature of the water at different seasons of the year, in storm and in drought, may be fully investigated.* Laboratory experiments on different methods of treating the water should be carried out, so that not only the widest possible variations, but also the best possible treatment of this particular water may be fully ascertained. In this connection, the addition of sodium carbonate might receive attention.

It must be added, however, that the problem of treating the water so as effectively to prevent its having any action on lead is rendered more difficult by the great lengths of lead piping which are frequently met with in Guisborough. I would recommend their replacement, wherever this is practicable, by iron or suitable tin-lined pipes.

I should like, in concluding, to express my sense of indebtedness to many persons who kindly assisted me during my inquiry, and more particularly to Mr. W. Richardson, clerk to the urban district council, to Mr. J. W. Clarke, secretary to the water company, and to Dr. W. W. Stainthorpe, medical officer of health, who spared neither time nor trouble in giving me all the assistance and information in their power.

FRANK SEYMOUR.

ADDENDUM A.

Note on Alterations made or now in progress at the Water Works.

In addition to complaints of the water causing plumbo-solvency, many representations have recently been made that the water was unsatisfactorily filtered, being coloured, and at times odorous, especially when heated.

The water as used for domestic purposes was markedly turbid and of a yellowish colour. No doubt the dryness of the summer caused what water remained in the reservoir to be unduly discoloured, but it did not appear to me that the filtration could be considered satisfactory, or more of the colour and turbidity would have been removed. I am informed that since my visit a quantity of mud and vegetable *débris* has been removed from the exposed portions of the bed of the reservoir.

The company have now erected a third Candy filter at a site nearer to the reservoir, and more elevated than that occupied by the two filters referred to. The latter have been removed to this site, where the lime treatment will also be carried out. A meter is being erected so that the actual daily consumption of water may be known. After filtration the water will run into a

* In this connection the suggestion of Mr. Fairley (p. 19) that the water may be intermittently affected by sulphuric acid derived from iron pyrites, might receive attention. It will be remembered that Dr. Houston found very little evidence of such action in the course of his investigations of a large number of gathering grounds yielding waters liable to act on lead, although in an isolated case (Rochdale) he showed the possibility of iron pyrites being occasionally a source of serious trouble.

covered service tank of 80,000 gallons capacity. This will serve two purposes: it will act to some extent as a sedimentation tank, and it will prevent water being rapidly drawn through any of the filters while one of them is undergoing cleansing.

ADDENDUM B.

Analyses, 1913.

(A).—*Results of analyses of various samples of water from the Guisborough Water Company's supply, carried out by Mr. Thomas Fairley, County Analyst, in September*, 1913.

No. 1. Taken from a tap in a private house in Guisborough. The sample was taken at an early hour, the tap not having been used since the previous evening.

No. 2. Ditto.

No. 3. Ditto.

No. 4. Taken from the Guisborough Water Company's surface water reservoir.

No. 5. Taken from the Guisborough's Water Company's spring service reservoir.

No. 6. Taken from a tap in Bow Street before washing of filters.

No. 7. From same tap during washing of filters.

No. 8. From same tap about three hours after the filters had been washed.

Nos. 1 to 5 were taken by me on 29th August, and Nos. 6 to 8 were taken by George Bradford, foreman to the water company, on 2nd September.

