A WATER-BORNE EPIDEMIC OF TYPHOID FEVER.

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(With Plate III, 3 Charts and 2 Plans.)

The village of Ecclefechan, situated about 10 miles north of Gretna, is known to the world as the birthplace of Thomas Carlyle. So distinguished a literary connection assured fame enough for any village; unfortunately it gained a brief notoriety of a very different sort during the late summer of 1930 when an explosive outbreak of typhoid fever caused widespread alarm in the neighbourhood. As it proved possible to identify its origin with a reasonable degree of certainty, it seems desirable to describe it in some detail.

Like the rest of the country, Dumfriesshire has experienced a great decrease in the incidence of the Enterica group of diseases during recent years. Chart 1, showing the yearly notifications since 1891, emphasises the extent and the rapidity of the fall. No single epidemic of any size is recorded during the period 1891–1929. The year of greatest prevalence (1895) comprised a number of small, apparently unrelated outbreaks, distributed over a considerable period and a wide area, the largest among them affecting fourteen persons. Study of the available records suggests that the main cause was personal infection, unchecked by facilities for hospital isolation, and uncontrolled by bacteriological tests of infectivity. This endemic type of typhoid fever has now disappeared, but the experience of 1930 shows that the occurrence of epidemic typhoid is still a possibility. It is likely that such accidental outbreaks, when they do occur, may be on a considerable scale, as the practical disappearance of endemic infection must have greatly increased the proportion of non-immunes in the population.

Cases from the County Landward are shown in Chart 1 as white columns, those from the small burghs are shaded, while those reported from Ecclefechan are black. The last indicate a somewhat higher incidence of typhoid in Ecclefechan than might be expected. Admittedly the figures are too small to permit much emphasis being laid on this, but it is interesting to note that the village, which comprises roughly 1 per cent. of the total population at risk, had, between 1891 and 1929, 4·6 per cent. of the cases.

The village of Ecclefechan has a population of about 630 persons. There is a considerable proportion of poor houses, and the general sanitary condition

has long been regarded as unsatisfactory. A few of the better-class houses have water-closets and cesspools; but in 1930 the great majority of the population still utilised dry closets.

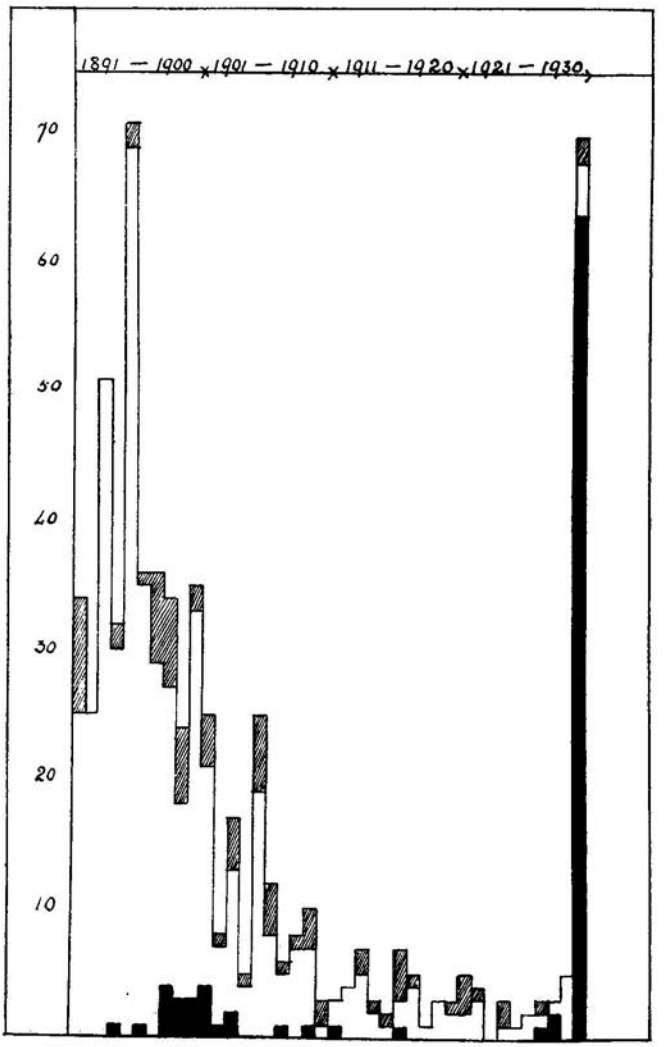
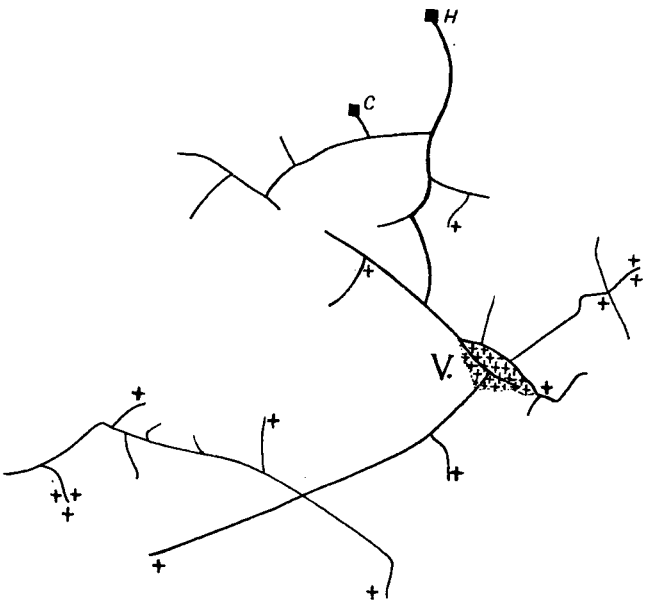


