

## Water-borne typhoid fever caused by an unusual Vi-phage type in Edinburgh

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### SUMMARY

Investigation of a small series of cases of typhoid fever infected in a river between 1963 and 1970 revealed that all were caused by a single source, a carrier of a rare phage type of *Salmonella typhi*. The contamination of the river resulted from an incorrect sewage connexion with a surface water drain outfall into the river.

### INTRODUCTION

Apart from occasional major epidemics, the incidence of typhoid fever in Britain is low and the actual number of cases attributable to water-borne infection is probably very small. Yet this danger cannot be overlooked. In the City of Edinburgh a total of 28 cases of typhoid fever were notified during the decade 1961–1970 (Annual Reports, 1961–70). Twenty of these probably acquired their infection abroad or during the two main epidemics occurring at Zermatt and Aberdeen in 1963 and 1964 respectively. But between 1963 and 1969, four cases occurred caused by one type of *Salmonella typhi*, Vi-phage type K1, which is rare in the United Kingdom. The cases were apparently unassociated socially but were infected in the City, and all had a reported connexion with a local river, the Water of Leith. Whenever the cases occurred efforts were made to trace their source by examination of the river water with Moore's swabs, (Moore, 1948; 1950), but without success. During the summer of 1970 a further opportunity to investigate this problem presented itself when four more cases of infection occurred with the same phage type and the consequent investigations revealed the infective source.

### HISTORY OF PRESENT OUTBREAK

The first case, an Edinburgh schoolboy aged 13 years, was admitted to the Infectious Diseases Hospital on 4 July 1970. He had been ill at home for 2 weeks with fever, headache and vomiting followed by diarrhoea, and he was diagnosed bacteriologically as typhoid fever. On inquiry at his home, it was found that the

patient and his friends had been collecting discarded bicycle parts in the Water of Leith near a muddy pool created by a rotting car seat and a fallen tree acting as a boom. Two of his friends stated independently that, while playing there together, the patient on more than one occasion had drunk the river water, probably about 7 June, but that they themselves had not done so. The home conditions of the patient were found to be very crowded, three brothers aged 19, 15 and 13 years all sleeping together on one bed settee in a small room. Bacteriological examination of 6 specimens of faeces and urine from close contacts of the patient yielded negative results; yet 24 days after the first boy's admission his brother was admitted to hospital with similar symptoms of a week's duration, and he also was shown to be suffering from typhoid fever. This boy had no connexion with the Water of Leith and had evidently been infected by his brother. This was the only secondary case in the series. However it emphasizes the need for careful surveillance of contacts of typhoid fever during the incubation period.

On 20 August a woman of 44 years who had been ill with general malaise and fever for 2 weeks was admitted to the Infectious Diseases Hospital in a confused mental state, unable at first to give a coherent history. She was an assistant in a fruit shop and had continued work until a few days before admission. On being interviewed a friend stated that they had picnicked together beside the Water of Leith on two occasions at the end of July, and that the patient had then drunk several cupfuls of the river water. She too was diagnosed bacteriologically as a case of typhoid fever.

On 17 September a boy of 11 years, one of a family of seven children, was admitted to hospital with a history of weakness and fever for 2 weeks. It was stated that he had been walking with his father and brother by the Water of Leith on 16 August. As reports had appeared in the newspapers concerning the earlier cases of typhoid fever and the association with the river, the children in this family had been told not to drink the water. Despite this the boy admitted to having done so when out of sight of the others. In his case *S. typhi* was isolated from the blood only, investigations of the faeces remaining negative throughout his illness.

These four bacteriologically proved cases completed the outbreak of 1970: three had definite association with the river, having actually drunk the water, and the fourth was a near contact of one of these in an overcrowded home.