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Total dissolved solids ...	7·19	7·61	7·02	6·84	7·81	—	—	—
Loss on ignition	1·40	1·68	1·77	1·66	0·28	—	—	—
Iron in solution (as Fe_2O_3)	0·44	0·28	0·33	0·79	Trace	—	—	—
Total Calcium (as CaO)...	0·99	1·02	0·96	0·60	1·77	—	—	—
Free Ammonia	0·001	0·002	0·001	0·003	0·001	—	—	—
Albuminoid Ammonia ...	0·004	0·007	0·005	0·009	0·001	—	—	—
Nitrates	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Nitrites	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Chlorides as Sodium Chloride.	2·54	—	2·80	2·54	2·80	—	—	—
Alkalinity as $CaCo_3$ (Indicator Methyl Orange.)	1·33	1·30	1·20	0·56	3·12	0·42	0·49	0·49
Lead in solution	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Oxygen absorbed in four hours.	0·14	—	0·16	0·19	0·01	—	—	—
Oxygen dissolved... ...	0·28	0·23	0·37	0·60	0·67	0·50	0·53	0·74
Smell at 100° F.	Faint earthy.	Faint earthy.	Faint earthy.	Faint earthy.	Nil	—	—	—
Colour in Lovibonds Units 2 feet (red, yellow and blue.)	10 *Y* + 4 *R* + 1·4 *B*	12 *Y* + 4 *R* + 1·5 *B*	10 *Y* + 3·2 *R* + 1 *B*	20 *Y* + 6 *R* + 2·1 *B*	0·4 *Y* + 0·5 *B*	—	—	—
Total hardness in Clarke's degrees.	2·2°	—	2·3°	1·8°	3·6°	—	—	—
Lead dissolved in one day	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Lead eroded in one day ...	Nil	Nil	Nil	Nil	Nil	1·40	1·75	1·05
Lead dissolved in three days.	0·35	0·35	0·35	0·70	Nil	0·52	Nil	Nil
Lead eroded in three days	Nil	Nil	Nil	Nil	Nil	2·31	3·40	1·22
Amount of lead in sediment from one gallon.	0·008	0·001	0·001	Nil	Nil	0·002	Nil	0·003

N.B.—The results are expressed as grains per gallon unless otherwise stated.

Remarks by Mr. Fairley.

Samples Nos. 1, 2 and 3 are marked as being taken from different consumers' taps. Their composition and general character is practically the same, except that the sediment of No. 1 contains eight times as much insoluble lead compounds as found in Nos. 2 and 3 sediments, but even in No. 1 the quantity is very minute. These samples have practically the same alkalinity to methyl orange—1·3 grains reckoned as calcium carbonate. In my experience this is quite sufficient to prevent any material action on lead, and this opinion is confirmed by the tests for solution and erosion which appear in the tabular reports, and also by the absence of lead in solution though the samples had been standing for some hours in lead pipes.

Sample No. 4 is from the reservoir outlet, and differs from the above in the much smaller proportions of calcium and alkalinity. The effect of the diminished alkalinity in increasing the plumbo-solvent action of the water is well shown by the three days' test for dissolved lead. This water, however, cannot be said to have a very marked action on lead. It is very highly coloured, so much so as to be objectionable.

Sample No. 5 differs in many respects from the above. It is not a peaty water; the calcium and alkalinity are much greater, and the water has no action in lead, as shown by the three days' tests.

The analyses, and the tests for plumbo-solvency and erosion, do not explain the cases of lead poisoning which, I understand, are prevalent among the consumers of this water, and I am of opinion that acid water (probably containing sulphuric acid derived from the oxidation of pyrites) is occasionally passing into the service pipes; such water would readily dissolve lead and produce the effects complained of. The increased use of No. 5, which is a water of good quality, would form an excellent antidote for such acid waters.

If feasible, the gathering grounds should be treated with an occasional lime dressing, and any stagnant pools should be filled up, especially if in the neighbourhood of shale.

Nos. 6, 7 and 8 were only partially tested. The alkalinity, calculated as calcium carbonate, is practically the same in each case and is much smaller than in Nos. 1, 2, 3 and 5. It is also slightly smaller than in No. 4.

These samples (Nos. 6, 7, and 8) have no dissolving action on lead in one day, but for the same period, each has an erosive action, this being most marked in No. 7.

For the three days' action on lead No. 6 has a dissolving action very similar to No. 4 in the previous samples. Nos. 7 and 8 have no dissolving power. As regards erosion during this period, No. 7 is the strongest, then No. 6, and lastly No. 8.*

No. 7 does not contain any lead in the sediment, and that found in the sediment of Nos. 6 and 8 is extremely minute.