Chart 1. Notifications of Enterica in Dumfriesshire, 1891–1930.

White cols. Notifications from County Landward (excluding Ecclefechan).
Black cols. Notifications from Ecclefechan.
Shaded cols. Notifications from small burghs.

The Ecclefechan Special Water District was formed in 1911 and a supply of gravitation water provided for the village and a considerable part of the parish round it. The supply is taken from a number of springs on the farm of H., about $1\frac{3}{4}$ miles north of the village, and from a smaller group on the farm

of C. (see Plan I). At both places springs issuing from a gravel bed were protected by enclosing them in vertical fireclay pipes, surrounded by puddle clay and closed by concrete covers. From the wells so formed the water was conducted by spigot and faucet fire-clay pipes to collecting tanks. That at H. has a capacity of about 45,000 gallons. The tank at C. is smaller, and, its outlet being controlled by a reflux valve, it does not come into action until the tank at H. is practically empty. No filters were provided at either source, it having been held, presumably, that natural filtration by percolation through gravel into the protected wells would be sufficient. The land surrounding the sources is rough moorland at C., but at H. is pasture, and in the latter case the farm



Plan I. Ecclefechan Special Water District showing pipe line, and distribution of primary infections. *V* indicates the village of Ecclefechan.

buildings, which lie at a distance of about 400 yards from the nearest spring, are at a distinctly higher level (see Pl. III, fig. 1).

No sewage passes from the farm towards the water-collecting area, and no agricultural drains are known to exist within a considerable radius of the buildings, as the steep gradient makes subsoil drainage unnecessary. It is therefore impossible that any contaminating matter from the house could gain accidental access to a field drain and thus be conveyed to the neighbourhood of the wells. On the other hand, the steep gradients between the farm and the collecting area make it inevitable that in time of heavy rain all surface washings from an extensive area of pasture must be carried down to the low ground where wells and tank are situated. Such surface washings were theoretically collected

by field drains in the lower part of the valley and conveyed past the tank by a 9 in. tile which empties into the head of the Ecclefechan Burn.

It will be seen from this description that the supply, being unprovided with any facilities for storage or controlled filtration, and inadequately protected against disturbance by flood water, would not to-day be regarded as entirely satisfactory. Nevertheless, had the system been in reality what it purported to be, little serious objection could have been taken to it. Unfortunately, as will be shown later, it was discovered that the water, after collection in the wells, might be exposed to pollution during its passage to the tank. Quarterly examinations, chemical and bacteriological, had been made of the supply ever since the works were constructed, and those had generally given quite satisfactory results.

The distribution of piping in the Special District will be understood by referring to Plan I. It supplies a population estimated in 1930 at 1013 persons, of whom 630 were resident in the village of Ecclefechan itself.

On 1. ix. 1930 the writer learned that several cases of obscure illness had occurred in Ecclefechan during the previous few days. The same afternoon, two samples of blood from members of different households in the village were reported from the County Laboratory as positive to Widal's reaction, showing agglutination with *B. typhosus*, but not with the Paratyphoids. A telephonic conversation with the local practitioner confirmed the existence of a number of cases of sickness. Preparations were at once made to deal with an outbreak of unknown extent, and removal of patients commenced. A list of all absentees from school was obtained and made the basis of a house to house visitation, so that within the first 48 hours a fairly accurate idea of the extent of the outbreak to date had been obtained.

