The Zermatt typhoid outbreak in 1963*

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INTRODUCTION

The major causes of typhoid outbreaks in the past have been food and milk contaminated by typhoid carriers, and water supplies also contaminated by carriers either directly or by admixture with sewage. Of these vehicles of infection water was probably much the most important. With the improvements in sanitation—both in sewage disposal and maintenance of the purity of water supplies—the incidence of waterborne outbreaks of typhoid fever has fallen sharply in the most advanced countries.

One of the most important waterborne outbreaks studied in the past 30 years was that in Croydon, England, in 1937 (Holden, 1939; Report, 1938). There were 310 cases with 43 deaths. This outbreak was due to contamination of a well by a workman who was a typhoid carrier. A waterborne outbreak occurred in Glion, Switzerland, in 1945 (Herter, 1947). There were 101 cases with 16 deaths. In both the above outbreaks the case fatality rate was high by present-day standards, 13·9 % in Croydon and 15·8 % in Glion. The introduction of chloramphenicol has dramatically changed the prognosis, the case fatality rate having now been reduced to the neighbourhood of 1 %.

The occurrence of a typhoid outbreak in an international holiday centre always presents special problems, but nowadays these are still further complicated by the rapid distribution of incubating cases, unaware of their infection, returning to their native countries by air. The tracing of the full extent of such an outbreak may thus be a very difficult task (see Anderson, 1964).

The present report is concerned with such an outbreak. This occurred in Zermatt during the winter season of 1963. There were 437 identified cases with a total of three deaths (0·7 %). The population at risk was estimated to be about 10,000 and the epidemic occurred at the peak of the tourist season. There were 260 tourists and 177 local inhabitants affected. The outbreak was due to *Salmonella typhi* Vi-phage-type E_1 (Beer, 1963); this was confirmed in ten laboratories of six countries whose nationals were infected. It was possible to estimate the probable period of infection because of information provided by the 260 infected tourists. The concomitant occurrence of an outbreak of influenza obscured the onset of

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the typhoid epidemic, so that the recognition of typhoid was delayed more than 2 weeks after the end of the period of infection (see Fig. 1). As will be shown, the outbreak was most probably waterborne.

DESCRIPTION OF THE EPIDEMIC

The outbreak occurred at Zermatt, in the Canton of Valais, one of the most famous holiday resorts of Switzerland, situated at 5300 ft. (1620 m.) at the southern end of a high valley of the Alps. The village has been well known to tourists and mountaineers for the last century, because of surrounding peaks such as the Matterhorn, Monte Rosa and Gornergrat.

Table 1. *Distribution of tourist population of Zermatt and attack rate of typhoid fever according to nationality*

Winter season...	1961/62	1962/63	February 1963 (= month of infection)				
	Guest-nights				Cases		Rate/1000
Nation	%	%	No.	%	No.	%	g.-n.
Switzerland	33·1	36·8	31,602	33·4	77*	29·6	2·44
Germany	22·9	20·95	20,031	21·2	33	12·7	1·65
France	12	10·9	13,153	13·9	37	14·2	2·81
Great Britain	11	10·1	11,105	11·8	78	30	7·02
U.S.A.	8·95	8·6	7,408	7·8	14	5·4	1·89
Other nations	12·05	12·65	11,255	11·9	21	8·1	1·87
Total	100 (724,197)	100 (505,683)	94,554	100 (94,554)	260†	100 (260)	2·75‡

* Besides these 77 Swiss tourists Zermatt had another 177 cases of infected inhabitants and seasonal employees bringing the total victims (†) to 437 cases.
‡ Mean attack rate if British cases are excluded = 2·18 per thousand.
g.-n. = guest-nights.

The village, with a basic population of about 2200 people, has two tourist seasons, one in winter, the other in summer. During these seasons its population rises to over 10,000 people. It is accessible only by a mountain railway which collects tourists from Brig, a town 3090 ft. (940 m.) lower and 27·4 miles (44 km.) from Zermatt. Because Zermatt was accessible only by rail, it was possible to calculate the exact number of persons entering and leaving Zermatt each day. This was of great value in the quantitative examination of the epidemic.

The Zermatt Municipality analyses its tourist seasons in terms of 'guest-nights'; that is to say, each visiting nationality provides a quantum consisting of the number of persons multiplied by the total number of nights spent in Zermatt. During the winter season 1961/62 each tourist spent a mean of 9·1 nights in Zermatt. The availability of these figures made it possible to estimate the proportional attack rates of typhoid fever in the various nationalities (see Table 1). This table shows that the proportionate national representation remains roughly constant from year to year. Although the attack rate in some nationalities corresponds roughly to their guest-night percentage, there is an obvious disproportion

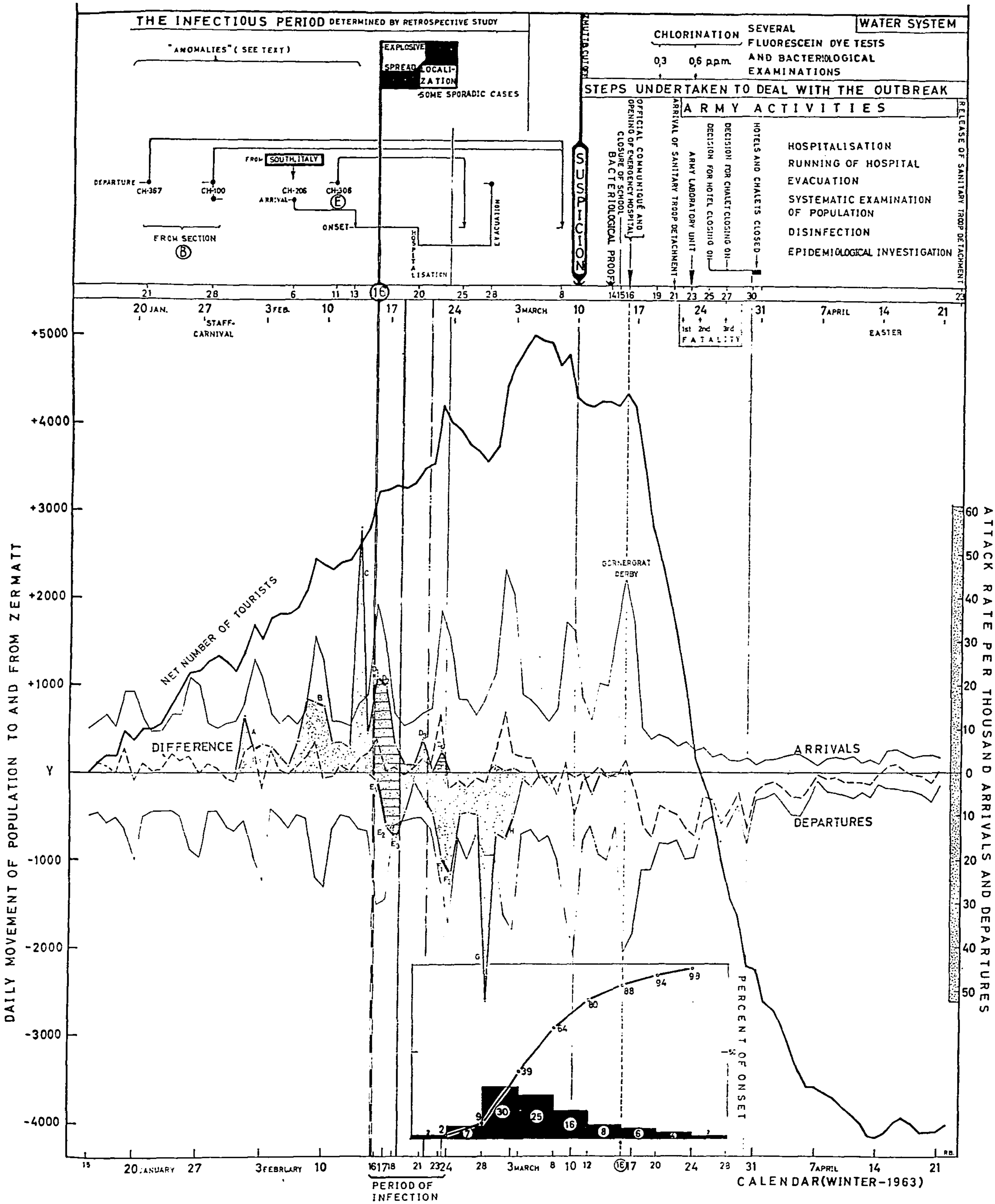

Fig. 1. Graphic summary of the Zermatt typhoid outbreak.

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in other nationalities. The most pronounced of these was in the case of Great Britain, of which the guest-night percentage was only 11·8, but which provided 30% of the tourist cases. In fact, Great Britain with 78 cases had the highest number of tourists affected. It can also be seen that the outbreak resulted in the loss of over 200,000 guest-nights.

On 10 March, one of the three local medical practitioners telephoned the Mayor of Zermatt announcing the existence of a suspected case of typhoid fever. The diagnosis was based on a report from a laboratory in Sion to which the patient's serum had been sent. At the same time this practitioner notified the Health Authorities of the Canton of Valais that he suspected that a typhoid epidemic was developing. Members of the Zermatt Local Authority met immediately and decided to ask the Canton Health Authority for help. They also arranged for sampling the water supply, for the closing of one of the branches of the water supply and for a warning on the subject of the outbreak to be issued to the local practitioners.

One of the practitioners reported to the Mayor that a miner from Southern Italy who was working on a hydro-electric project higher up the valley had been admitted to his clinic with an undiagnosed pyrexia on 20 February, and had been subsequently transferred to a hospital in Brig. In retrospect, he thought that this might have been a case of typhoid fever.