---

* The method adopted in testing for solution and erosion was as follows:—Pieces of bright lead, "shaved," measuring 1" × ½" were placed in test tubes

(B.)—*Analysis, by Mr. Fairley, of sediment from the interior of lead service pipe. The sediment was obtained by brushing with a small circular bristle brush the interior of lengths of lead piping which had been allowed to dry thoroughly.*

Moisture removed at 100° C.	7·42 per cent.
Loss on ignition	18·44 „
Total lead compounds (calculated as PbO)	44·93 „
Iron compounds (as Fe_2O_3)	22·10 „
Total sulphates (as SO_4)...	2·25 „
Traces of Cl, Ca, &c.	—
	95·14 per cent.

(C.)—*Result of an examination of the plumbo-solvency and erosion of four samples of water taken from feeders of the Guisborough Surface Water Reservoir on 27th September. The samples were obtained by the medical officer of health, and were examined by Dr. G. W. Monier-Williams.*

No.	Reaction of 100 c.c. of the water.	Amount of lead compound formed calculated in grains per gallon.			
		In one day.		In three days.	
		Soluble.	Insoluble (eroded).	Soluble.	Insoluble (eroded).
1	7 c.c. $\frac{N}{100}$ H Cl.	nil.	0·21	nil.	0·56
2	2·5 c.c. $\frac{N}{100}$ H Cl.	nil.	0·42	nil.	2·38
3	1·2 c c. $\frac{N}{100}$ Na OH.	nil.	1·19	nil.	1·12
4	2·3 c.c. $\frac{N}{100}$ Na OH.	0·56	0·63	nil.	0·98

(6″ × ¾″) and 10 cubic centimetres of the water to be tested was poured in and allowed to remain undisturbed for one or for three days.

When *no* erosion took place, as shown by the clear and transparent appearance of the water, an aliquot portion was removed and the amount of lead estimated.

Where solution and erosion both took place the lead in solution was estimated by filtering an aliquot portion through a minute Swedish filter paper and estimating the lead in the filtrate. Another aliquot portion of the shaken liquid is treated so as to dissolve the eroded lead in suspension, and the total lead then estimated. The amount eroded is obtained by difference.

ADDENDUM C.

Rainfall in inches.

Table showing

1° *Rainfall for each month from October*, 1912, *to September*, 1913.
2° *Average rainfall for each month. From October to March the rainfall average is for* 39 *years, and from April to September for* 38 *years.*
3° *The amount by which the rainfall for* 1912–13 *exceeded or fell short of the average in each month.*

Month.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
1st 10 days ...	0·43	0·66	0·28	1·10	0·64	0·68	0·88	1·28	0·71	0·98	0·15	1·03
2nd 10 days ...	0·42	1·64	0·42	1·53	0·14	1·01	0·86	0·03	0·67	0·00	0·15	0·20
Remainder of month	2·03	0·63	0·50	1·19	0·27	1·07	1·53	0·31	0·60	0·61	1·46	0·41
Total rainfall for month.	2·88	2·93	1·20	3·82	1·05	2·76	3·27	1·62	1·98	1·59	1·76	1·64
Average for month	4·273	3·519	2·888	2·075	2·022	2·233	2·118	2·481	2·299	3·299	3·308	2·403
Amount by which rainfall in 1912-13 *exceeded* the average.	—	—	—	1·745	—	0·527	1·152	—	—	—	—	—
Amount by which the rainfall in 1912–13 *fell short of* the average.	1·393	0·589	1·688	—	0·972	—	—	0·861	0·319	1·709	1·548	0·763

The above table is compiled from figures supplied to the Guisborough Water Company by Mr. W. I'Anson, Manager of the Cleveland Water Company, whose reservoir is some two miles distant from the Guisborough Reservoir, and at about the same altitnde. No observations had been made by the Guisborough Water Company.