It is worth noting here that no evidence could be obtained of any prevalence of gastro-intestinal disturbances—or, indeed, of any unusual amount of illness —precedent to the epidemic. In fact, it appeared that the district, until the latter part of August, had been unusually free from sickness.

Removals to hospital in September, 1930, were:

During week ending	6th	23
	13th	31
	20th	6
	28th	1
	Total cases	61

One confirmed case and two doubtful cases were isolated at home, making a total of sixty-four cases notified. By the end of September, two of the county hospitals and part of a third were entirely occupied by typhoid patients. Fortunately, other infectious diseases were not prevalent at the time, and the remaining hospital accommodation was sufficient to deal with them.

The dates of invasion, so far as they could be ascertained, are shown in Chart 2. From this are excluded (*a*) the two doubtful cases mentioned above,

(*b*) two cases in which the diagnosis was not confirmed after removal to hospital, and (*c*) three cases in which the history was obviously unreliable. On the other hand, three cases which were reported from areas outside Dumfriesshire are included. The five last cases, occurring on September 6th, 7th, 8th, 10th and 12th, were all members of households from which patients had already been removed and were regarded as secondary infections.

Information obtained regarding several persons in other parts of the country, who had apparently been infected in Ecclefechan and had developed the disease after returning to their homes, gave help in fixing the date at which infection had occurred. Two of those persons had left Ecclefechan on August

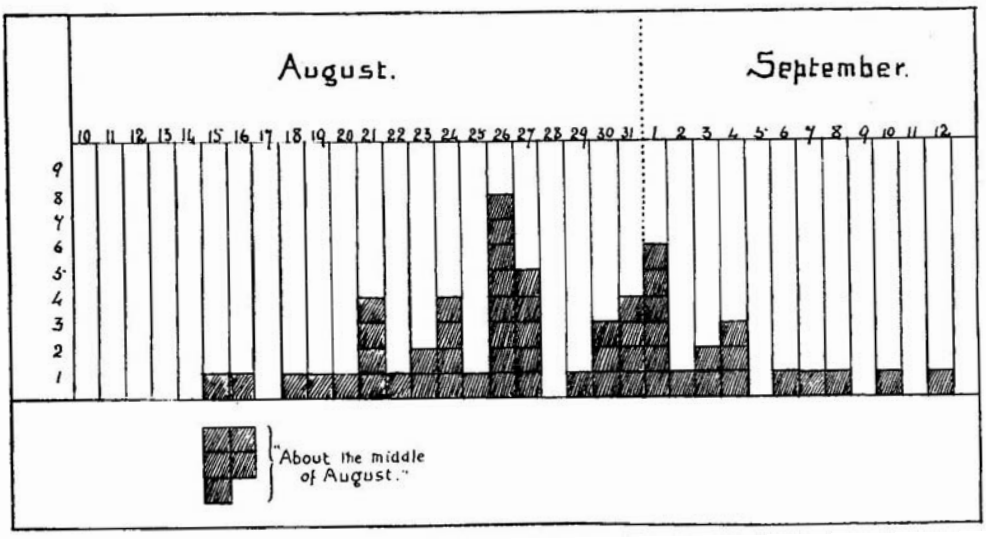


Chart 2. Presumptive dates of invasion.

10th and 11th respectively, while another did not arrive till the 12th. It was thus evident that infection had been present in the village at least during the period August 10th—12th.

The incubation period of typhoid fever may be taken as extending from a few days to at least 3 weeks, and, most usually, from 10 to 15 days. Chart 2 shows that all the primary cases occurred within 3 weeks of August 14th, and 60 per cent. within 15 days of that date. This supports the theory of an infection existing from August 10th to 14th, though of course it may have lasted longer.

The explosive nature of the epidemic suggested that the vehicle of infection must be water, milk or some foodstuff used in common by the sufferers. The following evidence seemed to support the hypothesis that the water was at fault:

(1) Cases occurred only among persons living, or who had recently lived, in the Ecclefechan Special Water District, and who had drunk from the public water supply.

(2) The case incidence (primary cases only) was 55 per 1000 of the inhabitants—a figure which suggests water rather than any other possible vehicle of infection, especially when it is remembered that much of the affected area is rural, and that opportunities for mass infection of any other sort are practically non-existent.