A considerable number of tourists and inhabitants suffered from gastro-enteritis as early as January, and an outbreak of influenza had occurred simultaneously. At that time a hotel manager advised his guests not to drink ordinary tap water as he had received complaints of gastro-intestinal upset which, because of its association with the village, had come to be known as 'Zermatitis'. On 13 March a physician in the village reported that he had over 50 patients, inhabitants and tourists, who had fallen ill since the beginning of the month. Although these patients suffered from headache and gastro-intestinal disorder, he did not at first think that their symptoms were indicative of typhoid fever. Suspicion then arose that some patients who had been treated for influenza might have been suffering from typhoid fever.

Assistance with the investigation was immediately provided by the Public Health Laboratory of the Canton of Geneva. Samples of blood and excreta from suspected cases were also sent from Zermatt to other laboratories in Switzerland. By 13 March, the sera of several patients yielded results suggesting infection with *S. typhi* and on 14 March *S. typhi* was identified from one specimen of faeces.

The first confirmed case in England of typhoid infection from Zermatt was reported on 9 March. The culture of this case was identified as phage-type E_1 by 12 March in the Enteric Reference Laboratory at Colindale, London. All cultures isolated subsequently in this outbreak belonged to this type. Because of reports of other cases in various parts of England, the Ministry of Health issued a general alert on the subject to Medical Officers of Health on 13 March. The Director of the Enteric Reference Laboratory at Colindale sent a letter on 14 March to the Director of the Swiss Centre for Enteric Phage Typing drawing his attention to a probable typhoid epidemic, apparently waterborne, originating in Zermatt.

SUBSEQUENT DEVELOPMENTS

Late on 14 March, administrative and medical authorities met to formulate an emergency programme. Emphasis was laid on the importance of detecting and isolating all persons with recent gastro-intestinal upset, unexplained pyrexia or other unexplained illness.

It was realized that extra hospital accommodation would be needed and the local school was commandeered on 15 March to provide this.

Between 13 and 15 March, eighteen suspected cases were removed to various hospitals in the Canton of Valais.

In spite of the unexpectedness of the event, administrative and medical action was rapid and the Chief Medical Officer of the Canton was able to arrange for the Emergency Hospital to receive patients by Saturday 16 March.

No public announcement of the existence of the epidemic was made at first, but on 16 March the Canton considered it advisible to issue an official bulletin on the subject. Thus, the news became known throughout Switzerland and acted as warning to anyone who intended to come to Zermatt. Nevertheless it was difficult to stop the tourist traffic from abroad. Although it was not considered necessary to close the resort immediately, the situation was publicized through press, radio and television. On the same day precise instructions were given to the hotel managers about immediate measures to be taken and, in particular, newly arriving tourists were warned of the existence of a typhoid outbreak in the town and were given the option of cancelling their reservations.

By Sunday 17 March, no further removal to hospitals outside Zermatt was needed, but admissions to the Emergency Hospital suggested that the epidemic was probably distributed throughout the village.

The Director of the Institute for Microbiology of the University of Geneva visited Zermatt on Tuesday 19 March and drew up a plan for the operation of emergency hospital, laboratory, local hygiene and epidemiological services. This was submitted to the Chief of the Swiss Army Medical Corps. As a result a Sanitary Troop Detachment was established in Zermatt between 21 and 23 March. Arrangements were made for the removal of patients by rail, once the diagnosis of typhoid fever was confirmed.

Chlorination of the water supply was raised to 0·3 p.p.m. on 19 March and to 0·6 p.p.m. on 23 March.

It must be stated that, in spite of the warning about typhoid fever, tourist activity continued unabated up to 17 March. The Gornergrat Derby, Zermatt's most important winter event, was about to start when the news of the epidemic was released. It was felt that, as the participants in this event were already in Zermatt, it was unlikely that the magnitude of the outbreak would be materially influenced by allowing it to take place. As events showed, this decision was justified. As Fig. 1 shows, the week-end of 16 and 17 March, during which this Derby was held, was not associated with an especially large influx of tourists, so that the extra number at risk was not disproportionately large. Moreover, 88% of the total number of cases were already ill at the time of the Derby, and subsequent investigations suggested that the period of infection had terminated a few days before the end of February.

Information about the outbreak was officially released by the Federal Health Authorities on 18 March, but tourists continued to arrive and the sports activities of the village were maintained. Nevertheless, the impact of the news was such that an exodus of tourists rapidly got under way, so that by 25 March the tourist population had dwindled by several thousand people. Because of this exodus, and because of the need for disinfection of premises and of bacterial examination of employees and residual guests, and following the advice of the military authorities, the hoteliers decided to close all hotels on 30 March. Similar action was taken 2 days later by the proprietors of pensions and chalets. In numerical terms, during the week 17–24 March, departures exceeded arrivals by 4000, whereas in the preceding week departures were balanced by arrivals (see Fig. 1). In the week ending 30 March the net tourist population had shrunk by a further 2500 people.

The effect of the epidemic on tourist movements is shown in Fig. 1, where the net number is maintained at about 9000 up to 17 March, and falls steeply thereafter.

EPIDEMIOLOGICAL INVESTIGATIONS

Zermatt is traversed by a small river, the Vispa, which empties into the Rhone. At the beginning of the investigations a spot map of cases and suspects showed that the epidemic was widely distributed throughout the village, but later a concentration on the left bank of the Vispa was evident.

On 1 April, the physicians in ten Swiss hospitals were telephoned. They were asked to obtain precise details of the clinical history of the patients in their care, paying particular attention to the dates of onset of illness. By 3 April we had details of 112 cases. It is doubtful whether such information would have been forthcoming had the inquiries been delayed beyond this point. The inquiry revealed that the most probable infective period was from 14 to 18 February, with possible extension on either side of these dates.

Valuable epidemiological information was also obtained by interrogation of patients in the Emergency Hospital in Zermatt. The special advantage of these local investigations was that they could be combined with epidemiological inquiry in the village itself.

By 10 April a total of 162 cases had been notified, most of them Swiss citizens. Information from abroad rarely reached our local centre, but it was estimated that there were probably a further 100 to 200 cases of which we had hitherto no knowledge. The Canton Public Health Authority decided that, for an intimate study of the outbreak, maximum information should be obtained about the cases in other countries. Accordingly, contact was established with the Health Services of the United States, Germany, France and Britain. Official lists of patients were obtained from various countries and help for our investigation was freely offered. Dr R. T. Ravenholt, at that time Epidemiological Consultant to the U.S. Embassy in Paris, was extremely helpful in initiating contact with several countries. Visits to the British Ministry of Health and to the Enteric Reference Laboratory, Colindale, London, arranged by the Swiss Federal Health Authority, were particularly valuable.

In addition, through the mediation of the Swiss National Tourist Office, details of some 200 cases were obtained.

These inquiries resulted in the identification of 437 cases of typhoid fever, infected in Zermatt. About 260 of these had left Zermatt before falling ill or at an early stage in the disease. Of these, 77 were Swiss subjects residing elsewhere in Switzerland; and 183 were foreigners. Our international liaison was so successful that we were able to obtain quite full personal and medical information about these cases. In particular, the hotels at which they stayed were identified and the duration of their visit was determined.

A precise calculation of the number of persons at risk was very difficult because we were dealing with a heterogeneous population: a stable component of inhabitants and employees on the one hand; and a floating population of tourists with a mean residence of 9·1 days on the other. The most reliable figures of tourist movement were obtained from the railway company. Figure 1 summarizes the tourist arrivals and departures from mid-January to 23 April 1963. As will be shown later, the probable period of infection lay between 16 and 24 February. This is indicated in Fig. 1.

A house-to-house investigation carried out by the writer produced the following result: (1) verification of the place of residence of all reported cases; (2) population at risk per house during the period of infection; (3) incidental information such as remarks about offensive smell and turbidity of the water during the critical period in the middle of February. The local tourist office provided the information needed about hotels.

In this way it was possible to define a population at risk for each residence.

EPIDEMIOLOGICAL FEATURES

Dates of onset

The number of cases with a clear-cut date of onset of illness in Zermatt or after returning home is indicated in Table 2, the most convenient analysis seeming to be on a basis of intervals of 4 days. The total figure of 405 includes 93 % of all notified cases (437) and the dates of onset of the cases fell between 21 February and 28 March. The last case in the entire series fell ill on 2 April.

Fig. 2A shows the distribution of these cases according to the precise dates of onset. This distribution is what would be expected from a single source of infection over a limited period. There were few cases at the end of February, an explosive increase at the beginning of March and a gradual decline thereafter. The succession of peaks of onset during the decline period may be due to the random distribution of incubation periods (which is expected) or to intermittency in the primary source. As is usual in typhoid outbreaks, there was no indication that secondary cases contributed materially to the total number.

