Survival of *S. typhimurium* in Floor Dust — A Possible Reservoir of Infection in Institutions

M. H. ROBERTSON
M.B., Ch.B., M.R.C. Path
Princess Alexandra Hospital, Harlow, Essex

An outbreak of *S. typhimurium* infection having the characters of both an acute explosive epidemic and a smouldering institutional outbreak in a boy's boarding school is described. The perpetuation of the smouldering phase is attributed to contamination of environmental dust and the epidemic was controlled by treating the premises with formalin vapour.* S. typhimurium* has been shown to survive in samples of ward floor dust for a period of at least 50 months.

Salmonella enteritis is an infectious disease transmitted in most instances by food contaminated directly from a variety of human or animal sources. Outbreaks may be explosive or smouldering (Taylor, 1963; Schroeder, Aserhoff & Brachman, 1968). The explosive outbreaks can frequently be associated with an identifiable contaminated foodstuff but the cause of the smouldering outbreaks which do not involve multiplication of organisms in food and occur in institutions such as hospitals, especially children's wards and nurseries (Parker, 1954; Datta et al., 1960) may be very difficult or impossible to ascertain. An incident which occurred among boys aged 11 to 17 years in a residential school is described as it shows features of both types of outbreak. The initial source of the explosive phase was not discovered but the subsequent smouldering phase appears to have been perpetuated by environmental contamination.

As a result studies were made to ascertain the period of viability of *S. typhimurium* in samples of ward floor dust.

**Observations**

Brief history of outbreak

Medical care for a boy's boarding school was provided by a general practitioner who attended several pupils for gastro-enteritis in early February 1965 but did not send stool samples for bacteriology until 15 February when a whole dormitory had been violently affected during the preceding night. One specimen was submitted from one boy and *S. typhimurium* of a non-phageotypable strain was isolated. Rectal swabs were taken from the entire school population on 19 February and four more boys and one master were found to be excreting the same organism. All had had symptoms and five of these six original cases continued to excrete the organisms, although symptom free, for periods of up to five weeks.

No source for this explosive outbreak was found. The hygienic arrangements at the school were not of the best. Washing facilities were minimal and running water was not available in the dormitory areas where the boys washed in water supplied in large jugs. The dormitories themselves were small and crowded. The kitchen facilities were poor and one symptomless member of the kitchen staff was found to be carrying the organism. This person did not live in the school and although she could possibly have been the cause of contamination of food eaten by the pupils, this seems unlikely as her home contacts, for whom she also prepared food, were symptomless and stool negative. The school purchased its meat supplies from a local shop where, also, all cold meats for the school were sliced on a machine.
The staff of this shop, the slicing machine, chopping benches and refrigerator hanging rail were thoroughly investigated, 7 separate parts of the slicing machine being sampled without positive findings. Articles of food sent to the boys from home were also examined with negative results.

The epidemic appeared to be of short, sharp duration controlled by the enforcement of generally improved hygiene, as no further clinical cases occurred for a fortnight when another boy complained of symptoms and the same organism was isolated from his stool. Two others had symptoms and positive stool cultures two days later and the whole school population was again examined by rectal swabbing. Five more boys were found to be symptomless excretors. The 16th and final case presented with symptoms on 28 March, 6 weeks after the original case. All the affected boys were aged from 11 to 17 years.

The outbreak was recognized to have changed its character in the second phase as cases occurred sporadically and there were subclinical infections suggesting a continuing source of infection rather than a common article of diet, as illustrated in Fig. 1 Dust was considered a possible reservoir (Bate & James, 1958). The dust of the sick room and 7 dormitories was examined.

No vacuum cleaner was available for sampling as no electric points were provided in the rooms and the samples were collected with a sterilized brush and pan. The organisms were easily isolated from all 3 dormitories where cases were occurring and the sick room but not from 4 other dormitories. Four blankets from the beds of affected boys failed to yield Salmonellae although much of the floor dust was composed of blanket fluff.

An untyppable strain of S. typhimurium was isolated from the dust on 17 March 1965 and again on 2 April 1965 just before the entire premises were treated with formaline vapour, the pupils having dispersed for the Easter vacation. No organisms were isolated from the dust 2 days later and when the school re-assembled for the new term no new cases occurred.