(3) At least nineteen separate milk supplies were used by patients. In several instances those were private supplies, used only by persons living at the farms where the cases occurred. No evidence of mixing milk could be obtained, and, in view of the conditions of the milk trade in the district, it is in the highest degree improbable that mixing ever occurs to an appreciable extent. Such large dairies as exist in the neighbourhood send all their milk to wholesale dealers outside the county, and the local trade is carried out by a number of small purveyors. Moreover, a careful examination of all dairy workers in the area (referred to later) produced no evidence of any missed case.

(4) The age and sex incidence of 55 confirmed primary cases was:

	M.	F.	Total
Under 5 years	1	2	3
5–10 „	6	5	11
10–15 „	6	5	11
15–25 „	5	6	11
25–45 „	9	4	13
45–65 „	4	1	5
Over 65 „	—	1	1
Total	31	24	55

The relatively heavy incidence on the higher age periods is evident. This is not, in itself, evidence in favour of a water-borne infection, though it is suggestive. Various writers have described a selective infection of the higher ages as characterising water-borne, in comparison with milk-borne, outbreaks. Hunt (1913, *J. Infect. Dis.* **12**, 415) states that in Pennsylvania practically all water-borne epidemics have had an incidence of 60–70 per cent.—sometimes as high as 80 per cent.—on the age groups between 10 and 30, while in milk-borne epidemics the prevailing age is well below 15. In the Rockford, Ill., epidemic (Jordan and Irons, 1912, *Ibid.* **11**, 21) about 68 per cent. of the patients were over 15 years old. At Quincey, Ill. (Jordan and Irons, 1913, *Ibid.* **13**, 16) 71 per cent. were between 15 and 30 years old, while at Des Moines, Cedar Falls and Waterville the incidence on the 10–30 age group varied from 64 to 72 per cent. (Grover, 1912, *Ibid.* **10**, 388). All those were epidemics ascribed to infected water.

On the other hand, Bigelow and Doering (1929, *Am. J. Hyg.* **9**, 445), analysing thirteen epidemics from various causes, found no significant age difference as between milk- and water-borne outbreaks. On occasion the victims of water-borne typhoid may be mainly children, as was the case at Ringwood in 1912, when more than four-fifths of the cases were under 15 years of age and the age group 10–14 suffered most heavily (H. A. Macewan, *Report to Local Govt. Board on Enteric Fever at Ringwood*, N.S. No. 74).

The inference appears to be that, as water is drunk at all ages, the incidence of water-borne typhoid will correspond more or less closely to that of all typhoid infections, which falls most heavily on persons of from 10 to 25 or 30 years of age. When the vehicle of infection is used by any special age groups, as is the case, generally speaking, with milk, ice-cream, etc., the incidence of infection is correspondingly altered.

A high proportion of male cases has been described as characterising water-borne typhoid. This was noted in the Ecclefechan outbreak, though the figures are too small to be significant.

(5) Milk having been excluded as a possible source of infection, the question of ice-cream was investigated. It was soon found that this possibility might be disregarded. A large number of the patients declared that they never ate it, and there was no reason to doubt the accuracy of their statements. No other article of food was common to any number of patients. In this connection it should be emphasised that Ecclefechan, except for the inhabitants of the village itself, is not a shopping centre, and that persons living in the vicinity often obtain their supplies from neighbouring towns.

(6) No man, resident in Ecclefechan but working elsewhere, is known to have contracted the disease.

(7) On the other hand, at least three men, living elsewhere but working in Ecclefechan during the first half of August, did contract it. In view of the fact that workmen generally take *food* with them from their homes, but obtain *water* in the locality where they work, this is significant. It was ascertained that two of the men referred to did drink large quantities of water while at work—to such an extent as to cause some comment by their mates—but none drank any milk.

(8) The weather during the earlier part of August was very hot and oppressive, and many patients admitted that they had drunk unusually large quantities of water during that time.

(9) A piece of negative evidence of considerable importance was that a private sanatorium situated close to the village and with accommodation for over 40 patients besides staff escaped entirely. This institution has a private supply of water, as well as that from the district mains. The private supply is exclusively used for drinking. The milk supply to the sanatorium was also used by seven households in which cases occurred.

That the public water supply was the vehicle of infection was therefore adopted as a working hypothesis.