#### FIELD INVESTIGATION

When the first case was diagnosed in July 1970 an investigation to trace the source of the infection was initiated by the City of Edinburgh Health Department in co-operation with the Central Microbiological Laboratories, the Lothians River Purification Board and the City Engineer's Department. This began with an intensive survey of the Water of Leith. The river is 21 miles long, rising in the Pentland Hills at a height of over 1000 ft., traverses Midlothian County and winds a tortuous course through the city, entering the estuary of the River Forth at Leith. It is popular for walks along its banks and is easily accessible for children playing and fishing. Its flow is fairly swift and it varies in depth from 1 to 3 ft. in dry

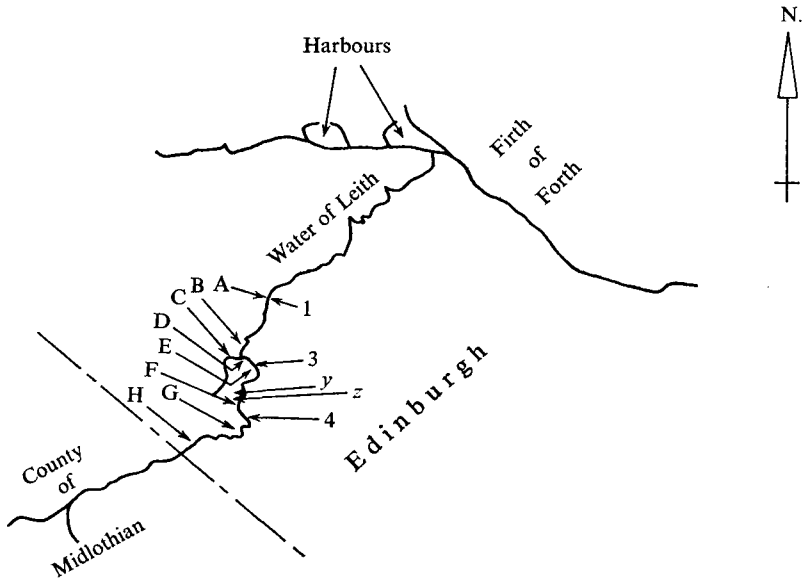


Fig. 1. Sites selected for bacteriological examination in relation to reported cases. 1, 3, 4: case connexions with river; A-H: swabs in river; *y-z*: swabs in sewer.

weather. The water is not used for domestic or horticultural purposes but has certain commercial uses for the mills and factories situated on its banks. For initial testing a stretch was chosen between the City of Edinburgh/Midlothian boundary and the furthest point downstream where those affected had had contact with the river, a distance of approximately  $5\frac{1}{2}$  miles. Sites were selected for the positioning of Moore's swabs in the river in relation to the points 1, 3 and 4 (Fig. 1). At the same time the swabbing of adjacent sewers was instituted. The main sewer effluent from residences on both sides of the river, and from mills further upstream runs parallel to the river and in places crosses it and occasionally overflows into it. Two sites (*y* and *z*) were selected for sewer swabs – point *y* because there the main sewer crosses the river in an open channel which may on occasion overflow, while point *z* was selected because of its accessibility.

In previous years, swabs similar to those recommended by Moore had been used but were tied at the ends to form a horse shoe. For the present investigation Harrington squares cylindrically folded were tried, but were soon superseded by White's No. 1 sanitary towels (A.C.P., 1967), which were considered to be more convenient to handle, more absorbent, and therefore useful in the drains and subsidiary sewers. A thin galvanized wire (s.w.g. 20) was passed through the main substance of the towel below the stitching to support the increased strain due to the flow in the main sewer and river. The towel was folded on itself and the loops tied by 6 ft. of nylon string to withstand the friction of water, stones or rodents. Approximately 1 ft. from the loop an iron nut was attached to the nylon string. The nut acted as a sinker, to allow the swab to billow out below the surface of the water and at the same time to prevent it becoming entangled in the mud and stones on the bed of the river. The swabs were placed in the river within 3 ft. of