**Technical Procedures**

*Isolation of S. typhimurium from floor dust*

Samples of dust, collected with a sterile brush and pan were sent to the laboratory in sterile glass jars and each sample distributed into three honey pots to which were added 20 to 50 ml of selenite broth, glucose broth or sterile saline and the jars incubated overnight at 37°C. The cultures were then subcultured on Desoxycholate Citrate Agar (D.C.A.) plates and colonies examined next day. *S. typhimurium* was identified by standard biochemical and serological methods.

The organism was isolated from the pots to which were added either selenite broth or glucose broth but not from those to which only sterile saline had been added.

*Sampling methods for blankets*

The blankets were examined by 4 methods:

1. Sweep plates using blood agar plates (Williams et al., 1966).
2. Imprint plates made by pressing the fabric against the surface of blood agar plates.
3. Swabbing 6 in² of material with a cotton wool swab soaked in sterile saline and then incubating in selenite broth, glucose broth or sterile saline and subculturing onto D.C.A.
4. Passing the fabric over the entry port of a slit-sampler for 2 min so that air was drawn through the material into the machine. Suspicious colonies were then subcultured and identified.

No salmonellae were isolated by any of these methods.
Survival of S. Typhimurium in ward floor dust

The ease with which *S. typhimurium* was isolated from floor dust in this outbreak stimulated an investigation into the viability of this organism in ward dust. Dust was obtained from a ward vacuum cleaner and dispensed into a number of sterile bijou bottles. This dust consisted of fine grey amorphous material among which could be distinguished blanket fluff, hair, cigarette ash and a few cigarette stubs and sweet papers. The last named larger items were removed before the dust was distributed into the bottles. Two drops from a 30 dropper pipette of an overnight broth culture of *S. typhimurium*, obtained from a clinical case, not part of the epidemic just described, were dispensed into each bottle of dust, the caps screwed home and the bottles stood in an open cardboard box on a laboratory shelf close to a window. The quantity of dust in each bottle was such that it was not appreciably wetted by the inoculum.

Bottles were cultured at intervals by unscrewing the cap and filling with either glucose broth or bile salt broth, incubating overnight and plating onto D.C.A. The colonies produced were identified as *S. typhimurium*, by slide agglutination with an anti-Salmonella 0, 4 antiserum.

*S. typhimurium* was recoverable from the dust for 4 years and 2 months by which time the last remaining bottle had been cultured. It was concluded that the organism was viable in ward dust for at least that period.

The amount of dust from which salmonellae may be grown undoubtedly varies and may be subject to considerable sampling error. Quantitative studies were not performed in this instance. The amounts, however, may be very small as *S. bareilly* has been isolated in this laboratory from as much dust as could be collected on a moist throat swab rubbed over 1 ft² of floor under the bed of a mother whose baby had gastroenteritis and was 'rooming-in'. The mother did not have diarrhoea and the baby was only mildly affected.

Table 1 summarizes the dates of isolations from the cases and dust samples.

<table>
<thead>
<tr>
<th>Patient or source</th>
<th>Symptomatic (S)</th>
<th>Asymptomatic (A)</th>
<th>Date of 1st isolation</th>
<th>Date of last isolation</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>NG</td>
<td>S</td>
<td></td>
<td>15 Feb.</td>
<td>31 Mar.</td>
<td>Initial case</td>
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<tr>
<td>BS</td>
<td>S</td>
<td></td>
<td>19 Feb.</td>
<td>19 Mar.</td>
<td></td>
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<tr>
<td>MT</td>
<td>S</td>
<td></td>
<td>19 Feb.</td>
<td>19 Feb.</td>
<td>Explosive outbreak</td>
</tr>
<tr>
<td>NB</td>
<td>S</td>
<td></td>
<td>19 Feb.</td>
<td>19 Mar.</td>
<td></td>
</tr>
<tr>
<td>JL</td>
<td>S</td>
<td></td>
<td>19 Feb.</td>
<td>9 Mar.</td>
<td>Master</td>
</tr>
<tr>
<td>GR</td>
<td>A</td>
<td>25 Feb.</td>
<td>2 Mar.</td>
<td>2 Mar.</td>
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<tr>
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<td>S</td>
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<td>1 Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CB</td>
<td>S</td>
<td>3 Mar.</td>
<td>3 Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>S</td>
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<td>26 Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>A</td>
<td>5 Mar.</td>
<td>5 Mar.</td>
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<tr>
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<td>A</td>
<td>9 Mar.</td>
<td>9 Mar.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DH</td>
<td>A</td>
<td>9 Mar.</td>
<td>9 Mar.</td>
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<td></td>
</tr>
<tr>
<td>JC</td>
<td>A</td>
<td>9 Mar.</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td>13 Mar.</td>
<td></td>
<td>Dormitories &amp; sick room</td>
</tr>
<tr>
<td>Dust</td>
<td></td>
<td></td>
<td>2 April</td>
<td></td>
<td>Dormitories &amp; sick room</td>
</tr>
</tbody>
</table>