The absence of public sewers in the district, the lack of any evidence of leakage which might permit of contamination being drawn into the pipes, and the distribution of the cases (see Plan I) suggested that infection had probably taken place at the source. This might be either in the collecting area at H. or at C. There is no human habitation near the latter, which, as noted above, is an auxiliary supply. Probably it was very seldom, if at all, in use during August, 1930, and investigations were begun at H.

No history of typhoid fever or of any disease resembling it could be obtained from anyone at the farm. Samples of blood were therefore taken from all the employees. Two of those gave a positive reaction. One, from an ex-soldier, agglutinated *B. typhosus* 1 in 50, *B. paratyphosus* A 1 in 50, and *B. paratyphosus* B 1 in 25. He had been inoculated while in the army, which seemed sufficient to account for the titre of his blood. The other, from *X*, a middle-aged man who had never been in the army and had never been inoculated, agglutinated *B. typhosus* in a dilution of 1 in 50, and showed no clumping with the Paratyphoids. *X* was at once warned that he might be a carrier and the necessary precautions explained to him. He was directed to submit specimens of faeces and urine daily, these being collected every morning by a member of the sanitary staff, and brought by motor to the County Laboratory in Dumfries. From the second faecal specimen, collected on September 11th, typical typhoid bacilli were cultivated.

Thus identified as a typhoid carrier *X* was at once removed to one of the county hospitals, as it was felt that to allow him to remain in a water-collecting area would be too great a risk, whatever precautions were taken. Repeated enquiry elicited no history of typhoid from him, but it transpired that a brother and sister had suffered from the disease some 40 years ago. Whether his carrier state was the result of that it is, of course, impossible to say, but it is at least interesting to note that he had lived at one time in intimate contact with cases of typhoid fever. Between September 7th, 1930 and February 24th, 1931, twenty-five specimens of his faeces were examined, and from those *B. typhosus* was isolated on sixteen occasions. His urine was always negative.

As it was impossible to keep him indefinitely in isolation, employment was found for him at one of the county hospitals under conditions which should make him innocuous in future.

The hypothesis that the infection was water-borne was thus strengthened by the discovery of a carrier in the water-collecting area. The next point to be investigated was the channel by which infection had gained access to the water system.

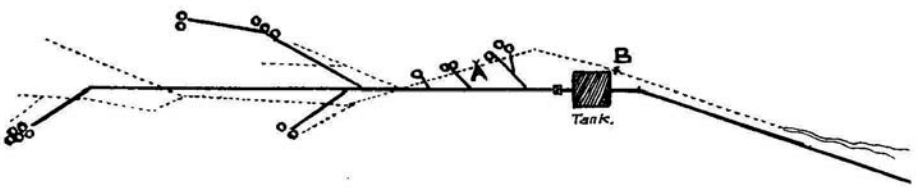
Reference to Plan II shows that the 9 in. field drain, which takes surface water past the collecting tank, is crossed by the pipes bringing water from springs 1 to 6. Examination of the drain itself showed an area of waterlogged ground near the tank. About the centre was an opening leading from the surface down to the drain, which had apparently been made to allow surface water to get away rapidly. A second opening, made presumably for the same purpose, was found at the corner of the fence round the tank. Both openings, needless to say, had been made without authorisation. They are indicated as *A* and *B* on Plan II. Direct communication between the surface of the ground and the field drain in the near neighbourhood of the tank was thus possible.

The tank itself was emptied and examined, but there was no evidence of any leak in its walls, floor or roof, by which infective matter could enter from the drain. The pipes from the springs were therefore exposed, and an obvious

channel of pollution was discovered. At the point where those pipes crossed the field drain, their joints were entirely open. The water from the springs and that in the field drain were mingling freely. Presumably the joints had been made, 20 years ago, with clay, and this, in the course of time, had been washed away. Pl. III, fig. 2 shows the field drain uncovered, and the faulty pipes from springs crossing it.

Assuming that specific contamination was deposited at any part of the valley in which the springs lie, it could be carried, in case of heavy flooding, towards the tank, which is at the lowest point, it might pass, through the surface openings *A* and *B* into the land drain, and thereafter must necessarily contaminate the spring water through the faulty joints of the water pipes.