Fig. 2B gives the cumulative percentage distribution of dates of onset for tourists (T) and inhabitants (I). Although this figure shows no apparent difference

Table 2. *Cases of typhoid fever with clear-cut onset date* (21 *February to* 2 *April* 1963 *grouped in* 4-*day intervals*)

Period	No. Guests	No. Inhabitants	No. Total	% Total	No. Guests	No. Inhabitants	No. Total	% Total	% Cumulation	Span
21–24 Feb.	7	1	8	2·0					2·0	21 Feb.
25–28 Feb.	21	6	27	6·7	28	7	35	8·6	8·6	28 Feb.
1–4 Mar.	71	47	118	29·1					37·8	1 Mar.
5–8 Mar.	64	36	100	24·7					62·5	to
9–12 Mar.	46	28	74	18·3	181	111	292	72·1	80·7	12 Mar.
13–16 Mar.	14	18	32	7·9					88·6	13 Mar.
17–20 Mar.	12	10	22	5·4					94·1	to
21–24 Mar.	9	7	16	4·0					98·0	2 Apr.
25 Mar.–2 Apr.	3	5	8	2·0	38	40	78	19·3	100·0	
Total	247	158	405	100·1	247	158	405	100·0	—	—

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in the rate of development of the outbreak between the two groups, a study of the three main subdivisions by date exhibited in the right-hand half of Table 2 suggests that the rate of development of the outbreak was more rapid in tourists than in inhabitants. This is supported by Fig. 2C, which gives the cumulative percentage distribution of onset dates in tourists and inhabitants, each group being regarded as complete within itself. The curve of tourist onset precedes that

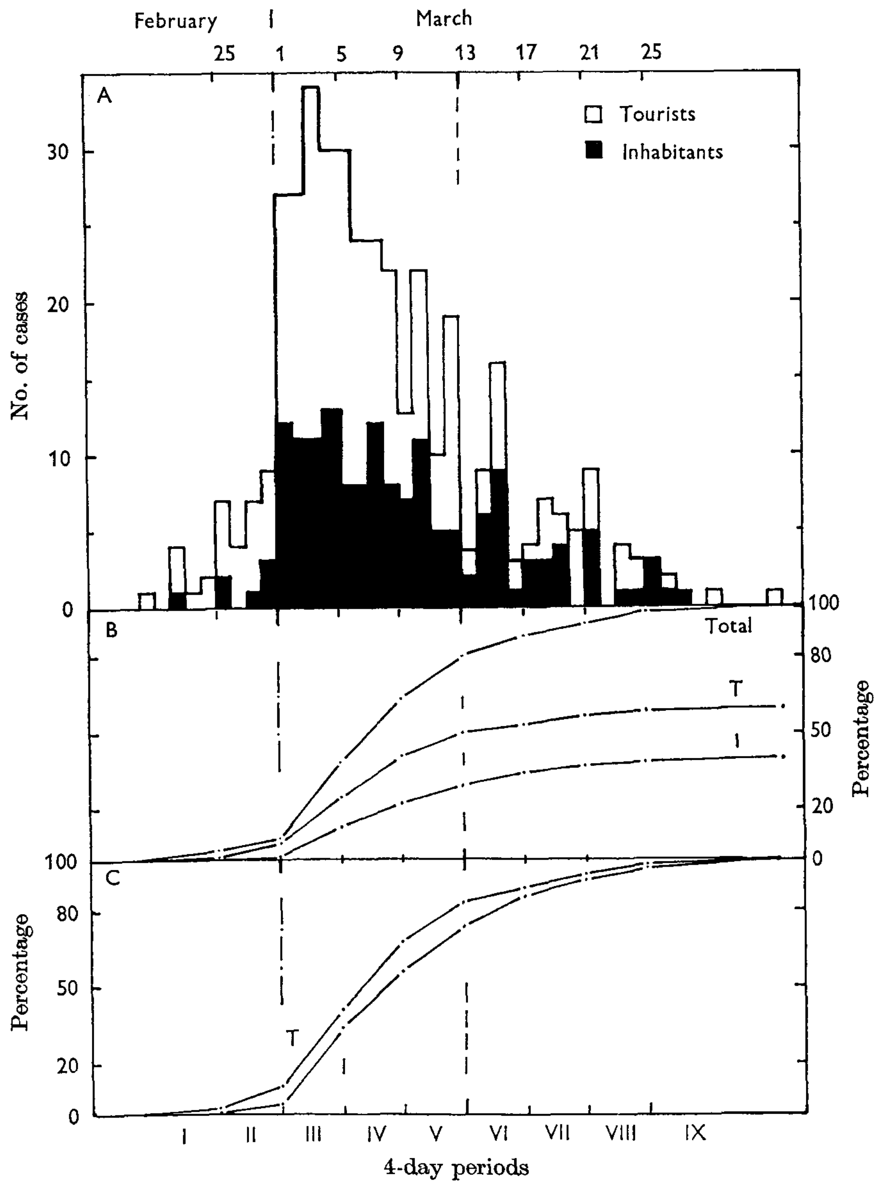

Fig. 2. Graphic analysis of onset dates in tourists and inhabitants. A, Distribution of onset in 405 patients presenting a clear-cut date of onset. B, Cumulative percentage distribution of tourists (T) and inhabitants (I) according to onset date. C, Cumulative percentage distribution of tourists and inhabitants according to date of onset, each group being regarded as complete in itself.

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of inhabitants' onset by an interval of 2 days. In fact, by the end of February, 7·1 % of all tourist cases were already ill, whereas symptoms had begun in only 1·7 % of infected inhabitants. This difference is statistically highly significant ($P < 10^{-8}$). There is nevertheless no explanation to give for it up to the present.

Sex and age distribution

Unfortunately, the age and sex distribution of the total population at risk could not be determined. However, Fig. 3 presents a subdivision of 425 cases of the Zermatt outbreak according to sex and age. The overall distribution between

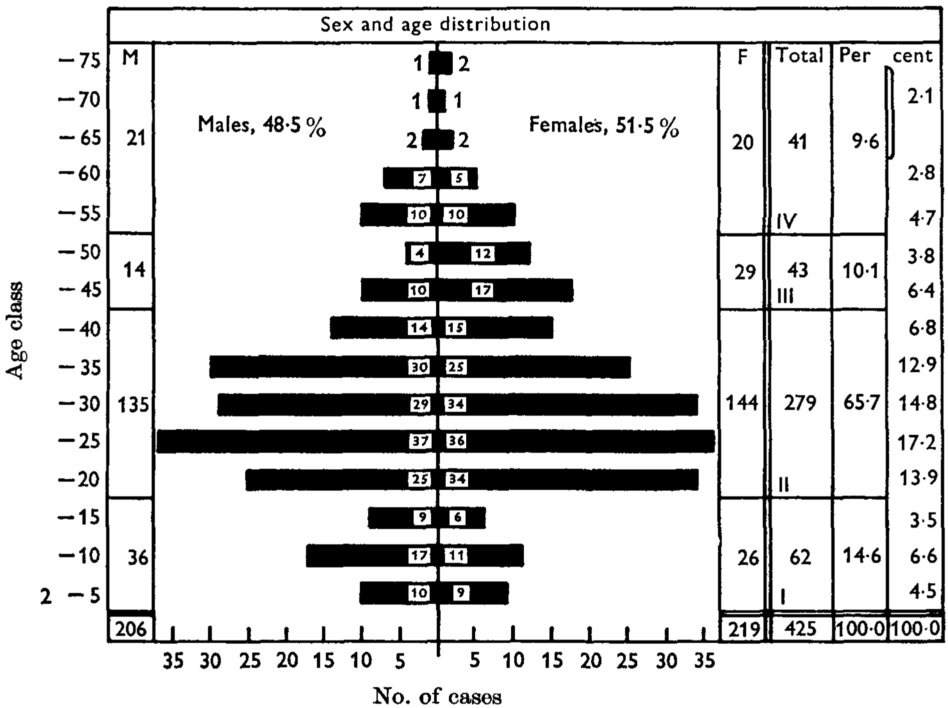

Fig. 3. Sex and age distribution of patients infected in Zermatt.

males and females was practically equal, but in the age group 41–50 there was a preponderance of infections in the females. This difference is on the margin of significance ($\chi^2 = 6{\cdot}87$, $n = 3$, $0{\cdot}1 > P > 0{\cdot}05$). In a winter sports centre the largest age group of visitors and employees lies between 16 and 45. It is therefore not surprising to find that 72 % of cases occurred within this age bracket. The age group 16–35 years included 58·8 % of cases with an equal distribution between males and females.

Incubation period and period of infection

The shape of the onset curve, as we stated before, suggests a widespread infection starting on a particular day, i.e. a definite interval before the explosive rise of cases. The earliest day of infection was calculated by determining the

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earliest date on which a visitor infected with typhoid left Zermatt. This was 16 February. The end of the period of infection was indicated by the latest date on which a newly arrived visitor was infected. If we exclude two cases infected on 2 and 3 March, the end of the main period of infection was on 24 February.

Figure 4 gives the attack rate per thousand tourists analysed separately in terms of arrival and departure. The periodic fluctuations in the curves correspond to the week-end periods of greatest tourist activity.

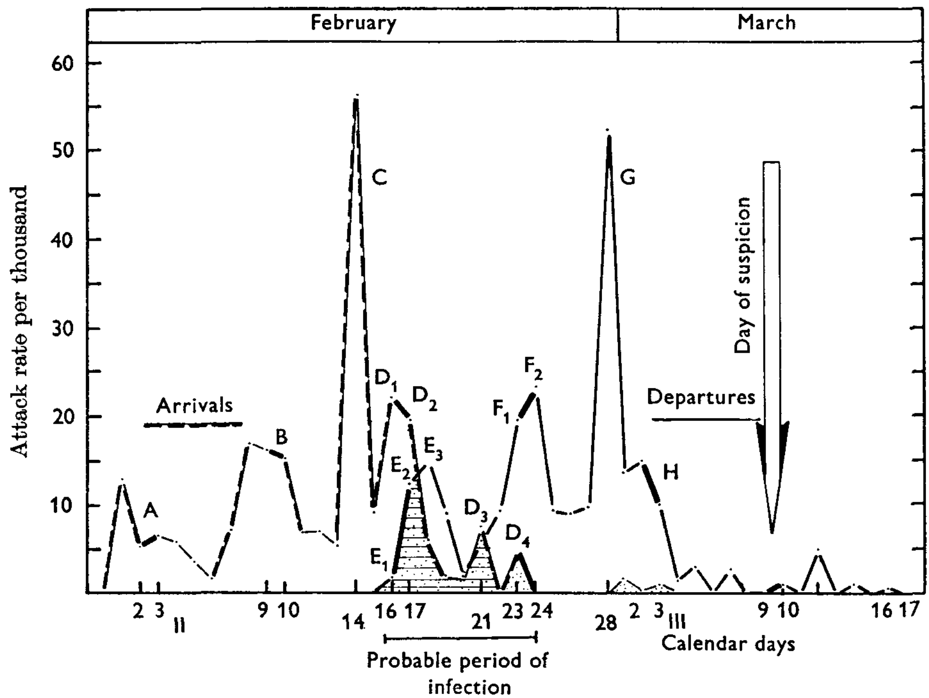

Fig. 4. Incidence of typhoid fever among guests according to arrival at and departure from Zermatt.