Dust after formalin vapour

No isolation 6 April

Whole school
Fig. 1. Time distribution of presentation of clinical cases and discovery of subclinical infections
Discussion

The importance of floor dust as a source of infection has been realized for many years. Garrod (1944) studied ward dust with particular reference to streptococci and found that daylight exerted an appreciable bactericidal effect. The bottles of dust in this experiment were exposed to partial illumination comparable to that found in the darker areas of wards such as under beds and behind lockers. Other organisms which can exist in viable and presumably infective form in dust for long periods include Staphylococcus aureus, Corynebacterium diphtheriae, Clostridium welchii, Clostridium tetani, Mycobacterium tuberculosis and Pseudomonas pyocyanea.

Some strains, at least, of this last named species, usually associated with damp reservoirs (Gould, 1963) can survive on dry ward floors for up to 5 weeks (Hurst & Sutter, 1966) and in dried burn eschar for even longer. Shigella sonne appear to die out in a short time in ordinary conditions but can survive up to 17 days in cool, dark, damp surroundings such as the floor of a school water closet (Hutchinson, 1956). Organisms in dust are generally regarded as being incapable of multiplying in that situation.

Contamination of kitchen premises and food utensils has long been recognized as a danger but the significance of widespread dry environmental contamination in gastrointestinal disease in institutions was not appreciated until the classic work of Rogers (1951) for enteropathic strains of Escherichia coli. The situation regarding salmonellae has not been so generally realized although previously Rubbo (1948), having isolated the organism from ward dust postulated transfer of S. derby by means of dust particles to food, food utensils and teats. Parker (1954) demonstrated contamination of floors, tables and ledges around the cots of infants suffering from S. typhimurium infections as far as 30 ft from the nearest infected child. Bate & James (1958) isolated S. typhimurium from dust in a vacuum floor-sweeper to which they attributed a smouldering epidemic in a children's ward which lasted for 11 months.

Numerous publications have described transfer of infection by means of nurses' hands or fomites or even by air-borne means (Neter, 1950; Laurell, 1952) but few investigators have actually looked for organisms in ward floor dust although this reservoir probably has always existed but not been frequently considered (Anderson, 1971). Rowe, Giles & Laing Brown (1969) attribute an outbreak in a maternity unit to gross environmental contamination with S. virchow but did not produce bacteriological proof. An exception is the outbreak described by Datta et al. (1960) who isolated S. typhimurium from ward dust and sheets. These authors also quote Tomlinson as isolating S. paratyphi B from ward dust and bedding. On the other hand Rogers could not isolate salmonellae from 1g of dust from a cubicle occupied by a baby infected with S. typhimurium although enteropathic E. coli could be isolated from much smaller amounts. Transmission of S. typhi to children playing in infected dust is mentioned as a possibility by Huckstep (1962, p. 211) who also warns against contamination of the environment from cattle manure (p. 258) as a possible source of infection with other salmonellae. The same author quotes Osler (p. 228) as attributing 57,684 cases of typhoid fever during the South African war to infected dust. Nowadays we would be more suspicious of the role of flies and inefficient sanitation under field conditions. Huckstep's warning of the dangers of environmental contamination from cattle is particularly apt in view of the present demonstration of the long viability of S. typhimurium in dust. Anderson (1968) has studied the ability of phage type 29 of this organism to acquire multiple antibiotic resistance and traces human infections to bovine sources.