the bank, anchored to roots and branches of trees or to 10 in. metal tent pegs driven into the ground above the high-water level and marked by bamboo canes. In the sewers, the swabs were attached to tent pegs which were driven into the mortar joints of the brickwork or to the metal access rungs within the inspection chambers. Swabs were left in for 7 days and this practice was strictly adhered to throughout. Great care was then required in extracting the swabs as they tended to disintegrate. On removal the swab was deposited into a 2 lb. domestic Kilner jar for transport to the Central Microbiological Laboratories. The laying and collecting of the swabs was undertaken by the Inspectors from the Health Department with strict adherence to the use of protective equipment – rubber boots, disposable gloves and pliers to minimize the risk of personal infection or its spread.

*S. typhi* was isolated from one of the first batch of swabs received at the laboratory on 27 July. This swab was collected at the outfall of a surface water drain which discharged rain water into the river (G in Fig. 1) and which had attracted attention because it was broken and was intermittently exuding a foul-smelling effluent with occasional traces of faeces which sprayed over the bank. The opening of this pipe was situated approximately 3 ft. above the normal river level and below a metal bridge carrying a feeder sewer across the river (Pl. 1). The isolation of *S. typhi* from this swab indicated that the drain was contaminated with sewage. Repeat swabs on 3 and 10 August yielded *S. typhi* from the surface water drain only. Thus, the contamination of the river at this site was conclusively established.

Reports on the phage types of these strains isolated were received by telephone in less than 24 hr. from the Enteric Reference Laboratory of the Central Public Health Laboratory at Colindale. All belonged to Vi-phage type K1.

As soon as the presence of the typhoid bacillus was reported measures were taken to divert the surface water into the sewer at the nearest inspection chamber. Retrograde tracing of the pathogen then began.

The surface water pipe runs through a rough bank of trees and bushes which rises steeply from the river to a street high above it which is lined on both sides with individual houses (Fig. 2). The drainage of the houses in this residential street was next explored by the City Engineer's Department. It was discovered that the foul drains from a group of houses had been connected to the surface water drain of the street. This was due to a faulty relationship between the surface water drain and the foul sewer, the former being below the other, contrary to normal practice. To narrow down the source of infection, samples of sludge were examined from the disconnecting traps between the house drain and the surface water drain at both west and east ends of this group of houses (Fig. 3). *S. typhi* was isolated from the west end sample but not from the east end sample.

Swabs were next placed at the ten access drain inspection chambers of the 12 houses as indicated in Fig. 3. The two samples at positions 9 and 10 were found to contain *S. typhi* (17 August) while the remaining eight were negative. This was confirmed by further swabbing.

It was assumed that the source of the *S. typhi* was a symptomless excreter and although the investigation of the sewage had pointed clearly to the two houses at