The region of overlap of the two curves indicates the minimum infective period. As has been mentioned, the first departing visitor to be infected left Zermatt on Saturday 16 February. Nineteen persons who left on 17 February and a further nine who left on 18 February developed typhoid fever. These figures correspond to a daily attack rate of 2, 13 and 14·9 per thousand departures respectively. Visitors leaving on the following week-end showed a much higher attack rate (23 and 24 March with 20 and 23 per thousand departures) which would be expected because they had been in Zermatt for a longer fraction of the total period of infection and therefore had a higher probability of being infected.

Turning now to the curve of arrivals, it is clear that the main infection period finished about 24 February, although two cases were infected who arrived on 2 and 3 March.

A question arises in relation to the distribution of initial infections in this outbreak. Are we dealing with a distribution of cases of which a regular number were

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infected daily, or were most patients infected at the beginning of the infective period?

Sartwell (1950) found that an almost linear plot was obtained for a simultaneous and unique infection of all cases if the relative frequencies of incubation periods cumulated on a probit scale were plotted against the logarithm of the time of incubation.

Knowing with reasonable precision the infection date of the fraction who left at the start of the period of infection (Fig. 4, fraction E), it is convenient to consider their onset curve simultaneously as the distribution of maximum incubation

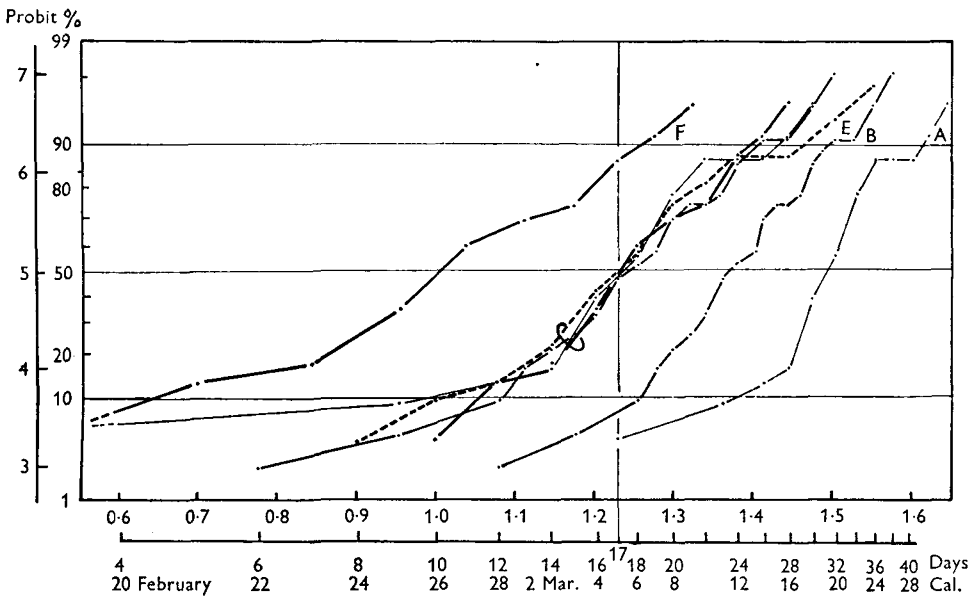

Fig. 5. Probit analysis of probable incubation periods. Cumulation of relative frequencies of incubation period groups on a probit scale; time of incubation in logarithms. *Curve E* (= best known infection date) represents the first leaving fraction with typhoid victims whose onset curve is considered as the most accurate distribution of incubation periods. The curve indicates a one-point epidemic with a median incubation period of 17 days and 11–25 days 80 percentile range. *Curves F, B, A* (= dates of infection unknown); see also Table 3. These curves are based on hypothetical infection dates and suggest one-point infections. Demonstration of a common and short infection period of all fractions: by shifting the individual curves by the difference from the best known mean incubation period (E = 17 days) all fractions fall together forming the bundle with its median incubation period of 17 days.

periods. In doing so a linear plot and a reliable median infective period of the outbreak should be obtained. Figure 5 gives the result of this procedure, the ordinate representing cumulative percentages of cases on a probit scale. The abscissa is the time scale on a logarithmic basis and simultaneously, for easier recognition, the arithmetical number of days of onset after the calculated initial infection (16 February). Curve E (Fig. 5), which is derived from fraction E (Fig. 4), shows that the mean incubation period of this group was 17 days with an 80 percentile range of

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11–25 days. This rather long incubation period is what would be expected in a waterborne outbreak of typhoid fever where the average dosage with *S. typhi* is low.

The question arises as to whether the patients represented in the different peaks, corresponding to successive week-ends, were infected at the same time as those who left Zermatt on the week-end of 16 February. We postulated for practical purposes that all groups for which a definite date of infection was not known were infected either on the day of arrival or the day of departure. Tracing the frequency distribution of hypothetical incubation periods of these patients on normal probability paper, the curves should be straight lines with individual hypothetical median values. If most patients were infected at the same time, the difference of position of these curves from that of curve E, in relation to the abscissa, should correspond to the number of days by which every group's date of infection was under- or overestimated. Insertion of the corresponding corrected curves, carried out by moving them along the abscissa by a distance corresponding to the calculated differences, should then bring them into the vicinity of curve E, if the various fractions were infected at closely similar dates. In Fig. 5 the curves of earliest arrivals and of departures (corresponding to fractions A and F of Fig. 4) and curve B (fraction B of Fig. 4) are plotted against curve E, which is that of those known to have been infected between 16 and 18 February.

As an example we may consider the first arrivals in Zermatt who were infected. These are fraction A (Fig. 4) and the curve A (Fig. 5). We see in Table 3 that this fraction has a 31-day median incubation period if common infection is postulated on the day of arrival. The corresponding 80 percentile range is 24–41 days. The difference from the best known median incubation period (17 days) is 14 days, which is the span by which the curve A must be shifted to the left on Fig. 5 if the estimate of a median incubation period of 17 days is correct. This will give a mean incubation period of 17 days for fraction A with an 80 percentile range of 10–25 days and a date of infection on or about 16 February.

The same procedure applied to all fractions of Fig. 4 suggested, as is seen in Table 3, a median incubation period of 15–17 days and an 80 percentile range from 11–24 days.

This supports the hypothesis that, in spite of the fact that we know the minimum infective period to lie between 16 and 24 February, the majority of patients were infected during a more limited number of days early in the infective period.

The fact that nine tourists who arrived on 23 February contracted typhoid fever indicates that infection was active on that date. With one exception these tourists stayed in the same hotel. No other tourist arriving 23 February was infected. It thus seems that the area of infection had become limited by that date (see Fig. 1).

As the infective period seems to have an initial concentration, the date of onset of each case can be regarded as a reasonably reliable guide to its incubation period, provided that the patient was in Zermatt on the week-end of 16 February. Obviously, those few who arrived in Zermatt later than that week-end must have eir maximum incubation period limited by their dates of arrival. Taking into

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Table 3. *Attack rates and probable incubation periods in tourists in the Zermatt outbreak*

(Attack rates by arrival and departure day. Hypothetical and real (calculated) incubation periods for homogeneous fractions of tourist victims with regard to arrival and departure dates. Localization of beginning of infective period (16 February) and assumption of infection of most victims on 16, 17 and 18 February.)

	Date of		No.				Incubation period: Hypothetical			Incubation period: Calculated	
Fraction	Arrival	Departure	Arrivals	Departures	Cases	Rate per 1000	80 percentile range	Median	Diff.	80 percentile range	Median
A	1 Feb.	—	778	—	10	12·8					
	2 Feb.	—	1288	—	7	5·4	24–41	31	−14	10–25	17
	3 Feb.	—	1073	—	7	6·5					
B	9 Feb.	—	1548	—	25	16·2	18–30	24	− 7	11–23	17
	10 Feb.	—	1248	—	19	15·2					
C–1	14 Feb.	—	794	—	17	56·7	9–31	18	− 2	7–29	16
C–2					28		12–29	17	− 2	10–27	15
D–1	16 Feb.	—	1909	—	42	22·0	10–27	17	0	10–27	17
E–1	—	16 Feb.	—	1510	3	2·0					
D–2	17 Feb.	—	1470	—	29	19·7	11–24	16	0	11–24	16
E–2	—	17 Feb.	—	1456	19	13·0	11–25	17	0	11–25	17
E–3	—	18 Feb.	—	606	9	14·9					
F–1	—	23 Feb.	—	1165	23	19·7	—	—	—	—	—
F–2	—	24 Feb.	—	1719	40	23·3	2–15	10	+ 7	10–23	16
G–1	—	28 Feb.	—	952	22	52·5	−2–17	5	+12	10–29	17
G–2	—				28		−3–15	3	+12	10–27	15
H	—	2 Mar.	—	1611	25	15·5	−2–11	3	+14	12–25	17
		3 Mar.	—	1793	18	10·0					
Determined incubation period of Zermatt incidence in tourists										11–24	16–17