The existence of a carrier in the water-collecting area, and a channel by which contamination from the surface of the ground might gain access to the tank were thus established. Both those factors, however, had been in existence for years, and it remained to be determined whether any special circumstances about August 10th–14th, 1930, had been specially favourable to pollution of the water supply. Admittedly, it is seldom possible to determine all the factors



Plan II. Collecting area at H. Springs ₀°₀ Water pipes ——— Field drains - - -

which combine to produce the conditions necessary for an epidemic. Knorr (1929, *Arch. f. Hyg. u. Bakt.* **102**, 10) writes: "Zufällig ist es vor Allem das so viele einzelne Faktoren ineinandergreifen müssen, damit derartige Epidemien entstehen können; sonst wären sie ja viel häufiger!" Yet amongst those factors that of rainfall is of such obvious importance that it must be taken into consideration.

We are greatly indebted to the Superintendent of the Meteorological Office in Edinburgh, for having supplied us with the necessary data. He pointed out that there was a remarkable dearth of rain from February till nearly the middle of July, followed by a wet period. During the five months February–June the rainfall in the Ecclefechan district was less than that of a normal 3-month period.

Chart 3 is constructed from the rainfall figures recorded at the two stations nearest the farm of H. One lies about 3½ miles to the north-west, the other about 2½ miles to the east. The chart records (1) the average daily rainfall during each week in June and July, (2) the daily rainfall during August, and (3) the invasion dates of the primary typhoid cases during August and September.

The curves show that the average rainfall at those stations during the first 10 days of August was not above that of the preceding 3 weeks, and that there was no excessive rainfall on any single day. As has been indicated above, the water was certainly infected by August 10th. The highest rainfall during the month was more than a week *after* that date (August 18th–20th), and this was followed after a 6–8 days' interval by the highest peak of incidence and again, 6 days later, by a second peak. The curve might be taken as indicating a succession of contaminations. Nevertheless, it is certain that the water was infected by August 10th, and as typhoid bacilli can certainly survive in faeces

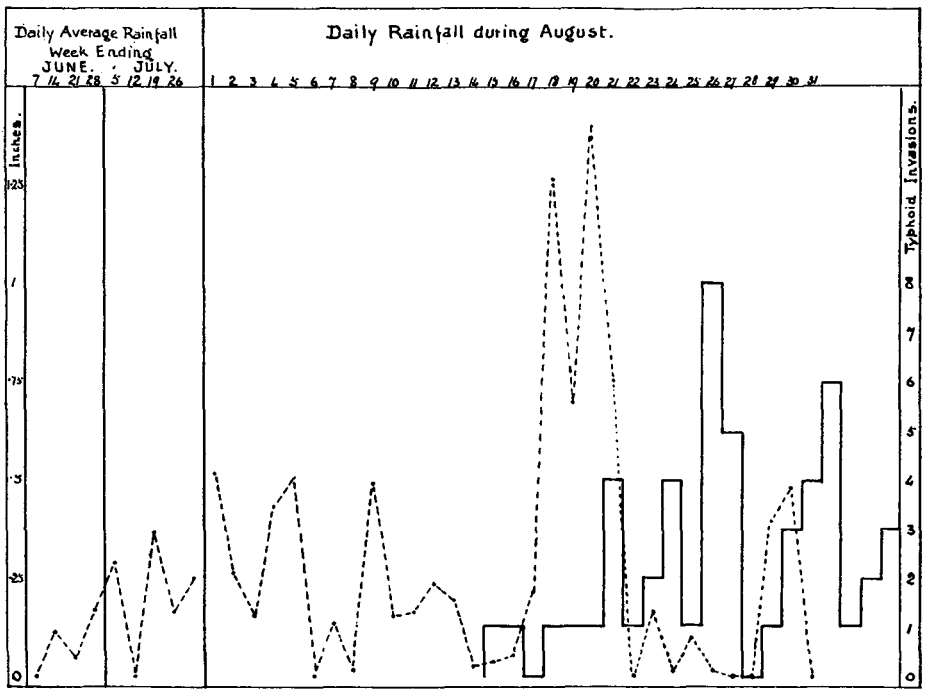


Chart 3. Rainfall and presumptive dates of invasion.

Rainfall - - - - - - Typhoid invasions ————

for over 5 days, a single contamination on August 10th might still be operative till at least the 14th. This, as the invasion dates of the primary cases show, is sufficient to explain the outbreak, and it seems unnecessary to postulate any other cause. At the same time it is impossible to say that infection may not have been due to a succession of contaminations over a somewhat longer period.