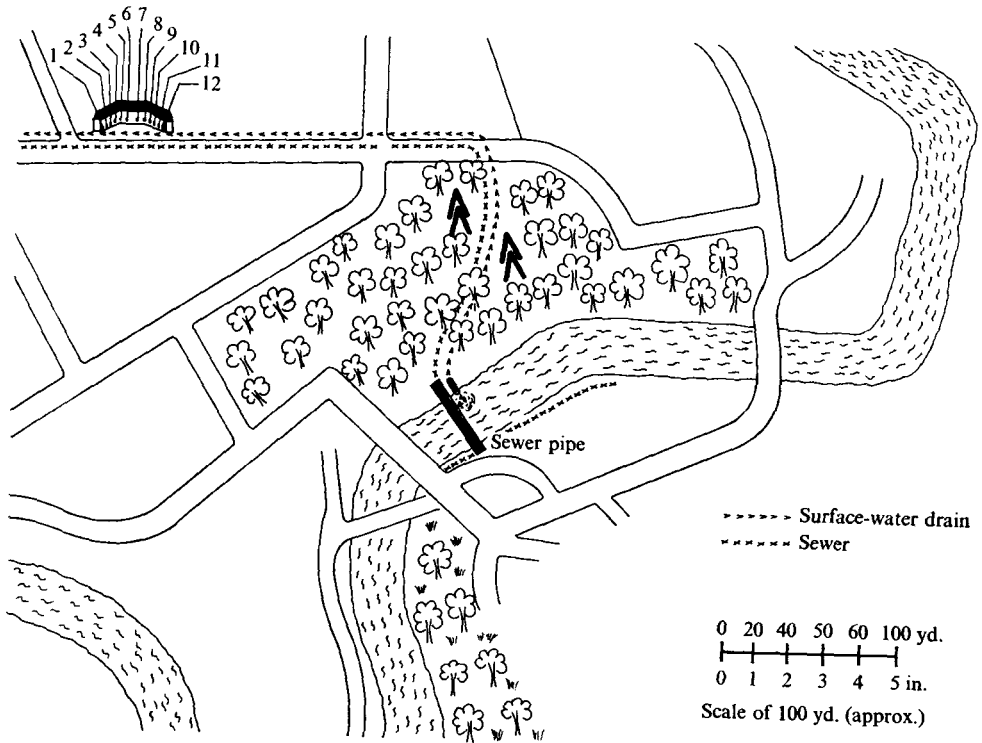


Fig. 2. Diagrammatic sketch of district showing the connexion of the sewers and drains of the houses with the river. This plan is only diagrammatic and does not give the true position of the carrier's house.

the west end of the group of twelve (P and Q, Fig. 3) it was decided to investigate the occupants of all the households to save embarrassment to anyone. Each was visited by a medical officer and invited to co-operate in this investigation to trace the source of the typhoid fever cases known to exist in the city. All agreed to participate: a history was taken in each case and arrangements were made for a series of faecal and urine specimens from each member of the households to be submitted for bacteriological examination. All specimens were negative except those from the occupant of house Q whose faecal specimens yielded *S. typhi*. The result of her Widal test suggested that she was infected with the typhoid bacillus. All strains isolated were phage typed and proved to belong to type K 1.

The whole investigation was completed within 2 months and the carrier was actually identified a fortnight before the last case was diagnosed.

#### BACTERIOLOGICAL METHODS

##### *Examination of Moore's swabs*

When exposed swabs were received at the laboratory double strength selenite F medium containing 0.8% lactose was poured onto the swab until it was completely submerged. The cap was replaced and the jar was incubated at 37° C. for 24 hr. Subcultures were then made by inoculating loopfuls of the selenite on

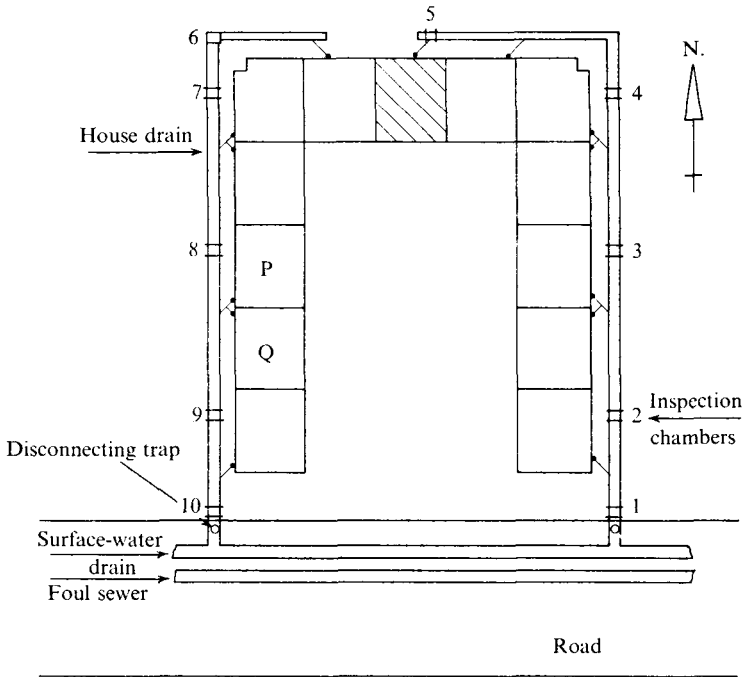


Fig. 3. Diagram of the drainage system of the 12 houses.