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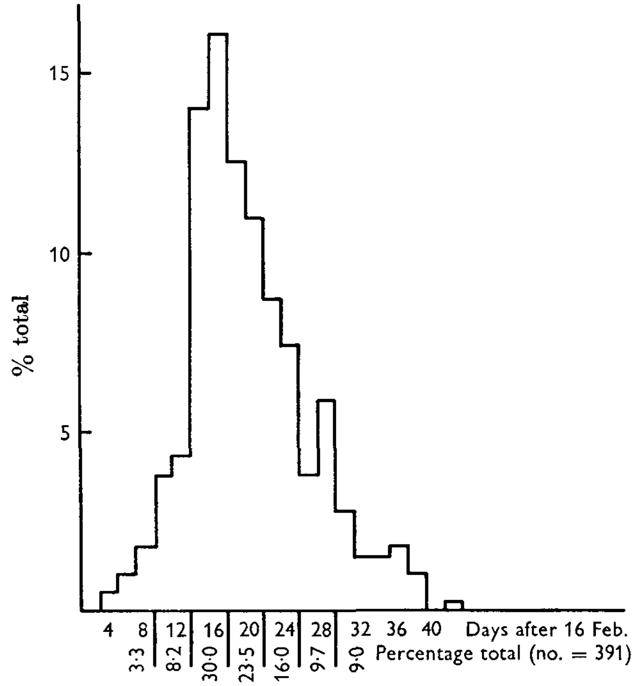
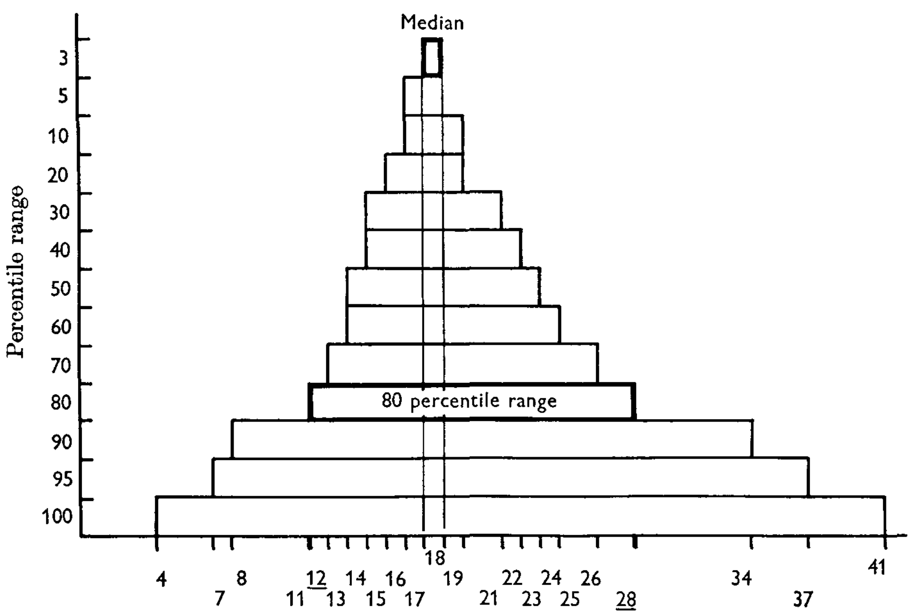


A



B

Fig. 6. Frequency distribution of incubation periods. A, Percentage frequency distribution of cases according to calculated incubation periods. B, Percentile ranges of incubation periods.

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account these factors, Fig. 6 was constructed to demonstrate the frequency distribution of incubation periods (Fig. 6A) and the corresponding percentile ranges (Fig. 6B). It must be emphasized that the right-hand portion of Fig. 6A is not so accurate as that to the left, because patients who were already in Zermatt on the week-end of 16 February could nevertheless have been infected on any day up to 24 February. The estimated incubation periods for these cases must thus be regarded as maxima. However, this does not materially affect the general distribution of real incubation periods. Fig. 6A shows that 70 % of all cases have an incubation period between 13 and 24 days and only 11·5 % have one of less than 13 days. Nearly 20 % of all cases presented an incubation period exceeding 24 days, the median was found to be 18 days and the mode was 15 days (37 cases, 9·5 % of the total).

Fig. 6B presents an analysis of the frequency distribution of incubation periods on a percentile basis. The maximum range is 4–41 days and the 90 percentile range 8–34 days. The median was 18 days and the 80 percentile range 12–28 days; these were probably the most accurate parameters of the distribution and are marked with a bold line in Fig. 6B. A long median incubation period and an 80 percentile range also on the long side are the characteristic features of this outbreak, which, as has been pointed out before, being waterborne, was almost certainly associated with low dosage of the infective organism. It is also interesting that the foregoing analysis of the entire outbreak could be applied with very small differences to the group of 31 cases represented in group E_{1-3} on Fig. 4.

GEOGRAPHICAL DISTRIBUTION

Distribution of nationalities

Tables 1 and 4 show that roughly three-fifths of all victims were Swiss; Great Britain had the highest figure for foreigners with 17·8 %. Two-fifths of all cases

Table 4. *Distribution of cases by nationality*

	Nations		Cases	Per cent total
Residents	Switzerland	Zermatt	177	40·5
Tourists	Switzerland	Rest of Switzerland	77	17·6
Tourists	Other nations	Great Britain	78	17·8
		France	37	8·5
		Germany	33	7·6
		United States	14	3
		Remaining nations	21	5
		Total	437	100·0

were local residents. As Table 1 shows, the attack rate per thousand is three times as high in British tourists as in the remaining visiting nationalities (182/83,449 = 2·18 per 1000 guest-nights). The reason for this preponderance of British cases is not apparent, but it may be due to the fact that there was a high attack rate in the hotel in which the majority of British tourists were staying during the infection period.

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Local distribution of cases

A provisional spot map drawn early in the outbreak showed a preponderance of cases on the left bank of the Vispa, with concentration in the lowest part of the village near the railway station. Fig. 7 shows the final distribution of cases. It is seen that 17·8 % were accommodated on the right bank with an evident concentration in two limited areas, whereas 82 % were staying on the left bank. There

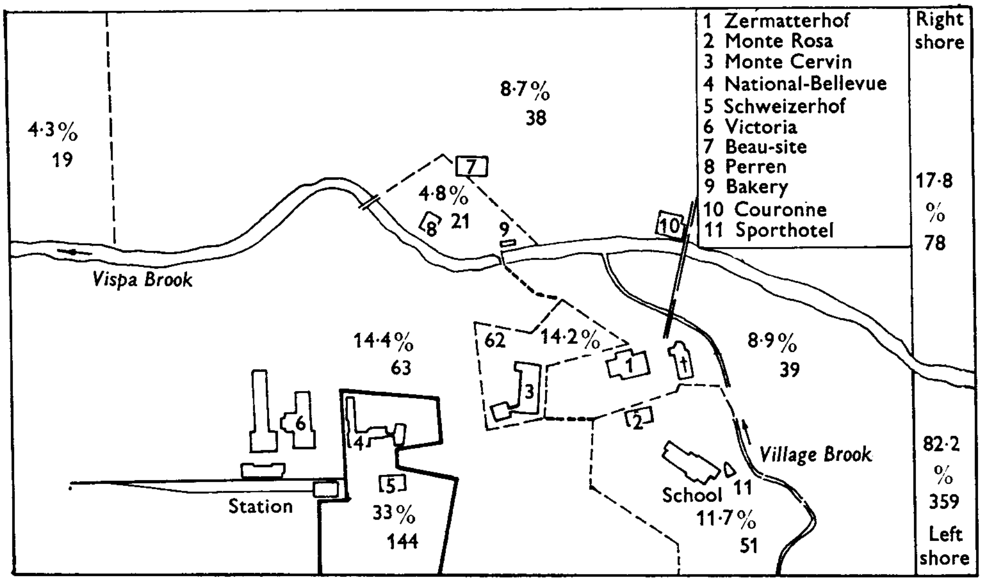

Fig. 7. Local distribution of cases (percentage total and number).

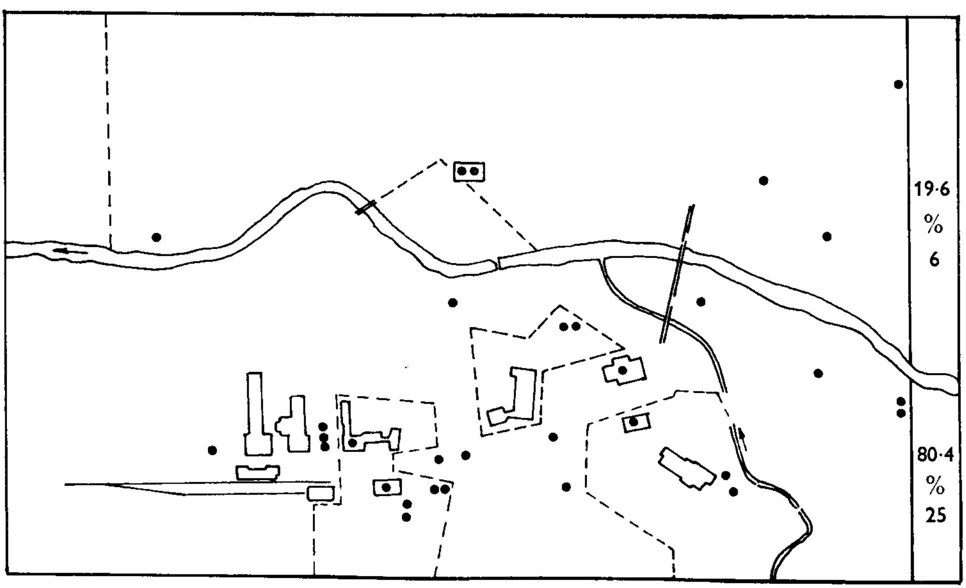

Fig. 8. Residence of tourist cases leaving on 16, 17 and 18 February. (Fraction E_{1-3}; first departures.)

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were also obvious concentrations of cases on this bank; in particular, a limited area contributed 33 % (= 144 cases) of all cases. The left bank represents the original village and contains most of the hotels.