Seligmann & Reitler (1965) report contamination of drinking water in Israel with salmonellae in greater numbers than E. coli. This they attribute to the greater resistance to
drying of salmonellae than *E. coli* in dust contaminating the water. Rappaport, Konforti & Davon (1956) record that both salmonella and shigella species are more resistant to drying than Escherichia.

The boarding school outbreak described, occurred in two distinct clinical phases—an acute phase affecting one master and 5 boys in a dormitory, with violent vomiting and diarrhoea, the victims continuing to excrete the causative organism in the stool for several weeks although symptoms free. The second or smouldering phase, which began 2 weeks later, consisted of 4 clinical and 5 subclinical cases housed in the same dormitories where the first phase cases had contaminated the surroundings with vomitus and were continuing to excrete the organism although 'isolated' by improved hygiene introduced in an attempt to control the disease. Between the 2 phases a symptomless kitchen worker was found to be harbouring *S. typhimurium* but whether she was the cause of or a victim of the whole episode remains uncertain.

The similarity to the outbreak described by Bate & James in children of a lower age group is striking and it seems possible that the infection was perpetuated by the dormitory dust acting as a continuing source of infection. The gap of 2 weeks between the 2 phases of the epidemic could be the time necessary for contamination to build up by continual addition from the carriers, to a level necessary for second wave cases to occur. While this conclusion cannot be claimed as definitely proven it is suggested by the failure to discover any other continuing source of infection and the isolation of salmonellae only from the rooms where cases were occurring, the whole school population was screened twice with the revelation of only one excreter among the food handlers who was removed from duty before the second phase occurred. No source was found among private stocks of food held by the boys nor was there any suspect food remaining in the kitchen. The meat supplier's premises were not contaminated and there was no similar episode occurring in the town population outside the school at this time. Cases isolated in space or time may give a clue to the origin of infection in outbreaks but in this instance the late, symptomatic case failed to provide this. Environmental contamination is now recognized as causing smouldering epidemics in institutions and multiplication of organisms in food is not a prerequisite for such occurrences. It is possible that food was again consumed in the dormitories after a fortnight of strict prohibition. Contamination of such food could occur while being shared out without organisms actually proliferating in it. On the other hand, such contamination could come as easily from the fingers of excreters among the boys as from environmental dust and the fact that salmonellae were isolated only from rooms where sporadic cases were occurring, could be a result of such cases rather than their cause. In view of the experience of Bate & James, attempts to rid the environment of salmonellae by washing or spraying with liquid antiseptics were not carried out but immediate recourse to formalin vapour had complete success. Whether or not this procedure prevented the establishment of a long, smouldering epidemic in the school cannot be proved but the evidence suggests that it played a part in so doing.

Survival time of enteric-pathogens in dry dust have been little recorded. Bate's strain of *S. typhimurium* remained viable in the vacuum sweeper bag for at least 3 years (Bate, 1961) and Rogers (1963) isolated enteropathic *E. coli* from cracks in a ward floor 16 months after the last recognized case of infection with that particular strain had been discharged. Information about survival of *S. typhimurium* outside hospitals, mainly in moist conditions is a little more plentiful. Josland (1951) records up to 24 weeks in pastures in New Zealand, 23 weeks in sand and 28 weeks in chaff, depending upon climatic conditions. Watts & Wall (1952) in Australia record at least 200 days in earth and Mair & Ross (1960) concluded the survival time was over 280 days in English garden soil. Henning (1939) in
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South Africa, records 1069 days as the survival period of *Salmonella dublin* in artificially dried cow manure and Thomas (1967) found *Salmonella paratyphi* B phase 1 var.6 (S. *java*) to exist for at least 259 days in Welsh farm soil. Thomson (1953) was able to isolate *S. paratyphi* B from dry flour for 45 weeks by which time none of the flour remained for further tests.

The present investigation shows *S. typhimurium* to be capable of survival for at least 4 years and 2 months in dry ward dust. The outbreak described suggests that contaminated floor dust may be a cause of perpetuation of smouldering epidemics in institutions.

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References