deoxycholate citrate agar (DCA) and MacConkey medium plates which were incubated for 48 hr. before examination. The jars were re-incubated for a further 48 hr. and subcultured to DCA and MacConkey plates as before. Non-lactose fermenting colonies were picked onto Kohn's two-tube medium (Kohn, 1954; Gillies, 1956) and after checking for purity, were identified as typhoid bacilli by routine biochemical and serological methods. Each strain was immediately sent for phage typing to the Enteric Reference Laboratory at Colindale. The positive results are recorded in chronological order in Table 1.

#### *Examination of excreta*

The final stage of the investigation was the examination of faeces and urine from the dwellers in the 12 houses. The faeces were streaked on MacConkey and DCA plates and inoculated into selenite F and Rappaport media. All media were incubated at 37° C. for 24 hr., and the two latter media were subcultured on MacConkey and DCA plates. Non-lactose fermenting colonies were again investigated as above.

Specimens of urine were centrifuged and the deposit inoculated into selenite F medium and incubated overnight at 37° C. Pale colonies from subcultures on MacConkey and DCA media were picked and investigated by the routine method. *S. typhi* type K 1 was isolated from three successive specimens of faeces from a lady aged 76 years who lived alone (Miss S). The isolations of *S. typhi* were derived from subcultures of the selenite and not from the Rappaport medium, probably because



Table 1. *Isolation of Salmonella typhi phage type K 1 in investigation of infection from Water of Leith*

| Date         | Source of specimen                         | Nature of specimen                       |
|--------------|--|--|
| 6. vii. 70   | Patient 1 (1970)                           | Blood and faeces                         |
| 27. vii. 70  | Moore's swab (No. 14) in W.o.L.*           | Drain outfall into river ('G' in Fig. 1) |
| 29. vii. 70  | Patient 2                                  | Blood and faeces                         |
| 3. viii. 70  | Moore's swab (27) in W.o.L.                | Drain outfall into river                 |
| 10. viii. 70 | Moore's swab (49) in W.o.L.                | Drain outfall into river                 |
| 10. viii. 70 | Moore's swab (46) in manhole drain         | Sludge from trap (West end of street)    |
| 17. viii. 70 | Moore's swab (75) in foul drain            | House sewage position 9 (Fig. 3)         |
| 17. viii. 70 | Moore's swab (76) in foul drain            | House sewage position 10 (Fig. 3)        |
| 19. viii. 70 | Moore's swab (77) in W.o.L.                | Drain outfall into river                 |
| 24. viii. 70 | Patient 3                                  | Blood                                    |
| 26. viii. 70 | Patient 3                                  | Faeces                                   |
| 4. ix. 70    | Miss S                                     | Faeces                                   |
| 7. ix. 70    | Miss S                                     | Faeces                                   |
| 8. ix. 70    | Miss S                                     | Faeces                                   |
| 17. ix. 70   | Patient 4                                  | Blood                                    |
| 14. x. 70    | Miss S                                     | Faeces                                   |
| 20. x. 70    | Moore's swab (94) in foul drain            | House sewage position 10 (Fig. 3)        |
| 20. x. 70    | Moore's swab (95) in W.o.L.                | Drain outfall into river                 |
| 27. x. 70    | Moore's swab (99) soil and stones (W.o.L.) | Below outfall into river                 |
| 27. x. 70    | Moore's swab (100) in W.o.L.               | Drain outfall into river                 |

\* W.o.L., Water of Leith.

the concentration of malachite green in the latter medium is toxic for this organism (Rappaport, Konforti & Navon, 1956).