It seemed probable that the infection had ceased before the existence of the epidemic was recognised. But to make sure that no infective matter had been carried into and retained in the tank, it was emptied and then refilled with water to which bleaching powder was added to give a concentration of free

chlorine equal to 10 parts per million. This was retained for 60 hours, and thereafter, as the discharge of a solution of this strength into the stream would have been dangerous to fish life and to stock watered on the banks, it was dechlorinated by the addition of sodium sulphite before emptying.

The tank was then taken into use again, and the pipe line overhauled. While this work was in progress the supply to the district was chlorinated, the efficacy of the chlorination being controlled by colour tests and examination for *B. coli* made daily at various points.

At a later stage the whole piping system was replaced, cast-iron pipes being laid, and sand filters constructed at both H. and C.

The milk supply had to be carefully supervised, as several patients had been removed from dairy farms and the occurrence of an unrecognised case might well have caused a secondary outbreak due to milk. Fortunately, the number of dairy farms in the affected district is small. The village itself and the immediate neighbourhood are supplied by nine dealers, generally in a small way of business and with few cows. There are four large dairies which send milk out of the county. In every instance, however, this milk is pasteurised at the creameries, to which it is consigned before being distributed to consumers.

To make certain that no mild case had been missed, every person connected with the milk trade in the district was seen by a member of the county staff, and a sample of blood from each one tested for agglutinins to *B. typhosus*. All were negative. In addition, all the cows were examined by one of the County Veterinary Inspectors, without anything suspicious being found.

Two patients died during the epidemic—a man aged 23 and a woman aged 51. In addition, the husband of one of the female patients had died of "pneumonia" a few days before she was notified. The history was inconclusive, but the possibility that he was a typhoid of the pneumonic type must be kept in view. If his death be included, the case fatality of the epidemic was 4·6 per cent., that among the cases actually notified was 3·1 per cent.

It was feared that the epidemic might result in a crop of carriers, with resultant secondary cases. The risk seemed all the greater in view of the rather primitive sanitary arrangements of the village. To guard, so far as possible, against such an eventuality, no case was released from isolation until three consecutive negative examinations of both urine and faeces had been obtained. The details of those examinations will be found in the section on the bacteriology of the outbreak.

From the date of the cessation of the epidemic to the end of 1931 only one case of enteric has occurred in the Ecclefechan district. Whether the absence of more secondary cases was due to the precautions taken to prevent the formation of foci of infection, or to a general raising of the communal immunity consequent on the epidemic would be difficult to say.

SUMMARY.

1. The outbreak of typhoid fever in the Ecclefechan Special Water District affected 55 per 1000 of the inhabitants (primary cases only).

2. The evidence available indicated the public water supply as the vehicle of infection.

3. A typhoid carrier was found employed in the water-collecting area.

4. Examination of the water pipes after excavation showed that surface pollution might gain access to the pipes conveying spring water to the collecting tank.

5. Secondary cases were few in number, and so far there is no evidence that foci of infection remain as sequelae of the outbreak.

(J. R.)

BACTERIOLOGY.

An organism was isolated from twenty-nine of the fifty-eight patients tested and in many cases it was isolated repeatedly. Only ten examinations were made before the sixth week of illness. The organism from these various patients was Gram-negative and motile, and it formed a typical colony (metallic black or occasionally green) on Wilson and Blair's "glucose-bismuth-sulphite-iron brilliant green" medium. The biochemical reactions were as follows: Incubated over a period of 24 hours, no action on lactose, saccharose, dulcitol or arabinose; but production of acid without gas, when grown in glucose, mannitol and xylose. Twenty-four hours was the time for routine examination, but several cultures were incubated for 10 days and no further change occurred. All the organisms isolated were agglutinated to full or almost full titre by an anti-typhoid serum. A number of the organisms were grown on gelatine but no liquefaction occurred; a number were tested for indole formation but none was found.

In the case of the carrier and in three of the patients, the organisms isolated were subjected to absorption tests. In each case, rabbits were inoculated and their sera shown to contain agglutinins for *B. typhosus* O and *B. typhosus* H and for the organisms themselves. The organisms isolated absorbed agglutinins for themselves from their own sera. Genuine O and H organisms absorbed the agglutinins for themselves; also absorption of specific O and H sera with the suspected strains removed the agglutinins for genuine O and H organisms.