A study of the geographical distribution of cases known to have been infected at the beginning of the outbreak showed that infection was distributed throughout the village from the start with a concentration on the left bank (Fig. 8). This is indicative of a common vehicle.

THE WATER SUPPLY OF ZERMATT

As may be seen in Fig. 9, various catchment areas yield the community water. A series of nearly twenty lateral moraine springs flow in a more or less protected conduit to a collecting chamber from which two pipes arise, one supplying the

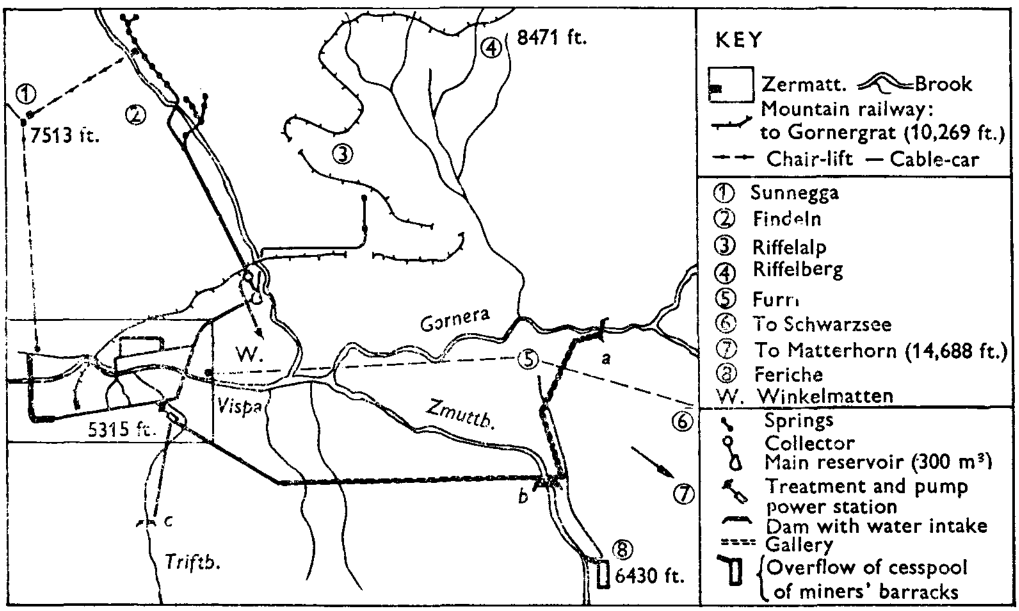


Fig. 9. The water sources of Zermatt.

nearby hamlet of Winkelmatten, the other conducting the excess to the main reservoir of Zermatt with a capacity of 300 m.³. The water of two other springs, collected on Riffelalp, is conducted directly to this reservoir. All this water is originally of good quality, but being surface water it is liable to repeated contamination. It must be emphasized that this raw water runs untreated into the general supply. Nevertheless, as Winkelmatten had no cases and as the right bank of the Vispa, which is essentially supplied by this water source, had the lowest attack rates, the Findeln catchment area may be excluded as a source of infection.

The second source of water is the catchment area of two glacier streams, the Gornera and Zmutt. From their respective dams the water is conducted in a joint main and serves first to provide power for the hydroelectric station of Zermatt, after which it is piped to the nearby water purification station.

The power station has another supply of water, the Triftbach; in the winter the region from which this water comes is uninhabited, so that at the time of infection it was unlikely to be contaminated. This is not true for the Zmuttbach area. About 400 yards (365 m.) above the water intake there was at the time of the outbreak a hostel accommodating over 100 Italian miners employed on a hydroelectric project. In addition to the fact that these workers very often defaecated directly into the Zmuttbach and on its banks, the overflow of the cesspool into which the lavatory accommodation of the hostel drained ran directly into the Zmuttbach. This cesspool was found to be filled to overflowing during the critical period.

The water leaving the Zermatt hydroelectric station was purified by filtration through quartz sand followed by chlorination with a Hottinger injector apparatus into the storage chamber, which was beneath the station and had a capacity of 30 $m.^3$. Three sand filters were used, one of which had been installed as recently as 1962. The water engineer discovered two important faults in the design of the treatment station. On the one hand it was determined with precision that about 70 $m.^3$ of unchlorinated water entered the general supply whenever the newly installed filter was cleaned (this was carried out every 1–2 days by reversed flow under pressure). The two older filters did not suffer from this fault. On the other hand, the holding time of the chlorinated water was found to be extremely short. It was calculated to be reduced to under 15 min. during the peaks of consumption (at about 6 p.m.).

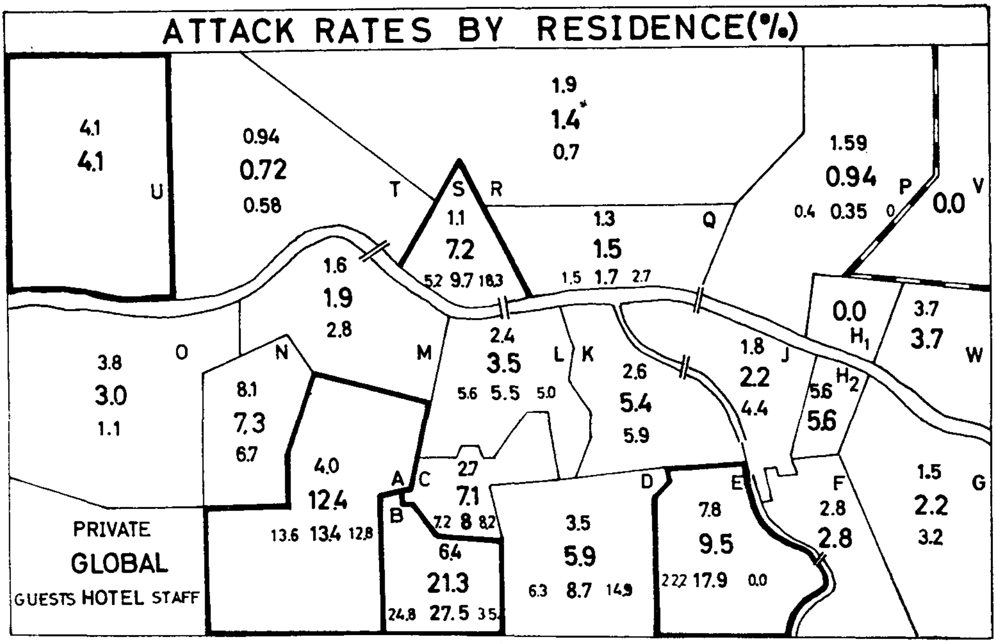
Calculation of the total consumption of hypochlorite for the first 3 months in 1963 revealed that the chlorination on average was reaching only one-third of the required 0·2 p.p.m.

In addition, the result of one of the rarely executed water examinations was available. Samples were taken on 11 February after complaints had reached the Municipality concerning the high incidence of 'Zermatitis' (gastro-enteritis). The water was sampled before and after treatment. The pre-chlorination sample was heavily positive for *E. coli*, while that after chlorination was negative. It was discovered that the residual chlorine in the chlorinated sample was not neutralized before it was received for analysis. There was therefore a period of at least 10 hr. during which the chlorine could exert its sterilizing action. Thus, no reliance can be placed on the results of examination of the chlorinated sample. This examination was carried out on 11 February, that is, 5 days before the postulated start of the period of infection (16 February). The director of the Laboratory who carried out the examination added the comment that water of such a degree of initial contamination should not be used for drinking.

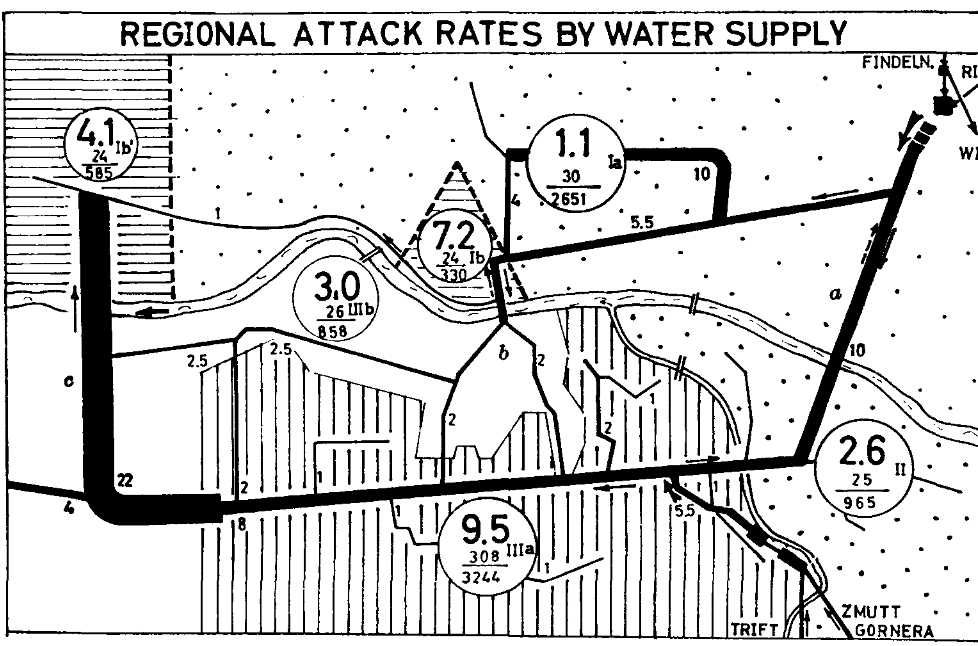
It may be added that the first decision on the initial day on which it was suspected that a typhoid epidemic was developing (see Fig. 1; 10 March) was to cut off the water from the Zmutt.

Distribution of cases according to the water supply

The water engineer subdivided Zermatt into *Sections* (designated A to U in Fig. 10A). Attack rates were calculated for each section and, with the water engineer's guidance, these sections were fused into *Regions* according to the origin of the water (Fig. 10B).