Widal tests were carried out on sera from the inhabitants of the west end group of houses. The serum of Miss S, who had no history of inoculation, showed a TH titre of 1/400, and a standard TVi titre of 1/40. The TO titre was less than 1/25. Since Miss S was symptomless, the TH and TVi titres supported the suspicion that she was a chronic carrier. A low TO reading is commonly found in typhoid carriers (Report, 1961). All other Widal tests carried out were completely negative.

Eighty-eight Moore's swabs were examined by the time the carrier was identified. Similar laboratory methods were employed in 'follow-up' swabs and faecal specimens after the sewer repair and treatment of the carrier had been undertaken. Both the sewer and the carrier remained positive until the second half of October (Table 1), but thereafter a total of a further 70 samples have proved negative.

#### DISCUSSION

This small outbreak has many of the characteristics of water-borne disease when the infecting water does not form part of the general supply to the community. And it has certain similarities to a small outbreak of typhoid fever described by Lendon & Mackenzie (1951) in which three children were infected with *S. typhi* in a river contaminated by typhoid-infected sewage. The cases in the present out-

break were apparently sporadic, eight known cases in 8 years, children being mostly at risk and acquiring the infection in the months of July, August and September, the ideal time of year for picnics to the river. The fact that they were all infected with a rare phage type, K 1, made a connexion between them a virtual certainty. They occurred singly in the years 1963, 1967, 1968 and 1969, but in 1970 four people were infected. The rise in the number of cases made an exhaustive investigation imperative.

Infections did not take place at the actual site of contamination of the river, possibly because access by the public at that area was difficult since the banks on both sides of the river were steep. More cases might otherwise have occurred, since the concentration of infection must have been much greater in the area of contamination.

Phage-typing was as usual of unique value in tracing the source of this outbreak. Attention had been focused on each case since 1963 as it occurred, because of the rarity of type K 1 in Britain. The type is one which is particularly associated with the Indian subcontinent, and except for Asiatic immigrants has seldom caused typhoid fever in the United Kingdom. No connexion with immigrants could be discovered in the carrier responsible for the present incident. Her history is that she has never been abroad, and had lived alone in her present house for 13 years. For 12 years before, she had been housekeeper to another lady living alone in the district who died of old age and who, as far as can be ascertained, had no connexion with the East. The carrier's father, a veterinary surgeon, had been in the Boer War and First World War and had travelled abroad subsequently to unspecified countries. She kept house for him for about 35 years before his death 25 years ago. Her sister when aged 33 years is reported to have suffered from some gall bladder condition for which she underwent an operation; within a short time she had a second operation for adhesions, from which she died. The carrier herself has apparently remained healthy throughout her life and it is impossible to judge where or when she acquired her infection. Her carrier state might never have been discovered had she not been living in a house of which the foul water drainage had been incorrectly connected with a surface water drain. Because of this, sewage containing typhoid bacilli reached a river where children played, swam and fished.

One curious historic comment completes our inquiry: according to the City Engineer's Department, no major repair to the drainage system of these houses has taken place over the years. This constructional fault has probably existed since they were built at the end of the last century. At that time the district was part of the County of Midlothian and only in 1920 was it included in the City of Edinburgh. Its houses and their drainage systems were then accepted as they stood. It was a further 50 years before the fault was demonstrated, and other cases of typhoid fever may have resulted from the coincident existence of the carrier and the incorrect sewage connexion. In the present investigation, Moore's swabs facilitated the isolation of typhoid bacilli from sewers and river, and the accuracy of phage-typing enabled us to identify cases back to 1963. Attempts are now in progress to cure the carrier; and the sewage system from these houses will be redirected so that the Water of Leith can no more be contaminated.





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EXPLANATION OF PLATE

The broken drain outfall into river below the bridge supporting the feeder sewer.