Methods of isolation. The method used for both faeces and urine was Wilson and Blair's medium referred to above, using a stock solution similar to that described in *J. of Hygiene*, **31**, 154. One hundred c.c. of sodium sulphite 20 per cent. were added to 50 c.c. of liquor bismuthi, and boiled together for 2 min. While still boiling, 10 grm. exsiccated sodium phosphate were added. When the mixture became cool 10 c.c. of an 8 per cent. solution of ferrous sulphate crystals were added. (This method was kindly communicated before

publication by Prof. Wilson.) When searching for the carrier in this outbreak, Wilson and Blair's brilliant green medium (as described in *J. of Hygiene*, **26**, 374) proved unsatisfactory in my hands when compared with MacConkey's bile-salt medium, and with the bile-salt medium using broth with brilliant green as a preliminary enrichment fluid. The newer method communicated by Prof. Wilson proved to be an excellent one. From each batch of plates made, one plate was planted out with *B. typhosus* as a control. A slight variation was noted in the time required to produce a black metallic colony, but otherwise the medium appeared to be consistently good in its isolation of *B. typhosus*. The newer method showed a marked superiority over MacConkey's bile-salt medium and brilliant green enrichment fluid. Consequently, when the time came to examine the urine and faeces of patients, before they left hospital, Wilson and Blair's medium (using one plate of the batch as a control) was the sole one used.

B. typhosus was isolated from twenty-nine patients. In ten of these, it was isolated from both faeces and urine, in fourteen patients from urine only, and in five patients from faeces only.

Seven patients were infective after the twelfth week.

	No.	Age		
Female	6	66	Urine + in 14th week	Faeces −
,,	9	8	Faeces + in 19th ,,	Urine + in 16th week
,,	50	42	,, + in 17th ,,	,, −
,,	55	18	,, + in 18th ,,	,, + in 15th week
Male	19	36	Urine + in 13th ,,	Faeces −
,,	23	30	,, + in 19th ,,	,, −
,,	54	24	,, + in 21st ,,	,, −

In the case of male 23, the positive urine was due to a relapse. No typhoid bacilli were found in the faeces during this relapse.

All cases examined gave three negative urinary examinations and three negative faecal examinations before leaving hospital, and no permanent carriers were detected. On p. 430 is appended a list showing the number of examinations and the period of illness during which they were made.

Serum reactions. The serum of each suspected case was submitted for agglutination reaction. In two cases the H agglutinin was absent up to the fifth week, but appeared later. In a third case the H agglutinin was absent during the fourth week, but no examination was made later. Agglutination with *B. typhosus* O cultures gave no reaction in these three cases. Organisms were isolated from these three cases, and these were proved to be *B. typhosus* by morphological, biochemical, and serological (including absorptive) tests. All three agglutinated to full titre with H anti-typhoid serum and produced higher agglutinating titres in rabbits for the H organism than for the O.

For *B. typhosus* O titres in twenty-four other cases, I am indebted to Miss E. F. Stubington of the Standards Laboratory, Oxford. The results show the serums to contain both O and H agglutinins.

Notes regarding the carrier. *B. typhosus* was not isolated from his urine, although twenty attempts were made to do so. Between 7. ix. 1930 and 24. ii. 1931 *B. typhosus* was isolated from his faeces sixteen times out of twenty-five attempts. Of the nine failures, three consecutive negative results appeared on two occasions. When the bacilli were isolated, they were usually very numerous. The carrier's serum agglutinates *B. typhosus* H in a dilution of 1 in 50, but not *B. typhosus* O.

	Faeces		Urine	
Week	Positive	Negative	Positive	Negative
2nd	1	—	—	1
5th	1	3	1	3
6th	1	11	3	11
7th	8	23	6	23
8th	2	22	9	12
9th	1	24	4	21
10th	—	31	3	27
11th	2	30	5	28
12th	2	24	7	17
13th	2	21	3	24
14th	2	22	2	22
15th	2	10	2	10
16th	2	5	1	7
17th	4	2	—	6
18th	2	5	—	7
19th	1	8	2	8
20th	—	3	1	2
21st	—	9	1	8
22nd	—	3	—	3
24th	—	1	—	1
	33	257	50	241

(E. A.)

EXPLANATION OF PLATE III.

Fig. 1. Showing enclosure round the collecting tank, with, in the background, the farm of H. The majority of the springs lie between the enclosure and the line of haystacks.

Fig. 2. Showing, at the further end of the cutting and in the immediate foreground, the field drain, formed, for the most part, of unjointed tiles. Two pipes carrying spring water to the collecting tank are seen crossing it. The joints of those pipes were quite open.

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Fig. 2

Fig. 1

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