A



B

Fig. 10. A, Percentage attack rates by residence. B, Regional attack rates by water supply.

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It can be seen at a glance that the region supplied by water from the treatment station showed a high attack rate, whereas that supplied by the Findeln source had a low attack rate. Thus in the region supplied essentially by water from the Zmutt and Gornera the morbidity rate (9·5 %) was about 9 times as high as that supplied essentially by Findeln water (1·1 %). The two systems are interconnected at three points and the origin of water at any point will therefore depend on the relative demand in the various areas.

To give a more accurate idea of the dynamics of the system the pipes are represented according to a volume coefficient scale; that is, their width is shown according to the square of their radii, and the corresponding coefficient, which is one-tenth of the figure, is given. For example, the coefficient '22' in relation to one of the three interconnexions ('*c*' in Fig. 10B) represents a value of 220 as the square of the radius of 14·83 cm. The diameter is therefore 29·66 cm.

On this basis the following observations may be made.

First, there is a quite uneven distribution of local static water in relation to various areas, the values ranging from 1 to 22. This means simply that more water was available from the larger mains. When it is remembered that internal resistance rises steeply with diminution in diameter, the preponderant supply of water from the larger mains is still further accentuated. This explains the relatively high attack rate in section U (I b′) on the right bank, which is predominantly supplied with water from the left bank through a wide-bored main. The water engineer calculated that this main held sufficient water to supply all of section U for 48 hr.; thus, it acted as a small local reservoir in which water could stagnate. This static water had to be consumed before a fresh supply could enter.

Secondly, as we have pointed out, the two banks of the Vispa had basically independent water supplies, the right bank from Findeln, the left from the Gornera–Zmutt–Trift streams. The contrasting attack rates on the two banks have already been mentioned (Region I a: 1·1 % and Region III a: 9·5 %). Nevertheless, at certain times each bank may be supplied by water coming from the system of the opposite bank, as on the one hand water not immediately consumed on the left bank is pumped to the reservoir which supplies the right bank and, on the other, during the time of maximum demand on the left bank Findeln water runs into the left bank system. The supply of water to the right bank from the left bank system explains the occurrence of cases on the right bank. The points of low incidence on the left bank are those receiving the water predominantly from the right bank supply (Region II and III b with 2·6 and 3 % respectively).

Thirdly, no hydrodynamic explanation can be given for the high attack rate of the region situated in a bend of the Vispa River (I b with 7·2 %). The water engineer stated that only one hotel, situated near the Vispa River, may be supplied essentially by left bank water and this during a limited time only. This hotel owns an adjacent bakery, employees of which take their meals with the hotel employees, and several sleep in the hotel. This hotel showed a much higher attack rate in its employees, including those of the bakery (32 %) than in its guests (7·2 %). We have as yet no explanation for this disparity (see Fig. 11).

The percentage attack rates subdivided according to water supply and popula-

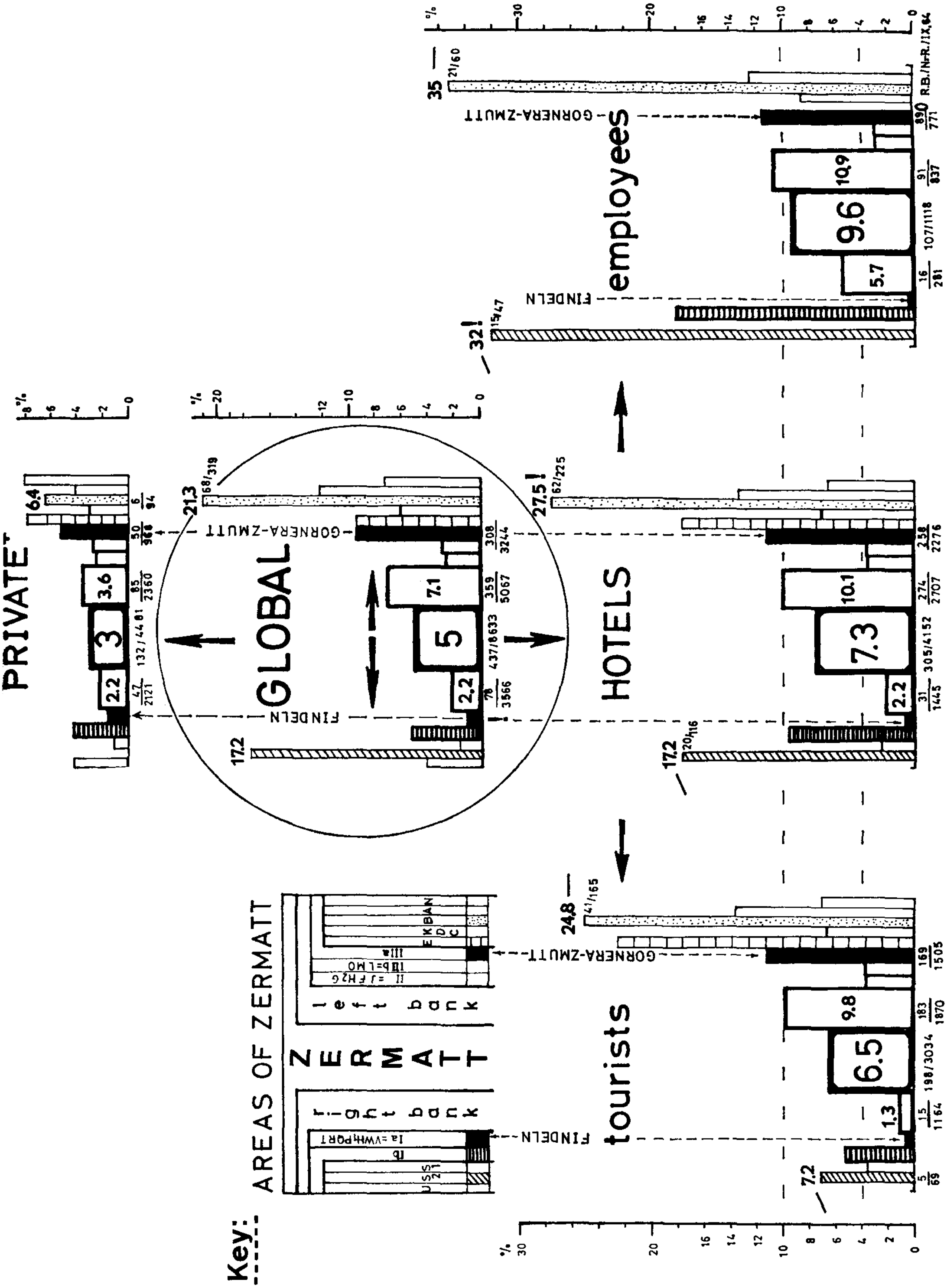

Fig. 11. Attack rates per cent by water supply and population category. The fractions present the number of cases (numerator) and the total number at risk (denominator).

tion category are represented in Fig. 11. This figure is a graphic summary of the entire outbreak. It should be studied from the centre circle in which the overall attack rate is shown to be 5 %. This figure shows that the left bank had an attack rate three times as high as that on the right bank (7·1 and 2·2 % respectively) and that the attack rate for hotels was more than twice as high as private houses (7·3 % and 3·0 % respectively) in which residents not employed in hotels and guests not booked in hotels were living.

INCUBATION PERIOD BY PLACE AND POPULATION FRACTION

Analysis of the incubation periods of guests and hotel employees yielded the surprising result that, whereas the median incubation period of the guests was found to be 16 days, that of the employees was 21 days. These hotels were situated in the areas A, B and C of Fig. 10A.

It was also found that the median incubation period increased as the source of water supply to their hotels received water from the right bank system. Thus, tourists in areas L, M and O had a median incubation period of 17 days, in F, G, H_2 and J 18 days and V, P, Q, R and T 20 days.

This may be due to reduced dosage with the typhoid bacillus as the water became progressively diluted with that from the right bank.

The finding of a 5 days' longer median incubation period for the employees than the tourists is consistent with the observation in Fig. 2C, which shows that the curve of onset of the tourists precedes that of the inhabitants. There is no evidence that there was any difference in dosage between tourists and employees. The only explanation that can be offered for the difference in incubation period, if it is significant, is that the hotel employees, many of whom came from regions of high typhoid incidence (southern Italy), may have had a basic immunity against typhoid fever, which retarded the development of the disease.

POSSIBLE ORIGINS OF INFECTION

We have demonstrated that this epidemic was due to water contamination. The question now arises of how the typhoid bacilli gained access to the water system. Two possibilities exist.

A labourer, aged 20 years, who had arrived from southern Italy on 6 February 1963, suddenly fell ill after working for 1 week on the hydro-electric project high above Zermatt. His symptoms were fever and gastro-enteritis. After a week in bed he was admitted to a Zermatt clinic and was transferred on 28 February to the hospital at Brig (see Fig. 1, case CH-206).

On 3 March a serological report stated that he had a TH titre of 1/400. It is known that from 20 February onwards he was treated with chloramphenicol. Examination of his excreta was not carried out until the end of February and this and all successive examinations were negative for the typhoid bacillus. The diagnosis of typhoid fever in this man hangs on the tenuous evidence of his single H-agglutination titration. Nevertheless, if he was indeed suffering from typhoid fever whilst still living in the hostel, the typhoid bacilli he may have excreted could have contaminated the Zmuttbach.

The second hypothesis is based on two things. The writer's inquiries revealed that, for a few days before the beginning of the suspected period of infection, the tap water was 'cloudy, offensive smelling, oily and contained black particles'. Secondly, it was discovered in November 1963, that is about 6 months after the outbreak, while operations for enlarging the holding tank were in progress, that a nearby sewage pipe was broken and investigations with fluorescein established that sewage from this leak had been entering the holding tank. The complaints about the conditions of the water immediately preceding the infectious period, which were specifically located in the neighbourhood of the purification station, suggest that this leakage of sewage was already taking place at that time. If an incubating case of the disease, or a tourist who was a chronic typhoid carrier, or a local resident who was a chronic carrier, was excreting the typhoid bacillus into this sewage area at that time, the organism could easily have gained access to the water-holding tank.

In view of the fact that it had been suggested that the holding time was too short for effective chlorination, either of the possibilities mentioned could have resulted in contamination of the general water supply, with concentration on the left bank of the Vispa.

ANOMALIES

Apart from the Italian worker, three cases present us with a problem. These are shown at the top of Fig. 1.

(1) A 20-year-old girl who stayed in Zermatt from 1 to 21 January 1963 fell ill on 8 March (case CH-367). From 21 January to the time of onset of illness she was staying at a finishing school in Lausanne. If she was infected in Zermatt her incubation period was at least 42 days. While admitting this possibility it should be remembered that the usual extremes of the incubation period of typhoid fever lie between 5 and 28 days. This patient was infected with type E_1, which was the epidemic type, but as this is the commonest type on the European continent it offers no proof that she was infected in Zermatt.

(2) An employee of the hotel Riffelberg came to Zermatt for a staff carnival on 28 January (case CH-100). She was in Zermatt for that night only and returned to the hotel early on the following morning. She fell ill on 8 March and proved to be infected with phage-type E_1. If she was infected in Zermatt her incubation period was 36 days. This is again longer than average and raises the suspicion that she may have been infected in Riffelberg.

(3) A middle-aged woman (case CH-306) left Zermatt on 11 February (from section E on Fig. 10 A) to work as cook in Findeln (see Fig. 9). On 25 February she became ill and was finally diagnosed as suffering from typhoid fever, the organism again proving to belong to phage-type E_1. There can be little doubt that this patient was infected in Zermatt and because of this it can be concluded that the typhoid bacillus had already entered the water supply on 11 February. This patient complained that the tap water was offensive on the days before leaving

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Zermatt. Combining the fact of her infection with the probability that there was sewage contamination of the water chlorination tank at that time, a suspicion strengthened by the complaints about the state of the water, it seems probable that the typhoid bacillus entered the water supply as early as 11 February, if not before. However, this early contamination may have been transient because the analysis of tourist cases indicated that the first day of continuous contamination was 16 February.

The two preceding cases can also be explained on the basis of a transient or minimal water contamination and, because under such circumstances their dosage with typhoid bacillus would probably be very small, their unduly long incubation periods would be explained.

DISCUSSION

The analysis establishes that the period of infection lasted for a limited span, 16–24 February, with a concentration during the first 3 days of this period. The epidemiological investigation shows clearly that the outbreak was waterborne and that the contamination of the water system took place at or before the treatment station. There seems to have been a possibility of some local intensification of attack rate because of unsatisfactory sanitary installation in some hotels, which allowed liquid to be aspirated from the sewage system into the water supply.

On examining the possibility of the origin of the outbreak, that is, the original source of the typhoid bacillus, two hypotheses present themselves:

(1) That the infection reached the Zmuttbach via the septic tank from the vicinity of the hostel housing predominantly Italian labourers. One of these was known to have a typhoid-like illness immediately preceding the onset of the outbreak. Unfortunately the investigation of this case was inadequate, and the organism was never isolated from him. The sole laboratory evidence that he may have suffered from typhoid fever was that a single examination of his serum revealed a TH titre of 1/400.

(2) The second hypothesis is that the treatment station or its reservoir became contaminated with *S. typhi*. At a rather late date it was discovered that there was a sewage leakage of long standing in the neighbourhood of the reservoir underlying the treatment station. It was established with fluorescein that sewage from this pipe leaked into this reservoir. Bearing in mind that several complaints about the unpleasant state of the drinking water immediately ante-dated the postulated period of infection, and that these complaints were located in the neighbourhood of the treatment station itself, it seems highly probable that the sewage leakage into the holding tank was occurring at that time. If an excretor of the typhoid bacillus was contributing to the sewage at that moment, the holding tank could have become contaminated with his organism.

It is impossible at this date to choose between these two hypotheses. What can be concluded however is that, had chlorination of the water been effective, the possibility of this outbreak occurring would have been greatly reduced.

SUMMARY

1. A description is given of the outbreak of typhoid fever in Zermatt in 1963.

2. There were 437 cases and three deaths, a case fatality rate of 0·7 %.

3. Information from 260 tourists established that the initiation of infection was explosive and allowed the period of infection to be determined.

4. The mean incubation period of various tourist fractions was probably between 16 and 18 days but was found to be significantly longer (20–21 days) for hotel employees.

5. The evidence favours a waterborne outbreak. Studies of the water supply showed that the catchment area and the surface streams and their water were liable to contamination.

6. One particular stream, the Zmuttbach, constituted a greater danger than the remainder.

7. The water purification at the treatment station was inadequate; in particular the holding time for chlorination was too short, and the required concentration of 0·2 p.p.m. was not reached consistently. In addition, there were periods during which completely unchlorinated water reached the general supply.

8. It was discovered, some months after the epidemic, that there was leakage of sewage, probably of long standing, into the chlorination tank. This seems to be the most likely source of the water contamination.

9. The typhoid excretor responsible for the outbreak was not discovered.

I am greatly indebted to Mr J. Bruderer, water engineer, for the valuable information he provided about the water supply, treatment station and sewage system. This information, which resulted from exhaustive studies, gives the most likely explanation of the cause of this outbreak. The encouragement of Dr P. Calpini, Chief Public Health Officer to the Canton of Valais was very helpful during the studies. I wish to thank Dr H. Reber, who commanded the Military Detachments concerned with the epidemic, for making his records freely accessible. The Ministries of Health of the countries mentioned in this report were all very cooperative in the collection of data. I am greatly indebted to Dr W. Kämpfen, Director of the Swiss National Tourist Office, whose collaboration simplified the collection of data. I gratefully acknowledge the information about the daily records so generously supplied by Mr A. Binz, Director of the railway company. The advice and encouragement of many specialists and scientists of the Swiss Universities were particularly helpful to me. The Swiss Embassy in France is acknowledged for its valuable technical assistance. The statistical calculations were carried out on a Tetractys calculator made available by the kindness of Messrs Olivetti in Paris. Finally, I wish to record my deep gratitude to Dr E. S. Anderson, Director of the Enteric Reference Laboratory, Colindale, London, for his help in the studies of this outbreak from the beginning, and for his guidance in the preparation of this report.

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RÉSUMÉ

1. L'auteur décrit l'épidémie de fièvre typhoïde survenue à Zermatt en 1963.

2. 437 cas ont été enregistrés, dont trois mortels, ce qui représente un taux de mortalité de 0,7 pour cent.

3. Les informations recueillies sur les 260 touristes infectés ont permis de déterminer le caractère explosif de l'épidémie et d'en fixer la période d'infection.

4. La période d'incubation moyenne estimée parmi certains groupes de touristes se situait probablement entre 16 et 18 jours, alors que celle calculée parmi les employés d'hôtels a été nettement plus longue (20–21 jours).

5. Les faits recueillis parlent en faveur d'une épidémie hydrique à caractère explosif et de courte durée. Les investigations menées à chef sur les diverses sources d'eau ont démontré que la région de captage et les torrents pouvaient être infectés.

6. Le torrent de Zmutt constituait, en particulier, un danger de contamination plus grand.

7. La purification de l'eau dans la station d'épuration laissait à désirer. Le temps de contact de l'eau avec le chlore a été estimé trop court et la concentration minimale de 0·2 mg/l. n'a pas été atteinte régulièrement. De plus, durant certaines périodes, de l'eau non chlorée entrait dans le réseau d'eau potable.

8. Quelques mois après l'épidémie, une infiltration d'eaux usées a été découverte dans la chambre de chloration. Il s'agit certainement d'une infiltration ancienne qui semble être la source la plus probable de la contamination de l'eau.

9. L'excréteur de germes responsable de cette épidémie n'a pas été déterminé.

ZUSAMMENFASSUNG

1. Der Autor bringt eine Epidemiographie der Typhusepidemie des Frühjahres 1963.

2. Es wurden insgesamt 437 Erkrankungsfälle gemeldet, 3 davon verliefen tödlich, was einer Letalität von 0,7 vH entspricht.

3. Die Bearbeitung der Angaben von 260 erkrankten Touristen gestattet es, die Epidemie als Explosivepidemie zu identifizieren und die Expositionszeit festzulegen.

4. Die mittlere Inkubationszeit bei mehreren Touristengruppen lag wahrscheinlich zwischen 16 und 18 Tagen und war signifikant kürzer als die bei Hotelangestellten mit 20–21 Tagen.

5. Die epidemiologische Analyse deutete auf eine explosionsartige, kurzdauernde Trinkwasserepidemie hin.

6. Die Untersuchungen der Trinkwasserversorgungsanlagen deuteten darauf hin, daß das Quellgebiet und die Quellbäche möglicherweise einer Verunreinigung ausgesetzt worden waren. Dies gilt besonders für den Zmuttbach.

7. Die Wasseraufbereitung ließ zu wünschen übrig, insbesondere war die Chloreinwirkzeit zu kurz, und auch die minimale Chlorkonzentration von 0·2 mg/l wurde nicht immer erreicht.

8. Einige Monate nach Erlöschen der Epidemie konnte festgestellt werden, daß Abwässer in den Chlorungstank eingedrungen waren. Hierin scheint auch der Grund für die Trinkwasserverschmutzung gelegen zu haben.

9. Ein bestimmter Bakterienausscheider, auf den die Epidemie zurückging, konnte nicht ermittelt werden.

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